Report of Science

at

Williams College

2013-2014

A Record of the Professional Activities of Faculty and Students in the Natural Sciences

Williamstown, Massachusetts
2014

Cover Image:

Fluorescent micrograph of a brain section from a mouse. Neurons that produce a protein called agouti-related peptide (AgRP) express Green Fluorescent Protein (GFP). Neurons that are active during conditions of hunger are stained red. Because all red neurons co-express GFP, they appear yellow in this image. AgRP neurons sense hormones from the body about nutrition and energy status and send axons to other brain regions to regulate hunger. Figure produced by *Anna Ryba '16* and *Zoe Trutner '16* in the laboratory of Matt Carter.

The Science Executive Committe wishes to express its gratitude to the extensive efforts of all of the science departmental executive assistants in preparing this publication.

Editor: Norman Bell
Coordinator of Science Facilities

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Williams College admits men and women of any background to all the rights, privileges, programs and activities generally accorded or made available to students at the College. It does not discriminate on the basis of race, color, religion, creed, sexual orientation, or national ethnic origin in administration of its educational policies, scholarship and loan programs, and athletic and other college administered programs. The College does not discriminate on the basis of sex in violation of the Title IX of the Education Amendments of 1973, or the regulations thereunder, in the education programs or activities which it operates, including employment therein. The College does not discriminate on the basis of handicap in violation of Section 504 of the Rehabilitation Act 1973, or the regulations thereunder, in admission or access to its programs and activities. Inquiries concerning the College's non-discrimination policies may be referred to the Dean of the College, Hopkins Hall, Williamstown, MA 01267.

Table of Contents

THE SCIENCES AT WILLIAMS COLLEGE

Students learn science best by doing it -- when they formulate and test their own hypotheses, using methods capable of producing convincing evidence. This is true at the introductory level, where students become interested in further study by encountering science as discovery rather than rote facts. It is even more important at advanced levels, where students are most likely to become interested in science careers by working as fully involved junior colleagues with professionally active faculty on research projects that explore new scientific ideas. The ability to conduct cutting-edge research at Williams helps to attract talented scientists as faculty and keeps them at the forefront of their disciplines, which in turn allows faculty to bring the excitement of their research work to their teaching and course development at all levels. The College has invested deeply in this ambitious program of research and teaching through research funding, laboratory space, shared instrumentation, and technical support. The relatively large faculty sizes in all the science departments promotes breadth and depth in both research activities and curricular scope.

Our science buildings have been upgraded to provide modern facilities for teaching and student-faculty research. Our model of the entire science division as a cohesive programmatic unit has flourished. In 2000, a $47 million science facility was completed to unify all science departments in a single complex surrounding a central science library. The new Science Center, ensures Williams' place as a leader in undergraduate science education. Plans have begun for a new science center renovation/construction project that will become the foundation for science at Williams in the 21st century. Funds for major equipment, for individual student-faculty research projects, and for stipend support of students doing research with faculty are coordinated on a division-wide basis by the Science Center Director, the Science Executive Committee and the Divisional Research Funding Committee. By working together, we are able to share not only facilities and equipment, but also ideas and enthusiasm, and so provide a "critical mass" of activity that might not be possible within an individual department at a small institution.

The class of 2014 had 523 graduates, with 204 majors in a science or mathematics discipline. Approximately 25% of students in 2014 have expressed interest in careers in scientific research. The quality of the College's science programs has nurtured this interest and this year 56 students were inducted into Sigma Xi as associate members, after being nominated by faculty and reviewed by members of the Williams College chapter of Sigma Xi. Williams College has become a leader in the training of future scientists with more than 50 students going on to Ph.D. programs in science each year. As a result of this commitment, Williams has ranked first among predominantly undergraduate institutions in students receiving NSF pre-doctoral fellowships, averaging about 7 per year over the past ten years. We attribute this success to an energetic faculty and staff dedicated to providing an excellent educational experience and to the many research opportunities available to Williams students at both advanced and introductory levels.

It has long been recognized that a positive undergraduate research experience is the single most important inspiration for future scientists. As documented in this report, more than 250 students were engaged in science research with Williams faculty this year. More than 85 students conducted independent research projects during the academic year and 174 students were engaged in fulltime research with Williams science faculty during the summer of 2014. Dozens of Williams students participated in conferences where they presented the results of their research, and more than 50 Williams students co-authored publications in peer-reviewed journals in the past academic year.

Concurrent with the increased student involvement in science, Williams has attracted talented and vibrant science faculty engaged in competitive research and dedicated to teaching undergraduates. As a result, the number of external grants awarded to support faculty research or curricular innovation puts Williams near the top of all non-Ph.D-granting institutions. Since 2009, Williams faculty members were awarded 21 NSF grants totaling $4,358,000 and 6 NIH grants totaling $1,622,104. The large number of individual faculty grants, together with recent

grants from the Sherman Fairchild Foundation, the Clare Boothe Luce Foundation, endowed funds from the Kresge Foundation, the Keck Foundation, and other sources, has enabled us to purchase and maintain state-of-the-art equipment for teaching and research.

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Stanford University physics professor and former U.S. Secretary of Energy Steven Chu with Professor Protik Majumder, Physics, Commencement Weekend 2014. Dr. Chu was awarded an honorary degree from Williams College on June 8, 2014. Steven Chu is the William R. Kenan, Jr., Professor of Humanities and Sciences and Professor of Physics and Molecular and Cellular Physiology at Stanford University.

MAJOR SCIENCE CENTER FUNDING

Kresge Foundation Equipment Grant

Williams was awarded a large grant from the Kresge Foundation in 1990 to replace and update major items of scientific equipment and instrumentation. This three-part grant is used not only to purchase new equipment, but also to support maintenance contracts and the repair of existing instruments, and also supports technical staff members who oversee the instruments. One aspect of the grant is that the College sets aside endowment funds for the depreciation and eventual replacement of items purchased under the grant. Through this grant the college has purchased and maintains a 24-inch optical telescope, a gas chromatograph mass spectrometer, a transmission electron microscope, a UV/Vis/NIR spectrophotometer, and an x-ray diffraction instrument. In recent years, Kresge endowment funds were used to replace earlier models of a scanning electron microscope, a nuclear magnetic resonance spectrometer, an atomic absorption spectrometer and an ion chromatograph. These expensive pieces of core equipment are heavily used by faculty and students in collaborative research projects and in teaching laboratories associated with courses ranging from introductory to advanced levels. Plans are underway this year to purchase a new $700,000 Transmission Electron Microscope with assistance from Kresge funds.

Sherman Fairchild Summer Science Research Foundation Grant

This new three year grant will primarily support freshman and sophomore students participating in summer science research in Biology and other targeted disciplines at Williams. Annual funding includes up to fifteen student stipends, housing and research supplies. Early and active participation in research will spark the interest of highly motivated younger students in majoring in science and lead them into long-term, productive research collaborations with faculty. Support from the Sherman Fairchild Foundation allows us to offer our students internship experiences *at Williams* that are equal in quality to those they might get at research universities or institutes.

Clare Boothe Luce Research Scholarships

Funded by the Luce Foundation, the Clare Boothe Luce research scholars grant will increase the number of female students at Williams who declare majors in astrophysics, computer science, geosciences, mathematics/statistics, and physics and to encourage a larger proportion of women in these majors; to conduct honors thesis research and to pursue doctoral degrees and careers in science. The Clare Boothe Luce research grant will support three cohorts, of eight women each, with funding for summer research stipends, research supplies and equipment, and attendance at professional conferences. Williams College will support the Clare Boothe Luce scholars program with funds for a second year of honors theses related research and to fund programmatic enhancements such as visits from CBL professors and cohort-building events during the academic year.

SMALL

Each summer the Math/Stats department runs a 10 week Research Experience for Undergraduates (REU) Program to introduce students to research. Named SMALL after the leading letters of the last names of the five founders, it's now in its 27th year. Funded primarily by the NSF and Williams, about 30 students each summer work in small groups closely with their advisor on open research problems, which are frequently in current, active areas of mathematics and statistics. Over 500 students have participated, now writing more than 10 papers each year and giving talks on their work the world over, from the Joint Meetings of the math societies to meetings in Canada, Japan, Spain, ... Recent topics include combinatorics, commutative algebra, ergodic theory, geometric origami, geometry, knot theory, multidimensional continued fractions, mathematical physics, number theory, probability and statistics. See http://math.williams.edu/small/ for more information.

MAJOR PROGRAMS IN THE SCIENCES

The **Astronomy** Department offers courses for students interested in studying and learning about the universe, and who would like to be able to follow new astronomical discoveries as they are made. Students can choose between broad nonmathematical survey courses (ASTR 101, 102 or 104) or a more intensive introductory course (ASTR 111) designed for those planning further study in astronomy or another science. All students in the introductory courses use the 24 inch telescope and other telescopes and instruments on the observing deck to study astronomical objects. The astrophysics major, administered jointly with the Physics Department, is designed primarily for students who plan graduate study in astronomy, astrophysics or a related field. The major emphasizes the structure of the universe and its constituents – including the Sun, stars and star clusters, galaxies and galaxy clusters, quasars and active galaxies, and the cosmic background radiation – in terms of physical processes. Majors in astrophysics usually begin their program with Introduction to Astrophysics (ASTR 111) as well as introductory physics courses. Intermediate and advanced level seminars introduce majors to current research topics in astronomy, while parallel study of physics completes their preparation for graduate work in astronomy or employment in a related field. The astronomy major is designed for students with a serious intellectual interest in learning about modern astronomy, but who do not wish to undertake all of the physics and math required for the more intensive astrophysics major. The astronomy major emphasizes understanding the observed properties of the physical systems that comprise the known universe. Students that are considering a major in the Astronomy Department, or a double major including Astronomy or Astrophysics, should consult with members of the Department about appropriate beginning courses. Independent research, extensive use of observational and image processing computer facilities, fieldwork at remote observatories or on eclipse expeditions and close working relationships with faculty are hallmarks of the Astronomy and Astrophysics majors.

The Williams College **Biology Department** curriculum has been designed not only to keep pace with new developments in the field, but also to afford students as broad a base as possible for understanding the principles governing life processes. Four courses, The Cell (BIOL 101), The Organism (BIOL 102), Genetics (BIOL 202) and a 400 level senior seminar, are required for the major. In addition, five electives may be selected from a wide range of courses including those in cellular biology, immunology, biochemistry, molecular biology, developmental biology, physiology, animal behavior, neurobiology, ecology and evolution. Over the past few years several new courses have been added to our curriculum: Integrative Bioinformatics, Genomics and Proteomics (BIOL 319) as well as new literature based senior level courses dealing with topics of current research interest including Developmental and genomic evolution of animal design and two 400 level tutorials. Every course changes from year to year to emphasize the latest concepts and to introduce and integrate new techniques and instrumentation used in modern biological research. Although the biology major is specifically designed to provide a balanced curriculum in the broader context of the liberal arts for any interested student, it is also an excellent preparation for graduate studies in medicine and life sciences.

The **Biochemistry and Molecular Biology (BiMo) Program** is designed to provide students with an opportunity to explore living systems on the molecular level. Biochemistry and molecular biology are dynamic fields that lie at the interface between biology and chemistry. Current applications range from the diagnosis and treatment of disease to enzyme chemistry, developmental biology, and the engineering of new crop plants. After completing the introductory biology and chemistry courses and organic chemistry, a student would normally take the introductory course in the program: Biochemistry I – Structure and Function of Biological Molecules (BIMO 321) and Biochemistry II Metabolism (BIMO 322). These courses, taken in conjunction with courses in genetics and molecular genetics, establish a solid background in biochemistry and molecular biology. The advanced courses and electives available from the chemistry and biology department offerings encourage

students' exploration of individual interests in a wide variety of topics. A senior capstone course, Topics in Biochemistry and Molecular Biology (BIMO 401), gives students the chance to explore the scientific literature in a variety of BIMO related research areas. Completion of the BIMO Program provides exceptional preparation for graduate study in all aspects of biochemistry, molecular biology, and the medical sciences.

Through a variety of individual courses and sequential programs, the **Chemistry Department** provides an opportunity for students to explore chemistry, an area of important knowledge about ourselves and the world around us. For those who elect to major in chemistry, the introductory course, Introductory Concepts of Chemistry (CHEM 151, or for those who qualify, CHEM 153 or CHEM 155), is followed by intermediate and advanced courses in organic, inorganic, physical, and biological chemistry. These provide a thorough preparation for graduate study in chemistry, chemical engineering, biochemistry, environmental science, materials science, medicine and the medical sciences. Advanced independent study courses focus on the knowledge learned in earlier courses and provide the opportunity to conduct original research in a specific field. For those in other majors who wish to explore the science of chemistry, the Chemistry Department offers courses that introduce the fundamentals of chemistry in a context designed to provide students with an enriching understanding of our natural world. Chemistry courses for non-majors include: Chemistry and Crime: From Sherlock Holmes to Modern Forensic Science (CHEM 113); AIDS: The Disease and Search for a Cure (CHEM 115); and Chemistry and Physics of Cooking (CHEM 116).

Computers play enormously important roles in areas as diverse as education, business, industry, and the arts. The **Computer Science Department** seeks to providestudents with an understanding of the nature of computation and the ability to explore the great potential of computers. The Department recognizes that students' interests in computer science vary widely, and attempts to meet these varying interest through 1) its major program; 2) a selection of courses intended for those who are interested primarily in an introduction to computer science; 3) recommended course sequences for non-majors who want a more extensive introduction to computer science in general or who seek to develop some specific expertise in computing for application in some other discipline. The computer science major equips students to pursue a wide variety of career opportunities. It can be used as preparation for a career in computing, for graduate school, or to provide important background for the student whose future career will extend outside of computer science. The first course for majors and others intending to take more than a single computer science course is Introduction to Computer Science (CSCI 134). Upper-level courses include computer organization, algorithm design and analysis, principles of programming languages, computer networks, digital design, distributed systems, advanced algorithms, theory of computation, computer graphics, artificial intelligence, machine learning, operating systems, and compiler design. For those students interested in learning more about important new ideas and developments in computer science, but who are not necessarily interested in developing extensive programming skills, the department offers three courses. The Socio-Techno Web (CSCI 102) introduces many fundamental concepts in computer science by examining the social aspects of computing. Creating Games (CSCI 107) introduces important concepts in computer science through the design and analysis of games, and The Art and Science of Computer Graphics (CSCI 109) introduces students to the techniques of computer graphics.

The **Program in Environmental Studies** commenced in 1970, after the 1967 establishment of The Center for Environmental Studies (CES) at Williams. The Major in Environmental Science was approved by the faculty in 2010. The ENVI Program allows students to major in traditional departments while taking a diverse series of courses in an integrated, interdisciplinary examination of the environment. Environmental Science majors can choose one of three tracks (Environmental Biology, Environmental Geoscience, or Environmental Chemistry) while taking a diversity of required methodological and project courses that represent the breadth and depth of a major. Both the ENVI Program and the ENVS Major are designed to help students understand

the complexity of issues and perspectives and to appreciate that many environmental issues lack distinct boundaries. The goal is to help students become well-informed, environmentally literate citizens of the planet who have the capacity to become active participants in their communities from the local to the global scale. The major and program seek to develop abilities to think in interdisciplinary ways and to use holistic-synthetic approaches in solving problems while incorporating the knowledge and experiences they have gained as undergraduates at the College.

CES maintains and operates the 2600 acre Hopkins Memorial Forest and its Rosenburg Center Field Station, 1.5 miles from campus, and is in the final phase of adding lands of the old Wire Bridge Farm along the Hoosic River near the Vermont border. The Environmental Science Laboratory in the Morley Science Laboratory building is a joint venture between the CES and the science division at Williams and is overseen by Technical Assistant jay Racela.

Professor David Dethier serves as chair of the Hopkins Memorial Forest Users Committee and continues to supervise activities in the Environmental Science Laboratory. Professor Hank Art is the Principal Investigator on a 5 year grant from the Luce Foundation Environment and Policy Program to incorporate renewable energy and sustainability into the environmental studies curriculum. He, along with the Hopkins Forest Manager Drew Jones, continued their collaboration with faculty and students from Massachusetts College of Liberal Arts and Berkshire Community College monitoring amphibian and reptile utilization of two vernal pools near Hopkins Forest.

The study of vegetation and landscape changes in the Hopkins Memorial Forest and ongoing meteorologic and hydrologic measurement have led to the designation of the Hopkins Memorial Forest as a gradient site in the National Ecological Observatory Network (NEON). Williams College is a founding member of NEON with David Dethier as our institutional representative.

Geosciences majors develop an understanding of the solid Earth and its fluid envelopes, including its physical and biological evolution and how it might change in the future. Internal forces shape mountain ranges and ocean basins. Waves, rivers, glaciers and wind sculpt the surface of the Earth, generating the landscapes all around us. Fossils entombed in sedimentary rocks supply the evidence for life's origins and evolution, and record Earth's changing climates. Introductory courses open to all students include The Co-Evolution of Earth and Life (GEOS 101); An Unfinished Planet (GEOS 102); Global Warming and Natural Disasters (GEOS 103); and Oceanography (GEOS 104). Geosciences courses provide the foundation for a professional career in the earth sciences, a background for economic pursuits such as the marketing of energy or mineral resources, or simply an appreciation of our human heritage and physical environment as part of a liberal arts education. Students may choose electives to focus in depth in a particular field: for example, students with life-science interests may choose courses concentrating on geobiological topics; those interested in the dynamic solid Earth may elect courses dealing with structure and tectonics; we also have a suite of climate related courses, in addition to ones that are environmentally themed. Most of our courses are accessible to both majors and non-majors

The Department of **Mathematics and Statistics** is designed to meet two goals: introducing the central ideas of mathematics, and developing problem solving ability by teaching students to combine creative thinking with rigorous reasoning. The department has recommended coursework for students interested in applied mathematics or other sciences, engineering, graduate school in mathematics, statistics, actuarial science, and teaching. The major requires calculus, linear algebra, a course in applied/discrete mathematics or statistics, two core courses in algebra and analysis, two electives, a senior seminar, and participation in the undergraduate colloquium.

The **History of Science**, fundamentally an interdisciplinary subject, traces the historical development of the social relations between science and society as well as the development and mutual influence of scientific concepts. The "external" approach emphasizes the relations between science and society, attempting to relate changes and developments in each to the other. The

"internal" approach concerns primarily the ways in which technical ideas, concepts, techniques, and problems in science developed and influenced each other. Courses offered in the History of Science Program introduce students who do not major in a science to the content and power of the scientific and technological ideas and forces which have in the past transformed western civilization and which are today transforming cultures the world over. Science majors are introduced to the historical richness and variety of scientific activity, as well as to how that activity reflects upon the changing nature of science itself and upon science's relationship to society as a whole.

The Program in **Neuroscience** consists of five courses including an introductory course, three electives, and a senior course. In addition, students are required to take two courses, Biology 101 and Psychology 101, as part of the program. Neuroscience (Neuroscience 201) is the basic course and provides the background for other neuroscience courses. Ideally, this will be taken in the sophomore year. Either Biology 101 or Psychology 101 serves as the prerequisite. Electives are designed to provide in depth coverage including laboratory experience in specific areas of neuroscience. At least one elective course is required from among those cross-listed in Biology (Group A) and at least one is required from among those cross-listed in Psychology (Group B). The third elective course may also come from Group A or Group B, or may be selected from other neuroscience related courses upon approval of the advisory committee. The senior course, Topics in Neuroscience (Neuroscience 401) is designed to provide an integrative culminating experience.

The **Physics** Department offers two majors, the standard physics major and, in cooperation with the Astronomy department, an astrophysics major. Either route serves as preparation for further work in pure or applied physics, astronomy, other sciences, engineering, medical research, science teaching and writing, and other careers requiring insight into the fundamental principles of nature. Physics students experiment with the phenomena by which the physical world is known, and the mathematical techniques and theories that make sense of it. They become well-grounded in the fundamentals of the discipline: classical mechanics, electrodynamics, optics, statistical mechanics, and quantum mechanics. We offer a variety of summer research opportunities in theoretical and experimental physics, and invite interested students at all stages of their Williams careers to participate. Physics offers several tutorial courses each year, and nearly all of our majors take more than one. Many majors do senior honors projects, in which the student works individually with a faculty member in either experimental or theoretical research.

The **Psychology** Department offers a wide variety of curricular and research opportunities for both major and non-major students. Courses are grouped into the areas of behavioral neuroscience, cognitive psychology, developmental psychology, social psychology, clinical psychology, and psychology of education. After completing Introductory Psychology (PSYC 101), majors take Research Methods and Statistics (PSYC 201), in which they learn the tools used to generate knowledge in psychology, and at least three 200 level courses, which are comprehensive surveys of each of the subfields. They then take the 300 level courses, which are advanced seminars; many of these are lab courses in which students do an original empirical study, others are discussion seminars, and some are also tutorials or writing intensive courses. In each, the professors expose students in depth to their specialty areas, and students read and discuss primary literature. The major sequence ends with a cap stone course, Perspectives on Psychological Issues (PSYC 401), a discussion/debate oriented seminar. A variety of research opportunities are offered in the psychology department through research assistantships, independent study, senior thesis work and the Bronfman Summer Science Program.

The psychology major provides an opportunity for liberal arts students to consider the nature of mind and behavior from different perspectives. It provides sound preparation for graduate study in both academic and professional fields of psychology and is relevant to careers in education, business, law, and medicine. The latest external review of the department highlighted the "rigorous curriculum that exposes students to the core areas of the discipline; provides training in the methods

and writing of psychologists; engages students in the development of research ideas, hypothesis testing, data collection and analysis; and provides an opportunity to get senior majors engaged in cross disciplinary discussion and writing." The reviewers found that the depth and breadth of these activities, particularly our 300 level lab courses, "set Williams apart from even the best undergraduate programs in psychology" as well as undergraduate programs at major universities, and "are likely contributors to the success of Williams in producing students who are coveted by the finest Ph.D. programs in the sciences." In addition to the psychology major curriculum, our students often become concentrators in related programs across the college including Cognitive Science, Legal Studies, Public Health, and Neuroscience.

The role that **Science and Technology Studies (STS)** have played in shaping modern industrial societies is generally acknowledged, but few members of those societies, including scientists and engineers, possess any understanding of how that process has occurred or much knowledge of the complex technical and social interactions that direct change in either science or society. The Science and Technology Studies Program is intended to help create a coherent course of study for students interested in these questions by providing a broad range of perspectives. Courses examine the history or philosophy of science and technology, the sociology and psychology of science, the economics of research and development and technological change, science and public policy, technology assessment, technology and the environment, scientometrics, and ethical value issues.

The **Tutorial Program at Williams** is in many ways one of its signature features. And for good reason. In these classes, pairs of students meet for intensive, weekly two-on- one interactions with faculty members, taking leadership roles in their own education. While the traditional format for such courses in humanities disciplines involves students writing and critiquing papers on a weekly basis, the various science departments at Williams have embraced the essential value of the tutorial format, in a variety of discipline-specific ways. These include reading, presenting, and critiquing papers from the current scientific literature, or in other cases solving and then discussing and presenting solutions to challenging problem set questions on advanced topics. We find that the independence, critical thinking, and oral presentation skills demanded of students in these courses provide the ideal preparation for graduate study as well as a many other post-graduate activities.

The **Williams Mystic Maritime Studies Program** is an interdisciplinary, cross-divisional program that examines the literature, history, policy issues, and science of the ocean. Because of the interdisciplinary nature of the course of study, the professors and concentrators have a variety of majors and primary areas of study, ranging from theatre to economics to geology to history. All share, however, a deep respect for the world's oceans. In 1975/76 the Williams faculty and the Mystic Seaport's board of directors voted to establish the Williams Mystic Program in American Maritime Studies. In 2002/03 Professor Ronadh Cox and several other Williams faculty wrote a proposal for a concentration in maritime studies. In the fall 2003, the faculty voted almost unanimously to establish the Maritime Studies concentration. This new concentration is designed to utilize the Williams Mystic program, but requires courses both before and after the Mystic semester at Williams. Candidates for the concentration in Maritime Studies must complete a minimum of seven courses: the interdisciplinary introductory course, Oceanography (GEOS 104), four intermediate core courses at Williams Mystic, an elective, and the senior seminar.

WINTER STUDY 2014 SCIENCE OFFERINGS

ASTR 25: Astronomy in the Twenty-First Century: California and Washington

In the late 19th-century, the center of astronomy moved from the east (where Alvan Clark, who had made his first telescope for Williams College in 1851 ultimately made what is still the largest refracting telescope in the world, in Wisconsin in the 1890s) to California, where first the 100" and then the 200" telescopes on Mt. Wilson and Palomar Mountain, respectively, were the largest in the world from 1917 through 1995. The current largest generation of telescopes, about 400 inches across in Hawaii (built by Caltech and the University of California system) and Spain, are being superseded by 30-meter (1200-inch) telescopes, the Thirty Meter Telescope (www.tmt.org) and the Giant Magellan Telescope (gmto.org), both based in California, as well as by the 39-meter European Extremely Large Telescope (E-ELT; www.eelt.org). We will visit the headquarters of the TMT and of the GMT in Pasadena, California, to learn about the optical, laser, mechanical, and other aspects of the planning, as well as NASA's ExoPlanet Science Center at Caltech. We will also visit the latest observational facilities at the Mt. Wilson Observatory, including the new interferometric array, and at the Palomar Observatory. Our two weeks of travel will follow participation in the annual meeting of the American Astronomical Society near Washington, DC, where these and other contemporary observational projects, such as the Large Synoptic Survey Telescope, will be discussed. Schedule: January 5-10 in and near Washington, DC; January 10-20 in and near Pasadena, CA. We will finish WSP with discussion and consideration in Williamstown of what the current status of observational astronomy is.

BIOL 21: Science Beyond Williams

Are you interested in hands-on experience in a science-related field beyond the Purple Valley? Are you curious to explore science in a university or medical school research lab, a government agency, or a not-for-profit organization? This course is designed to help students take part in scientific work or research going on outside of Williams in order to provide them with a broader sense of what it is like to work in a professional scientific setting. Any field of science or technology can be explored via this course.

CHEM: 10 Zymurgy

An introduction to the science, history, and practice of brewing beer. This course aims to supply the general chemical concepts and hands-on technical experience necessary to enable creative brewing and an appreciation of diverse beer styles. Lecture topics include the biochemistry of yeast, sanitary practices, analytical methods, malt types and preparation, extract vs. all-grain brewing, hops, water chemistry, the chemistry of off-flavors, and beer judging. In the lab, students progress from brewing a commercially available extract kit to producing a full-grain brew of their own original recipe. The class will also meet professional brewers and microbiologists during a private tour of a local brewery.

CHEM 12: Tech Entrepreneurship

Designed for students interested in careers in biotechnology and information technology, this course will give students a working knowledge of how tech startups work. We will utilize a case study approach that will pair each student with a Boston area startup (host). Students will first perform a retrospective analysis of each host company through literature review, patent review, and phone interviews. Students will then visit host companies individually to tour and meet with key staff. Following that, students will develop a forward-looking analysis of markets, product strategies, and growth. Students will summarize their findings in a case study to be submitted as the final project and shared with respective host companies.

Examples of the kinds of startups students might study include The Echo Nest in Cambridge, MA, Foundation Medicine in Cambridge, MA and T2 Biosystems in Lexington, MA. The course will include a mandatory two-day trip to Boston for individual and class meetings.

CHEM 14: Beyond Hooking Up: Creating Meaningful Relationships

Looking back on past loves and crushes, have you ever wondered "What on earth was I thinking?!" or "Why do I keep picking the wrong guys/girls for me?" While intense sexual attraction or urges may

first call the shots, people who take the time to carefully choose and build caring, mutual relationships tend to be happier, healthier and more successful in their lives than those who don't. So how do we get there from here and make sense of all this? Well, no matter where you are on the dating spectrum, this self-exploration and relationship-skill-building course is for you if you are ready to learn how to follow your heart AND your mind to co-create a fulfilling relationship within the vortex of the "hook up" culture. The Myers-Briggs Type Indicator, How to Avoid Falling In Love with A Jerk, and Keeping the Love You Find. Curricula will guide this introspective, interactive relationship mastery course through meaningful discussions and exercises that explore the common issues, dirty fighting tactics, subconscious directives and emotional allergies that often sabotage relationships. Experiential exercises, personal experiences and journaling will also give you the opportunity to practice effective communication and conflict resolution skills that honor the constructive use of differences and promote intimacy.

CSCI 13: The Williams Game Jam

The main goal of the course is for students to successfully participate in a game jam; a concentrated creative effort with the primary goal being the production of a full video game by an individual. In the first week, there will be an introductory lecture explaining the basics of game jams, familiarizing students with the tools available, and demonstrating games produced in other successful game jams. The rest of in-class time will be lab sessions where students will work on their individual game jam games. Game jams are traditionally 24-48 contiguous hours where participants can work on their game; we will modify the experience to fit in the 20 hours-per-week schedule of Winter Study courses. We will have 2 full game jams during the course, with an intermediate period preparing for the second jam.

CSCI 14: Bots, Malware, and The Underground Economy

It is estimated that between 10 and 20% of all broadband connected systems in the US are infected with some form of bot or malware. With the rapid growth of android based infections, this problem is rapidly migrating from Windows PCs onto phones, tablets, and other machines. Malware based attacks have stolen millions, perhaps billions of dollars over the last few years, through credit/bank fraud and identity theft. Malware based DDOS have knocked major corporations, and even some governments, offline. This, in turn, has caught the attention of governments around the world, with most passing some new form of cybersecurity legislation as a result.

This course will sit at the intersection of software, cybersecurity policy, and the underground economy. Students will learn about bots (what they do, why they're used, and how they work), the underground economy (from the dropper that infects the machine to the herder who runs the infection to mules that clean out the bank accounts), and how governments have reacted with modern cybersecurity legislation. Students will examine past and current bots and malware, they will review past criminal cases (and possibly some current ones, depending), and they will review proposed and current US and foreign cybersecurity legislation.

Most reading material for this class will be made up of online articles, papers, and blog posts...although some printed books may be used. The class format will consist of reading and research assignments, with individual (or pairs of) students being assigned specific areas to present to the class at the next meeting. These presentations will then lead to class discussion, and additional lecture from the professor if required. If possible, there will be a lab exercise to analyze live malware.

GEOS 15: Geology of the National Parks (Same as ENVI 15)

A vicarious trip through a variety of national parks and monuments in the U.S. and Canada, with emphasis on the geological basis for their spectacular scenery. Areas to be studied will be selected in order to portray a wide range of geologic processes (volcanism, desert erosion, mountain-building, glaciation, etc.). The class will meet most mornings during the first two weeks for highly illustrated lectures and discussions, supplemented by the interpretation of topographic and geologic maps and by out-of-class study of rock samples. Readings will be from a paperback text *(Parks and Plates)* as well as short publications by the U.S. Geological Survey and various natural history associations. The second part of the month will involve independent study and the

preparation of an oral presentation about the geology of a park or monument of the student's choice. The student oral reports during the final week will be comprehensive and well illustrated, using PowerPoint, maps, samples and other reference materials. A detailed outline and bibliography will be distributed by the presenter at the time of the report.

MATH 12: The Mathematics of Legos

Since their introduction in 1949, Legos have challenged and entertained millions. In this course we'll explore some of the connections between Legos, mathematics and popular culture. Topics include the following:

Given a collection of Lego bricks, how many different structures may be built using only the standard snapping? The analysis requires us to develop some of the theory of combinatorics, and deal with the issue of two configurations that look different but are the same after standard moves (such as rotation, flipping about a line, and so on). We will use this problem as a springboard to study related issues in mathematics, especially in game theory.

Given a collection of Lego bricks, how can you build desired objects? This ranges from building miniature replicas to functional items (which can now be done through 'special' pieces).

The business model of the Lego Group has changed greatly since the '40s and '50s. While they still hold their products to the highest standard, the generic themes (such as city and space) are now greatly supplemented by various alliances (Superheros, *Star Wars*, *Harry Potter*, *Lord of The Rings*, ...). We will examine some business cases involving Lego in order to get a sense of how companies determine priorities, including a discussion of the recent Lego Friends line and gender issues.

One of the greatest computational advances is the ability to parallelize certain computations. Some programs must be run in order, where Step N cannot be done until Step N–1 is completed. Other problems, however, are such that multiple steps can be done simultaneously; examples include GIMPS (the Great Internet Mersenne Prime Search), SETI, mapping the human genome, factorizing numbers, and checking the Riemann Hypothesis. We will discuss the general theory of such computations and its effect on attacking important problems. We will implement our skills by parallelizing the building of the LEGO Star Wars Superstar Destroyer; as it is 3152 pieces, we see the need of having a good, efficient strategy if we are to complete it during the course!

MATH 10: A Revolution: Physical Mathematics

Through most of history, when math and science have interacted, it has overwhelmingly been the case that it is the mathematics that has shaped the science: Mathematics => Science.

In the early 1980s, the arrow was reversed, resulting in a profound change in how new mathematics is being discovered. This revolutionary approach is increasingly being called Physical Mathematics. This course is a popular introduction to this revolution. For example, we explore the intimate link between how heat flows in a frying pan, how stock prices change and how curvature of three dimensional objects can vary. We investigate how properties of real numbers have been discovered by examining the mathematics behind why ice melts. We see the truly remarkable idea that understanding particle physics can explain how many conics are tangent to five fixed conic curves in the plane (here the point is these two types of problems should have no obvious connection). Future generations will see Physical Mathematics as one of the key ideas of our era.

PHYS 13: 3D Printer Construction: Beyond the Basics

3D printing is a technology used to create three dimensional objects from digital information. During Winter Study 2013, students built and operated the first 3D printer on the Williams campus. The printer is a "RepRap," based on an open-source project aimed at developing a self-replicating 3D printer. In this course, we will design and build hardware to extend the applications and capabilities of the RepRap 3D printer. We will modify the printer to a dual print-head design. With two heads, the printer will be capable of creating objects with two different materials, or printing at different resolutions. The second printing extruder can also print a water soluble, thermo-plastic support structure, enabling the construction of items with overhangs and complex

designs. Separately, we will fabricate a plastic filament extruder that will manufacture low-cost printing filament from raw materials, including recycled plastics. In the final week, we will concentrate on creating complex, functional or artistic objects from our own CAD designs, culminating with a presentation of the hardware and objects. The printer and filament extruder created by the class will remain in the Bronfman Science Shop, available throughout the year to support faculty and student projects.

PSYC 12: Alcohol 101: Examining and Navigating the College Drinking Scene

Seventy-two percent of college students report that they used alcohol at least once within the past 30 days. Here is the line between fun and danger? This course will examine the realities of the role of alcohol in the social lives of college students. Students will engage in active discussions of readings, videos, and myths vs. facts, as well as personal observations and opinions. Participants will learn scientific facts about alcohol, including how it gets metabolized in the body differently in men and women, and how to recognize and respond to the signs of alcohol poisoning. Films will include evocative footage and interviews, such as *College Binge Drinking and Sober Reflections*. We will hear from emergency personnel about alcohol-related medical emergencies and problem-solve strategies to stay safe when choosing to use alcohol. Statistical data from colleges here in the Northeast will be reviewed, including survey results from the Core Institute and the Harvard School of Public Health Alcohol study.

Students in *GEOS 312T: Mass Extinctions* examining evidence of an ancient impact event in the Marche region of Italy

SCIENCE CENTER PROGRAMS

The Science Center complex links the Bronfman Science Center with the Thompson Biology, Chemistry, and Physics Laboratories, Schow Library, and the Morley Science Laboratory; Clark Hall completes the Science Center complex. Serving as the home for astronomy, biology, chemistry, computer science, geosciences, history of science, mathematics and statistics, physics, and psychology, this facility fosters interdisciplinary interaction among faculty and students within the Sciences. This interaction is facilitated through the sharing of core research equipment and services; through interdepartmental programs; and, to a great extent, by the proximity of faculty with common interests regardless of their departmental affiliation. Several Science Center activities promote this further by specifically encouraging discourse among scientists at Williams. This is carried out in a number of ways, including informal faculty presentations at Tuesday lunches (during both the summer and academic year), the maintenance of a weekly science calendar, the annual publication of the Report of Science at Williams, and faculty research lectures sponsored each semester by the local Sigma Xi chapter.

The Science Center administration coordinates the distribution of more than $650,000 in internal funds annually to support faculty research projects and student research participation. In addition, the Williams faculty have historically earned more outside research support from federal agencies than any other non-Ph.D.-granting institution. In 2013-2014, there were eight individual Williams College science faculty members with active NSF grants totaling more than $3.5 million. Faculty and student research projects and summer research opportunities supported by internal divisional funds, as well as those supported by external grants, are detailed below and in the various departmental reports.

Summer Student Research Participation

Summer Research Fellowships were awarded to 174 individuals at Williams during the summer of 2014. Many of the summer research students are entering their senior year and beginning work that will lead to senior honors research. A new grant from the Sherman Fairchild Foundation awarded fellowships targeted to rising sophomores and juniors who were getting their first taste of independent research. This summer was also the start of a new three-year grant from the Clare Boothe Luce Program of the Henry Luce Foundation that will fund up to eight sophomore women majoring in astrophysics, computer science, geosciences, mathematics, statistics and physics. In addition to their summer stipends, Clare Boothe Luce Scholars were each granted $3,000 for research materials and $3,000 for conference related expenses. The summer research program also included students from outside Williams who were supported both by the NSF/REU "SMALL" program in the Mathematics and Statistics department, as well as by the Keck Foundation.

The summer is a time when both faculty and students can focus intensively on research projects, but in a more relaxed atmosphere without the added responsibilities of formal coursework. In addition to the actual research experience, the Science Center sponsors a weekly Tuesday luncheon featuring a member of the faculty lecturing on current research and a poster session at the end of the summer where summer research students present their results.

Support for summer research, which includes a $400/wk stipend and free housing on campus, comes from a variety of sources including internal College funds, external grants to individual faculty, foundation grants, and endowed fellowships provided by generous donations from alumni and friends of the sciences. The Wege-Markgraf endowment, gifts from Peter Wege and the Class of 1952 in honor of J. Hodge Markgraf ’52, Emeritus Professor of Chemistry, supports summer research fellowships in chemistry. The John A. Lowe III 1973 fund also supports summer research fellowships in chemistry. The Betty and Lewis Somers ’48 Student Summer Internships Fund and the Thomas Synnott Fund support summer research fellowships in physics. The Williams Bicentennial Psychology Scholarship Fund supports summer research fellowships in psychology. The Whitehead Scholarship Fund, a gift from John Whitehead ’67 to provide an opportunity for Williams students and faculty to interact with scientists at the prestigious Whitehead Institute. The Arnold Bernhard Foundation Endowed Summer Science

Fellows Program, made possible by the generosity of Jean Buttner, Williams Trustee from 1982-1997, and the Class of 1951 Summer Research Fellowship fund supports summer research fellowships across divisions.

Summer Science Research Funding Sources

Funding source	number of 10 week positions funded
American Physiological Society	1
Arnold Bernhard Foundation Summer Fellowships	17
Bronfman Science Center Fund	3
Camille & Henry Dreyfus Foundation	1
Clare Boothe Luce Scholarships for Women in Science	7
Class of 1951	4
Finnerty Fund - Applied Mathematical Research	3
Herbert J. Louis 1950 SSR Fellowship	1
Keck Geoscience	1
Keck Northeast Astronomy Consortium	1
Lowe 1973 Chemistry Fellowships	7
Markgraf JH 1952 Fellowships	4
NASA	1
NSF/NIH grants to individual faculty	11
NSF/Small Program Mathematics	14
Petroleum Research Corporation - Chemistry	1
Science Center funds (SO & DISC)	36
Sherman Fairchild Foundation	15
Somers B & L 1948 Physics Internships	1
Sperry Fund - Geosciences	0.3
Summer Science Program Alums	6
Synott TW 3rd 1958 Physics Internshipsw	0.8
Wege Markgraf Chemistry Fellowships	5
Williams Bicentennial Psychology Scholarship	1
Whitehead Scholars Program - Biology	2
Total number of 10 week stipends	144.1

2014 Summer Science Students and their Faculty Advisors

Astronomy

Muzhou Lu	Jay Pasachoff
Michael May	Steven Souza
Adam Schiff	Jay Pasachoff
Christina Seeger	Jay Pasachoff
Sarah Stevenson	Steven Souza

Biology

Bethany Berry	Steven Zottoli
Brent Bomkamp	Derek Dean
Ethan Borre	Steven Swoap
Lauren Casey	Hank Art
Achala Chittor	Lois Banta
Ivy Ciaburri	Manuel Morales
Isaiah Clark	Lois Banta
Caitlin Conlon	Manuel Morales
Sarah Cottrill	Derek Dean
Raza Currimjee	Lois Banta
Ruby Froom	Tim Lebestky
Emily Gaddis	Claire Ting
Garrick Gu	Smith, David
Amelia Hidalgo	Steven Swoap
Michelle Higgins	Savage
Intekhab Hossain	Steven Swoap
Elissa Hult	Claire Ting
Abigail Kelly	Joan Edwards
Adin Krieger-Benson	Savage
Catherine Landers	Susan Engel
Brian Levine	Dan Lynch
Alexander McInturf	Manuel Morales
Michael McPhee	Luana Maroja
Alexander Meyer	Luana Maroja
Ashley Ngo	Steven Zottoli
Elise Pitmon	Tim Lebestky
Molly Prindle	Hank Art
Anna Ryba	Matt Carter
Diana Sanchez	Claire Ting
Emily Shea	Dan Lynch
Kairav Sinha	Susan Engel
Alice Stears	Joan Edwards
Gabe Stephens	Heather Williams
Zihan Su	Lois Banta
Ali Tafreshi	Heather Williams
Zoe Trutner	Matt Carter
Maria Vincent-Allende	Steven Swoap
Daniela Zarate	Luana Maroja

Biology-Mystic

Rebecca Barnard	James Carlton
Andreas Dunchus	James Carlton

Center for Environmental. Sciences

Hannah Brown	Jay Racela
Lauren Moseley	Jay Racela

Chemistry

Dylan Barber	Sarah Goh
Cecilia Castellano	Charles Lovett
Selena Castro	Anne Skinner
Katherine Cavanaugh	Richardson (& Thoman)
Tamuka Chidanguro	Chris Goh
Matt Davies	Chris Goh
Kevin Eagan	Anne Skinner
Mmaserame Gaefele	Charles Lovett
John Hammond	Jimmy Blair
Tony Huang	Jimmy Blair
Taylor Jackvony	Jimmy Blair
Willis Koomson	Charles Lovett
Claire Lidston	Chris Goh
Miguel Mendez	Charles Lovett
Terrance Mensah	Anne Skinner
Lindsey Moran	Jimmy Blair
Kimthanh Nguyen	Chris Goh

Oladeji Odewade	Charles Lovett
Ian Outhwaite	Becky Taurog
Denise Park	Sarah Goh
Allison Rowe	Thoman (& Richardson)
Marissa Shieh	Thoman (& Richardson)
Chris Stefanik	Richardson (& Thoman)
Gregory Stone	Peacock-Lopez
Katherine Susa	Becky Taurog
Kaleb (Yitong) Tseo	Becky Taurog
Edgar Vega	Charles Lovett

Computer Science

Sarah Abramson	Jeannie Albrecht
Derrick Bonafilia	Duane Bailey
Samuel Donow	Morgan McGuire
Daniel Evangelakos	Morgan McGuire
Gordon Finnie	Jeannie Albrecht
Matthew LaRose	Andrea Danyluk
Jamie Lesser	Tom Murtagh
Alexander Majercik	Tom Murtagh
Austin Paul	Tom Murtagh
Jose Raventos	Bill Lenhart
Diwas Timilsina	Duane Bailey
Kelly Wang	Morgan McGuire
Lauren Yu	Andrea Danyluk

Geosciences

Caroline Atwood	Mea Cook
Jorge Castro	Mea Cook
Nell Davis	Bud Wobus
Joshua Harrington	Ronadh Cox
Mary Ignatiadis	Phoebe Cohen
Spencer Irvine	Phoebe Cohen
Victor Major	David Dethier
Rosalia Pembroke	Ronadh Cox
Laura Stamp	Phoebe Cohen
Kelly Tellez	Phoebe Cohen
Nakita Van Biene	Mea Cook
Oona Watkins	Ronadh Cox
Will Wicherski	David Dethier

Geosciences Mystic

Katherine Enright	Lisa Gilbert
Alana McGillis	Lisa Gilbert

Mathematics & Statistics

Owen Barrett	Steven Miller
Andrew Best	Steven Miller
Wyatt Boyer	Frank Morgan
Phillip Brockman	Klingenberg
Bryan Brown	Frank Morgan
Julien Clancy	Cesar Silva
Craig Corsi	Loepp, Susan
Patrick Dynes	Steven Miller
Xixi Edelsbrunner	Steven Miller
Rina Friedberg	Cesar Silva
Feixue Gong	Mihai Stoiciu
Karen Huan	Steven Miller
Indraneel Kasmalkar	Cesar Silva
Benjamin Kaufman	Steven Miller
Isaac Loh	Cesar Silva
Alyssa Loving	Frank Morgan
Blake Mackall	Steven Miller
Nathan Kornell McCue	Klingenberg
Brian McDonald	Steven Miller
Olivia Meyerson	Mihai Stoiciu
Jeremy Meza	Mihai Stoiciu
Jasmine Powell	Steven Miller
Matthew Radford	Heggeseth
Christina Rapti	Steven Miller
Patrick Ryan	Steven Miller
Sarah Tammen	Frank Morgan
Kimsy Tor	Steven Miller
Sahana Vasudevan	Cesar Silva
Abigail Ward	Mihai Stoiciu
Madeleine Weinstein	Steven Miller

Karl Winsor	Steven Miller

Neuroscience

Jacob Kim	Martha Marvin
Anuj Shah	Martha Marvin
Sarah Wieman	Martha Marvin

Physics

Samuel (Teddy) Amdur	Fred Strauch
Benjamin Augenbraun	Protik Majumder
Talia Calnek-Sugin	Protik Majumder
Allison Matt Carter	Ward Lopes
Saumen Cheng	Protik Majumder
Weng-Him Cheung	Fred Strauch
Julia Cline	Ward Lopes
Rebecca Durst	Kevin Jones
Sarah Fleming	Kevin Jones
Michael Flynn	Daniel Aalberts
Will Kirby	Charles Doret
Brandon Ling	Bill Wootters
Bijan Mazaheri	Fred Strauch
Cole Meisenhelder	Charles Doret
Ashwin Narayan	Daniel Aalberts
Elena Polozova	Fred Strauch
Gabriel Samach	Bill Wootters
Ariel Silbert	Ward Lopes

Psychology

Lillian Audette	Laura Sockol
Natalie Bernstein	Kate Stroud
Julia Cheng	Steven Fein & Savitsky
Erin Curley	Kate Stroud
Yedidya Erque	Nathan Kornell
Adlyne Harris	Amie Hane
Aaron Jordan	Ken Savitsky
Caroline Kaufman	Laura Sockol
Minica Long	Alison Sachet
Carey Marr	Kate Stroud
Moneesha Mukherjee	Lauren Williamson
Abra Owens	Heatherington
Abigail Pugh	Moher & Alison Sachet
Raea Rasmussen	Steven Fein
David Rosas	Nathan Kornell
Laura Ureste	Nathan Kornell
Lilly Wellenbach	Amie Hane
Sarah Wieman	Kate Stroud

Science Shop

Gregory Kehne	Michael Taylor
Samuel Steakley	Michael Taylor

Physics Ephs at Frank Lloyd Wright's Monoma Terrace Convention Center for the annual meeting of the Division of Atomic, Molecular and Optical Physics (DAMOP), June 2-6, 2014.

Summer Science Research Poster Session: August 15, 2014

At the end of the summer, individual students (or teams) who were engaged in Summer Science Research can choose to present a poster highlighitng the reasearch they had been working on. Posters are reviewed by their peers and a winning poster is selected. This year 73 posters were presented from 12 departments. Student's posters are listed below with their faculty advisor(s).

Astronomy

Jay Pasachoff	Tina Seeger	Using Eclipse Images to Monitor Solar Activity
Steven Souza	Michael May '17 and Sarah Stevenson '17	"Narrowband Color-Magnitude Diagrams for Young Open Clusters

Biology

Lois Banta, Janis Bravo	Achala Chittor, Zihan Su	Characterization of Agrobacterium-elicited defense gene expression in Arabidopsis seedlings
Lois Banta	Isaiah Clark/Raza Currimjee	Role of the T6SS in modulating Agrobacterium stimulated defenses in Arabidopsis seedlings
Matthew Carter	Anna Ryba and Zoe Trutner	Visualization of AgRP Neurons in the Mouse Brain
Alex Engel	Kiki Landers and Kairav Sinha	Subcellular Localization of Immune Receptors; Microscopy and Fractionation Approaches
Martha J. Marvin	Anuj Shah	The Effects of Early Life Stress on HPA Axis Development in Zebrafish
Manuel Morales	Ivy Ciaburri	Ants, Treehoppers, and Goldenrods: Mutualisms and Biochemical Defense Pathways
Steven Swoap	Amelia Hidalgo, Maria Vicent-Allende	Therapeutic Hypothermia: A Comparison of Torpor in Mice to Common Cooling Methods
Claire Ting	Emily E. Gaddis, Elissa M. Hult, Diana S. Sanchez	A Capacity for Change: The Genomics and Physiology of Prochlorococcus and its Response to Environmental Stress
Heather Williams	Gabe Stephens	Dopaminergic Modulation of Syntax Variability in Bengalese and Zebra Finches by Area X Spiny Neurons

Center for Environmental Sciences

Jay Racela & David Dethier	Lauren Moseley & Hannah Brown	Hurricane Irene and the Deposition of Heavy Metals Along the Hoosic River Watershed

Chemistry

Jimmy Blair	John Hammond, Tony Huang, Taylor Jackvony, and Lindsey Moran	Analysis of small molecule inhibitors of CckA

Enrique Peacock-Lopez	Gregory Stone	Spatial Temporal Patterns in Protection Mutualism
David P. Richardson, John W. Thoman Jr.	Marissa Shieh and Allison Rowe	Polychlorinated Biphenyl (PCB) Levels in Hoosic River Crayfish and Trout
David P. Richardson, John W. Thoman Jr.	Katherine T. Cavanaugh '16 and Christopher J. Stefanik '16	Further Sythesis and Stereochemical Analysis of sp3-hybridized Deuterocarbons
Anne Skinner	Selena Castro	Investigating the Middle Paleolithic: Electron Spin Resonance Dating of Tooth Enamel from Pešturina, Serbia
Anne Skinner	Kevin Eagan	Tracking Neanderthals with Electron Spin Resonance Dating
Anne Skinner	Terrance Mensah, Nancy Piatczyc	The mystery of the Achatina snail shell: using physical methods to examine one of the oldest shells ever found
Rebecca Taurog	Ian Outhwaite, Vitong Tseo	Investigating Catalytic Conformational Changes of Methionine Synthases
Rebecca Taurog	Katherine Susa	Large-scale Catalytic Conformational Changes in Cobalamin-dependent Methionine Synthase
Computer Science		
Jeannie Albrecht	Sarah Abramson	Predicting Power Use and Generation for Kellog House
Jeannie Albrecht, Andrea Danyluk	Gordon Finnie III	Energy Disaggregation and Machine Learning
Duane Bailey	Diwas Timilsina	Working with FPGA's
Duane Bailey	Derrick Bonafilia	Implementation of a TupleSpace Based Coordiantion Language
Andrea Danyluk	Lauren Yu	A Hierarchical Approach for Classification in Applications with High Class Imbalance
Andrea Danyluk	Matt LaRose, Andrea Danyluk	Genetic Algorithm to Optimize Object Recognition in Digital Images
William Lenhart	Jose Raventos	Characterization of Trees with Convex Obstacle Number 3
Morgan McGuire	Samuel Donow, Daniel Evangelakos	An Efficient and Accurate Approximation for Light Transport
Morgan McGuire	Kelly Wang, Morgan McGuire	The Algorithms of Cinematography and Interactive Media
Geosciences		
Phoebe Cohen	Mary Ignatiadis	A Diverse Neoproterozoic Microfossil Assemblage from Coal Creek Inlier, Yukon

Phoebe Cohen	Laura Stamp	Geobiology of the Mount Slipper Formation, Yukon, Canada
Phoebe Cohen	Kelly Tellez	Organic Walled Microfossils Across the Late Devonian Mass Extinction Event
Mea Cook	Caroline Atwood	Using Radiocarbon to Understand Ventilation Anomalies in the Berind Sea
Mea Cook	Jorge Castro	The Relationship of Climate Change and Productivity Throughout Ice Age Cycles In the Bering Sea
Mea Cook	Nakita VanBiene, Mea Cook	Identifying Tephras in Sediment Cores from the Umnak Plateau in the Bering Sea
Bud Wobus	Nell Davis, Richard Hazlett, Jeffrey Karson	Correlation of Northern Iceland Rootless Spatter Cones and Syracuse Lava Project "Lava Bubbles"
Mathematics		
Bernhard Klingenberg	Matthew Radford	Interactive Statistical Web Apps
Nathan McNew and Steven Miller	Andrew Best, Karen Huan,Jasmine Powell, Kimsy Tor, Madeleine Weinstein	Complex Ramsey Theory
Steven Miller	Xixi Edelsbrunner, Karen Huan, Blake Mackall, Jasmine Powell, Madeleine Weinstein	A Benford Walk Down Wallstreet
Steven Miller	Patrick Dynes, Brian McDonald, Christina Rapti	On a Variant of the Lang-Trotter Conjecture Involving Binomial Elliptic Curve Coefficients
Steven Miller	Jesse Freeman	Fredholm determinants and vanishing of L-functions at the central point
Steven Miller	Karl Winsor, Christina Rapti, Blake Mackall	Biases in Elliptic Curve Families
Steven Miller	Karl Winsor, Kimsy Tor, Xixi Edelsbrunner	Toward Combinatorial Proofs of the Sato-Tate Law and the Weyl Bound
Steven Miller, Alan Chang	David Mehrle, Tomer Reiter, Joseph Stahl, Dylan Yott	A generalized Newman's conjecture for function field L-functions
Steven Miller, Caroline Turnage-Butterbaugh	Owen Barrett, Brian McDonald, Patrick Ryan, Karl Winsor	Large gaps between zeros of GL(2) L-functions
Steven Miller, Caroline Turnage-Butterbaugh	Owen Barrett, Christina Rapti, Patrick Ryan	Finite conductor models for twists of GL(2) L-functions

Steven Miller, Caroline Turnage-Butterbaugh	Owen Barrett, Patrick Ryan, Karl Winsor	One-level density for cusp forms of prime square level.
Steven Miller, Caroline Turnage-Butterbaugh	Andrew Best, Patrick Dynes, Xixi Edelsbrunner, Brian McDonald, Kimsy Tor, Madeleine Weinstein	Zeckendorf Decompositions
Steven Miller, Alvaro Lozano-Robledo	David Mehrle, Tomer Reiter, Joseph Stahl, Dylan Yott	A Family of Rank Six Elliptic Curves over Number Fields
Cesar Silva	Indraneel Kasmalkar	Lebesgue Spaces of Infinite Measure
Cesar Silva	Julien Clancy, Rina Friedberg, Indraneel Kasmalkar, Isaac Loh, Sahana Vasudevan	Ergodicity of Products in Infinite Measure
Mihai Stoiciu	Feixue Gong, Olivia Meyerson, Jeremy Meza, Abigail Ward	Explicit Bounds for Matrix Pseudospectra
Benjamin Weiss, Steven Miller	Andrew Best, Patrick Dynes, Jasmine Powell	The Emergence of 4-Cycles Over Extended Integers
Neuroscience		
Martha Marvin	Sarah Weiman, Jacob Kim	Physical and Chemical Mechanisms for Enlarged Valves in H5pb7MO Treated Zebrafish
Martha Marvin	Anuj Shah	Effects of Early Life Stress on the Development of the HPA Axis.
Physics		
Charlie Doret	Cole Meisenhelder and Will Kirby	Starting from Scratch or: How I Learned to Stop Worrying and Lock the Laser
Daniel P. Aalberts	Michael Flynn	Building RNA Macrostates
Daniel P. Aalberts	Ashwin Narayan	An observation of and explanation for symmetry breaking in microRNA base composition
Ward Lopes	Julia Cline, Allison Carter, and Ariel Silbert	The Evolution of Order in Striped Systems
Tiku Majumder	Ben Augenbraun	A Precise Measurement of the Stark Shift in the Indium 5p1/2 - 6s1/2 - 6p1/2 Transition in an Atomic Beam
Tiku Majumder	Talia Calnek-Sugin, Sauman Cheng	Construction of a 671 laser towards two-step laser spectroscopy of Thallium
Frederick Strauch	Samuel Amdur	Optimal Control of Large Dimensional Quantum Systems
Frederick Strauch	Elena Polozova	Are Higher-Dimensional Bell Inequalities More Resistant to Noise?

Frederick Strauch	Bijan Mazaheri	Optimizing Qudit Systems: Analytical Decomposition of the Generalized Hadamard Gate
Frederick Strauch, Steven Miller	Weng-Him Cheung	A Statistical Model for Benford's Law: New Bounds and Limits
William Wootters	Sarah Fleming, Rebecca Durst	The Boltzmann Factor and Quantum-Classical Correspondence
William Wootters	Brandon Ling	Decoherence in Real-Amplitude Quantum Theory
William Wootters	Gabriel Samach	Wavepacket Evolution in Real-Amplitude Quantum Theory

Psychology

Laura Sockol	Lillian Audette	Maladaptive Coping, More Than Inadequate Social Support, is Associated With Increased Stress In Female Undergraduate Students

Science Shop

Michael Taylor	Gregory Kehne	Design and Construction of a 3D Data Collection System for Gigapan Microscopy
Michael Taylor	Sam Steakley	Squeezing Plastic: The Williams College filament extruder

Statistics

Brianna Heggeseth	Matthew Radford	Modeling Correlation Structures of Centered Longitudinal Data with Applications to Mixture Models

Ben Augenbraun '15 explains his poster to Katherine Susa '15 and Professor Ward Lopes.

Photo: Mei Chan '17

Summer Science Research Colloquia 2014

Lunch is provided every Tuesday for participants in the Summer Science Research Program. Faculty members from the science departments give talks on their research after lunch, with opportunity for discussion afterwards.

Speakers for Summer 2014	
Norman Bell	General Lab Safety at Williams College
James Carlton	"Studying Extraordinarily Rare Phenomena in the Sea: Marine Biology and Japanese Tsunami Marine Debris"
Matt Carter Julie Blackwood	“Law and Order: Food Intake Investigation Unit”
	"Rabies transmission in vampire bats: insights from mathematical models"
Morgan McGuire	"Vicarious Visions' Making of Skylanders: SWAP Force"
Nate Kornell	How to Teach an Old Dog New Tricks
Charlie Doret	"Atoms at Work: Applying Atomic Physics Tools to Research and Technology"
Ronadh Cox	How to give an island a facelift: a sedimental journey

Pre-Frosh Summer Science Program

In its twenty-seventh summer in 2014, the Summer Science Program (SSP) provides an enriching and intensive five-week immersion in science, mathematics, and English for a talented group of science-oriented incoming Williams students. SSP targets members of groups that have been historically underrepresented in the sciences, and the goal of the program is to promote and encourage continuing participation by SSP students in science and science related studies at Williams and ultimately careers in research science and science education.

Twenty-one students took classes in chemistry (including a major laboratory component), biology, mathematics and English (literature and expository writing). Although not replicas of Williams academic year offerings, the Summer Science Program classes are taught at a college level, thus introducing participants to the rigors and demands of college academics. In addition to the regular classes, the students participated in geology laboratory and field experiments. They also engaged in a variety of extracurricular activities including a play at Oldcastle Theatre and a weekend trip to Woods Hole Oceanographic Institution.

Enthusiasm for the program has been high. Participants have taken full advantage of the opportunity to study at Williams in the summer. As a result of the Summer Science Program, their academic year experiences have been successful and many of the students have continued their studies in science or mathematics. A significant number of former participants have returned to campus in the summer as full-time research students in science and mathematics, have become tutors for the Summer Science Program, or have secured positions elsewhere in science research institutes.

Faculty involved in the teaching for the Summer Science Program included Professors Charles Lovett and David Richardson (Chemistry), Professors Mihai Stoiciu and Cesar Silva (Mathematics), Professor Dan Lynch (Biology), Professor Cassan-

dra Cleghorn (English), and Professor Phoebe Cohen conducted the geology in the field laboratory.

The Summer Science Program has been funded primarily by Williams College as part of its commitment to encourage the participation of traditionally under- represented groups in the sciences. Since 1991, SSP has received additional funding from a biological sciences grant from the Howard Hughes Medical Institute. This grant contributed support for several SSP components, and has provided summer research stipends for SSP stu- dents after their first year at Williams. Special thanks go to the many science faculty and students of Williams College who, during the summer as well as during the academic year, have contributed to the success of the program and of its participants.

2014 Pre-First Year Summer Science Program Participants

Students		**Faculty**
Seema	Amin	Cassandra Cleghorn
Tiffani	Castro	Phoebe Cohen
Jennyfer	Galvez	Charles Lovett, Dir.
Madeleine	Gonzalez	Dan Lynch
Diego	Guimaraes-Blandon	David Richardson
Leila	Jean-Mary	Cesar Silva
Ezekiel	King Phillips	Mihai Stoiciu
Charles	Laurore	
Nallely	Lopez	
Flor	Marmolejo	**Tutors**
Xianglong	Meng	Jonathan McDougal
Natalia	Miller	Terrance Mensah
Gregory	Mora	Richard Ruberto
Nicole	Perez	Isabella Tillman
Cassandra	Pruitt	
Malcolm	Singleton	
Joshua	Teruneh	
Miranda	Villanueva	
Alonso	Villasmil Ocando	
Lauren	Steele	
Stella	Worters	

Williams College Sigma Xi Chapter

The Williams College Sigma Xi Chapter has played an active role on the Williams Campus since it was founded as the Sigma Xi Club in 1969. Sigma Xi is a national society honoring and encouraging research in science. The officers for 2013-14 were Professor Jay M. Pasachoff of the Astronomy Department, President, and Associate Professor Lois Banta of the Biology Department, Secretary/Treasurer.

This year, the local Sigma Xi chapter sponsored two excellent sets of talks directed to broad community audiences. In November, we cosponsored a presentation from Dava Sobel, author and writer in residence at Smith College. She spoke about her book A More Perfect Heaven: How Copernicus Revolutionized the Cosmos. In April, Claire Ting, Associate Professor of Biology, presented a talk on "The Alphabet of Revelations: (Meta) Genomics as a Means to Understand Microbes and their Complex Ecosystems." The lecture was followed by a lively and well-attended reception in the Science Center Atrium.

The Williams College Sigma Xi Chapter sponsors a High School Science Award for a student at Mount Greylock Regional High School, Williamstown, MA, in recognition of a high level of motivation and accomplishment in science courses. This year the award was given to Laura Galib.

One of the primary purposes of Sigma Xi is to recognize graduating science students who have demonstrated exceptional ability and promise for further contributions to the advancement of scientific research. These students are elected as associate members of Sigma Xi and are inducted into the society at a ceremony during commencement weekend. On Class Day, the chapter honored 56 newly elected associate members from the class of 2014 in a ceremony in the '62 Center for Theatre and Dance. The names of this year's honorees are listed below and detailed descriptions of their research projects are presented in the student abstracts section of this report.

Sigma Xi nomination ceremony, graduation weekend 2014.

Photo by Marcela Villada Peacock, Davis Center

2014 Associate Sigma Xi Inductees

Astrophysics
Allen B. Davis
Kerrin G. Hensley

Biology
Luke D. Faust
Eric J. Hagen
Elizabeth M. Hart
Kathleen W. Higgins
Nina B. Horowitz
Manasi Iyer
Kelsey D. McDermott
H. McEntee
Zachary M. McKenzie
Catherine J. Pang
Kaijie Zheng

Chemistry
Todd A. Brenner
Craig M. Burt
Peter L. Clement
Jessica Monterrosa Mena
Lilliana S. Morris
Julia H. Nguyen
Georgiana M. Salant
Kassandra V. Spiller
Bianca A. Ulloa
Anna S. Zhou

Computer Science
Daniel Seita

Geosciences
Eloise C. Andry
Johanna S. Eidmann
Kalle L. Jahn
Michelle E. Paradis

Mathematics
Ilya D. Amburg
Craig M. Corsi
Philippe P. Demontigny
Carson M. Eisenach
Jared Hallett
Yang Lu
Victor D. Luo
Byron J. Perpetua
David F. Stevens
Sean M. Sutherland
Kirk C. Swanson
Samuel W. Tripp

Neuroscience
Jenna C. Adams
Megan H. Trager

Physics
Nathan R. Bricault
Jr.,Richard Eiselen Jr.
Isaac M. Hoenig
Joseph R. Iafrate
Maxwell C. LaBerge
Cesar Melendez
Gabrielle D. Vukasin

Psychology
Alida A. Davis
Alexander S. LaTourrette
Fanny R. Mlawer

Statistics
Shi Wen Chen
Vu Le
Faraz W. Rahman
Jirapat Samranvedhya

Academic Year Science Lunch Colloquia 2014

Presenter	Title
Bud Wobus, Geosciences	"From the Quarry to the Quad...The Petrology of the Quintessential Orthopyroxene Norite of Hodge's Table"
Matthew Carter, Biology	"Shining light on the neural basis of innate, homeostatic behaviors"
Nate Kornell, Psychology	Taking a test enhances learning, but does it prevent forgetting?
Paul Schechter, Astronomy	"Mapping the distribution of dark matter in galaxies with gravitational mirages"
Andrea Danyluk, Computer Science	Feature Selection via Probabilistic Outputs
Lee Park, David Tucker-Smith, and Chris Goh	"Discussion with CEP on majors and curriculum pressures"
Jim Carlton, Williams-Mystic	Japanese Tsunami Marine Debris and Marine Bioinvasions
Joan Edwards & Matt Carter, Biology	Darwinian Gastronomy: The Mystery of the Miracle Berry
Wendy Wang, Mathematics	"Getting more out of n"
Eric Gaze, Bowdoin College	Assessing quantitative reasoning
Hank Art, Biology	Fire Island: Paradise Lost -- Up, Down, and Sideways (But Not in That Order)
Stephanie Dunson, Dir. Writing Program & Lee Park, Chemistry	Conversation with Stephanie Dunson, director of the Writing Programs - how can Div III get more involved?
David Tucker-Smith, Physics	Dark forces
Lois Banta, Biology	Discussion of associate membership in Sigma Xi
Brian Penprase, Pomona College, and Andrea Nixon, Carleton College	A discussion of online learning technologies in the context of Liberal Arts College teaching
Mea Cook	The link between ocean circulation, climate and productivity in the Bering Sea since the last glaciation.
Brianna Heggeseth, Math/Stats	Searching for Development Patterns: An Application to Childhood Growth Trajectories
Becky Taurog, Chemistry	A biochemist's breakfast: miracle berries, proteins and vitamins
Edward Hanson, Math/Stats	q
Jay Pasachoff, Astronomy	The 2013 Total Solar Eclipse in Gabon

The Charles W. Morgan sailing en route to Newport on June 15, 2104.

"Traveling aboard the Charles W. Morgan, a 173-year-old whaling ship on its 38th Voyage, I'm struck by its paradox: this vessel which spent years chasing and killing whales is now helping us to study these magnificent creatures." Lisa Gilbert

Lisa Gilbert is an Associate Professor of Geosciences and Marine Sciences at Williams College. Gilbert earned her Ph.D. in Oceanography from the University of Washington...

Photo credit: Courtesy of Mystic Seaport.

In Memoriam

The Science Center was terribly saddened by the sudden death of our electronics technician **Larry George**, who was killed by an impaired driver. Larry had been at Williams since 2010 and had provided invaluable expertise in keeping our equipment working. We will miss his cheerful smile.

Angie Giusti passed away this year at the age of 85. Angie worked as an administrative assistant in the Psychology department from 1966 until her retirement in 1993. She will be missed by all who knew her.

The Science Center was shocked by the sudden death of **Debbie Pierce** in a car accident. Debbie worked in the Eco Cafe since 2006 where she helped innumerable students get the coffee and snacks to get through their day.

ASTRONOMY DEPARTMENT

Faculty of the Astronomy Department included Karen B. Kwitter, Chair and Ebenezer Fitch Professor of Astronomy; Jay M. Pasachoff, Field Memorial Professor of Astronomy and Director of the Hopkins Observatory; and Steven P. Souza, Lecturer in Astronomy (becoming Senior Lecturer on July 1, 2014). Bryce A. Babcock, who retired as Staff Physicist and Coordinator of Science Facilities, has continued at Williams as Associate of the Hopkins Observatory. Paul Schechter, the William A. M. Burden Professor of Astrophysics at MIT, spent his sabbatical year at Williams, with the title of Research Associate.

Professor **Karen Kwitter** continued her research on the chemical compositions of planetary nebulae (PNe) and their role in galactic chemical enrichment. These ejected shells of dying sun-like stars contain products of nuclear processing – helium, nitrogen, carbon – inside their parent stars, and so are valuable probes into the chemical enrichment history of the Milky Way and other galaxies. Kwitter's research concentrates on PNe in the Milky Way and in the neighboring Andromeda Galaxy (M31), 2.5 million light-years away, and a near twin. She and colleagues Bruce Balick (U. Washington), Romano Corradi (Instituto de Astrofísica de Canarias), and Dick Henry (U. Oklahoma) have observed a total of 26 outer PNe in M31, 10 with the 10.4-meter Gran Telescopio Canarias (GTC). *Kerry Hensley '14* did her senior honors thesis on the analysis of GTC spectra for eight of these M31 PNe. Hensley confirmed an enriched, solar-like abundance profile for these objects, which was unexpected since the ordinary stars in the same vicinity exhibit less chemical enrichment. One intriguing possible explanation for this anomaly is that these PNe are the result of a burst of star formation from already-enriched interstellar gas about 2 billion years ago in the wake of a close encounter between M31 and another nearby spiral galaxy, M33. To study this idea further, Kwitter and colleagues have more time during the fall of 2014 to observe at the Astrophysics Research Consortium 3.5-m telescope at Apache Point Observatory (APO) in New Mexico. They hope to extend the observed range of distances from M31's center over which PN observations are available. Williams College is now part of a consortium of small colleges that has entered into a three-year agreement for purchasing telescope time at APO; we are very grateful to the College for making this investment.

Kwitter continued working with colleagues on their Hubble Space Telescope project to study the structure and composition of PNe in the Milky Way. In particular ultraviolet spectroscopic data reveals abundant ions of elements like carbon, which are difficult to detect in the optical region. The resulting ratios of carbon to nitrogen and to oxygen supply important constraints on the processes of evolution and nucleosynthesis inside PNe parent stars.

Kwitter serves on the International Astronomical Union's *Working Group on Planetary Nebulae*. She contributed to and edited a White Paper in which members of the Working Group present a summary of current planetary nebula research and anticipated future advances. She continued as the coordinator for the summer intern program of the Keck Northeast Astronomy Consortium (KNAC). In September, she attended the KNAC Student Research Symposium at Vassar College, and in July she attended the KNAC faculty meeting at Haverford College. In June she and Kerry Hensley attended the 224th meeting of the American Astronomical Society in Boston. Kwitter presented a poster on her group's Hubble Space Telescope data, and Hensley presented a poster on her thesis results.

Professor **Jay Pasachoff** with colleagues, an alumna, and his thesis student observed the total solar eclipse of November 3, 2013, from Lopé National Park in Gabon with support from the Committee on Research and Exploration of the National Geographic Society. Our team included *Allen Davis '14* as part of his senior thesis research, and *Zophia Edwards '04*, now a graduate student at BU studying the economy and sociology of Gabon. Also participating was Marek Demianski, who will again be visiting professor of astronomy at Williams during spring 2015. In addition, Pasachoff observed the partial solar eclipse of April 29, 2014, from Albany, Australia. It was his 59th solar eclipse observation. See http://totalsolareclipse.org.

During the Gabon trip, The Pasachoff team was, in particular, studying the solar corona, which is now near its maximum appearance corresponding to the maximum of the solar-activity cycle. With alumnus *Dan Seaton '99*, who is now director of the SWAP telescope on the European Space Agency's PROBA2 spacecraft, they produced high-resolution imaging of the corona, which was assembled into various compound images.

Work has continued on analyzing the data from the 2012 and 2013 eclipses with *Muzhou Lu '13* during the summer 2013 and with *Tina Seeger '16 and* Adam Schiff of Middlebury College during the summer of 2014. The studies of the annular and total eclipses of 2012 are supported by a grant from the National Science Foundation Solar Research Program of the Atmospheric Sciences Division.

Work continued with Dale Gary of the New Jersey Institute of Technology on high-resolution observations of the sun made with the Jansky Very Large Array outside Socorro, New Mexico, as part of an NSF-sponsored project.

Professor Pasachoff continued his solar-system work, together with Bryce Babcock and colleagues from MIT and the Southern African Astronomical Observatory, on studying the atmosphere of Pluto and other aspects of the outer solar solar system through the method of stellar occultations. The teams had two articles accepted in the journal *Icarus* about the analysis of their observations of a double occultation by Pluto and its largest moon, Charon, in 2011. They continued with plans for observing several Pluto occultation events during the summer of 2014 from the Mt. John University Observatory in Tekapo, New Zealand with coordinated observations from Australia. The work is supported by a grant from NASA's Planetary Astronomy Program. The Pluto observations are especially timely, given the flyby of NASA's New Horizon's spacecraft during July 2015, so up-to-date ground-based observations of the state of Pluto's atmosphere are important for planning and for eventual data reduction of the spacecraft observations.

Pasachoff continued as Chair of the Working Group on Eclipses of the International Astronomical Union's solar commissions and as a member of the Johannes Kepler Working Group of the History of Astronomy commission. Through 2015 he will continue as chair of the Historical Astronomy Division of the American Astronomical Society. He was involved in planning the sessions at National Harbor, MD, for the January 2014 meeting, and he added Historical Astronomy Division sessions jointly with the Division of Planetary Sciences at their Denver meeting in October 2013 and at the Solar Physics Division meeting held in Boston in June 2014. He continues as U.S. National Liaison to Commission 46 on Education and Development of the International Astronomical Union. He is also head of the Program Group on Public Education at the Times of Eclipses of the Commission on Education and Development. Pasachoff continues as representative of the American Astronomical Society to the American Association for the Advancement of Science's Astronomy Division.

In January 2014, Pasachoff attended the 223rd meeting of the American Astronomical Society in National Harbor, Maryland, and in June, he attended the 225th meeting in Boston. He attended the AAS's Division of Planetary Sciences meeting in Denver, in November 2013, the Solar Physics Division's July 2013 meeting in Bozeman, and the June 2014 meeting in Boston, presenting papers at each.

Pasachoff continues his work with Schneider on their Hubble Space Telescope observations of a transit of Venus as seen in reflection off Jupiter in September 2013, and also with observations with NASA's Cassini spacecraft in orbit around Saturn about the transit of Venus that, working with Phil Nicholson of Cornell and Matt Hedman of the University of Idaho that they think they have barely detected. The work provides a parallel to observations of exoplanets being carried out with NASA's Kepler spacecraft's data, providing a relatively close-up look at all the contributors to an exoplanet-transit light curve.

Pasachoff continued his work with Roberta J. M. Olson, Curator of Drawings at the New-York Historical Society, on the overlap of art and astronomy. For the eighth conference on The Inspiration of Astronomical Phenomena (http://www.insap.org) they prepared a paper on the eclipse of 1918 which appeared in *Nature* in April 2014.

Pasachoff continued as President of Williams College's Sigma Xi chapter and as the Williams representative to the NASA-sponsored Massachusetts Space Grant. He attended the Space Grant Consortium meeting at the Museum of Science in Boston in May 2014.

Pasachoff continues as astronomy consultant for the McGraw-Hill Encyclopedia of Science and Technology and its yearbooks. He also continues on the Physical Science Board of World Book. Pasachoff continues as science book reviewer for *The Key Reporter*, the Phi Beta Kappa newsletter. He continues as advisor to the children's magazine *Odyssey*. He is as a Fellow of the Society for Skeptical Inquiry and serves on the editorial board of the *Skeptical Inquirer*. In June 2014, his letter appeared in The New York Times on the subject of the importance of vaccination.

One of Pasachoff's eclipse images, with data taken in conjunction *Allen Davis '14* and *Dan Seaton '01* was the Astronomy Picture of the Day for November 11, 2013.

In collaboration with the College-wide Year of the Book emphasis for 2014-15, Pasachoff devised a new course for spring 2015 titled *Great Astronomers and Their Original Publications* (ASTR 340) with the collaboration of Wayne Hammond of the Chapin Library. This course will use use some of Pasachoff's first-edition books held in Chapin as well as works from the college's collection.

In September, Pasachoff received the Janssen Prize of the Société Astronomique de France in Paris France.

Steven Souza continues to conduct and supervise the astronomy observing program, indoor labs, and daytime observing. He hosted numerous observatory visitors, including planetarium groups, Summer Science Program participants, alumni, Family Days attendees, and student previews and prospectives. In his efforts to maintain and improve the observatory, Souza oversaw the overhauling of our Optomechanics 10C spectrograph with a new CCD camera, lens, and entrance slit, enhancing its utility and extending its useful life. He recently upgraded the astronomy department server, and replaced our failed Geochron (mechanical day/night world map) with a computer-driven flat screen display.

Souza continued his research effort to monitor variations in H-alpha emission in massive stars in open clusters, resulting in two publications. He began remote observing with the 0.5-m ARCSAT telescope at Apache Point Observatory, to obtain data complementary to that obtained at the 0.6-m telescope at Williams College. Souza attended the Keck Northeast Astronomy Consortium (KNAC) Faculty Meeting in June 2013 and the KNAC Student Symposium in October 2013, both at Vassar College, and the 224th meeting of the American Astronomical Society in Boston, MA in June 2014. He served as summer research advisor for *Mona Sami '16* and Gillian Beltz-Mohrmann (Wellesley '16; KNAC exchange student).

Professor **Paul Schechter**, visiting Williams College's Astronomy Department for the year from MIT, concluded a study of the stellar content of distant galaxies. In our own Milky Way we can see and count individual stars, and get a census of the relative contributions of stars of different types to the total stellar mass. But even for the nearest galaxies beyond the Milky Way we cannot get a complete census, and there is reason to believe that the contribution of stars of different types to their masses might be different from what we see in our own galaxy (and from each other). Schechter has used the phenomenon of gravitational microlensing to estimate stellar masses for a particular class of galaxies known as ellipticals. He analyzed data from ten such

galaxies, which by chance coincidence lie along the line of sight to a more distant object called a quasar. Such quasars emit X-rays, and the brightness of the X-rays seen from these quasars fluctuates with the density of stars in the intervening galaxies. The gravity from each star causes it to act like a small (compared to the galaxy) lens and their combined effect produces changes in the brightness in a background object that is seen through them – gravitational microlensing. While there have been previous efforts to estimate the stellar masses of such galaxies, they have relied upon a careful analysis of the light they emit. But there are classes of stars that emit so little light that one cannot gauge their contribution to the total stellar mass. One must therefore extrapolate from what one can measure. By contrast, the microlensing technique is sensitive to the mass all of the stars in the galaxy. Schechter and colleagues Jeffrey Blackburne, David Pooley and Joachim Wambsganss conclude that the stellar mass is probably larger than previously estimated by roughly 50%. A paper describing their work has been submitted to *The Astrophysical Journal.*

Class of 1960 Scholars in Astrophysics

Allen B. Davis Kerrin G. Hensley

Postgraduate Plans of Astronomy Majors

Charles F. Baxter	Oak Hill Advisors as a junior trader in Structured Products Group
Allen B. Davis	Ph.D. in Astronomy at Yale University
Kerrin G.Hensley	NASA/JPL Internship (Summer 2014), Fulbright teaching fellowship in Taiwan
Nathan Saffold	Backpacking through Europe then research assistant at Pritzker School of Medicine
Gabrielle Vukasin	Graduate studies in Mechanical Engineering at Tufts University

Astronomy Colloquia

(Other colloquia held jointly with the Physics Department)

Karen B. Kwitter

"Exploding Stars, Colliding Galaxies, and You"

TEDxWilliamsCollege presentation (January 2014)
http://www.youtube.com/watch?v=wdeM1wcCRH0&feature=youtu.be

Off-Campus Astronomy Colloquia

Jay M. Pasachoff

"2012 Transits of Venus from Earth, Jupiter, and Saturn"

L'Observatoire de Paris July 2013

"The Eclipse Triptych of Howard Russell Butler"

American Museum of Natural History and the Hayden Planetarium, Eighth Meeting on The Inspiration of Astronomical Phenomena, New York July 2013

"The Sun and Solar Eclipses"

CUREA (Consortium for Undergraduate Research and Education in Astronomy) on Mt. Wilson August 2013

"Venus' thermospheric temperature field using a refraction model at terminator: comparison with 2012 transit observations using SDO/HMI and NSO/DST/FIRS"

Copernicus meetings, European Geosciences Union General Assembly April - May 2014

"Messier, Copernicus, Flamsteed: The SAF Rare-Book Collection in Paris"

Historical Astronomy Division, 223rd American Astronomical Society Meeting, National Harbor, MD June 2014

"Observations of the Black-Drop Effect at the 2012 Transit of Venus"

Historical Astronomy Division, 223rd American Astronomical Society Meeting, National Harbor, MD June 2014

BIOLOGY DEPARTMENT

Working closely with the many interdisciplinary programs on campus: The BIMO Program, the Neuroscience Program, the Environmental Studies Program, the BiGP Program and the Public Health Program, the Biology Department's goal is to provide students with the opportunity to do hands-on individual research with a professor in addition to offering state of the art academic courses. To that end the department had 19 honors students working in faculty labs this past year. Of these, 11 were inducted into the Sigma Xi Honors Society. For the academic year 2014-2015, the department will have 25 students conducting honors work. The department is committed to providing a positive research and learning experience for all biology students.

As a result of our commitment to undergraduate research, several Biology students were awarded grants or fellowships to pursue their studies after graduation. Molly McEntee received a Stratton Fellowship to further her studies. The department also has 43 students doing summer research in 2014, either at Williams or off campus including *Emily Shea '16* and *Brian Levine '16* who will be working at the Whitehead Institute.

Funding for summer research comes from various sources including individual research grants and Division funding. At least half of the biology faculty has outside research funding from either NSF or NIH. This allows many students to travel to professional meetings throughout the year to present posters on their research at Williams. In February 2014, recent BIOL and/or BIMO alumni *Jamie Lahvic '10*, *Erik Tillman '10* and *Emily Behrman '09* returned to campus to share their post-graduate research experiences with students. Through a poster presentation and panel discussion they gave current students an opportunity to learn firsthand about life as a graduate student.

Each year at graduation, the Biology Department awards competitive prizes to its outstanding graduates. *Manasi Iyer* and *Megan Trager* each received the Benedict Prize in Biology. *Kathleen Higgins* received the Dwight Botanical Prize. *Melinda Wang* received the Conant-Harrington Prize for exemplary performance in the biology major, and *Zachary McKenzie* received the William C. Grant, Jr. Prize for demonstrating excellence in a broad range of areas in biology.

This year the biology department welcomes two new faculty members. **Dawn Carone** joins us as Assistant Professor in the Fall semester 2014. Dawn comes to us following her post-doctoral research at the University of Massachusetts Medical School. She is a molecular biologist and cytologist with extensive training in nuclear structure and chromatin biology in mammalian model systems. Dawn will be teaching *RNA Worlds* (BIOL 408) and a section of *Genetics* lab (BIOL 202) this fall.

Also starting in the Fall 2014 semester is **Ben Carone** as a Visiting Assistant Professor. Ben comes to us following his post-doctoral research at the University of Massachusetts Medical School. His interests are primarily in genetics/genomics with extensive training in chromatin biology and epigenetics. Ben will be teaching *The Cell* labs (BIOL 101) this fall.

Additionally, we have **Anne Farewell** joining us as a STINT Fellow for one year. Anne is an Associate Professor in the Department of Chemistry and Molecular Biology-Microbiology at Göteborg University, Göteborg, Sweden. Anne will be teaching *Microbiology* (BIOL 315) in the fall.

Professor **Hank Art** taught the redesigned *Communities and Ecosystems* (BIOL 302) course that included extensive fieldwork in the Hopkins Forest and on Mt. Greylock. The course made use of the Hopkins Forest on-line databases. In Spring 2014 Prof. Art taught the senior seminar *The Ecology of Sustainable Agriculture* (BIOL/ENVI 422) and also *Introduction to Environmental Science* (ENVI 102), a course that used the Hoosic River Watershed as the focus for examining local environmental issues that were then connected to the Hudson River, Atlantic Ocean, and global environment. Prof. Art also taught a lab section of *Genetics* (BIOL 102) during the spring semester.

During the summer of 2014, Prof. Art collaborated

with *Jamie Dickhaus '14*, *Alice Stears '15*, and *Laurel Stamp '16* on a continuation of the special survey of old growth woodlots (the Beinecke Stand and Ira Whitney Farm Forestry Unit) and the quarter-acre permanent plots that were impacted by the extreme wind event of May 29, 2012. This field research, along with the HMF permanent plot 2010-2011 resurvey project, provided the data for Jamie Dickhaus' senior thesis in Biology. Professor Art also supervised the independent studies projects of *Russell Train* '14 (in English) and *Laurel Hamers* '14 (In Environmental Science).

Associate Professor **Lois Banta** continued her research on the soil bacterium *Agrobacterium tumefaciens*. This plant pathogen is best known for its unique ability to deliver DNA and proteins to host plant cells, thus stably altering the genetic makeup of the plant and causing crown gall tumors ("plant cancer") to form at the infection site. One major goal of the lab's current research is to characterize the host defense responses elicited by the bacterium. Honors student *Melinda Wang* '14, along with independent study student *Chiara del Piccolo* '14 and post-doctoral fellow Janis Bravo, pursued this line of investigation. They were joined in the lab by *Sam Lewis* '15 and Winter-study students *Aubrey Kenefick* '16 and *Breanna Nguyen* '15 who also contributed to this project. This research is funded by a new, three-year individual research grant to Professor Banta totaling $462,000 from the National Science Foundation. Honors student *Betsy Hart* '14 and summer student/research assistant *Tendai Chisowa* '16 continued to explore the lab's discovery by *David Rogawski* '08 that the recently identified Type VI Secretion System (T6SS) in *A. tumefaciens* influences the formation of biofilms, large aggregates of bacterial cells that are resistant to antibiotics, antibody attack, and even chlorox bleach.

In the fall semester, Professor Banta taught the sophomore core course, *Genetics* (BIOL 202). Students in this course learned about population and molecular genetics, and carried out multi-week research projects in which they mapped a novel fruit fly gene and used recombinant DNA technologies to construct and characterize plasmids. In Professor Banta's literature-based spring course, *Microbiology* BIOL 315, the students explored microbial diversity in pond sludge from Woods Hole, MA and from local ponds and agricultural sites. As part of a semester-long focus on the contributions of the bacterial communities in the gut to human health, immune system development, and obesity, several students chose to carry out independent projects comparing the microbial composition of feces from a variety of animals, while others performed bioinformatic analyses of metagenomic sequence data, generated by students in an earlier iteration of the course, on the canine gut microbiome.

Professor Banta is the Chair of Public Health and coordinator for the Global Health track of the International Studies Area of Concentration. In January, she delivered a TEDx talk on *The Curious Epidemiology of Transmissible Cancer among Tasmanian Devils as part of the College's inaugural TEDx event. The talk, which was inspired by a topic in her Infectious Disease tutorial course, can be viewed at* http://tedx.williams.edu/videos/ http://www.youtube.com/watch?v=H-JYDw_09coE

During this academic year, Professor Banta was a reviewer for the National Science Foundation, *Journal of Bacteriology, Plant Journal, MicrobiologyOpen* and *PLoSOne*. Within Williams, she served on the Biochemistry/Molecular Biology advisory committee, the Bioinformatics, Genomics and Proteomics advisory committee, and the Environmental Studies advisory committee. Finally, she continues to serve as Secretary/Treasurer of the Williams College Chapter of the national science honor society Sigma Xi.

This year, Assistant Professor **Matt Carter** set up his new lab at Williams and made Williamstown his new home. In October, his paper "Genetic Identification of a Neural Circuit that Suppresses Appetite" was published in the journal *Nature*. He taught *Neural Systems and Circuits* (BIOL 311) during the Fall semester and the senior seminar *Topics in Neuroscience* (NSCI 401) in the spring. Carter advised two honors students this year, *Manasi Iyer '14* and *Allison Graebner '14*. Manasi studied the neuroanatomical connections of a population of neurons in the hypothalamus to determine a mechanism for how they may regulate behavior in mice. Allison studied downstream pathways of osmosensitive "thirst" neurons in mice. During the year, Matt gave invit-

ed talks at McGill University and the annual Winter Brain Meeting.

Assistant Professor **Tim Lebestky** taught *The Cell* (BIOL 101) in the fall semester and *Neural Development and Plasticity* (BIOL 310) in the spring semester. He continues his research on dopamine and serotonin in the regulation of innate behaviors in the fruit fly *Drosophila melanogaster*. Undergraduate researchers in the Lebestky lab this year included: thesis student *Zachary McKenzie '14*, Independent study student *Gabriel Stephens '15*, and research assistants *Elijah Fromm '17*, *Ruby Froom '16*, and *Kairav Sinha '15*. Froom and *Ellie Pitmon '16* will join Professor Lebestky in the summer '14 to continue existing projects in the lab.

Research in the lab was primarily focused in two areas. First, Kairav, Gabriel, and Ruby worked on the relationship of the Type I Dopamine Receptor (DopR) in the regulation of *D. melanogaster* grooming behavior. From initial experiments in the BIOL 310 class taught in 2013, DopR mutants appear to groom more poorly than wild type animals. This has been further characterized by visual quantification of fluorescent dust as well as a highly quantitative method adapted from Andrew Seeds, a postdoctoral fellow from the Simpson Lab (HHMI Janelia Farm Research Institute). The new methodology relies on "dusting" flies with brilliant yellow dust and then allowing animals to recover and groom, followed by dissolving the dust remaining in solvent and quantifying using a spectrometer in the yellow visual range. Current experiments are focused on using these quantitative methods in concert with restoring the DopR+ circuits in the thoracic ganglion that are believed to be responsible for mediating the dopaminergic grooming signal.

Working in our other research interest, Zach and Elijah were focused on the role of Dopamine in the mushroom body (MB) as it pertains to sleep and arousal behaviors. Through genetic rescue experiments the students conducted mapping studies by using a wide collection of MB specific Gal4 drivers to selectively restore DopR function in discrete parts of the drosophila DopR mutant brain. Initial results suggest that 3 very specific subsets of MB neurons may play a role in maintaining normal daytime sleep behaviors, and further immunohistochemical studies as well as both gain and loss of function circuit manipulations will be used to follow these initial results and characterize these DopR+ neural subsets.

Professor Lebestky presented his research during the fall at Bowdoin College in an invited lecture titled: *Sleep, Arousal, and Dopamine*. He attended the Drosophila Neuroscience Conference at Cold Spring Harbor Laboratories on Long Island, NY in the fall. He was also one of three invited speakers to discuss research and teaching in liberal arts colleges at a career symposium at Janelia Farm, and has since adapted that discussion to two short form articles (one in print and one on-line) that are to be published in *Science* magazine in the Science Careers section later this summer. He will be on leave during the next academic year and plans to continue research on campus at Williams College, as well as collaborating with researchers at UCLA and NYU.

During this past year Professor **Dan Lynch** taught two sections of *The Cell* (BIOL 101). In the spring he taught the lecture and one lab section of *Biochemistry II: Metabolism* (BIMO/BIOL/CHEM 322).

Lynch continued his research on plant sphingolipid biochemistry in the moss *Physcomitrella patens*. The moss provides certain advantages over typical flowering plants in studies of sphingolipid metabolism and function. Students working in the lab included *Yoelkys Morales '14*, *Cesar Dominguez '17* and *Yanira Guerra '17*. He also co-advised, with Professor Steve Swoap, a senior thesis student, *Shayna Barbash '14*, who examined changes in gene expression and lipid composition of brown adipose tissue in mice under different housing conditions.

In the summer of 2013, Professor **Joan Edwards** worked with *Molly McEntee '14* and *Elissa Hult '14* to study pollinators in the field at Isle Royale Wilderness National Park. We conducted a field experiment where insects of different weights were introduced into caged bunchberry dogwood inflorescences. We found that inflorescences which had large or both large and small pollinators introduced had significantly higher seed set than inflorescences with no or only small pollinators, thus demonstrating that large visitors increase female fitness. In another study, we filmed four plots of bunchberry dog-

wood simultaneously for the entire bloom period (~3weeks) and scored the videos for flower visitors. In all, we scored over 33,000 visits to the four sites in 992 hours of video time. The patchy distribution of insect visitors and the uniqueness of visitors to each site indicate that flowers draw on local resources to carry their pollen and that pollinators, themselves, are locavores. During the academic year, Professor Edwards worked with Molly to score the videos and analyze the data from the field experiment. Professor Edwards also worked with *Evelyn Tran '14* and *Elizabeth Jacobs '16* to conduct high speed filming of seed dispersal in *Oxalis* species and of gemmae from the gemmae cups of *Marchantia*. These tiny splash cups (~2mm in diameter) produce disc shaped gemmae that harness the energy of falling raindrops to propel the gemmae from the parent plant. She also worked on filming spore dispersal in *Equisetum* and continues with her long-term studies of both arctic plants on Isle Royale and of garlic mustard in Hopkins Memorial Forest.

Professor Edwards taught *Biology and Social Issues* (BIOL 134) in the fall and *Field Botany and Plant Systematics* (BIOL 220) in the spring. She advised a senior honors thesis by Molly McEntee who studied weight-based pollination in *Cornus canadensis*. They are working on a publication to develop a new field technique to score visitors to flowers using long-term time-lapse cameras, which can record all of the insects visiting a flower over its lifetime.

In October, Professor Edwards gave an invited seminar titled *Botanical Explosions: The Evolutionary Impact of Ultra-fast Plants* at the University of Connecticut and she gave two talks at Isle Royale National Park during the summer.

Professor Edwards published a paper in collaboration with Assistant Professor *Luana Maroja* and *Tarjinger Singh '12* on microsatellite markers for *Sagina nodosa*.

Assistant Professor **Alex Engel** initiated his research program in immune sensing and cell biology. The lab investigates how key immune sentinels are positioned within cells, a feature that influences immune responses to bacterial, viral, and parasitic invaders. Additionally, this positioning diminishes the probability of autoimmune reactions, in which immune responses are triggered by molecules of the host animal. Students *Angela Lui '15*, *Minwei Cao '17*, *Roya Huang '17*, *Alex Meyer '16*, *Raza Currimjee '16*, and *Greg Stone '16* performed techniques in cell biology and biochemistry to address immune sensor positioning. To analyze their experiments these students used techniques including epifluorescence and confocal microscopy, digital chemiluminescence imagery, and flow cytometry.

Professor Engel taught *Immunology* (BIOL 313) in the fall. Students studied the anatomy and development of the immune system, the molecular mechanisms of pathogen sensing and immune counterattacks, and the investigation, diagnosis, and courses of action taken in clinical cases of immune failure or hyper-reactivity. In the accompanying laboratory sessions, students used modern immunology techniques to differentiate macrophages from immature and stem cell precursors. Other laboratory experiments used a flow cytometry analyzer to quantify the capacity of macrophages to engulf large particles, the composition of a complex mixture of immune cell subpopulations, and the magnitude of immune receptor-induced responses to bacteria and chemically synthesized ligands. Additionally, Professor Engel developed a new seminar course, *Dynamics of internal membrane systems* (BIOL 406). In this discussion course, students read the hallmark primary literature articles that elucidated how eukaryotic cells build and maintain membranous intracellular structures. These structures allow organization, efficiency, and specialization of cellular functions. Three investigators who supervised experimental work covered in this course were awarded the 2013 Nobel Prize in Physiology or Medicine.

Assistant Professor Luana Maroja spent her sabbatical year at Cornell University working on mapping genes related to speciation and barriers to gene exchange in hybridizing crickets. Her work showed that genes that cannot cross the species barriers are concentrated in the X-chromosome. She is now working on a manuscript regarding these results. This past academic year, Maroja published the work of previous honor student *Tarjinder Singh '12* and another paper in collaboration with three students, *Joy Jing '12*, *Zach McKenzie '14* and *Elizabeth Hart '14* along with Professor David Richardson (Chem-

istry). Maroja will participate in the Evolution 2014 conference in Raleigh, North Carolina in June with her upcoming honor student *Daniela Zarate '15*, who was awarded an NSF Evolution undergraduate diversity travel award. For the next academic year, Maroja will be advising three honor students and will be teaching *Genetics* (BIOL 202) and *Evolution* (BIOL 305).

In the summer of 2013, **Professor David Smith** worked with *Luke Faust '14* to continue his 30+ years of studies of the boreal chorus frog population on Isle Royale National Park. This study has resulted in one of the longest records of any amphibian population. Professor Smith also collaborated with *Josh Van Buskirk '82*, who is currently at the University of Zurich and who was Professor Smith's second honors student at Williams. He also worked with Professors Joan Edwards and Luana Maroja to sample plant populations in Newfoundland. Professor Smith's research examines factors that drive population changes (e.g., climate, storms, predation) and that account for the numerical and spatial limits of the populations, as well as how these ecological attributes are shaped by short-term evolutionary processes, particularly natural selection, migration and population structure. The frog population study focuses mainly on basic questions about population biology, but is also important in monitoring the effects of climate change and in providing base line data for assessing any impacts in the event of an environmental disaster (e.g. an oil spill from nearby shipping lanes).

Professor Smith taught *Ecology* (BIOL 203) in the fall and *Evolution* (BIOL 305) in the spring.

Associate Professor Claire Ting was on sabbatical during the 2013-14 academic year and continued to teach and mentor students in her laboratory as well as pursue her National Science Foundation funded research on photosynthesis in the ecologically important marine cyanobacterium *Prochlorococcus*. This blue-green bacterium is one of the most abundant photosynthetic organisms on Earth and is an important carbon sink. Research in her laboratory aims to establish how differences at the genomic level translate into physiological advantages in photosynthetic capacity and in tolerance to environmental stress. In addition to laboratory research, her group has conducted field work in the Sargasso Sea, which is an open ocean region where *Prochlorococcus* thrives. This past year her laboratory continued to work with the bacterioplankton samples they collected from the Sargasso Sea for metagenomic and metatranscriptomic analyses, and with the metagenomic sequence database they established for characterizing the Sargasso Sea microbiome.

Professor Ting is the sole author of an editor-reviewed book chapter (*The architecture of cyanobacteria, archetypes of microbial innovation*) that was published this year. She and her students *Katharine Dusenbury '13*, *Reid Pryzant '16*, *Kathleen Higgins '14*, *Catherine Pang '14*, *Christie Black '15*, and Ellen Beauchamp *'12* also submitted an article this year which is currently in revision. In addition, Professor Ting and her colleagues from the Georgia Institute of Technology submitted an editor- and peer-reviewed book chapter (*Microbial strategies for survival under extreme nutrient starvation: evolution and ecophysiology*) that is currently under review. Professor Ting was invited to present the Williams College Sigma Xi Spring Lecture in April 2014 on The Alphabet of Revelations: (Meta)Genomics as a Means to Understand Microbes and their Complex Ecosystems. Her laboratory also presented their research at the American Society for Microbiology 114th General Meeting in Boston in May.

Undergraduate students who participated in research in her laboratory this past year included Kathleen Higgins and Catherine Pang, who conducted their honors thesis research on the molecular and physiological responses of *Prochlorococcus* to light stress. In addition, Christie Black and *Diana Sanchez '17* continued as research assistants in the laboratory and collaborated with Catherine and Kathleen on their projects. The *Prochlorococcus* strains they focused on have evolved distinct differences in their photosynthetic apparatus, including in their light-harvesting complex antenna proteins. Through their research they were able to establish that key physiological factors, including growth rates, maximum cell densities and photosynthetic efficiencies, are not conserved between strains cultured under identical irradiance levels, temperatures and nutrient conditions. Their work lends support to the laboratory's hypothesis that although *Prochlorococcus* isolates exhibit close

phylogenetic ties, they have evolved significant differences in their photosynthetic strategies that permit them to thrive in specific ecological niches in the open oceans.

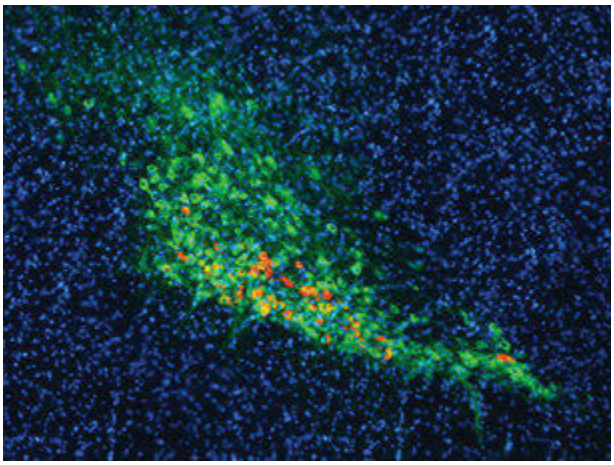
Reid Pryzant also continued as a research assistant in the laboratory during the summer and academic year, and focused on metagenomic analyses of the Sargasso Sea microbiome. His goals include extending our understanding of *Prochlorococcus* from the laboratory to the open oceans and examining how environmental selection might shape *Prochlorococcus* populations at different depths in the water column. The Ting lab has hypothesized that the composition and functional landscape of microbial communities will differ as a function of water column depth (40 m versus 100 m) in the Sargasso Sea. Using a range of computational methods, his research revealed that the three major phyla present in the lab's 40 m and 100 m samples belong to the Cyanobacteria, Proteobacteria and Firmicutes. However, while the 40 m Sargasso Sea microbiome is dominated by Cyanobacteria, and specifically, *Prochlorococcus*, the 100 m microbiome exhibits greater diversity. Notably, community functions are broadly conserved between both depths.

Professor **Heather Williams** taught a tutorial, *Animal Communication*, along with two sections of the new discovery lab program for BIOL 101. She was on sabbatical in the spring, part of which she spent on a small island in the Bay of Fundy, continuing her work on cultural evolution in bird song.

During the fall semester, Professor **Steve Zottoli** taught *Introduction to Neuroscience* (BIOL 212). In the spring he was on leave. A long-term goal of the Zottoli laboratory is to understand the neuronal basis of behavior and the recovery of behavior after spinal cord injury. He uses identified neurons in the goldfish as a model system. *Ashley Ngo '16* and *Bethany Berry '16* worked as Research Assistants using the transmission electron microscope to study supramedullary neurons in cunner fish. *Kelsey McDermott '14* was an Honors student working on aberrant pathway choice by identified neurons in the Trinidadian guppy. Zottoli published a paper in the Journal of Comparative Neurology with several co-authors including *Tina Wong '07*.

Professor Zottoli continues to conduct summer research at the Marine Biological Laboratory in Woods Hole, MA where he is an Adjunct Senior Scientist in the Eugene Bell Center for Regenerative Biology. He continues as a Life Trustee of The Grass Foundation.

The Biology Department continued to participate in the Class of 1960 Scholars program. In addition to the returning alumni who were sponsored by the Class of 1960 Scholars program, the department invited Dr. Rebecca Nelson from Cornell University and *Dr. Elissa Hallem '99* from UCLA to be Class of 1960's Scholar speakers.



Fluorescently labeled substantia nigra in the brain of a mouse. This structure is important in the regulation of movement.

Photo by Mathew Carter, Biology.

Class of 1960 Scholars in Biology

Christina Chen	Isaiah Clark	Daquan Daly
Emily Gaddis	Kathleen Higgins	Carolina Jaramillo
Diana Kang	Aubrey Kenefick	Young Sun Lee
Angela Liu	Sierra McDonald	Molly McEntee
Ashley Ngo	Alison Smith	Gabriel Stephens
Adrienne Strait	Ali Tafreshi	Evelyn Tran
Hector Trujillo		

Biology Colloquia

Hank Art

"Disturbing News About the Hopkins Forest"
Tuesday Summer Science Lunch July 30, 2013

"Fire Island: Paradise Lost …Up, Down, and Sideways (But Not in That Order)"
Tuesday Science Lunch February 18, 2014

Jesse Bellmare, Smith College

"Climate Change and Plant Conservation in the Forests of Eastern North America"

Magdalena Bezanilla, University of Massachusetts

"Myosin and actin steer plant cell division"

Stephen DiCarlo, Wayne State University

"Sympathetic Neuroplasticity Following T5 Spinal Cord Transection Increases the Susceptibility to Ischemia-induced Sustained Ventricular Tachycardia"

Ajay Dhaka, University of Washington, Seattle

"Investigating Temperature and Pain: TRP Channels and Beyond"

Melina Hale, University of Chicago

"Development of fin morphology and movement in the context of changing functional demands"

Elissa Hallem '99, UCLA

"Host-seeking behaviors of parasitic nematodes"

Hadley Horch, Bowdoin

"He Said, She Said: Sexually Dimorphic Responses to Injury in the Auditory System of the Cricket"

Richard Morimoto, Northwestern University

"Proteostasis - Protecting the Proteome in Biology, Aging, and Disease"

Jennifer Morgan, Marine Biological Laboratory

"Roles for Synuclein in Spinal Cord Injury and Parkinson's Disease"

Rebecca Nelson, Cornell University

"Understanding Disease Resistance in Maize: Genetic Architecture, QTL and Pleiotropic Effects"

Off-Campus Biology Colloquia

Hank Art

"Fire Island Dynamics: Nutrients, Storms, Deer and Humans"
Fire Island National Seashore Lecture Series, Patchogue, NY, 28 August 2013

"Exploring the Interface: Earth, Air, Water, and Life on Fire Island"
Keynote Address at the 9th Biennial Science Conference Fire Island National Seashore, Patchogue, NY, 28March 2014

Matt Carter

"Genetic Identification of Neurons that Suppress Appetite"
McGill University, December 16, 2013

"Genetic identification of an appetite suppression circuit"
Winter Brain Conference, January 26-30, 2014

Joan Edwards

"Botanical Explosions and the Isle Royale Flora"
Isle Royale National Park, July 2013.

"Botanical Explosions: The Evolutionary Impact of Ultra-fast Plants."
University of Connecticut, October 2013.

Luana Maroja

"Spatial and Temporal Population Genetic Structure in an Arctic Plant Disjunct Population", With Carrie Tribble '13
Evolution Conference 2013, Snowbird, Utah, June 2013

"Cuticular Hydrocarbons, Calling Intensity and Mate Choice Between the Field Crickets *Gryllus firmus* and G. *pennsylvanicus*"
Evolution Conference 2013, Snowbird, Utah, June 2013

"Candidate barrier genes between *G. firmus* and *G.pennsylvanicus* are concentrated on the X-chromosome" with E. Larson and R. Harrison
Evolution Conference 2014, Raleigh, NC

"Are mpi and pgi Under Balancing Selection in *Heliconius* Butterflies?", with R. Jenks
Evolution Conference 2014, Raleigh, NC

Luana Maroja and Joan Edwards

"Development of microsatellite primers and population genetics of an arctic-alpine species, *Toefiledia pusilla*", with D. Zarate
Evolution Conference 2014, Raleigh, NC

Martha Marvin

"Localization and function of small heat shock protein Hspb7 in cardiovascular and laterality development", with J. Sanderson, K. Zheng, M. Springel, and J. Wosen
11th International Zebrafish Meeting, June 24-28, University of Wisconsin, Madison, WI.

Claire Ting

"The *Prochlorococcus* Carboxysome: Evolution, Diversification and Links to Ecotype differentiation", with *Ellen Beauchamp '12, Christie Black '15, Katharine Dusenbury '13, Kathleen Higgins '14, Catherine Pang '14,* and *Reid Pryzant '16*
American Society for Microbiology (ASM) 114th General Meeting, Boston, Massachusetts, 2014

Steve Zottoli

"Functional regeneration of the central nervous system of fishes"
Gilliam Fellow Meeting, HHMI, July 24-26, 2013

"Unpublished observations on the regeneration of the Mauthner cell in goldfish"
Bell Center for Regenerative Biology and Tissue Engineering , MBL, 2013

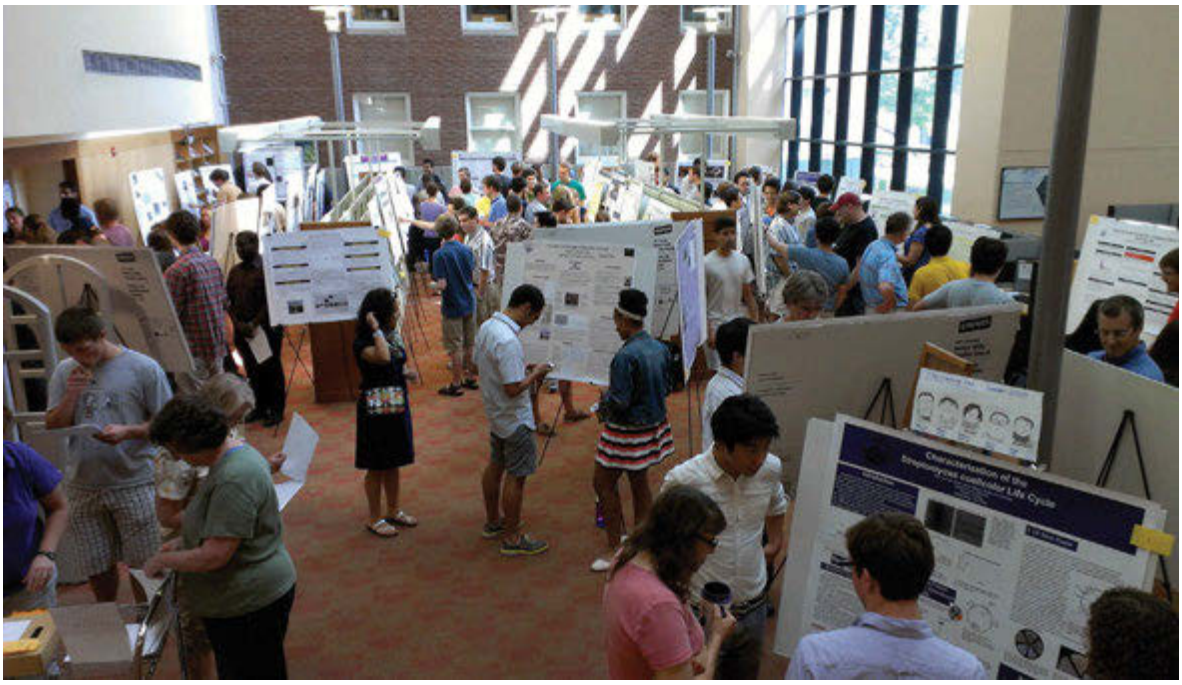
"Does a 'magic bullet' cure exist to allow functional recovery after spinal cord injury?"
UPR Medical School Campus, April 3, 2014
Institute of Neurobiology, Old San Juan, Puerto Rico, April 8, 2014

Post-graduate Plans of Biology Majors

Name	Plans
Tala Abujbara	unknown
Jenna Adams	unknown
Shayna Barbash	RA in Seattle at UW Radiology
Heather Biehl	Clinical Research Assistant, Boston Children's Hospital, Boston, MA
Leslie Blackshear	Clinical Research Assistant, Tisch MS Research Center of New York
John Bourke	unknown
Cristina Bravi	unknown
Meagan Clark	unknown
Tre'Dez Colbert	unknown
Hayley Cook	unknown
Elizabeth Cornett	unknown
Chiara Del Piccolo	PhD in Molecular and Cellular Biology at Oregon Health & Science University (Portland, Oregon)
Jamie Dickhaus	Apply to graduate schools for biology, particularly zoology or wildlife science. I will also being applying to wildlife conservation internships like one in North Carolina at the Sea Turtle Hospital (the Karen Beasley Sea Turtle Rescue and Rehabilitation Center) and the New England Aquarium.
Stephanie Durell	Farm + Garden Intern for one year at North Country School/Camp Treetops, Lake Placid, NY
Peter Ellis	Software Tester/Quality Assurance at Epic Systems, Madison, WI
Allyne Ensor	unknown
Luke Faust	Research assistant, then grad school
Maria Galvez	unknown
Anna Garzon	unknown
Sarah Gottesman	unknown
Allison Graebner	Research Assistant, Beth Israel Deaconess Medical Center, Boston, MA
Christopher Greeno	Associate Consultant, Clarion Healthcare, Boston, MA
Eric Hagen	unknown

Laurel Hamers	Media Services Intern, American Institute of Physics, College Park, MD then to a science writing master's program (location undecided)
Lacey Hankin	unknown
Elizabeth Hart	Research Technician at Weill Cornell Medical School in NYC
Kathleen Higgins	Research Associate at the Broad Institute/Mass General Hospital, Cambridge, MA (two year position in the Mootha Laboratory)
Karina Hofstee	unknown
Anna Hopkins	Science Teacher, The Barrie School, Silver Spring, MD
Nina Horowitz	Undecided
Manasi Iyer	Lab technician in a neuroscience lab at UCSF or Stanford or Berkeley
Patrick Joslin	Continuing research with Professor Swoap before embarking on a 'Himalayan Health Exchange' program in Northern India (Kashmir-Ladakh region)
James Kinney	unknown
Peter Labovich	unknown
Son Le	unknown
Daniel Levine	unknown
Jingyi Liu	unknown
Maximiliano Magana	unknown
Kelsey McDermott	This summer I am starting as a research assistant at the Tisch MS Center in NYC. After two years there I hope to go on to graduate school.
Molly McEntee	Working with the Michigan State University Hyena Project in the Masai Mara, Kenya
Zachary McKenzie	Research tech at Dana Farber and then onto an md/phd program.
Yoelkys Morales	unknown
Karina Moy	unknown
Stephanie Nguyen	MS in Medical Sciences, Loyola University
Emily Norkett	Research Assistant in the Division of Psychiatry at Boston Children's Hospital in Boston, MA with plans to attend medical school in two years.
Catherine Pang	Research Assistant at the University of Massachusetts Medical School (Worcester, MA)
Jonathan Pekar	unknown
Emma Rickles	unknown
Emma Rouse	Student in Quetzaltenango, Guatemala with the Somos Hermanos program
John Sanderson	Research Technician for two years at the Center for Neurodegenerative Disease, Boston, MA, then Medical School
Rahul Sangar	Graduate school in neuroscience.
Jesse Sardell	Undecided
Thomas Stephens	Cardiovascular Research, Brigham and Women's Hospital, Boston, Ma

Megan Trager	Research technician at Stanford and then apply for Ph.D. programs in Neuroscience
Evelyn Tran	Research assistant, then medical school.
Melinda Wang	Teach for America, Bay Area Corps
Olivia Wang	Research assistant, then medical school.
Alexandra Weaver	Coordinator for International Relations, JET Program, Japan
Jessica Wicker	Biking cross-country, from the coast of North Carolina to the coast of Oregon
Kaijie Zheng	Research Associate, Zhang Lab, Broad Institute, Cambridge, MA



A busy scene as students present their research at the end of Summer Science.

Photo by Alicia Romac

CHEMISTRY DEPARTMENT

The Chemistry Department had an eventful 2013-14 academic year. We had 36 senior majors this year, 13 of them completed thesis projects. We are very pleased to announce Dr. Patrick Barber who will be starting his three-year Visiting Assistant Professor appointment in July 2014. Dr. Barber specializes in inorganic chemistry with research interests in environmental and biological imaging using luminescent lanthanide ion complexes. He will teach *Instrumental Methods of Analysis* (CHEM 364) in the fall and *Inorganic/Organometallic Chemistry* (CHEM 335) in the spring. We would also like to congratulate Professor Lee Park who has been appointed Associate Dean of Faculty. Professor Park will be serving a two-year term in the Dean of Faculty Office. We wish her luck in her new endeavor. Another important development in the Chemistry Department was the promotion of Professor Christopher Goh to Associate Professor with tenure. We congratulate Chris on his accomplishments in the department.

Each year, individual students are recognized with departmental awards. In the Class of 2014, the John Sabin Adriance prize went to *Chau Vo* for outstanding work throughout his chemistry career. The James F. Skinner prize was awarded to *Peter Clement* for his distinguished achievement in chemistry and his future promise as a researcher. The Leverett Mears prize went to *Todd Brenner* in recognition of both his abilities in chemistry and future in medicine. *Georgiana Salant* was awarded the American Chemical Society Connecticut Valley Section Award for her sustained scholastic excellence. *Zachary McKenzie* was awarded the American Institute of Chemists Student Award for outstanding scholastic achievement, *Ashley Kim* was the recipient of the ACS Division of Analytical Chemistry Award, *Lilliana Morris* received the ACS Undergraduate Award in Inorganic Chemistry, and *Craig Burt* was presented with the ACS Division of Organic Chemistry Award.

In addition, a number of awards were presented to undergraduate chemistry students for outstanding scholarship. *Matthew Gross '17* and *Intekhab Hossain '17* received the CRC Awards as the outstanding students in CHEM 151 and CHEM 155, respectively. *Dongheon Lee '17* was presented with the Raymond Chang First-Year Chemistry Award for his exceptional work in CHEM 153. Recognized for their achievement in organic chemistry, *Christopher Bravo '16* received the Polymer Chemistry Award and *Lucy Page '16* was the recipient of the Harold H. Warren Prize. We are very proud of all of our students and their achievements.

The Chemistry Department continued to participate in the Class of 1960 Scholars Program. This year we invited Professor Dilip Kondepudi from Wake Forest University and Professor Susan Marqusee from the University of California, Berkeley to meet with our students and present a seminar. Nine students were selected by the faculty to be Class of 1960 Scholars during 2014. These students participated in the seminar program which included a preliminary meeting with a Chemistry Department faculty member to discuss some of the papers of the seminar speaker, attendance at the seminar/discussion, and an opportunity for further discussion with the seminar speaker at an informal reception or dinner.

During the summer of 2014, approximately 30 Williams College chemistry students were awarded research assistantships to work in the laboratories of departmental faculty. We gratefully acknowledge support from the American Chemical Society, the Camille & Henry Dreyfus Foundation, College Divisional Research Funding Committee, the J.A. Lowe III '73 summer research fund, the J. Hodge Markgraf '52 Summer Research Fund, the National Science Foundation, Research Corporation, the Sherman Fairchild Foundation, Summer Science Program funds, and the Wege-Markgraf Fund.

Associate Professor **Dieter Bingemann**, with the help of work study student *Khan Shairani '15*, and winter study student *Chase Epstein '17* continued the search for the fundamental reason behind the dramatic slowdown of the motion in glasses at their arresting point. Glasses, describing in the technical sense a type of material characterized by molecular disorder, are ubiquitous in our world, having replaced even metals as the most common material. The poorly understood reasons behind their solid-like behavior, despite their liquid-like disordered structure, are therefore rather disconcerting.

The Bingemann lab has investigated this unsolved puzzle through a combination of computer simulations and single molecule spectroscopy experiments. The lab has made significant progress towards preparing stable samples of thin molecular glass formers to investigate in the single molecule

setup. These types of glasses allow more stringent tests of the prevailing theories than the polymer glasses previously used.

In the classroom, Professor Bingemann taught *Principles of Modern Chemistry* (CHEM 155) in the fall. He taught *Thermodynamics* (CHEM 366), using a project-based teaching approach that borrows heavily from the popular tutorials, in the spring.

Assistant Professor **Jimmy Blair** had a full and exciting year. In June 2013 he and his wife welcomed their daughter Adeline Nicole, and he reports that one of his favorite memories of the year was sharing pictures of baby Addie with his classes. During the school year, he again taught *Organic Chemistry: Intermediate Level* (CHEM 251) in the fall and *Chemical Biology: Discoveries at the Interface* (CHEM 326) in the spring. His CHEM 251 had a very large enrollment of 122, which was just enough to fit as one section in Wege Auditorium. His CHEM 326 course, like the year before, was a small seminar of 13 juniors and seniors, and together, they studied the field of chemical biology with an emphasis on critical reading of the primary literature.

Professor Blair' research works to develop new antibacterial agents targeting histidine kinases using the α-proteobacterium *Caulobacter crescentus* as a development platform. Histidine kinase-mediated signaling pathways are well conserved across bacterial species and are essential for virulence in many pathogenic bacterial strains, suggesting that discoveries in *Caulobacter* will open the door to potential new antibacterial strategies effective against a broad-spectrum of bacteria. Caulobacter contains essential histidine kinase signaling pathways that his lab targets to assess whether pharmacological inhibition of these pathways provides a new mechanism for antibacterial action. Over the summer *Shannon Zikovich '15* and *Becca Dryer '15* joined him to work on biochemical testing of small molecules against CckA, an essential histidine kinases to *Caulobacter*. By testing drug-like molecules that inhibit Hsp90, a eukaryotic chaperone protein that is a distant homolog of histidine kinases, they discovered a lead molecule for their drug discovery effort. Thesis students *Chau Vo '14* and *Anna Zhou '14* spent the school year in the Blair Lab following up on these results. They now have a preliminary understanding of the structural features of these molecules that are necessary for inhibiting histidine kinases, which sets the stage for a productive summer of science research later this year. In addition to Zikovich and Dryer, *Liz Berggren '15*, and *Ron Golvin '17* joined the effort during the school year as work study students.

Associate Professor **Amy Gehring** kicked off the academic year teaching the non-majors course *AIDS: The Disease and Search for a Cure* (CHEM 115) in addition to laboratory sections for *Introductory Concepts of Chemistry* (CHEM 153) and *Biochemistry* (CHEM 321). As always, she enjoyed the opportunity to get new students excited about science during CHEM 115. For the spring semester, Professor Gehring was on sabbatical and thus was able to focus on her laboratory research.

Since Professor Gehring stayed on campus during her sabbatical, she pursued this research in collaboration with undergraduates throughout the year. The lab is broadly focused on understanding the biochemical basis of the life cycle of the model soil bacterium *Streptomyces coelicolor*; *Streptomyces sp.* are of particular interest as prolific producers of antibiotics and other pharmaceutically-useful molecules. Research got off to a great start during summer 2013, with *Won-Jun Kuk '14*, *Brian Leland '16*, *Jessica Monterrosa Mena '14*, and *Megan Steele '16* studying various aspects of *S. coelicolor* biochemistry and genetics, including the activity of a phosphodiesterase enzyme in the control of antibiotic biosynthesis and the roles of proteases, sigma factors and a cluster of genes of unknown function in the organism's developmental process that culminates in sporulation. In addition, *John Chae '16* studied oscillations in a bacterial gene expression network in collaboration with Professor Enrique Peacock-Lopez. During the academic year, both Jessica Monterrosa Mena and *Georgiana Salant '14* pushed forward the group's research on sigma factor and phosphodiesterase activity, respectively, through their honors thesis projects. They were joined throughout the year in this ongoing work by *Selena Castro '17*, John Chae, Megan Steele, *Doug Wassarman '16*, and during Winter Study by *Roya Huang '17* and *Susie Paul '16*.

Professor Gehring continued serving as the chair of the Biochemistry and Molecular Biology (BIMO) program. Some highlights of the year for the BIMO program were hosting Class of 1960 Scholars seminars by distinguished scientists Dr. Rick Morimoto from Northwestern University and Dr. Mike Snyder from Stanford University. She was additionally able to stay connected with the broader scientific community by serving as a manuscript or grant reviewer for journals *Applied and Environmental Microbiology*, *Applied Microbiology and Biotechnology*,

International Journal of Molecular Sciences, *Journal of Bacteriology*, *Molecular Microbiology* and the National Science Foundation.

Associate Professor **Christopher Goh** taught *Introductory Concepts of Chemistry* (CHEM 151) in the fall, and *Inorganic/Organometallic Chemistry* (CHEM 335) in the spring. He served on the Committee for Educational Policy, as the departmental seminar coordinator and as a reviewer for the journal *Macromolecules*, and was involved in a teachers' roundtable discussion on Teaching in the diverse classroom and in the Liberal Arts Consortium for Online Learning (LACOL).

During the summer 2013, *Jeff Brewington '14*, *Tamuka Chidanguro '15*, *Lillian Ma '15*, *Lilli Morris '14* and *Areli Valencia '14* continued the group's research in the field of transition-metal mediated homogeneous catalysis. Jeff and Lilli started a project on the controlled polymerization of epoxidized fatty acids. Fatty acids can be obtained from plant oils and represent a renewable resource for the polymer industry. Jeff's project was supported by a summer research grant from the Center of Environmental Studies. Lilli also brought a project on the epoxidation of fatty acids to a close, and we were able to submit a manuscript for publication later in the fall. Areli expanded the project on the use of homogeneous iron catalysts for the oxidation of alkenes by initiating work on amino acid based ligand frameworks. Tamuka and Lillian meanwhile continued the group's work on copper-based atom transfer radical polymerization (ATRP) catalysts. These catalysts provide the power to dictate the composition and size of macromolecules and to precisely control their architecture. Applications are many-fold, and include the syntheses of new materials for packaging, automotives and medical uses. The students demonstrated that changes in catalyst structure had a significant impact on catalyst performance and discovered active catalyst compositions.

Lilli and Areli continued their work as senior thesis students, and were joined over Winter Study by *Jake Huerfano '15* and *Kimthanh Nguyen '17*. Tamuka and Lillian meanwhile continued their projects as research assistants during the fall and spring semesters with *Cecelia Hurtado '18* joining their team. All considered it was a lively and productive year for the group.

Associate Professor **Sarah Goh** spent the summer of 2013 hosting four students in her laboratory: *Todd Brenner '14*, Niek Crone (University of Leiden), *Denise Park '15*, and *Luxi Qiao '16*. Together, they furthered a project on amino-acid based micelles, looking at the effect of chiral side chains on polymeric micelle stablility. This project was taken up by *Julia Nguyen '14* in the fall as part of her thesis. Denise and Luxi presented their summer work at a local ACS conference in April. Todd initiated a derivative project for this thesis, combining these amino acid polymers with antioxidants to develop scaffolds that can not only deliver therapeutic payloads, but also mitigate inflammatory responses with in cells. *Bianca Ulloa '14* returned to the lab in the fall to focus on her thesis of the effects of glass transition temperature on micelle stability. Synthesis was the focus of research this year, getting these projects closer to fruition. 2013-14 was otherwise a year of introductory teaching for Goh. She taught the advanced section of *Concepts in Chemistry* (CHEM 153) in the fall and *Introductory Organic Chemistry* (CHEM 156) in the spring.

Combining her research and teaching interests, Goh is working with a consortium of polymer scientists to develop PUNKpolymer.org, an online resource for integrating polymer chemistry, physics, and engineering teaching tools into all levels of the undergraduate curriculum. The website's initial startup is funded by the Dreyfus Foundations Special Grant Program in the Chemical Sciences. More details coming in 2014.

Professor **Lawrence J. Kaplan** taught *Biophysical Chemistry* (CHEM 367) in the fall and *Chemistry and Crime* (CHEM 113) in the spring semester.

He continues to administer Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS, the successor to the Center for Workshops in the Chemical Sciences) with his colleagues Professors Jerry Smith of Georgia State University, David Collard of Georgia Institute of Technology and Patricia Hill of Millersville University. Since its founding thirteen years ago, the cCWCS has received major grants from the National Science Foundation and continues with the current collaborative grants to Williams, Georgia Tech, and Georgia State for approximately four million dollars for five years. The cCWCS sponsors workshops related to a wide range of chemical disciplines including Food Chemistry, Chemistry and Art, Environmental Chemistry, Material Science and Nanotechnology, Fundamentals of Proteomics, Biomolecular Crystallography, and Forensic Science. In addition to offering workshops, the cCWCS continues to develop a series of Communities of Scholars. With

the workshops and their alumni serving as the nucleus, the Communities will continue to develop high-quality course content and pedagogy, propagate the use of successful teaching strategies, and provide discussion venues such as online discussion boards and video conferencing. The website for the Forensic Science Scholars Community, launched in 2010 has been significantly expanded with many more members and more educational resources.

Kaplan taught a weeklong CWCS workshop in forensic science during the summer of 2013 at Williams. Sixteen participants from colleges and universities as well as community colleges became criminalists for the week. They processed crime scenes and analyzed evidence such as glass and soil, fibers and fingerprints, drugs and alcohol, blood and bullets, and, of course, DNA. Deborah Morandi, Administrative Assistant of the Chemistry Department and Tony Truran, Technical Assistant and Lecturer in Chemistry, assisted Kaplan in the organization and instruction of the workshop.

Kaplan, in conjunction with the Justice and Law Program, sponsored a Winter Study course entitled The Work of the Supreme Court: A Simulation (SPEC 12; JLST 12) taught by Robert S. Groban, Jr. '70, Tom Sweeney '70 and Jay Nelson '70. The objective of this course was to provide students with an understanding of the personal, theoretical, and institutional characteristics that impact the decision making process of the nation's highest court. At the beginning of the course, the students were provided with briefs, relevant decisions and other materials for a case pending before the court. Four students (two on each side) were assigned to prepare and present oral arguments to the "Court", which consisted of the other eight students, each playing the role of a Supreme Court Justice. After the oral argument, the "Court" conferred and prepared majority and minority opinions, which were announced in "open court" at the conclusion of the Winter Study term.

Kaplan was invited by Chancellor Mark A. Nordenberg of his alma mater, the University of Pittsburgh, to represent him and be a delegate at the inauguration of Dr. Mariko Silver as the 10th President of Bennington College in April.

Kaplan reviewed numerous papers for the *Journal of Chemical Education*.

During the past year Professor **Chip Lovett** continued to serve as Chair of the Bioinformatics, Genomics, and Proteomics Program and Director of the Summer Science Program for Students from backgrounds traditionally underrepresented in the sciences.

Professor Lovett continued his research on the *Bacillus subtilis* SOS response to DNA damage which comprises a set of DNA damage-inducible genes (SOS genes) that code for DNA repair and cellular survival functions. During the past 29 years Lovett and students working in his lab have discovered more than 30 SOS genes and characterized their genetic regulation in response to DNA damage. Based on recent evidence implicating the SOS response in the development of antibiotic resistance in bacteria, research in the Lovett lab has focused on finding SOS response inhibitors. Lovett and his research students developed a high throughput assay to search a library of 14,400 bioactive compounds for SOS response inhibitors and last year they developed an in vivo assay to test the inhibitors' ability to block the SOS response in bacteria. During the past year Lovett's students screened nearly 7000 compounds and found 16 compounds that inhibit the SOS response. During the summer of '13 *Christopher Bravo '16*, *Jorge Castro '16*, *Pushpanjali Giri '14*, *Willis Koomson '14*, and *Hector Trujillo '16* worked on this project. In addition, Pushpanjali Giri and Willis Koomson continued as independent research students in the Fall semester. Professor Lovett also supervised work study students *Kimberly Kiplaget '16*, *Jacqueline Harris '16*, and *Edgar Vega '16*.

Last summer, Professor Lovett taught the Chemistry lectures component of the Williams College Summer Science Program. Together with Professor David Richardson, he also taught in the 13th year of science camp for elementary school students and teachers.

Professor Lovett served as a reviewer for the *Journal of Bacteriology,* and as a consultant for the Sherman Fairchild Foundation's Scientific Equipment Grant Program.

Professor Lee Park did not have any teaching responsibilities this year due to significant committee work over the last several years. Nevertheless, she continued offering and refining her problem solving sessions for first-year chemistry students, during the summer of 2013 and the fall of 2013. In addition, she offered a full semester course during Winter Study of 2014 titled It's a Material World – What's It Made Of?. This was an intensive course experience for both the students as well as Professor Park,

but was worth it for all involved.

The Park Lab was busy this year, with thesis students Peter Clement, '14, independent study student Vera Gould '14, as well as Chelsea Boydstun '15, Dylan Freas '16, Miguel Mendez '16, and Melissa Cendejas '16 all working on various aspects of the design, synthesis, and characterization of a series of novel conjugated oligomers that may find use in small molecule-based organic electronics. The group has made progress in characterizing small conjugated molecules and hopes to tie up some of the current work in the near future. Melissa, Chelsea, and Miguel will accompany Park to the National ACS meeting in San Francisco in August of 2014.

Park served again as Chair of the Committee on Educational Policy, as a member of the Business Plan Advisory Board, and as a member of the ad hoc Task Force on Faculty Planning. She also worked with the Office of Institutional Diversity in making visits to Columbia University and UC Berkeley to recruit and advertise the C3/LADO-based initiatives whose goal is to promote diversification of the professoriate. Park also served the larger chemistry community as a continuing member of the Committee on Professional Training for the ACS, and as a reviewer for various journals and funding agencies including ACS-Petroleum Research Fund, Research Corporation, the South Carolina GEAR program and other academic institutions. Park will be making a transition in the summer of 2014 to her new 2-year appointment as Associate Dean of Faculty. She joins the rest of the Chemistry Department in welcoming Patrick Barber who will be joining us as a Visiting Assistant Professor during Park's absence from the department.

In 2013-2014 Professor **Enrique Peacock-López** spent most of his sabbatical leave working on biochemical regulatory mechanisms. During The Winter Study period, Peacock-López taught *Introduction to Research in Physical Chemistry* (CHEM 24), and in collaboration with *Anuj Shah '15* extended his analysis of chemical self-replication. Chemical self-replication is a necessary to develop models of the origins of life, and competition between chemical systems must also be included in the discussion. To include competition in our analysis of chemical self-replication, we study a two-template system competing for one common reagent, which reduces to a five-variable model. The system exhibits a range of dynamic behaviors including chaos, complex oscillations, and synchronization.

During the spring semester, Professor Peacock-Lopez spent seven weeks as a Distinguished Scientist Visitor at the Department of Chemistry of the Ben-Gurion University of the Negeve in Beer-Sheva, Israel, where he extended his work on self-replication to self-replicating peptide networks. At Ben-Gurion University, Professor Gonen Ashkenazy has been synthesizing several self-replicating peptide systems, which show interesting networking. While there, in collaboration with Dr. N. Wagner and Professor G. Ashkenazy, Peacock-Lopez analyzed the smallest closed peptide network that shows bi-equilibrium. The application of his findings to larger peptide networks will be continued in the future.

While continuing with his research, Professor Peacock-Lopez, Gisela Demant, our stockroom manager, and Cheryl Ryan, a teacher from Hoosac Valley High School, organized and taught chemistry to eight local high school students. These students came five times during the year to complete some of the labs from the Williams Advanced Chemistry Lab Program and a newly developed organic synthesis lab. The latter experiment was implemented and adapted by Gisela Demant to include the synthesis of aspirin from salicylic acid and included the characterization of the product purity by TLC and melting point determination. Concurrently, one of the high school students, Mr. Sean Ryan studied the stability of discrete economical models as part of his senior research project under the direction of Peacock-Lopez.

Finally, Peacock-Lopez joined the Editorial Board of *The Scientific World Journal*, and he continued to serve as reviewer for the National Science Foundation, *Nonlinear Dynamics, Applied Mathematics and Computation, Journal of Chemical Physics, Nonlinear Analysis Series A: Theory Methods and Applications, Physica A, Physics Letters A, Journal of Chemical Education, Chaos, and Taylor* and the Francis Publishing Company.

In the fall, Professor **David Richardson** taught *Toxicology and Cancer* (CHEM 341) with 32 students and *Organic Chemistry, Intermediate Level-Special laboratory Section* (CHEM 255) with 13 students, while in the spring he taught *Synthetic Organic Chemistry* (CHEM 342), with two lab sections, to 25 students.

Professor Richardson continued his research with isolation of biologically active molecules from South East Asian plants, supervising studies conducted by work-study students *Amanda Walker '15* and *Naomi Fields '16* in collaboration with Professor Chip Lovett. Working together with Jay Racela of the Williams Environmental Studies Lab, he also supervised the research efforts of work-study students *Marcel Brown '15* and *Gabriela Suarez '17* who initiated a new project focused on determining the phosphorus content of environmental samples, particularly soils. He also supervised the final stages of the senior honors thesis project of *Gordon Bauer '13* involving the carbon mitigation potential of solar oven distribution projects in Central America.

Professor Richardson continued his supervision and maintenance of the Department's 500 MHz nuclear magnetic resonance spectrometer. He also continued his service as a reviewer for several scientific journals, including *Steroids*, *The Journal of Natural Products*, *Magnetic Resonance in Chemistry*, *The Journal of Heterocyclic Chemistry*, *The Journal of Organic Chemistry*, and *Natural Products Communications*, and reviewed an early section of the 5th edition of Smart and Hodgson's *Molecular and Biochemical Toxicology*.

During July 2013 he taught the Chemistry laboratory portion of the Williams College Summer Science Program and, together with Professor Chip Lovett, he hosted the Department's Summer Science Camp program for local 5th and 6th graders. He also served on the Board of the New England Tropical Conservatory. Together with Professors Janneke van de Stadt and James Manigault-Bryant, he served as co-Chair of the College's First Program for new faculty at Williams.

Senior lecturer emerita **Anne Skinner** continued her research into the age of *Homo sapiens* fossils from Tanzania, with the assistance of the second year of a Senior Science Mentor Grant from the Dreyfus Foundation. In September 2013 she gave a presentation on a site in Brazil to the Solid State Dosimetry conference in Recife, Brazil, covering a Brazilian early occupation site. In April, with *Kassandra Spiller '14*, she went to the Paleoanthropology and American Association of Physical Anthropologist meetings in Calgary, Canada, presenting the latest results on the Tanzanian site, which confirm the early dates of the fossils. Then in May she presented a preliminary study of the paleolithic Thames River to the 40th International Symposium on Archaeometry in Los Angeles.

Professor **Tom Smith** spent his sixteenth year at Williams pursuing his research in Asymmetric Methods for the Synthesis of Pyran-Based Anticancer Natural Products, under an AREA grant from NIH and a Henry Dreyfus Teacher-Scholar Award. Senior honors student *Craig Burt '14* continued work toward the synthesis of a new cytotoxic marine natural product, enigmazole A. In addition to his duties as Department Chair where he initiated a departmental curricular review, Professor Smith was a "Super Lab Instructor" for multiple sections of introductory and intermediate organic chemistry.

In her first year at Williams, Assistant Professor **Becky Taurog** taught *Biochemistry I: Structure and Function of Biological Molecules* (BIMO/BIOL/CHEM 321) and two sections of the associated lab. In the spring she returned to topics she had studied intensely as a graduate student in *Enzyme Kinetics and Mechanism* (CHEM 324). Additionally, she and her students delved into the current literature in *Topics in Biochemistry and Molecular Biology* (BIMO 401), the capstone seminar for BIMO concentrators.

The Taurog lab got off to a good start with the help of students *Won-Jun Kuk '14* and *Caitlin Yumori '14* who worked to set the groundwork for the ongoing study of the enzyme cobalamin-dependent methionine synthase. This enzyme requires cobalamin (vitamin B12) to catalyze the biosynthesis of the essential amino acid methionine. During the catalytic cycle, the enzyme undergoes large motions to bring each of the different substrates into proximity with the vitamin cofactor. The Taurog lab is interested in investigating the three-dimensional structures of the different positions (conformations) using transmission electron microscopy and other biophysical methods.

In the spring, *Linamarie Miller '15* conducted independent study with Professor Taurog. Lina cloned, expressed and purified the protein reductase flavodoxin, which binds to and reactivates methionine synthase when the cobalamin is oxidized. During spring break Prof. Taurog presented a poster at the Keystone Meeting on "Frontiers of Structural Biology" where she gained a number of new ideas about how to probe the conformational changes in methionine synthase and other biologically important enzymes.

This winter Professor Taurog collaborated with Nicole Steinmetz of Case Western Reserve on a paper

based on work performed as postdoctoral researchers at The Scripps Research Institute in La Jolla, CA. The paper was published in the journal *Virology* and explores the potential use of non-pathogenic virus particles for nanotechnology.

Professor **Jay Thoman** returned to classroom teaching in fall 2013 after a year-long sabbatical. He taught *Physical Chemistry: Structure and Dynamics* (CHEM 361), a lab section of *Principles of Modern Chemistry* (CHEM 155), and with Professor Amy Podmore cosponsored an independent study (ARTS 497) in glassblowing. *Nathan Bricault '14* and *Julia Cline '15* learned some off-hand glass blowing and also collaborated on two large flameworked pieces which were displayed in the rear atrium of the Morley Science Center. In spring 2014, Thoman reintroduced *Chemistry and Physics of Cooking* (CHEM 116). This course is designed for non-science majors and had not been taught in decades.

During summer 2013, Thoman worked with Professor Dave Richardson, *Christian Gronbeck '15*, and *Becca Staff '15* to synthesize some new model compounds to probe the stereochemistry of a deuteration reaction useful in synthesizing deuterofluorobarbon molecules. Richardson, Thoman, *Mandy Schott '15* and *Austin Paul '16* continued on a long-term project studying PCB pollution in the Hoosic River watershed. Mandy and Austin showed that the concentration PCBs in crayfish from the Hoosic River are of concern primarily in crayfish collected near a known point source of pollution. In June 2014, Thoman stepped down from chairing the Review Committee for the Chemistry GRE.

Class of 1960 Scholars in Chemistry

Dylan Barber	Dylan Griswold	Claire Lidston
Chelsea Boydstun	Tiantian (Karen) He	Lillian Ma
Tamuka Chidanguro	Ashley Kim	Amanda Walker

Chemistry Colloquia

Dave Arnold, Food Science Writer
"Science and Technology in the Kitchen"

Christian Bruckner, University of Connecticut
"The Breaking and Mending of Porphyrins: Synthesis of Porphyrinoids Containing Non-pyrrolic Building Blocks"

R. John Davenport '92, Brown University
"Forming Bonds in Brain Science"

Gerald B. Hammond, University of Louisville, Charles Compton Lectureship
"Does Pixie Dust Exist? The Quest for a Universal Reaction Promoter"

Dilip Kondepudi, Wake Forest University, Class of 1960 Scholars
"The Enigma of Asymmetry"

Casey Londergan '97, Haverford College
"Using Infrared and Raman Spectroscopy to Determine Dynamic Protein Structures"

Susan Marqusee, University of California, Berkeley, Class of 1960 Scholars
"Beyond the Native State: Uncovering the Sequence Determinants of a Protein's Energy Landscape"

Rick Morimoto, Northwestern University
"Proteostasis – Protecting the Proteome in Biology, Aging and Disease Using C. Elegans as a Model System"

Off-Campus Chemistry Colloquia

Todd Brenner ’14, Niek S. A. Crone, Alex Lou ’13, Denise Park ’15, Luxi Qiao ’16, and Sarah L. Goh
“Synthesis of amino acid-containing di-block copolymers”
Poster, ACS CT Valley Section 2014 Undergraduate Symposium, Amherst, MA, 2013

Todd Brenner ’14, Niek S. A. Crone, Denise Park ’15, Luxi Qiao ’16, and Sarah L. Goh
“Synthesis of amino acid-containing di-block copolymers”
Poster, ACS CT Valley Section 2014 Undergraduate Symposium, Amherst, MA, 2013

Tamuka Chidanguro ’15, Lillian Ma ’15, Sarah L. Guillot ’13, Zachary D. Remillard ’12, Christopher Goh
“Ligand donor effects of polydentate pyridine-amine ligands for copper in the ATRP of styrene”
BRIC (Boston Regional Inorganic Conference), Dartmouth College, Hanover, NH, May 2014

Enrique Peacock-López
“Chaos Control and Seasonality in Discrete Ecological Models”
Jacob Blaustein Institutes for Desert Research (BIDR), Ben-Gurion University of The Negev, Sede Boqer Campus, Midreshet Ben-Gurion, Israel, April 2014
“Chemical Self-replication as a Nonlinear System”
Department of Chemistry, Ben-Gurion University of The Negev, Beer-Sheva, Israel, April 2014

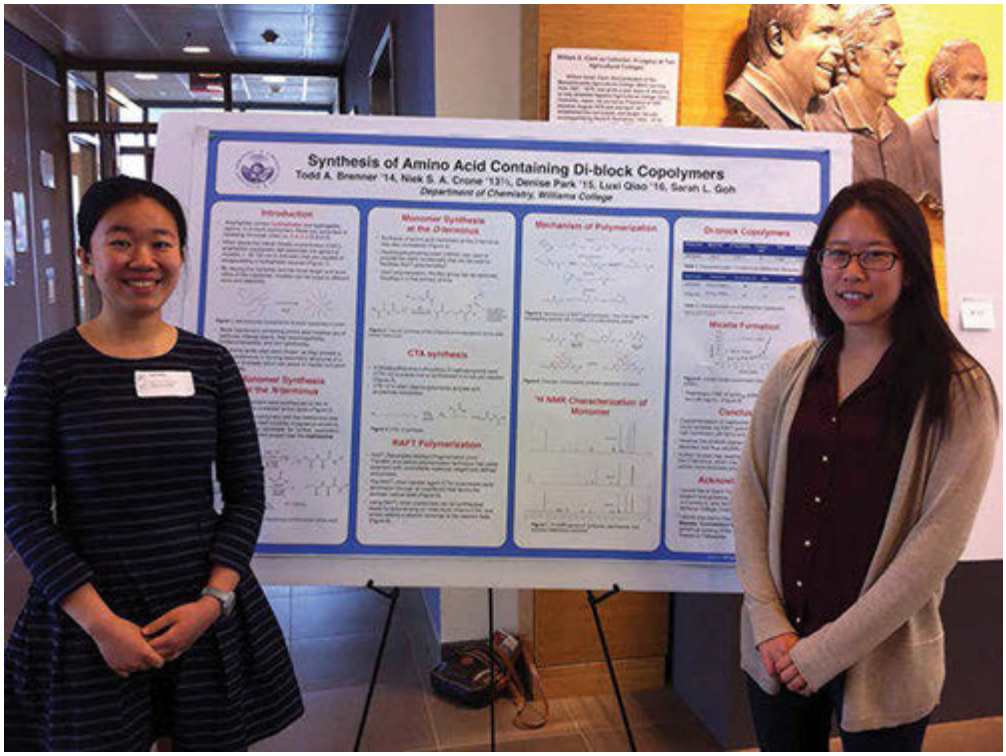
David Richardson, Jay Thoman, and Austin Paul ’16
“The Current State of PCB Pollution in the Hoosic River Watershed: An Update on Crayfish”
Hoosic River Watershed Association’s Annual State of the River Conference, November 2013

Anne Skinner
“Looking for the first settling of the New World: The Moendas site, Brazil”
17th International Conference on Solid State Dosimetry, Recife, Brazil, September 2013
“Dating Applications of Archaeology and Paleoanthropology”
University of Sao Paulo, Ribeirao Preto, Brazil, September 2013
“Dating Early Modern Human Occupation in Southern Tanzania”
AAPA 2014, Calgary, Alberta, Canada, April 2014
“Dating of Submerged Landscapes by Electron Spin Resonance”
40th International Symposium on Archaeometry, UCLA and Getty Villa, Los Angeles, CA, May 2014

Post-Graduate Plans of Chemistry Majors

Gordon Bauer	Working then to graduate school
Todd Brenner	IRTA Fellow, NIAID, Bethesda, MD, then M.D./Ph.D. programs
Jeff Brewington Jr.	Teach for America
Craig Burt	Ph.D., University of California, Irvine
Tiffany Chang	Research Associate, Harvard Business School, Boston, MA
Peter Clement	Working for Green Corps, Boston, MA, then to graduate school
Jennifer Doctolero	Unknown
Kathryn Dryer	Unknown
Liam Gallagher	Unknown
Pushpanjali Giri	Unknown
Michael Gold	Teaching in New Haven, CT
Vera Gould	Assembling an art portfolio
Kathleen Higgins	Research Associate, The Broad Institute, Cambridge, MA
John Ho	Executive Administrator, Asians and Pacific Islanders with Disabilities of California (APIDC), Los Angeles, CA
Willis Koomson	Unknown
Won-Jun Kuk	Work at Match Corps, Boston, MA, then to medical school
David Lee	M.D., University of California, San Francisco
Matthew McCarron	Unknown
Myya McGregory	Unknown
Zachary McKenzie	Unknown
Jessica Monterrosa Mena	Working in a research position, then graduate school
Anna Moriondo	Research Technician, Massachusetts General Hospital, Boston, MA
Lilliana Morris	Ph.D. in Chemistry, Cornell University
Julia Nguyen	Ph.D. in Chemistry, University of Washington
Liliane Nienstedt	M.A. in teaching, University of Louisville
Jackline Odhiambo	Work for Partners in Health
Georgiana Salant	Ph.D. in Biochemistry, University of Colorado, Boulder
Joon Hun Seong	Working at American Solar Partners
Kassandra Spiller	Research & Development Technician, PointCare, Marlborough, MA
Bianca Ulloa	Research Assistant, Tisch MS Research Center, New York, NY
Areli Valencia	High School Chemistry Teacher, Chicago, IL
Chau Vo	Research Technician, Boston Children's Hospital, Boston, MA
John Wawrose	Unknown

Scott Wieman	Unknown
Caitlin Yumori	Volunteer Coordinator, Rebuilding Together (AmeriCorps), NYC, then to medical school
Anna Zhou	Unknown



Luxi Qiao '16 (L) and *Denise Park '15* (R) presenting at the Undergraduate Symposium of the Connecticut Valley Section of the American Chemical Society at the University of Massachusetts in April 2014.

COMPUTER SCIENCE DEPARTMENT

The Computer Science Department was a busy place this past year. We had record numbers of majors and students in our classes, and many participated in research and independent projects that examine topics including machine learning, graph drawing problems, recognition codes, graphics algorithms, program analysis, and NAND memory based file systems.

In October *Christine Cunningham '15*, *Jenna Maddock '15*, *Jaclyn Porfilio '15*, *Abigail Zimmermann-Niefield '15*, *Rebecca Lewis '16*, and *Mia Smith '16* attended the Grace Hopper Celebration of Women in Computing in Minneapolis, MN, along with Professor Andrea Danyluk and Research Associate *Kelsey Levine '10*. We are also delighted to report that Kelsey was recently appointed the Head Alpine Ski Coach at Williams College.

In other news, Bill Lenhart returned to teaching classes in our department after a sabbatical following his tenure as Provost. It is great to have him back. *Brent Yorgey '04* is also returning to Williams next year as a Visiting Professor. He has just completed his dissertation at the University of Pennsylvania and will be teaching introductory computer science, as well as a new elective on functional programming.

After returning from maternity leave, this spring Professor **Jeannie Albrecht** continued to investigate techniques for using computing to decrease the energy impact of society. She primarily focused on challenges related to occupancy detection using only aggregate power usage. Extending results obtained by *Jennifer Gossels '13* in her honors thesis, last summer *Sarah Abramson '15* and *Kelsey Levine '10* used data generated from hundreds of sensors and power meters installed in Albrecht's home to explore ways to detect and predict home occupancy. Leveraging these results, Albrecht also worked with Professors Prashant Shenoy, and David Irwin, and graduate students Dong Chen, and *Sean Barker '09* at UMass Amherst on several algorithms for preventing occupancy detection in smart homes. Albrecht described some of the initial results obtained from this work during the faculty lecture series in the spring. Sarah Abramson will continue her work in summer 2014. Moving forward, they plan to leverage our previous experience in smart home instrumentation and install sensors in the newly designed Kellogg House, hopefully enabling that house to be certified as a Living Building.

During the past year, Albrecht continued to develop Gush, which is a framework for configuring and controlling distributed applications (http://gush.cs.williams.edu). Gush is part of a National Science Foundation (NSF) funded project for creating GENI - a Global Environment for Network Innovations (http://www.geni.net). Recently, Albrecht has been investigating ways to infuse the new technologies developed as part of the GENI project into classroom exercises and projects, particularly at the undergraduate level. Last October, Albrecht organized an NSF sponsored workshop at the GENI Engineering Conference that encouraged the use of GENI in undergraduate and graduate networking and distributed systems classes. The workshop brought together researchers and educators from colleges and universities nationwide to discuss how to effectively use GENI tools in a classroom setting.

Professor **Duane Bailey** returned from leave this year and taught a section of the department's Data Structures course in Python, using a draft of his new text, *Python Structures*. The new, free text is accompanied by a comprehensive package of data structures, written in Python, that represents the result of three years of studying best practices with *Jennifer Gossels '13* and *Derrick Bonafilia '17*. A second fascicle, focusing on the conversion of Python classes to native code is currently being prepared.

Bailey also worked with several students this year on independent research projects. *Tong Liu '16* and *Michael Shaw '16* did a focused investigation of the efficacy of left-leaning red-black trees (LLRBs), a simplification of red-black trees described by Sedgewick. Their work suggests that LLRBs may be useful in supporting databases where few records are ever removed. Liu and Shaw presented their work at the department's research colloquium. Their implementation is now available as part of Bailey's structure packages in both Java and Python.

Jenna Maddock '15 worked with Professor Bailey on the development of near-regular quad meshes. Their hope is to ultimately investigate the robustness of cellular automata embedded graphs whose connectivity is similar to tissue topologies found in nature. The work is the first step in a loose collaboration with researchers at Utah State, where plant tissues appear to have emergent behaviors similar to those seen in regular automata.

Professor **Andrea Danyluk** continued her research in machine learning, working on a number of different projects. She supervised the work of two honors students, *Joshua Geller '14* and *Daniel Seita '14*. Josh's work considered feature selection in the context of multiclass classifier learning algorithms. As their name suggests, these algorithms generate classifiers from labeled training examples. Each example is an instance of the type one would want to classify, represented as a vector of features. The problem of feature selection is determining the minimal set of features from which a high-accuracy classifier can be learned. Daniel's work focused on probabilistic graphical models. These models can be used for probabilistic reasoning and, like classifiers, can be learned from data.

Danyluk looks forward to working on three projects in summer 2014, all of which involve applying machine learning to practical real-world problems. With one summer student, she will continue a project on applying computational techniques to automatically identify individual spotted salamanders from digital images. With a second, she will work on active learning in domains with highly skewed class distributions. In addition, she will begin a new project with Professor Albrecht in the area of green computing.

Professor Danyluk wrapped up her service as a member of the steering committee for the ACM/IEEE Computer Science Curriculum 2013. The committee was tasked with developing international curriculum guidelines for undergraduate programs in computer science. The final report came out in December 2013. This extensive document outlines the principles guiding the CS2013 process, commentary on desired characteristics of computer science graduates, professional practice, and institutional challenges, as well as the "body of knowledge," which describes topics and learning outcomes for 18 knowledge areas spanning computer science. It also includes the Williams Computer Science Department as an example of how the curricular guidelines can be implemented at a liberal arts college.

Danyluk also continued her work as a board member of the CRA-W, the Computing Research Association's Committee on the Status of Women in Computing Research. As a member of the CRA-W, her primary responsibility is to administer an undergraduate research grant program, but she also works to develop and disseminate resources on best practices for mentoring undergraduate research.

Professor **Stephen Freund** is finishing his tenure as Department Chair and is looking forward to a half-year sabbatical during which he will split his time between visiting scholar appointments at University of Massachusetts, Amherst, and University of California, Santa Cruz.

Freund's research focuses on tools to help programmers find defects in software, particularly in the area of multithreaded software designed to run, for example, on multicore processors. He presented work on this topic at the European Conference on Object-Oriented Programming. At that conference, his paper, titled *RedCard: Redundant Check Elimination for Dynamic Race Detectors* received the Best Paper Award. He also gave a talk on his research at IBM and at the University of Massachusetts, Amherst.

In summer 2013, Freund worked with *Emma Harrington '15* on dynamic escape analysis. That analysis identifies which data in a program is used by multiple threads and thus prone to potential interference if those threads manipulate the data at the same time without coordination. In addition, *Parker Finch '14* just completed an honors thesis under Freund's supervision. Parker's thesis examined how to use source code analysis to speed up run-time detection of race conditions, one particular type of potentially-damaging thread interference.

Freund is currently serving on the Programming Languages Education Board, the national committee in his research community that focuses on issues surrounding undergraduate education.

Associate Professor **Brent Heeringa** spent the last

year on sabbatical from the Computer Science Department. He spent a majority of his time working as Research Scientist at Fiksu, a mobile advertising technology company. At Fiksu, Heeringa helped design and develop algorithms to improve performance in real-time bidding auctions. Heeringa continued his collaboration with Nate Kornell (Psychology) and *Carson Eisenach '14* on recognition codes, which encode arbitrary pieces of information in representations that are human-friendly.

Heeringa reviewed papers for the Symposium on Theory of Computation (STOC) and the European Symposium on Algorithms (ESA). In addition he traveled to Portland, OR for the Symposium on Algorithms and Data Structures.

Professor **Bill Lenhart** returned to full-time teaching and research this year after serving in multiple administrative positions at the College and taking a well-earned sabbatical. He continued pursuing his interests in graph drawing and computational geometry, focusing on problems involving the embedding of graphs and geometric objects in two and three dimensions subject to various constraints.

One project considers straight-line embeddings of graphs having the property that the number of distinct slopes used by the edges of the graphs is small. One product of this investigation was the paper *Planar and Plane Slope Number of Partial 2-Trees* co-authored with Giuseppe Liotta of the University of Perugia, and Debajyoti Mondal, and Rahnuma Islam Nishat, Ph.D. students at the Universities of Manitoba and Victoria, respectively. This work was presented at the Twenty-First International Symposium on Graph Drawing in Bordeaux, France in September 2013. In this paper the authors establish tight bounds for the planar and plane slope numbers of partial 2-trees of bounded degree and answer a long-standing question about the angular resolution of planar straight-line drawings of series-parallel graphs of bounded degree.

A second project investigates classes of "almost-planar" graphs, in which the notion of a planar graph has been weakened in various ways. The goal is to explore the extent to which efficient algorithms for the extensively-studied class of planar graphs can be extended to these broader classes. This work, joint with Will Evans of the University of British Columbia, Michael Kaufmann of Universität Tübingen, Giuseppe Liotta, Tamara Mchedlidze of the Karlsruher Institut für Technologie, and Steve Wismath of Lethbridge University, resulted in the paper *Bar 1-Visibility Graphs and their relation to other Nearly Planar Graphs* which has been submitted for publication. In the paper, the authors establish containment (or non-containment) relations among a number of well-studied classes of graphs that themselves contain all planar graphs. We also show that 1-planar graphs and the (undirected) squares of planar 1-flow networks are weak bar 1-visibility graphs and that these graphs are quasi-planar graphs.

Another line of research involves what are known as obstacle drawings of graphs. These are straight-line planar drawings in the presence of polygonal obstacles with the property that no edge of the graph can intersect an obstacle, and each non-edge of the graph is intersected by at least one obstacle. Bill worked with *Philippe Demontigny '14* on problems in this area and served as the supervisor for Philippe's senior thesis in Mathematics. Philippe and Bill were able to completely characterize those trees that have convex obstacle number at most 2; that is, those graphs that have an obstacle representation consisting of at most two convex obstacles.

Bill also had the pleasure of serving on the program committee for the 21st International Symposium on Graph Drawing, which was held in Bordeaux, France this past September. The only greater pleasure would have been actually attending the conference!

On sabbatical this year, Associate Professor **Morgan McGuire** celebrated the publication and success of three large projects that he's worked on for many years. The Skylanders SWAP Force video game by Vicarious Visions, published by Activision, was the #1 children's video game in 2013. The Call of Duty: Ghosts video game by Treyarch, published by Activison was the #1 non-children's game of the year. The third edition of the Computer Graphics: Principles and Practice textbook was launched at the ACM SIGGRAPH annual conference with parties and signing events.

The computational graphics lab at Williams published a significant study of methods for efficiently representing 3D unit vectors, culminating two years of work by undergraduates *Zina Cigolle '12*, *Samuel Donow '16*, *Daniel Evangelakos '15*, and *Michael Mara '12*. The study established new best practices for the field and gave definitive analysis of all known techniques. The new methods were quickly adopted throughout the industry and have already led to improved image quality in video games and non-entertainment graphical applications.

Professor **Tom Murtagh** continues to investigate techniques for optimizing the performance of NAND memory based file systems. Manufacturers have packaged NAND memory with interfaces that imitate disk interfaces so that NAND memory devices can be used in place of disks without any change in system software. This approach works, but it cannot work well. Because the software is fooled into viewing the NAND memory as a disk, it makes data placement decisions optimized for disk device rather than for the constraints of NAND memory. During the last year, Tom worked with *Kyle Cheng '16*, to design of new file system for NAND memory based on generalizing techniques used in log structured file systems by having the system maintain multiple logs simultaneously. This summer, Tom will be working with *Austin Paul '16* and *Alexander Majercik '17* to construct an experimental implementation of this file system and evaluate its performance.

Ziang (Lucky) Zhang '14 giving a short presentation during our weekly colloquium.

Class of 1960 Scholars in Computer Science

Sarah M. Abramson '15
Derrick J. Bonafilia '17
Simon C. Chase '14
Kyle S. Cheng '16
Samuel A. Donow '16
Daniel Evangelakos '15
Parker S. Finch '14
Gordon M. Finnie '16
Joshua E. Geller '14
Emma K. Harrington '15
Matthew D. LaRose '16
Isaiah H. Leonard '15
Jamie R. Lesser '17
Tong Liu '16
Nile M. Livingston '15
Alexander S.N. Majercik '17
Brianne C. Mirecki '14
Pamela F. Mishkin '16
Austin J. Paul '16
Jose M. Raventos '16
Daniel T. Seita '14
Michael G. Shaw '16
Diwas Timilsina '16
Kelly A. Wang '16
Lauren J. Yu '16

Computer Science Colloquia

Vijay Ramachandran, Colgate University
"Interdomain Routing and Game Theory, a.k.a., Why It's (Sometimes) OK to Tell the Truth"

Computer Science Faculty, Williams College
"Graduate School - Everything You Need To Know"

Catherine McGeoch, Amherst College
"Experimental Evaluation of an Adiabatic Quantum Computer for Combinatorial Optimization"

Andrea Danyluk, Williams College
"Feature Selection via Probabilistic Outputs"
Science Lunch Series at Williams College

Andrea Danyluk, Williams College
"Identification of Individual Spotted Salamanders"
Inside Williams at Williams College

Ran Libeskind-Hadas, Harvey Mudd College
"The Hitchhikers Guide to Coevolution"

Joshua D. Ain '03, Google

Michael Gnozzio '07, Cogo Labs

Kristof Redei '07, TurningArt

Katherine L. Weyerhaeuser '11, Fiksu
"Computer Science after Williams: A Career Panel"

David Kauchak, Middlebury College
"Learning To Simplify Text One Sentence at a Time"

Mark Crovella, Boston University
"Inferring Invisible Internet Traffic"

Computer Science Faculty, Williams College
"Faculty Research Talks"

Jeannie Albrecht, Williams College
"Detecting and Predicting Occupancy in a Smart Home"
Faculty Lecture Series at Williams College

Michael T. Mara ‘12, NVIDIA with Simon Chase ‘14, Joshua Geller ‘14, Ethan Gracer ‘14, Daniel Seita ‘14, and Lucky Zhang ‘14
“Next Steps after Williams CS: Applying for Technical Jobs and Graduate School”

Stephen Majercik, Bowdoin College
“Nature Inspired Optimization Techniques”

Benjamin Hescott, Tufts University
“Going the Distance for Protein Function Prediction”

Computer Science Student Colloquia

Nico Ekasumara ‘14, Parker Finch ‘14, Jaclyn Porfilio ‘15, Daniel Seita ‘14, and Lucky Zhang ‘14
“Student Summer Talks Part I”

Domonique Carter ‘15, Conor Dowling ‘14, Joshua Geller ‘14, Llewellyn Smith ‘15, Benno Stein ‘15, Aaron Willey ‘16, and Abigail Zimmermann-Niefield ‘15
“Student Summer Talks Part II”

Parker Finch ‘14
“Static Coalescing of Race Checks”

Joshua Geller ‘14
“Black Box or Composite: Approaching Multi-Class Feature Selection”

Daniel Seita ‘14
“Building Sum-Product Networks”

Tong Liu ‘16 and Michael Shaw ‘16
“An Alternative Implementation of Red-Black Trees”

Daniel Seita ‘14
“Building Sum-Product Networks”

Parker Finch ‘14
“Decoupling and Coalescing Race Checks”

Joshua Geller ‘14
“Multi-Class Feature Selection”

Off-Campus Computer Science Colloquia

Jeannie Albrecht
“Using GENI to Bring Big Systems to Small Schools”
GENI Engineering Conference 18, October 2013

Andrea Danyluk
“Prototype Support Vector Machines: Supervised Classification in Complex Data Sets”
COPEM Workshop held at ECML/PKDD, Prague, Czech Republic, September 2013

“Undergraduate Research Internships”
Grace Hopper Celebration of Women in Computing Conference, Minneapolis, MN, October 2013

“Designing a Senior Faculty Career Mentoring Workshop”
Grace Hopper Celebration of Women in Computing Conference, Minneapolis, MN, October 2013

“Experiences Mapping and Revising Curricula with CS2013”
SIGCSE 2014, Atlanta, GA, March 2014

"Work/Life Balance and Time Management"
New Educators Workshop at SIGCSE 2014, Atlanta, GA, March 2014

Stephen Freund

"Dynamic Analyses for Data Race Detection"
University of Massachusetts, Amherst, MA, November 2013

"RedCard: Redundant Check Elimination for Dynamic Race Detectors"
European Conference on Object-Oriented Programming, Montpellier, France, July, 2013

Morgan McGuire

"Vicarious Visions' Making of Skylanders: SWAP Force"
Brown University, Providence, RI, April 30, 2014

University of Montreal, Montreal, Canada, February 27, 2014
Union College, Schenectady, NY, February 19, 2014

"Efficient Parallel Simulation of Indirect Illumination"
University of Montreal, Montreal, Canada, February 26, 2014

Computer Science alumni Josh D. Ain '03, Kristof Redei '07, Mike Gnozzio '07, and Kaylee Weyerhaeuser '11 reflect on their post-Williams experiences during a career panel for majors.

Post Graduate Plans of Computer Science Majors

Nathan R. Bricault	Graduate school	University of Cambridge Cambridge UK
Jason R. Briggs	Rastech Software	
Simon C. Chase	BBN Technologies	Boston MA
Conor W. Dowling	Graduate school	
Carson M. Eisenach	Graduate school	Princeton University Princeton NJ
Nico P. Ekasumara	Amazon	Seattle WA
Daniel F. Ferreira	Undecided	
Parker S. Finch	Cognius	Cambridge MA
Joshua E. Geller	Facebook	
Ethan D. A. Gracer	Software development	
Nickolas J. Maziarka	Undecided	
Brianne C. Mirecki	Undecided	
Tucker B. Moore	Undecided	
Nehemiah A. Paramore	Undecided	
Lily K. Riopelle	Undecided	
Daniel T. Seita	Graduate school at University of California	Berkeley
Nicholas G. Wolf	Undecided	
Ziang (Lucky) Zhang	Software Engineer at Google	Mountain View CA

During Spring semester, Duane Bailey's VLSI Design class collectively implemented two versions of hardware that use SIMD-based parallel processing to support game-play in the currently popular 2048 puzzle. The 180nm CMOS hardware (one implementation shown here) measures 0.85mm on a side. It takes input from four direction buttons, and generates serialized output to drive 16 4-digit 7-segment displays.

GEOSCIENCES DEPARTMENT

Comings and goings are integral to the rhythms of a college. We love the excitement of new arrivals and we regret the loss of students and colleagues as they move on. This year we welcome our largest ever group of incoming majors. The class of 2016 will include 20 budding geoscientists, which is 20% more than our previous largest class and also our most diverse class ever. This group also brings a vibrant collective energy that we expect will make the department hum over the next two years! We are sorry to say goodbye to the class of 2014, but we are delighted with their accomplishments and expect that they will make a mark in the world as they begin their post-Williams careers. We also say goodbye to Dave Backus, who moves this summer to Davidson College in North Carolina where he will be teaching Oceanography, joining his wife Wendy Raymond (formerly Professor of Biology at Williams). Dave has been a stalwart member of our department for many years and we will miss him.

Senior Geosciences major *Eloise Andry '14* was selected among nearly 700 applicants nationwide to receive a Watson Fellowship. She will use her fellowship to pursue a project titled *Solid as a Rock? Life on a Volcano*. Her research will take her to Iceland, Chile, New Zealand, Vanuatu, and Indonesia. Eloise and *Nell Davis '15* were co-recipients this year of the Lauren Interess Fellowship. They spent part of Winter Study traveling through New Mexico exploring various volcano sites. Nell was awarded a scholarship from the David Major Fund to attend a summer field camp through the Black Hills Natural Sciences Field Station in the Himalayas. In April the Keck Geology Consortium held its annual symposium at Mt. Holyoke. In attendance were *Johanna Eidmann '14*, *Michelle Paradis '14*, and Professors Phoebe Cohen, Mea Cook, and Bud Wobus. The annual Freeman Foote Prize for best presentation of a senior honors thesis was awarded to *Kalle Jahn '14* and *Johanna Eidmann '14* was give the David Major Prize for an outstanding Geosciences senior.

After a busy year of teaching, the faculty are gearing up for summer research, and we have a wide range of ventures about to launch. Students of all levels, from current freshmen to rising seniors, will be undertaking projects in the Yukon, Ireland, Iceland, Colorado and here in Williamstown, among other locations. Their projects are varied, and include collecting Precambrian microfossils, monitoring boulder movements, making their own lava flows with molten basalt, measuring erosion rates, and analyzing climate records in deep-sea sediments.

Assistant Professor **Phoebe Cohen** spent the summer finishing setting up her new lab facility in Bronfman, while working with summer research student *Quinn Griffin '15*, and taking a short trip to the Cambrian of Newfoundland to collect samples for a new project. In the fall *Kelly Tellez '17* and *Spencer Irvine '16* began working in Phoebe's lab. Spencer will be working on a project involving 750 million year old fossilized amoebas which he turned into a Winter Study 99 project and continues to work on in the spring semester. Phoebe attended the national meeting of the Geological Society of America in Denver, Colorado, in October where she gave a presentation on new diversity assessments of the Proterozoic Eon fossil record. At this meeting, Phoebe also received the *Journal of Paleontology* Best Paper Award for 2012.

In the spring, Phoebe taught the new class *Mass Extinctions* (GEOS 312T) which is a travel tutorial funded through an award from the Freeman Foote Travel Fund. Phoebe traveled to Italy for 8 days over spring break with 10 tutorial students and fellow Geosciences faculty member Mea Cook to explore evidence for the Cretaceous-Paleogene mass extinction event (where the dinosaurs went extinct) and to investigate the geological history of the Umbria-Marche region. In the lab, Phoebe added *Mary Ignatiadus '16* to her lab in the spring, who has been working on processing samples from the Newfoundland field trip. Phoebe served as the advisor for *Michelle Paradis's '14* senior Keck thesis on dolomite formation in Deep Springs Lake, CA. Michelle and Spencer both presented preliminary results of their research at a mini-conference at Smith College sponsored by the NSF funded Sedimentary Geology, Time, Environment, Paleontology, Paleoclimatology & Energy (STEPPE) consortium.

In June, Phoebe will travel to Yukon, Canada, with *Laura Stamp '16* to collect samples for her NASA Astrobiology funded research and kick-start Lau-

ra's CBL-funded summer research. Laura will be joined in the lab this summer by current lab members Spencer Irvine and Kelly Tellez as well as Mary Ignatiadus who is also working on a CBL-funded summer research project. This year, Phoebe served as a reviewer for *Geology*, and as the Social Media Coordinator, member of the Education Committee, and Geological Society of America Joint Technical Program Committee representative for the Paleontological Society.

Mea Cook attended the 11th International Conference on Paleoceanography in Sitges, Spain, and the American Geophysical Union annual meeting in San Francisco, California, and presented her work reconstructing ocean circulation and productivity in the North Pacific Ocean from the end of the last ice age. Five research assistants worked on projects in her lab learning about the importance of the Pacific Ocean circulation in climate changes during the ice age cycles, and preparing deep-sea sediment samples and microfossils for isotope measurements reconstructing productivity, nutrients, climate, and circulation from the past. Cook was invited to give colloquia on her work at U Mass, Amherst, the Woods Hole Oceanographic Institution and McGill University.

In summer 2013, **Rónadh Cox** took thesis student *Kalle Jahn '14* and field assistant *Will Wicherski '15* to Shetland to measure boulder ridges. Kalle's project in this new location builds on work by several previous generations of students in the west of Ireland, aimed at understanding the sedimentology of coastal boulder deposits, and relating them to storm wave processes. This work will continue further in summer 2014, when she takes a group of seven students (a rising sophomore, five rising juniors, and one rising senior) back to the west of Ireland to measure boulder movements. The winter of 2013-14 in the northeastern Atlantic region was exceptionally stormy, with strong wind and high waves causing substantial coastal erosion and damage to infrastructure. The field research group will use the archive of field photos generated during previous projects as a benchmark for measuring changes in boulder ridge geometry and the movements of individual large boulders. The rising senior, *Oona Watkins '15*, will use these data for her honors thesis project.

Rónadh continues as chair of the department and as a Science Editor for the journal *Geology*, as well as being a member of the Geological Society of America's Publications Committee. At GSA's annual meeting in October 2013 she presented results from the boulder ridges project, and at a Lunar and Planetary Institute meeting in August 2013 she presented results, co-authored with *Aaron Bauer '11*, on numerical simulations of cometary impacts into Jupiter's moon Europa. In the coming year she hopes to write these results up for publication.

David Dethier was on leave during 2013-14 and worked to get some of his NSF-sponsored research in the Colorado Front Range into published form. That research, with students from Williams College and Keck projects, focused mainly on the measurement of geomorphic and geochemical processes in the Boulder Creek "critical zone" (CZO), which includes the mantle of soil and weathered material above fresh bedrock. In July, in cooperation with the NSF CZO project, he collaborated with *Will Ouimet '01* (now teaching at UConn), *Ian Nesbitt '13* and *Victor Major '15* in the Boulder Creek watershed and Fourmile burn areas, returning in the fall after catastrophic floods swept the Front Range. Those floods will be the focus of a Keck project in July 2014. *Paul Bierman '85* (Univ. of Vermont), *Greg Balco '91* (Berkeley), Ouimet and Dethier continued investigations of Front Range weathering and erosion rates using meteoric and in-situ cosmogenic ^{10}Be and bomb-isotope (ex. ^{137}Cs) techniques. Dethier also worked in the City of Boulder watershed and adjacent areas with Matthias Leopold (Univ. of Western Australia) and other colleagues from the Technical University of Munich, using resistivity and ground-penetrating radar to non-destructively image the shallow subsurface in a suite of mainly alpine study areas.

Dethier helps to coordinate ongoing collection of weather, streamflow, precipitation chemistry and other environmental data from Hopkins Memorial Forest and their analysis in the Environmental Science Lab in the Morley Science Center. Real-time weather and groundwater data and archived weather data from 29 years of monitoring are available at http://oit.williams.edu/weather/; archived watershed data are at: http://web.williams.edu/weather/watershed/index.php.

Since 2010, Dethier has been Chair of the Kellogg Building Committee, which is helping to guide construction of a new Environmental Center adjacent to the newly opened library. When the new Center opens in early 2015, it will house the Center for Environmental Studies and the Zilkha Center for Environmental Initiatives, make all of its energy using PV panels, and collect all its water from the roof! http://env-center.williams.edu/

InterRidge postdoctoral researcher Emanuele Fontana from the University of Milan and senior Caroline Gregory (Williams-Mystic Spring 2013; Hamilton '14) spent the summer of 2013 in **Lisa Gilbert's** lab to study the structural and petrophysical character of the lava/dike boundary of oceanic crust from several drill holes and the Troodos Ophiolite in Cyprus. Throughout 2013-14, Gilbert has also been working on origin and evolution of the Walvis Ridge, seamounts in the South Atlantic Ocean, with colleagues from the University of Oregon and undergraduates Alana McGillis (Williams-Mystic F13; Smith '15), Gabriela Serrato Marks (Williams-Mystic F13; Bowdoin '15), Amanda Ketting-Olivier (Williams-Mystic S14), Molly Weiner (Williams-Mystic S14; University of Rochester '16), and Katherine Enright (Wesleyan '15).

In addition to her seafloor research, Lisa Gilbert is collaborating on two NSF-funded national efforts related to geoscience education. Gilbert and others have been developing interdisciplinary teaching materials related to sustainability science, with a specific focus on hurricane hazards and risks. The materials include an educational video on hurricane formation, by Gilbert and *Phoebe Hall '16*, a Video Intern at OIT, which is published on the Science Education Resource Center website and has already been used in geoscience classes across the country. In 2013, Gilbert participated in summer institutes at Carleton College in Minnesota and University of Colorado-Boulder and presented results of collaborative research at the American Geophysical Union Fall Meeting and Geological Society of America Annual Meeting.

Emeritus professor **Markes Johnson** and research scientist Gudveig Baarli continue with academic work on a wide range of topics from their office in Mather House. In November 2013, Markes traveled to Baja California to check on a new study site at El Pulpito related to a marine terrace on the Gulf of California. Also during the fall semester, Gudveig completed a research paper on extinction patterns enlarged from her presentation at the conference on "Early Palaeozoic Global Change" held in July 2013 at Lund University in Sweden (see under publications).

In February 2014, Markes and Gudveig were the faculty representatives on two back-to-back excursions through the Galapagos Islands organized for Williams College alumni. Markes gave a series of lectures with a focus on the discoveries made by Charles Darwin during the voyage of the Beagle. The trip made it possible to collect photos of Pliocene to Recent fossil deposits on several islands that will be used to illustrate a review of Darwin's 1844 volume on volcanic islands. The University of Arizona Press released Markes' new book on the landscapes and geology of islands and peninsular shores of the Gulf of California on March 13 in time for the Tucson Festival of Books celebrated March 15-16, 2014. In Tucson, Markes promoted his book by participating in two panel discussions and by offering his own workshop on "Nature Writing." As an extension of this promotional trip, Markes was invited to give a lecture before the San Diego Alumni Club meeting at Scripps Oceanographic Institute on March 18 and for the San Diego Association of Geologists on March 19.

In April, the Portuguese-Spanish research team with whom Markes and Gudveig have worked since 2010 initiated a new project on Miocene stratigraphy and paleontology in the Algarve region of southern Portugal. The project makes it possible to compare patterns in Miocene limestone deposition already completed in the Cape Verde Islands on a broader regional scale in the context of changing Miocene climate. Aspects of this program with a special emphasis on fossil rhodoliths were presented by Markes during his participation in the Eleventh International Workshop on "Palaeontology in Atlantic Islands" held on Santa Maria Island in the Azores from June 19 to 28, 2014.

Professor of Geosciences **Paul Karabinos** continued research on his grant from the National Science Foundation to support an educational initiative Vi-

sualizing Strain in Rocks with Interactive Computer Programs. This project, in collaboration with Chris Warren from the Office of Information Technology, aims to create new computer programs written in Java, and accompanying modules for classroom and laboratory use, to enhance student learning of fundamental concepts of strain analysis in rocks. He also began work on another NSF-funded educational initiative called GEODE- Google Earth for Onsite and Distance Education. This collaborative effort involves a dozen geoscientists, computer specialists, and cognitive psychologists. Its goal is to create a comprehensive set of demonstrations, exercises and tools for instructors to use in a wide variety of educational settings.

Karabinos attended the National meeting of the Geological Society of America in Denver, Colorado, in October, 2013, where he gave two presentations: *Creating and Disseminating Interactive 3D Geologic Models* and *Interactive 3D Geologic Models Created with SketchUp*. He was co-author on *Terrane Accretion and Foreland Basin Formation in the Northern Appalachians*.

He attended a Penrose Conference, Linkages and Feedbacks in Orogenic Processes, in Asheville, North Carolina, in April, 2014, where he presented a talk entitled *Deformation Gradients in the Day Mountain Thrust Sheet, Massachusetts: Implications for Strain Localization* with *Elizabeth Pierce '07*.

He was co-author on an abstract with Chuck Mitchell (SUNY Buffalo), Francis Macdonald (Harvard), and James Crowley (Boise State) given at the Geological Association of Canada/Mineralogical Association of Canada meeting in Fredricton, New Brunswick, in May, 2014, entitled *Linked Histories of Allochthon Emplacement, Pulsed Subsidence and Faunal Evolution in the Taconic Foreland Basin*.

He helped organize the third Structural Geology and Tectonics Forum held in Golden, Colorado, in June 2014. He led a one-day workshop called *Strain Programs for Teaching and Research*, and presented a talk entitled *Creating, Disseminating, and Testing Interactive 3D Models for Teaching Structural Geology*.

He published an article in *Geology* with Francis Macdonald (Harvard), Juliet Ryan-Davis (Middlebury), Ray Coish (Middlebury), and James Crowley (Boise State), entitled *A Newly Identified Gondwanan Terrane in the Northern Appalachian Mountains: Implications for the Taconic Orogeny and Closure of the Iapetus Ocean.*

Professor **Bud Wobus** advised *Eloise Andry '14* on her NSF-REU-sponsored thesis study of the construction and petrologic evolution of Stawberry Crater in the San Francisco Volcanics Feld, northern Arizona. Eloise presented a poster on her thesis at the annual meeting of the Geological Society of America in Denver in October, where Wobus organized a reunion of about 25 alumni and faculty and students attending the meeting. Also at GSA he represented Williams for the 27th year on the governing board of the Keck Geology Consortium (keckgeology.org). In December he attended the meeting of the American Geophysical Union in San Francisco, again nucleating a casual gathering for 20-25 Geosciences alumni and faculty attending the meeting or working in the Bay area.

During WSP he helped to plan and was advisor for a two-week field study of volcanic centers in New Mexico, where Andry and *Nell Davis '15* utilized the Interess Travel Grant they were awarded by the department. Also in January he worked with the Careers Office to sponsor a weekend workshop on *Geoscience Careers*, with 8 alumni returning as panelists. In April he attended the board meeting and symposium of the Keck Geology Consortium at Mt. Holyoke College.

This summer he will become the advisor for Nell Davis' senior thesis sponsored by the Keck Consortium. Her multi-faceted project involves field study of young lava flows in Iceland and experimental production of lava structures at the Syracuse University "Lava Project," both to be compared with recent images from Mars rover exploration. During alumni reunion weekend he will again lead his annual walk, *Williams Rocks…a geological tour of the campus to see what Williams is built in, on, and of.* In July he will direct the 24th edition of the week-long Alumni College in the Rockies, which began the Williams alumni travel-study program in 1981. At its conclusion he will offer a weekend field seminar for the Florissant Fossil Beds National Monument, CO, on the mid-Tertiary Thirtynine Mile Volcanics Field.

Class of 1960 Scholars in Geosciences

Caroline Atwood
Hannah Brown
Alice Chapman
Nell Davis
Joshua Harrington
Kathleen Higgins
Ailan Hurley-Eschevarria
Spencer Irvine
Abigail Kelly
Stephen Mayfield
Connor McLane
Cody Remillard
Jeffrey Rubel
Christina Seeger
Laura Stamp
Kelly Tellez
Nakita VanBiene
Caroline White-Nockleby

Geosciences Colloquia

Dr. Alex Apotsos, American Association for the Advancement of Science
"Coastal Dynamics: Setting Up the Surfzone"

Miranda Bona '13
"Learn about the Geosciences Major and the Transition into Environmental Consulting"

Dr. Diana Boyer, SUNY, Oswego
"How to Make a Mass Extinction: A Case Study from the Devonian of New York State"

Dr. Seth Finnegan, Univ. of California, Berkeley
"How Do You Survive Rapid Climate Change?: Lessons from the Late Ordovician Mass Extinction"

Dr. Heather Ford, Lamont-Doherty Earth Institute
"El Niño and El Padre: The Pliocene Warm Period as an Analogue for Future Climate Change?"

Dr. Lisa Gilbert, Williams-Mystic
"Adventures in the Deep Sea: Rocks Younger than You"
Faculty Lecture Series at Williams

Dr. Amy Barr Mlinar, Brown University
"Formation of the Ganymede/Callisto Dichotomy by Impacts During the Late Heavy Bombardment"

Dr. Maureen Raymo, Lamont-Doherty Earth Observatory
"Orbital Forcing of Climate Over the Last 3 Myr: Puzzles to Ponder"

"Sea Level During Past Warm Periods"

Dr. Gavin Schmidt, NASA-GISS
"Can We Use Paleo-Climate to Constrain Future Climate?"

Dr. R. A. Wobus, Geosciences Dept.
"From Quarry to Quad – the Quintessential Orthopyroxene Norite of 'Hodge's Table'"
Science Lunch, September 2013

"Williams Rocks"
Williams campus geological tour, Alumni Weekend, June 2014

Geosciences Student Colloquia

Eloise Andry ’14 and Nell Davis ‘14
“Volcanic Adventures”

Eloise Andry ‘14
“The Eruptive History of Strawberry Crater, San Francisco Volcanic Field, Northern Arizona”

Johanna Eidmann ‘14
“A Paleoclimate Reconstruction of Lake Linné: Interpreting the Influence of Sediment Sources Through Time”

Kalle Jahn ‘14
“Sedimentology of Storm Deposits: Ireland, Shetland, and Beyond”

Paul De Konkoly Thege ‘14
“A Radiocarbon Reconstruction of the Deglacial Bering Sea”

Michelle Paradis ‘14
“Porewater Sulfate Content at Deep Springs Lake, California: Applicability to the “Dolomite Problem”?

Off-Campus Geosciences Colloquia

Phoebe Cohen
“Progress and Challenges in Assessing Proterozoic Eukaryotic Diversity”
Denver, Colorado, October 2013

“Life Before Snowball Earth: The Fossil Record of a Changing World”
Whitehorse, Yukon, June 2014

Mea Cook
“Reconstructing North Pacific Circulation with Radiocarbon”
Univ. of Massachusetts, Amherst, MA, October 2013

“Productivity and Circulation in the North Pacific During the Last Deglaciation”
Woods Hole Oceanographic Institution, October 2013

“Ventilation and Productivity in the North Pacific During the Last Deglaciation”
McGill University, Montreal, Canada, November 2013

“Productivity, Ventilation and Oxygenation in the North-Central Bering Sea During the Last Deglaciation”
American Geophysical Union Fall Meeting, December 2013

Rónadh Cox
“Through the Ice, Exposing the Ocean: Impact Breakthrough Parameters for Europa”
Sudbury, Canada, August 2013

“Movie ‘Man of Aran’ as a Documentary Source for Studying Boulder Transport by Storm Waves”
Denver, Colorado, October 2013

Lisa Gilbert
“Seamounts, Mid-Ocean Ridges, and Seafloor Exploration”
Mystic Seaport, July 2013

“The Geology of Change Along the Connecticut Coast”
Yale-NUS, Mystic Seaport, July 2013

"Hawaii's volcanic history and current activity"
Pine Point School, February 2014

"Geology and Oceanography of the Charles W. Morgan's 38th Voyage"
Mystic Seaport, March 2014

"Expedition to the End of the World" Panel
Environmental Film Festival at Yale University, April 2014

Markes Johnson

"Power of Place in Writing"
Tucson Festival of Books workshop, Tucson, Arizona, March 2014

"Finding Ways into Untamed Landscapes"
Tucson Festival of Books workshop, Tucson, Arizona, March 2014

"Nature Writing"
Tucson Festival of Books workshop, Tucson, Arizona, March 2014

"Uncovering Secrets in the Landscapes of Baja California: Treasures Large and Small from Peninsular Shores and Gulf Islands"
San Diego Association of Geologists, San Diego, CA, March 2014

"Taphonomic Range and Sedimentary Dynamics of Modern and Fossil Rhodolith Deposits from North Atlantic Islands"
Eleventh International Workshop on Palaeontology in Atlantic Islands, Azores, Portugal, June 2014

Paul Karabinos

"Creating and Disseminating Interactive 3D Geologic Models"
Geological Society of America National Meeting, Denver, CO, October 2013

"Interactive 3D Geologic Models Created with SketchUp"
Geological Society of America National Meeting, Denver, CO, October 2013

"Deformation Gradients in the Day Mountain Thrust Sheet, Massachusetts: Implications for Strain Localization" with Elizabeth Pierce '07
Penrose Conference, Asheville, North Carolina, April 2014

"Strain Programs for Teaching and Research" Workshop
Structural Geology and Tectonics Forum, Golden CO, June 2014

"Creating, Disseminating, and Testing Interactive 3D Models for Teaching Structural Geology"
Structural Geology and Tectonics Forum, Golden CO, June 2014

R. A. Wobus

Geological Tour for the Town of Hawley, MA
Hawlay, MA, June 2014

"Geology of the Berkshires"
Sweetwood, June 2014

Postgraduate Plans of Geosciences Majors

Eloise C. Andry	Watson Fellowship to study volcanos and the lives of the people living near active volcanos in five countries (Iceland, Chile, New Zealand, Vanuatu, and Indonesia) for a year
Johanna S. Eidmann	working at Geosyntec, an environmental consulting firm in the Boston area next year
Kalle L. Jahn	Working in environmental consulting for Iris Environmental in Oakland, CA.
Meg C. O'Connor	Teaching intern at St. Paul's Advanced Studies summer program, helping to teach marine biology to rising seniors in high school. After that, plans are to relocate to Louisiana to pursue interest in coastal restoration and other issues that relate to both the environment and the quality of life of people in the Gulf area
Michelle E. Paradis	Undecided

Sedimentology students at the famous Taconic Unconformity in Spring 2014. The steeply-dipping late Silurlan Rondout Formation overlies vertical beds of the Ordovician Austin Glen Formation near Catskill, NY. The unconformity records the Taconic mountain-building event, almost half a billion years ago.

MATHEMATICS AND STATISTICS DEPARTMENT

In April 2014, we were very proud to learn that the Williams College Mathematics Department was named the 2014 Exemplary Program by the American Mathematical Society (http://math.williams.edu/williams-wins-2014-ams-exemplary-department-award/).

The citation indicated that 84% of Williams College students take our courses, 48% take multivariable calculus, and 60% take statistics. It commends our large number of majors, national teaching awards, books, SMALL undergraduate research project, faculty research, advanced courses, monthly dinners, other social activities, and colloquium.

We now offer a major in Statistics, with 19 new Stats majors along with 69 new Math majors in the rising junior class. Fourteen seniors did honors theses during the 2013-14 academic year.

Our department grew substantially this year with the addition of three new tenure track positions. Leo Goldmakher received a Ph.D. in Analytic Number Theory from the University of Michigan and has spent five years at the University of Toronto as a postdoc and Assistant Professor. Eyvindur Palsson received a Ph.D. in Functional Analysis from Cornell and is currently Visiting Assistant Professor at the University of Rochester. Pamela Harris, who will join us in the fall of 2016, received a Ph.D. in Lie Algebras from the University of Wisconsin-Milwaukee and is currently Davis Research Fellow at the Army Research Lab and Assistant Professor at West Point.

At our spring banquet, Professor Johnson thanked visitors Michael Biro, Holley Friedlander, and Ed Hanson, and recognized members of SMASAB, the student math advisory board: *Craig Corsi '14*, *Philippe Demontigny '14*, *Jared Hallet '14*, *Caroline Miller '14*, *Faraz Rahman '14*, *Jiripat Samranvedhya '14*, *David Stevens '14*, *Kirk Swanson '14*, *Sam Tripp '14*, *Carrie Chu '15*, *Jesse Freeman '15*, *Joe Kinney '15*, *Anna Spiers '15*, *Phonkrit Tanavisarut '15*, *Jaclyn Porfilio '15*.

We presented a large number of awards to our outstanding math majors this year: The Rosenburg Prize for outstanding senior was awarded to *Ilya Amburg '14* and *Vu Le '14*. The Goldberg Prize for best colloquium went to *Nina Horowitz '14*, who spoke on *The Mathematics Behind Playing Hard to Get* and *Joseph Iafrate '14*, who spoke on *Random Walk, Random Strikeout: Baseball as a Markov Chain*. The Wyskiel Award in teaching went to *Jeff Brewington '14*. The Morgan Prizes in Applied Math and Teaching went to *Carson Eisenach '14* and *David Stevens '14*. The Kozelka Award for outstanding student of statistics went to *Faraz Rahman '14*. The Beaver Prize for department service went to *David Stevens '14*. The 1st Place Benedict Prize for outstanding sophomore went to *Peter McDonald '16* and the 2nd Place prizes to *Eva Fourakis '16* and *Elizabeth Frank '16*. The colloquium attendance prizes went to *Michael Gold '14* and *John Bihn '16*. The Witte Problem Solving Prize went to *Samuel Donow '16*, *Jared Hallett '14*, and *Benjamin Kaufman '16*. Over 2% of the campus took the national Putnam Exam and Williams successfully defended the Green Chicken against Middlebury. In addition, Jared Hallett also won a Churchill Scholarship and *Samantha Petti '15* and Jesse Freeman won Goldwater Scholarships.

Over a hundred local 10th graders attended our annual Mathblast on December 9. Students and teachers each chose three thirty-minute workshops to attend from among seven choices, which included Gambles, Games and Group Dynamics, Guarding Art Galleries, Invalid Inversions, The Mathematics of Voting, MP3 Files and Digital Compression, Square Holes, Spirographs and the Wankel Rotary Engine, and Why Knot?

Last summer, Associate Professor Alison Pacelli launched the Williams College Math Camp for mathematically talented high school students. For one week, 19 students from across the country experienced campus life, studied number theory and the art of mathematical proof, and attended special lectures on knot theory and the mathematics of soap bubbles.

Four members of our faculty members were on leave during the 2013-14 academic year: Satyan Devadoss, Dick De Veaux, Allison Pacelli (Spring), and Cesar Silva (Fall). Professors Klingenberg, Morgan, and Pacelli (Fall) will be on leave 2014-15.

In summer 2013, **Colin Adams** worked with seven students on research in the SMALL undergraduate

research program. They produced two papers, which are in the process of being submitted for publication. Adams spoke at the following locations: at a special session on knot theory at Mathfest in Hartford, at the EPaDel MAA meeting, at the Princeton Plasma Physics Lab, at an American Mathematical Society Meeting in St. Louis, for the Arkansas Public Lecture and as an X-STEM speaker for the USA Science and Engineering Festival. He also ran a minicourse teaching faculty how to teach applied topology at the national math meetings in Baltimore in January, where he also put on humorous mathematical theater. In addition to other committee work, Adams chaired the Morgan Prize Committee that determines the winner of the prize for the best undergraduate math research.

Assistant Professor **Julie Blackwood** completed (and thoroughly enjoyed) her first year at Williams College. She taught two sections of *Calculus I* (MATH 130) in the fall and developed and taught *Mathematical Modeling of Ecological Systems* (MATH 310) in the spring.

Blackwood continues her research in math modeling, and her work on rabies transmission in vampire bats was published in the journal *Proceedings of the National Academy of Sciences*. This work was also featured in a Research Highlight in *Nature*. She gave a talk on this work for a Log Lunch lecture as well as at Holy Cross College and at the University of Arizona.

Since arriving at Williams, Blackwood has started a new project on the control of invasive fruit pests as well as a project on white nose syndrome (WNS) in little brown bats. Her thesis student, *David Stevens '14*, developed and analyzed mathematical models of the transmission dynamics of WNS. Blackwood also advised three teams of Williams College students who all successfully competed in COMAP's Mathematical Contest in Modeling.

Professor **Satyan Devadoss** spent a wonderful sabbatical at Stanford University during the 2013-14 academic year. His research is in the areas of topology and geometry on which he gave several invited talks from around the country. He attended conferences and workshops on genetics at UC Berkeley, at the Institute for Mathematics and its Applications, and at the Simons Institute for the Theory of Computing. In Silicon Valley, he also served as a consultant for companies learning the language of the tech start-up culture.

Professor **Dick De Veaux** was on sabbatical in Paris this year where he worked on various book projects and traveled around the world to give talks, invited talks, keynote addresses and workshops on teaching and data mining. He also continued to serve on the Board of Directors of the American Statistical Association.

Professor **Tom Garrity** continued his research in number theory. He has had three papers accepted this year in the journals *Journal of Integer Sequences,* in the *International Journal of Number Theory* and in Monatshefte für Mathematik. Details of these papers can be found in the abstract section at the end of this book.

In June, he gave three lectures at the International Conference on Multidimensional Continued Fractions at Technical University in Graz, Austria. He spent most of July 2013, as he will for July 2014, at the Park City Mathematics Institute (PCMI) in Park City, Utah, as a member of PCMI's steering committee. While there, he gave a talk on Stern sequences to high school students. In October, he spoke at a Gathering for Gardner at the University of Northern Colorado. In December, he spoke at the conference Approximation and Numeration at the University of Paris Diderot (Paris 7). In February he spoke at a MathCounts competition in Hartford. In March he spoke at Sacred Heart University in Bridgeport CT. In April, he spoke at the Hypergeometric Function Special Session of the AMS Sectional Meeting at Texas Tech in Lubbock, Texas.

Assistant Professor **Brianna Heggeseth** just finished her first year at Williams College. In the fall, she taught two sections of *Introductory Statistics* (STAT 101) and she taught the advanced introductory course (STAT 201) in the spring. She also enjoyed developing and teaching the relatively new *Introduction to Statistical Modeling* (Stat 202) course as a bridge to the upper-level courses.

She continued her statistical methodology research as well as public health collaborations with the CHAMACOS study, headquartered in Berkeley, CA. Her paper on misspecification of mixture models was published by *Statistics in Medicine* in July 2013

and two papers from epidemiological collaborative work in were published in *Obesity* and *PLoS One* this year. She submitted a paper on clustering longitudinal data by development pattern to *Biometrics* and is finishing up a paper describing the application of these methods to childhood growth trajectories to study the relationship between physical development and in-utero exposure to chemicals such as DDT. Since arriving at Williams, Heggeseth presented her statistical methodology research at the Joint Statistics Meetings in August 2013 in addition to giving two invited talks at area colleges and universities and two colloquia on the Williams campus. She is excited to continue her research with a talented Williams student during the summer 2014.

Professor **Stewart Johnson** remains active in dynamical systems and optimal control, with an emphasis on computation. He is currently developing computational methods for optimal control problems, particularly for controls with bounded acceleration and/or curvature. He is also developing massively parallel computational tools for exploring spatial games.

Associate Professor **Bernhard Klingenberg** was an invited speaker at the Conference on Simultaneous Inference at the Leibniz University Hannover (Institute of Biostatistics), Germany and gave a full day short courses on modeling ordinal data for the Division of Biostatistics at the FDA in Silver Spring, Maryland and at the City of Hope National Medical Center in Duarte, California. Professor Klingenberg was elected to the editorial board of the Journal *Statistical Modelling* and published in the *Proceedings of the 28th International Workshop on Statistical Modelling*. Together with his summer science and thesis student *Faraz Rahman '14*, he contributed a chapter in the forthcoming book on Clinical Trial Biostatistics and Biopharmaceutical Applications, to be published by Chapman and Hall/CRC in the fall of 2014. Other publications by Prof. Klingenberg include a statistical methodology article in the Journal *Statistics in Medicine* and one on measuring quality of life for patients in the journal *Healthcare*.

Professor **Susan Loepp** gave a Mathematical Association of America invited address at MathFest in August. At that conference, she also gave a talk in the AMS-MAA Special Session on Coding Theory, and she co-organized an MAA special session on Developments in Commutative Algebra. In September, Loepp gave the keynote address at the WIMIN (Women In Math In New England) conference at Smith College.

Loepp served as the 2013 SMALL director, and advised the Commutative Algebra research group that summer. The Commutative Algebra group proved original results, and their manuscript based on those results has recently been accepted for publication in the *Journal of Commutative Algebra*. Several of the students in the group attended the Joint Mathematics Meetings in Baltimore in January. They gave a talk and presented two posters based on their SMALL research results. Loepp also attended the JMM in Baltimore where she enjoyed attending her students' talks and poster presentations, as well as research talks in the commutative algebra special session. During the 2013-14 academic year, Loepp advised the senior honors thesis of *Byron Perpetua '14* and *Craig Corsi '14*. Both proved original results in commutative algebra.

Associate Professor **Steven Miller** received a three year individual NSF grant to continue his investigations in number theory and probability. With Cesar Silva, he wrote the Math/Stat department's successful renewal of its summer program for undergraduate research, SMALL. He and his students published over 10 papers and gave over 50 talks. He has continued his mathematical outreach activities, ranging from his successful math riddles page (http://mathriddles.williams.edu/), which is used in schools around the world, to writing computational modules for high school classes and giving continuing education lectures to junior high and high school teachers, to publishing a cryptography book designed for liberal arts. He introduced a new course, *Introduction to Operations Research* (MATH 317). In *The Mathematics of LEGO Bricks* a team of Williams College students built the 3152 piece LEGO Star Wars Super Star Destroyer in under 10.5 minutes, a world record. A time lapse video of the effort can be found at http://web.williams.edu/Mathematics/sjmiller/public_html/legos/.

With Professors Michael Biro, Ed Hanson and Mihai Stoiciu he ran math puzzle nights, Project Euler lunches and math contests; highpoints include over

2% of the campus taking the Putnam and a successful defense of the Green Chicken by an all-frosh, all-soph Williams contingent (led by *Philip Brockman '17*, *David Burt '17*, *Sam Donow '16* and *Ben Kaufman '16*). He was the primary thesis advisor to *Carson Eisenach '14* and *Victor Luo '14* in sabermetrics, *Yang Lu '14* on Benford's law, and *Kirk Swanson '14* in random matrix theory, and was the secondary advisor to two others. Miller has also expanded his involvement in using online resources in teaching; all his course lectures are available online through YouTube, as are talks at conferences he organizes.

Professor **Frank Morgan** is continuing his study of minimal surfaces, densities, and tilings with a number of collaborators and his undergraduate research Geometry Group. He appeared with his students in an American Mathematical Society "Mathematical Moment" video titled *Working up a Lather—Bubbles and Foam* (Parts 3 and 4). He gave 21 talks, including one at a gathering in Bangalore of the top Indian high school science students. He is proud of the new departmental webpage.

Associate Professor **Allison Pacelli** founded the Williams College Math Camp in the summer of 2013, a one-week residential camp for mathematically gifted high school students. She received an MAA Dolciani grant again this year, and an AMS Epsilon grant, to continue and expand the program in 2014.

Pacelli was named a member of the ICERM Education Advisory Board. She also continues to serve on the steering committee of the Hudson River Undergraduate Math Conference, now in its twenty-second year.

Pacelli continues her research in Algebraic Number Theory, and her paper *Arithmetic Properties of Generalized Rikuna Polynomials* with John Cullinan and her 2010 SMALL group was accepted for publication in *Publications Mathématiques de Besançon*. She was also a contributing author and editor for *Thinkwell Precalculus* by Edward B. Burger.

During the past year, Pacelli gave talks at Union College and here at Williams, including the 2013 Math Blast for local high school students. She also gave a series of professional development seminars to K-2 and 3-5 teachers in the Albany Central School District and to high school teachers in the Gouverneur Central School District.

In summer 2013, Professor **Cesar Silva** supervised four students on research projects during our SMALL summer research program: Francisc Bozgan (UCLA), Anthony Sanchez (Arizona State), David Stevens '14, and Jane Wang (Princeton). We completed a paper that was submitted for publication. They all presented talks at MathFest in August 2013 where Bozgan and Wang won outstanding talk awards, and also presented two posters at the annual 2014 AMS meeting in Baltimore, which both won Outstanding Presentations awards. Wang also presented our work at a special AMS session which Silva co-organized at the annual meeting. Sanchez and Stevens were selected to present a talk at the Young Mathematicians conference at Ohio State last summer. Both Sanchez and Wang, and another student from SMALL 2012 (Evangelie Zachos) won NSF graduate fellowships in mathematics this year, and Stevens won honorable mention. Silva was invited to attend the International Conference and Workshop on Surfaces of Infinite Type, in Morelia, Mexico, July 29 – August 2, 2013.

In the fall semester, Silva was on leave. He spent time in France visiting colleagues at the universities of Bordeaux, Paris 13, and Rouen, where he gave talks and collaborated on research. Silva gave several talks this year, including at two special AMS sessions, seminars at Cornell, Bordeaux, Rouen, and Maryland, and at conferences in Chicago, Chapel Hill, and Torun, Poland. He also co-organized a special session at the annual AMS meeting in Baltimore. He has two papers accepted for publication and submitted several other works that are in the process of being reviewed.

Associate Professor **Mihai Stoiciu** taught three sections of *Multivariable Calculus* (MATH 150) during the Fall Semester. During the year, he continued his research on spectral properties of random and deterministic operators. He had a paper accepted for publication in the Journal *Mathematical Modelling of Natural Phenomena*.

Stoiciu was invited to present his research at seminars at University of Albany, University of Texas, San Antonio, and at the AMS Special Session on Spectral Theory in Albuquerque, NM. He also gave a Mathematics Colloquium at Bryn Mawr College and was an invited participant and speaker at the Interna-

tional on Conference Constructive Functions 2014, held at Vanderbilt University in Nashville, TN. At Williams College, Stoiciu gave a talk for high school students at the Williams MathBlast 2013 and a faculty seminar on his recent research in spectral theory.

In May 2014, Stoiciu participated as the Chair of the AMS Menger Prize Committee in the International Science and Engineering Fair (ISEF) held at the Los Angeles Convention Center. He was also a member of the Special Judging Team which awarded the 2014 Intel ISEF Grand Awards.

Assistant Professor **Qing (Wendy) Wang** continued her research in the area of Nonparametric Statistics. She had one paper accepted for publication at *Statistica Sinica* which will appear in July 2014. In addition, she has a couple of other papers in revision or in progress. She advised the two senior honors theses of *Shiwen Chen '14* and *Vu Le '14* during the past year.

Wang attended several statistical conferences and meetings during the year. She was an invited speaker at the Second Taihu International Statistical Forum in Suzhou, China, and was invited to give a talk at Colby College. She also presented her research at the Joint Statistical Meeting in Montreal, Canada in August 2013. This year, she received the Junior Researcher Travel Awards and presented a poster at the 2014 Women in Statistics Conference in North Carolina in May 2014.

Wang also enjoyed sharing ideas with her colleagues in the science division. She introduced the idea of resampling and talked about how to "get more out of n" at the science lunch, and presented the R package "boot" in realizing bootstrap algorithms at Oakley seminar series. She participated in the half-day event of MathBlast, talking about invalid inversion for conditional probabilities to local high school students.

Mathematics and Statistics Colloquia

Colin Adams, Thomas Garrity, Susan Loepp, Frank Morgan, Williams College
"ICM Day"

Colin Adams, Williams College
"Multi-Crossing Number of Knots"

"Blown Away: What Knot To Do When Sailing"

Julio Andrade, Brown University
"L-Functions and Number Theory in Two Parallel Worlds"

Michael Biro, Williams College
"Wrapping, Packing, and Driving"

"Planar Graphs with Many Perfect Matchings"

"Folding Cubes and Tetrahedra"

Julie Blackwood, Williams College
"Rabies Persistence in Vampire Bats: Immunity, Pathogenesis and Immigration"

Jonathan Bloom, Dartmouth College
"The Enumeration of Patterns, Permutations, and Placements"

Ben Brubaker, University of Michigan
"Symmetric Functions and Square Ice"

Holley Friedlander, Williams College
"Weyl Group Multiple Dirichlet Series"

"On Writing Numbers"

Thomas Garrity, Williams College
"Some Functional Analysis in Number Theory"

Leo Goldmakher, University of Toronto
"Bounds on the Least Quadratic Nonresidue"
Edward Hanson, Williams College

"Introduction to Leonard Pairs"

Pamela Harris, United States Military Academy
"Representations of Lie Algebras and a Connection to Tiling"

Brianna Heggeseth, Williams College
"Searching for Development Patterns: An Application to Childhood Growth Trajectories"

Aaron Hill, University of North Texas
"On the Existence of Universal Groups"

Neil Hoffman '04, University of Melbourne, Australia
"Verified Computations for Hyperbolic 3-Manifolds"

Stewart Johnson, Williams College
"Moving Pictures: Spatial Games and Parallel Computing"

Nathan Kaplan, Yale University
"Curves and Surfaces Over Finite Fields and Coding Theory"

Bernhard Klingenberg, Williams College
"Ordinal Models"

"Interactive Stats"

Susan Loepp, Williams College
"Completions and Polynomial Rings"

"Generic Formal Fibers in Characteristic p"

Florian Luca, Instituto de Matemáticas de la UNAM
"Diophantine Equations With Generalized Fibonacci Numbers"

Beth Malmskog, Colorado College
"Fixing Communication Failure: Correcting Errors With Codes and Curves"

Steven Miller, Williams College
"Number Theory and Probability"

"Mind the Gap: Distribution of Gaps in Generalized Zeckendorf Decompositions"

Frank Morgan, Williams College
"Minimizing Perimeter"

"Barcelona"

Duy Nguyen, Massachusetts College of Liberal Arts
"A Stochastic Approximation Approach for Trend-Following Trading

Allison Pacelli, Williams College
"The Kronecker-Weber Theorem in Number Fields and Function Fields"

Eyvindur Ari Palsson, University of Rochester
"Finite Point Configurations and Multilinear Radon Transforms"

Cesar Silva, Williams College
"Notions of Measurable Sensitivity in Ergodic Theory"

"On Infinite Rank-One Transformations and Weak Mixing Notions and Examples"

Mihai Stoiciu, Williams College
"The Rubik's Cube and Its Wonderful Mathematics"

"Spectral Properties of Random Schrodinger Operators With Small Coupling Constants"

Qing Wang, Williams College
"An Improved Bandwidth Selection Method Using Second-Order Extrapolation"

Mathematics and Statistics Student Colloquia

Alexandra Albright
"Benford's Law: How It Turns Out That One is Not the Loneliest Number"

Samuel Austin
"Random Walks on Lattices"

Amy Berg
"Hartog's Extension Theorem"

Jeff Brewington
"The Marriage Problem – When is it the Right Time to Say 'I do?'"

Christopher Chandler
"Do Me a Platonic Solid"

Martin Clarke
"Weyl's Equidistribution Theorem"

Eric Coffin-Gould
"The Group Law on Elliptic Curves"

Henry Coats
"Winning with Non-Transitive Dice"

Conor Dowling
"Square Roots and Continued Fractions"

Julian Drobetsky
"Conway Napkin Problem"

William Edwards-Mizel
"Who Should've Played for the BCS Title? Ranking With Incomplete Information"

Nico Ekasumara
"Bertrand's Paradox"

Thomas Engleby
"The Mathematician's Cup of Coffee: The Brouwer Fixed Point Theorem"

Allyne Ensor
"Deming Regression"

Parker Finch

"Bounds on Error Correcting Codes"

Catherine Gerkis
"Penalized Regression: Ridge and LASSO Regressions"

Michael Gold
"Fermat's Last Theorem for Polynomials"

Vera Gould
"Fractal Analysis of Jackson Pollock's Paintings"

Gabor Gurbacs
"Satan Oscillate(s) Metallic Sonatas"

Jared Hallett
"An Intuitive Approach to the Fourier Transform"

Ernest Higginbotham
"The ABC Conjecture and Polynomial Analogues"

Christopher Higgins
"Predicting Revolutions and Epidemics: Explosive Percolation Achlioptas Processes"

Nina Horowitz
"The Mathematics Behind Playing Hard to Get"

Joseph Iafrate
"Random Walk, Random Strikeout: Baseball as a Markov Chain"

Samuel Kurland
"How to Draw a Straight Line: Planar Linkages and Their Applications"

Marnie Lanphier
"Buffon's Ball Problem"

Daniel Levine
"Voting Systems and Arrow's Impossibility Theorem"

Trust Mandevhana
"Resultants, Polynomials and Matrices"

Michael Mayer
"The Gamma Function"

Rebecca McGovern
"An Example of Euler's Brilliance: Proving **Σ** 1/(n^2)=(n^2)/6"

Courtney McLaughlin
"Newton's Method"

Trust Mandevhana
"Resultants, Polynomials and Matrices"

Cesar Melendez
"The Continuous Nowhere-Differentiable Takagi-Weierstrass Function"

Matthew Micheli
"Game Theory: Learn How to Coach Federer"

Caroline Miller
"Grids to Graphs: The Mathematics of Sudoku"

Lilliana Morris
"Sum of Three Squares Theorem"

Daudi N'geno
"Stable Matching"

Min Hae Park
"Gambler's Ruin: A Mathematical Approach"

Wade Phenicie
"Counting Cheaters Using Randomized Response Models"

Adam Reich
"15-Puzzle"

Daniel Seita
"Grading a Test Without Knowing the Answers"

Corey Smith
"Convoluting Polynomials: The Weierstrass Approximation Theorem"

Paul Taylor
"Quadratic Reciprocity"

Michael Vercillo
"Kind of Random: Generating Pseudo-Random Numbers"

Gabrielle Vukasin
"Beat the Bookie: How to Correctly Guess Coin Flip Sequences"

Emily Wickstrom
"Simple Random Walks: Recurrence and the Stock Market"

Nicholas Wolf
"The Game of Hex and Brouwer's Fixed Point Theorem"

Kaijie Zheng
"Non-Negative Matrix Factorization"

Off-Campus Mathematics and Statistics Colloquia

Colin Adams

"Blown Away: What Knot To Do When Sailing"
Williams MathCamp, July 2013
Bridgewater State University, November 2013
Princeton Plasma Physics, Lab, Princeton, NJ, February 2014
Arkansas Public Lecture, University of Arkansas, Fayetteville, April 2014
EPaDel MAA Sectional Meeting, Scranton, PA, April 2014

"Turning Knots into Flowers"
Mathfest, invited paper session on accessible problems in knot theory, Hartford, CT, August 2013

"Ubercrossing and Petal Number of Knots"
Special Session on Invariants of Knots, AMS Sectional Meeting, Washington University, St. Louis, MO, October 2013

"Applied Topology Minicourse" with Robert Franzosa
Joint Mathematics Meetings, Baltimore, MD January 2014

"Why Knot"
USA Science and Engineering Festival, Washington, DC, April 2014

"Mathematically Bent Theater"
Mobiusbandaid Players, Joint Mathematics Meetings, Baltimore, MD, January 2014

Julie Blackwood

"Rabies Persistence in Vampire Bats: Immunity, Pathogenesis, and Immigration"
Holy Cross College
University of Arizona

Satyan Devadoss

"Invited Speaker"
ILM and Lucasfilm Studios

"Invited Lecture"
Stanford School of Design

"Kaori Kitao Lecture"
Swarthmore College

"Rall Symposium Lecture"
North Central College

"Geometry Topology Seminar"
University of California, Davis

"Colloquium"
Claremont Colleges
San Diego State University
Louisiana State University

"Geometry Physics Seminar"
Northwestern University

"Algebra Seminar"
University of Southern California

"Algebra and Geometry Seminar"
San Francisco State University

"Combinatorics Seminar"
University of California, Berkley

"VIGRE Student Lectures"
Louisiana State University

"Topology Seminar"
Stanford University
University of Chicago

"SUMO Seminar"
Stanford University

"Plenary Speaker"
Association of Christians in the Mathematical Sciences

"Veritas Forum"
California Polytechnic SLO
University of Southern California

Claremont Colleges
University of California, Berkeley
University of Chicago
Northwestern University
University of California, San Diego
University of California, Davis

Richard De Veaux

"Aging and Sports"
Keynote Address, JMP Discovery Conference, San Antonio, TX, September 2013
Yale NUS (Yale at National University of Singapore), Singapore, February 2014

"J. Stuart Hunter, An Appreciation"
Joint Statistical Meetings, Montreal, Canada, August 2013 in Celebration of Hunter's 90th Birthday

"Data Mining: Fool's Gold? Or the Mother Lode?"
Fisher Colloquium, Georgetown University, January 2014
Absolute Business Solutions Corporation, Fairfax, VA

"Panel on the Future of Statistics Education"
Workshop on the Future of Statistics, London, UK, November 2013

"Predictive Analysis Workshop"
Brooklyn, NY, October 2013
Santa Clara, CA, October 2013
Dallas, TX, November 2013
Irvine, CA, May 2014
Princeton, NJ, June 2014

"Successful Data Mining in Practice Workshop"
Traveling Course for the American Statistical Association, Eastern Kansas Section, Kansas City, October 2013
Missouri Section, University of Missouri, October 2013
Short Course at the Joint Statistics Meetings, Montreal, Canada, August 2013
Invited Workshop at the Living Analytics Workshop, Singapore, February 2014

"Enhancing Big Data Projects Through Statistical Engineering Workshop"
Conference on Statistical Practice (with Ron Snee and Roger Hoerl), Tampa, FL, February 2014

"Presentation Skills Workshop"
Joint Statistical Meetings, Montreal, August 2013

"Statistics in the 21st Century: Are We Teaching the Right Course?" with Danny Kaplan
Electronic Conference on Teaching Statistics (ECOTS), May 2014, Webinar

"WAMC Speakers Corner" with Alan Chartock, August 2013

Thomas Garrity

"On the Hermite Problem and Multidimensional Continued Fractions"
Multidimensional Continued Fractions Conference, Technical University, Graz, Austria, June 22, 2013

"On TRIP Maps and the Hermite Problem"
Multidimensional Continued Fractions Conference, Technical University, Graz, Austria, June 24, 2013

"Some Functional Analysis Behind Multidimensional Continued Fractions: Transfer Operators"

Multidimensional Continued Fractions Conference, Technical University, Graz, Austria, June 25, 2013

"Pascal With Memory"
Park City Mathematics Institute, July 2013

"On Writing Numbers"
Gathering for Gardner Colloquium, University of Northern Colorado, October 21, 2013
MathCounts, University of Hartford, CT, February 1, 2014

"A Generalized Family of Multidimensional Continued Fractions: TRIP Maps"
Approximation and Numeration Conference, University of Paris Diderot (Paris 7), December 19, 2014

"Physical Mathematics: The Revolution"
Sacred Heart University, March 18, 2014

"On Some Functional Analysis Behind Multidimensional Continued Fractions"
Special Session on Applications of Special Functions in Combinatorics and Analysis, Texas Tech University, April 13, 2014

Brianna Heggeseth

"Searching for Development Patterns: An Application to Childhood Growth Trajectories"
Statistics Seminar, University of Massachusetts, Amherst, November 18, 2013
Mathematics and Statistics Seminar, Colby College, April 28, 2014

"Vertically Shifted Mixture Models for Clustering Longitudinal Data"
Joint Statistical Meetings, Montreal, QC, August 8, 2013

Bernhard Klingenberg

"Comparing Margins of Multivariate Binary Data"
Conference on Simultaneous Inference, Leibniz University Hannover (Institute of Biostatistics), Germany, September 2013

"Modeling Ordinal Categorical Data"
Office of Surveillance and Biometrics, Center for Devices and Radiological Health, Food and Drug Administration, Silver Spring, MD
Department of Information Sciences, City of Hope National Medical Center, Duarte, CA

Susan Loepp

"Algebra, Analysis, and the Way You Eat Corn: The Complete Story"
MAA Invited Address, Mathfest, Hartford, CT, August, 2013

"Using Coding Theory for Quantum Cryptography"
AMS-MAA Special Session on Coding Theory, Mathfest, Hartford, CT, August 2013

"Polynomials, Power Series, and Confessions of a Commutative Algebraist"
WIMIN13, Keynote Address, Smith College, September, 2013
Pi Mu Epsilon Induction Talk, College of the Holy Cross, April, 2014

"Polynomials, Power Series and Cool Theorems Proved by Undergraduates"
Middlebury College, April, 2014

Steven Miller

"From M&Ms to Mathematics, or, How I Learned to Answer Questions and Help my Kids Love Math"
Hampshire College, July 2013

"Mind the Gap: Distribution of Gaps in Generalized Zeckendorf Decompositions"
Maine-Quebec Number Theory Conference, October 2013
AMS-Special Session on Difference Equations Temple University, October 2013

"Problems in the Theory of Low-Lying Zeros"
Simons Symposium on Families of Automorphic Forms and the Trace Formula
Puerto Rico, January 2014

"Results in the Theory of Low-Lying Zeros"
Simons Symposium on Families of Automorphic Forms and the Trace Formula
Puerto Rico, January 2014

"Closed-Form Moments in Elliptic Curve Families and Low-Lying Zeros"
Simons Symposium on Families of Automorphic Forms and the Trace Formula, Puerto Rico, January 2014

"From the Manhattan Project to Elliptic Curves"
Colloquium, UMass Boston, February 2014

"From Sato-Tate Distributions to Low-Lying Zeros, Frobenius Distributions of Curves"
CIRM, February 2014

"From the Manhattan Project to Elliptic Curves"
Number Theory Seminar, The Ohio State University, March 24, 2014

"Virus Dynamics on Star Graphs"
AMS Special Session on Difference Equations, March 29, 2014

"Coin Flips, Fibonacci Numbers and Gaps!" with Phil Tosteson
AMS Special Session on Difference Equations, March 2014

"Cookie Monster Meets the Fibonacci Numbers. Mmmmmm -- Theorems!"
Yale University Math Society, April 2014
Stuyvesant High School, May 2014

"Finite Conductor Models for Zeros of Elliptic Curves"
Number Theory Seminar, Yale University, April 2014

"From the Manhattan Project to Elliptic Curves"
Plenary Speaker, South Eastern Regional Meeting on Numbers (SERMON XXVII), Wofford College, April 2014

"YouTube University: The Benefits of Recording Lectures"
Blended Learning Conference, Bryn Mawr College, May 2014

Frank Morgan

"Minimal Interface Structures"
SIAM, Philadelphia, June 9, 2013

"Densities from Geometry to Poincaré"
Fairfield University, July 1, 2013

"Optimal Pentagonal Tilings"
MathFest Student Lecture, August 1, 2013
Siena College, September 24, 2013
Rowan University, April 5, 2014

"The Log-Convex Density Conjecture"
Barcelona, September 3, 2013

"Baserunner's Optimal Path, The Isoperimetric Problem With Density"
University of California, Irvine, October 8, 2013

"Isoperimetric Problems With Densities"
Union College, November 19, 2013

"Optimal Tilings"
Vijyoshi National Science Camp, Bangalore, India, December 8, 2013
Millersville University

"The Log-Convex Density Conjecture Proved"
Joint Mathematics Meetings, Baltimore, Maryland, January 16, 2014

"The Least-Perimeter Tile With n Faces"
Newton Institute, Cambridge, England, February 27, 2014

"Soap Bubbles and Mathematics"
Berkshire Community College, March 13, 2014
Northampton Community College, April 3, 2014

"Soap Bubbles and Snacks"
Northampton Community College, April 3, 2014

"The Soap Bubble Geometry Contest"
Southwestern University, President Edward Burger's Inauguration, March 24, 2014

"Blanding, Soap Bubbles and Mathematics"
Utah State University, April 12, 2014

"The Convex Body Isoperimetric Conjecture"
Hudson River Undergraduate Mathematics Conference, April 26, 2014

"Best 3D Tiles"
Millersville University, May 1, 2014

"Chambers Proves LCD Conjecture"
Tetrahedral Geometry/Topology Seminar, PA

Allison Pacelli

"Primes, Primes, and More Primes"
Union College, May 19, 2014

"Grades 3-5 Common Core Overview & Progressions"
Albany Central School District, Professional Development Series, January 18, 2014

"Grades 3-5 Common Core Standards for Practice"
Albany Central School District, Professional Development Series, January 25, 2014

"Grades K-2 Common Core Overview & Progressions"
Albany Central School District, Professional Development Series, February 8, 2014

"Grades K-2 Common Core Standards for Practice"
Albany Central School District, Professional Development Series, March 8, 2014

"Grades K-2 Common Core Fluency & Lesson Planning"
Albany Central School District, Professional Development Series, March 15, 2014

"Grades 3-5 Common Core Fluency & Lesson Planning"
Albany Central School District, Professional Development Series, April 5, 2014
Gouverneur Central School District, Professional Development Series, March 19-21, 2014

Cesar Silva

"Mixing-Like Notions and Rational Ergodicity for Infinite Rank-One Transformations"
Séminaire de Théorie Ergodique et Systemes Dynamiques, Université Paris France, November 2013

"On Rationally Ergodicity and Mixing-Like Properties for Infinite Rank-One Transformations"
Université de Rouen, France, November 2013

"One Proof is Not Enough"
MAA Session on Topics and Techniques for Teaching Real Analysis, AMS Annual Meeting, Baltimore, MD, January 15, 2014

"Mixing Phenomena in Infinite Measure and Examples in Rank-One Transformation"
Dynamics Seminar, University of Maryland, College Park, December 2013

"Weak Mixing Notions and Examples for Finite Measure-Preserving Transformations"
AMS Special Session on Substitution and Tiling Dynamical Systems, Baltimore, MD, March 2014

"Notions and Examples of Weak Mixing in Infinite Measure"
Dynamics Seminar, Cornell University, April 2014

"R-Set Weak Mixing and Weak Mixing Notions and Examples in Infinite Measure"
Recent Advances in Measurable Dynamics: A Celebration of the Contributions of Andres del Junco, DePaul University, Chicago, IL, May 2014

"Weak Mixing Notions and Examples in Infinite Measure"
Ergodic Theory and Dynamical Systems, Torun, Poland, May 2014

Mihai Stoiciu

"Analysis Seminar"
University at Albany, March 2014
University of Texas, San Antonio, March 2014
Harvard University

"Mathematics Colloquium"
Bryn Mawr College, March 2014

"Spectral Theory"
Constructive Functions 2014 – Conference at Vanderbilt University, Invited Talk in the Special Session, May 2014
AMS Western Spring Sectional Meeting, University of New Mexico, April 2014Qing Wang

"Subsampling-Extrapolation Techniques and Nested Cross-Validation in Kernel Density Estimation"
Second Taihu International Statistical Forum, Suzhou, China

"Subsampling-Extrapolation Techniques in Kernel Density Estimation"
Joint Statistical Meeting, Montreal, Canada

"How Does the Eruption Time of Old Faithful Vary?"
Colby College

"Improving the Performance of Cross-Validation in Kernel Density Estimation"
2014 Women in Statistics conference, Cary, North Carolina

Post Graduate Plans of Mathematics and Statistics Majors

Alexandra Albright	Working as a Research Fellow at Stanford Law School for Prof. John Donohue
Ilya Amburg	Assistant Lab Instructor, Williams College Physics Department
Amy Berg	Fulbright English Teaching Assistantship to Turkey
Jeff Brewington	Teaching math in Oklahoma for Teach for America
	Working at Boston Children's Hospital while applying to medical school
Shiwen Chen	Working in Boston
Henry Coats	Management Consulting at Bain in Boston
Craig Corsi	Pursuing a Ph.D. in Mathematics at the University of Minnesota, Twin Cities
Philippe Demontigny	Pursuing a Master's degree in Computer Science at the University of Waterloo
Conor Dowling	Pursuing a Masters in Computer Science at the University of Massachusetts, Amherst
William Edwards	Junior Research Analyst at the Research Board, an enterprise IT thinktank in New York City
Carson Eisenach	Pursuing a Ph.D. program in Operations Research at Princeton University
Nico Ekasumara	Working as a software engineer at Amazon
Gregory Eusden	Working for a management consulting company called the Parthenon Group in Boston, MA.
Catherine Gerkis	Awarded a Fulbright Scholarship and will spend the 2014 – 2015 academic year in Taiwan teaching English
Gabor Gurbacs	Exchange Traded Fund Analyst at Van Eck Global Securities
Jared Hallett	Heading to Cambridge
Samuel Kurland	Working on the pensions, endowments, and foundations desk in the Sales and Trading Division at Goldman Sachs in New York
Joseph Iafrate	Pursuing a Ph.D. in Applied Physics at the University of Michigan
	Pursuing a Ph.D. in Computer Science at Princeton University
Marnie Lanphier	Working as an analyst at an asset management firm called the Blackstone Group in New York City
Vu Le	Working as a global macro research analyst at Acadian Asset Management in Boston
Yang Lu	Working at an investment management firm in Boston
Rebecca McGovern	Associate Consultant at the Parthenon Group in Boston
Courtney McLaughlin	Working at Audax, a private equity firm in Boston
Matthew Micheli	Working in fixed income sales and trading at Morgan Stanley
Caroline Miller	Working as an analyst in the Securities Division at Goldman Sachs
Lilliana Morris	Pursuing a Ph.D. in Chemistry at Cornell University

Byron Perpetua	Working as a data analyst at Achievement First
Wade Phenicie	Working at Cogo Labs in Cambridge as a Quantitative Data Analyst
Faraz Rahman	Working as an analyst in the Investment Banking Division at Goldman Sachs
Adam Reich	Working at the Real Estate Investment Banking Group at JP Morgan
	Pursuing a Ph.D. in Organizational Behavior
Jirapat Samranvedhya	Graduate study in Statistics at North Carolina State University
Daniel Seita	Pursing a Ph.D. in Computer Science at the University of California, Berkeley
Corey Smith	Enrolled in the Medical Physics Ph.D. program at the University of Chicago
David F. Stevens	Going to Hong Kong for an applied math program, Research in Industrial and Applied Mathematics (RIPS), run by UCLA
Sean Sutherland	Working at OC&C Strategy Consulting in Boston as an associate consultant
Kirk Swanson	Working at a proprietary trading firm in Chicago
Samuel Tripp	Investment management in Boston
Gabrielle Vukasin	Entering the Mechanical Engineering program at Tufts University
Emily Wickstrom	Working at OC&C Strategy Consulting in Boston
Kaijie Zheng	Research Associate, Zhang Lab, Broad Institute, Cambridge, MA

Professor Tom Garrity and his math students take advantage of fine spring weather during a fire alarm to conduct class outside as a firefighter looks on.

Photo by Norm Bell

NEUROSCIENCE DEPARTMENT

The neuroscience program at Williams College experienced significant change during this academic year. Professor Zottoli, one of the founding members of the program, retired leaving a long and impressive legacy. The program celebrated his contributions to the program by bringing over a dozen of his former students back to campus in January to share their stories of working with Dr. Z and the ways in which their Williams experiences shaped their life paths. It was a wonderful day! We also welcomed Professor Matt Carter to the program. Professor Carter uses a variety of histological, electrophysiological, optogenetic, and behavioral tools to studying the circuits underlying homeostatic behaviors.

Our students continue to engage in sophisticated coursework and hands-on research experiences. Our students take courses that exploring topics ranging from molecular neuroscience to social neuroscience. Students conducting research with neuroscience faculty have explored topics ranging from neurochemical influences on arousal in Drosophila to cultural and genetic influences on social behavior in songbirds. Fifteen graduating seniors completed the neuroscience concentration in 2014 with six completing honors theses. *Jenna Adams* and *Megan Trager* were co-winners of the Patricia Goldman-Rakic Prize in Neuroscience for 2014.

Professor Heather Williams will be reassuming the position as Chair of the program as Professor Noah Sandstrom steps down in order to serve as the Co-Director of the Williams-Exeter Programme at Oxford University. *Lauren Williamson '07*, who recently received her doctorate in psychoneuroimmunology, will be joining the program for two years beginning this summer. We're very excited to have her back!

The Neuroscience Program Class of 1960 Scholars program co-sponsored a variety of speakers during the year. In addition, several students attended the 14th Annual Symposium of the Center for Neuroendocrine Studies at the University of Massachusetts.

Martha Marvin investigates the role of small heat shock proteins in preventing birth defects. The model organism she uses is the zebrafish, a small tropical fish that develops rapidly. The small heat shock protein *hspb7* protects embryos from environmental stress, and also serves essential developmental roles. Reduced levels of the small heat shock protein *hspb7* cause both left-right asymmetry and heart migration defects in zebrafish embryos. Previous work in the lab demonstrated that deficiency of *hspb7* caused the malformation of cilia in a transient organ known as Kupffer's vesicle, which establishes a distinct left and right side of the embryo through asymmetric fluid flow. Furthermore, reduced *hspb7* causes heart defects including a small ventricle and overgrown heart valves.

A number of other students worked in the Marvin lab this year: *Kaijie Zheng '14* showed that the heart valve defects caused by loss of *hspb7* depend on a later role of hspb7. In contrast, the growth of the cardiac ventricle depends on an early phase of *hspb7* expression. *John Sanderson '14* demonstrated that an antibody against human HSPB7 recognizes the zebrafish Hspb7 protein. John's work demonstrated that Hspb7 protein is first localized to the cytoplasm in Kupffer's vesicle as the cilia form, but then is shuttled away from KV into the yolk syncytial layer as KV matures. This type of movement has rarely been observed and never published. We will continue to characterize the localization of Hspb7 protein during cilia formation. *Ashley Ngo '16* assisted with the final stages of preparing a paper for publication and investigated the question of whether flow-sensing cilia are present in the developing fish heart.

With the assistance of *Rahul Sangar '14*, *Anuj Shah '15*, *Jackie Harris '16* and *Sonia Cheung '16*, the lab developed a zebrafish model for environmental stress. Using transgenic fish that glow green in the presence of heat shock or the stress hormone cortisol, we investigated the response of fish to glucocorticoids, caffeine, nicotine, alcohol, and salt, as well as any influence of anesthetics or fluoxetine (Prozac) in combatting stress. Dr. Marvin combined the zebrafish stress project with watershed education activities for the 8th grade at Mount Greylock Middle School. This study introduced the students to the effects of runoff and pollution on water quality both locally and in the oceans, and used the stress-sensitive fish assays to investigate local water quality.

Dr. Marvin teaches the laboratories for *Neuroscience* (NSCI 201) and also taught a lab section of *Physiology* (BIOL 205). She advised two honors students this year, along with three research assistants. She again co-taught a Winter Study course called *Project BioEyes*, which trains Williams students to teach genetics and development, and also engages local 4th grade students at two elementary schools in scientific investigation.

Neuroscience Colloquia

Mark Springel '12, Jonathan Wosen '13, Ji, Y., Jonah Zuflacht '11, Paloma Marin '12, Jamie Lahvic '10, Hutson, L.D., Amack, J., and Martha Marvin

"Cardiac laterality, migration and morphogenesis depend upon small heat shock proteins"
11th International Zebrafish Meeting, Madison, WI. June 24-28, 2014 (poster).

Postgraduate plans of Neuroscience Concentrators

Tala A. Abujbara,	Unknown
Jenna C. Adams,	Unknown
Meagan J. Clark,	Planning to attend graduate school in a program with either a medical science, biological or nutrition focus.
Robin M. Gimm,	Teaching English at the Chinese University of Hong Kong with the Williams-in-China United College teaching fellowship.
Laurel C. Hamers,	Unknown
Manasi Iyer,	Unknown
Katherine J. Kiernan,	Unknown
James M. Kinney,	Unknown
Theresa B. Legan,	Planning to attend graduate school for neuroscience.
Jingyi Liu,	Unknown
Kelsey D. McDermott,	Working at the Tisch MS Research Center of New York as a research assistant.
Zachary M. McKenzie,	Unknown
Rahul Sangar,	Unknown
Megan H. Trager,	Working as a Research Assistant at the Bronte-Stewart Movement Disorders Lab in Stanford University's Neurology Department.
Olivia Y. Wang,	Unknown

PHYSICS DEPARTMENT

The Physics Department is very pleased to welcome (or to be precise, welcome back), Professor Charles Doret as a new assistant professor. A 2002 graduate of Williams, Professor Doret was awarded the American Physical Society's Apker Award for outstanding undergraduate research in recognition of his thesis project "*A Precise Measurement of the Stark Shift in the* $6P_{1/2}$ *->* $7S_{1/2}$ *378 nm Transition in Atomic Thallium*" conducted under the guidance of Professor Tiku Majumder. He went on to receive his PhD from Harvard University in 2010, where he worked with John Doyle and (Nobel Laureate) Wolfgang Ketterle on "*A Buffer-gas Cooled Bose-Einstein Condensate of Metastable Helium.*" After Harvard, with an eye towards eventually moving into a faculty position at a liberal arts college, Dr. Doret sought out a postdoctoral research position where he could master a new area of experimental atomic physics that utilized equipment on a scale practical to have at an undergraduate institution. He spent three postdoctoral years in the Quantum Information Systems Group at Georgia Tech developing his expertize on cooling and trapping ions. After a year teaching at Harvey Mudd College, he joined the department here at Williams in July 2014. He actually arrived early in Williamstown in order to supervise a couple of research students for the summer. We are thrilled to welcome Professor Doret back to Williams and look forward to his establishing a vibrant, on-campus experimental research program.

This summer we say goodbye to Professor Michael Seifert who has been a visitor here for the past three years taking on, amongst other things, the teaching of two of our signature tutorial courses a growing population of physics majors. Professor Seifert is leaving to take a tenure track position at Connecticut College and we wish him well in this new endeavor.

Student interest in physics remains strong. In June 2014, we graduated 21 students majoring in Physics or Astrophysics. The next two classes currently have a combined total of 35 majors. During the summer of 2014 we have 18 students on-campus doing research in physics, including 4 students who have just finished their first year at Williams. These students are being supported by a combination of outside research grants, endowed funds given by generous alumni and foundation support, and this year also includes funds from the Clare Boothe Luce Foundation specifically to support women in sciences where they are typically underrepresented.

Professor **Daniel Aalberts** was awarded $255,000 by the National Institutes of Health for "Optimizing gene expression with mRNA free energy modeling and algorithms," a collaboration with the Northeast Structural Genomics Consortium. He spent his sabbatical year working on this research, modeling the information content of the March Madness tournament, studying statistics and programming, and learning about protein folding in Vijay Pande's lab at Stanford.

As Co-Director of the Northern Berkshire Center for Religion and Science, Emeritus Professor **Stuart Crampton** gave several talks to students and local adult groups about the relationship of science to religion. He continues to serve as a scientific consultant to the Murdock Trust, a foundation supporting science in the five northwest states. He is an Emeritus Director of Research Corporation for Science Advancement, America's oldest foundation devoted exclusively to science.

Professor **Kevin Jones**, working with scientists at the National Institute of Standards and Technology (NIST) in Gaithersburg, MD, published a paper in *Nature Photonics* describing an experimental investigation of the transport of information through a "fast light" medium. Their experiment took advantage of the technology and understanding developed in recent years in the context of quantum information science. In particular, they first produced a pair of entangled "squeezed vacuum" beams. Measurements of the electric field in either beam by itself shows only random noise but the noise on the two beams is highly correlated so that each beam carries information about the other. Inserting a fast light medium (with a negative group velocity) into one of the beams shifted the time of maximum correlation between the two beams showing that the quantum fluctuations on the beam going through the fast light cell had been sped up relative to those going through free space. The team then went on to study the quantum information transmitted through the medium

and showed that while the time of peak information transport can indeed be advanced by a fast light medium, the amount of information is degraded in just such a way that the leading edge of the information is not advanced.

In May Professor Jones was an invited speaker at a select international meeting "Frontiers of Cold Matter" held at the Joint Quantum Institute at the University of Maryland. This conference also served as a celebration of the scientific work of Dr. Paul Julienne, a leading figure in the development of the field of ultra-cold atomic collisions. Professor Jones was honored to be invited to attend and contribute to this celebration.

Assistant Professor **Ward Lopes** taught *Quantum Physics* (PHYS 301) in the fall and *Foundations of Modern Physics* (PHYS 142) in the spring. This past year, in his laboratory, *Richard Eiselen '14* worked on and completed his thesis project. Richard worked to characterize the performance of a holographic optical trapping system. Holographic Optical Trapping (or HOT) uses optical forces to move small objects (like cells or viruses) instead of mechanical forces (like directly touching the object with tweezers. It is capable of moving hundreds of objects at a time and it uses holograms to direct the light used in the process. Building on the work of *Alyssa Barlis '13*, Richard was able to address many issues with the HOT system in the lab that previous students did not have the time to correct. His thesis provides a road map for the correct operation of the system for any student who follows.

This summer, *Ariel Silbert '16*, *Allison Carter '16*, and *Julia Cline '15* will be working with a set of molecules, diblock copolymers, which self-assemble (or arrange themselves) into a pattern of stripes. They will create a number of thin film samples of these molecules and study the patterns in the stripes, which form. Since the stripes in one section of the film do not know about the stripes in other sections of the film at the time when the stripes form, the molecules do not form a well ordered pattern. Instead, the pattern looks more like fingerprints. As the sample is heated, though, the sample obtains a higher degree of order by moving and annihilating defects. Julia will continue this work in her senior thesis research during the academic year. In addition, Professor Lopes is working in collaboration with Professor Morgan McGuire in Computer Science to study the models frequently used in computer graphics to simulate the scattering of light off of surfaces.

During the 2013-14 academic year Professor **Tiku Majumder** continued his term as Director of the Science Center and Chair of the Science Executive committee. In his administrative role, he has supervised and supported faculty research funding, the student research program, and has focused on numerous facilities, development, and a potential construction project relating to the Science Center. He taught *Thermal and Statistical Physics* (PHYS 302) and its associated laboratory, to a group of 16 students in the spring of 2014. He continued to pursue diode laser and atomic physics experiments in his research lab, teaming up with senior thesis students *Nathan Bricault '14* and *Gabby Vukasin '14*. The group said goodbye in Sept 2013 to postdoc Gambhir Ranjit, who had been with the group for the past 2 and a half years. With funds from a new ($350K) NSF grant beginning in the fall of 2014, Professor Majumder will be hiring a new postdoc to join the group.

The Majumder lab continues to pursue high precision measurements of atomic structure of the heavy metal elements thallium and indium. These measurements test state-of-the-art calculations of atomic structure in these multi-electron atoms, and are useful in providing 'table-top' tests of fundamental physics of the sort normally associated with elementary particle theory and high-energy accelerators. The two current experimental projects in the Majumder lab involve the use of various semiconductor diode laser systems and atomic sources of thallium (in heated vapor cells) and indium (in a high-vacuum atomic beam apparatus). Nathan Bricault followed up on an experiment completed in 2013 to experiment to precisely measure the Stark shift (atomic energy level shift in a large static electric field) in an atomic beam of indium. Nathan extended the work of predecessor *Nathan Schine '13* to perform two-step spectroscopy in indium with two diode lasers. Nathan collected preliminary data, demonstrating 'proof of principle' for this method and experiment. In WSP and spring 2014,

he was joined by research assistant *Ben Augenbraun '15*, who will be picking up this experiment as his thesis project beginning in June. Ben accompanied Professor Majumder to Madison, WI to the annual APS Division of Atomic, Molecular, and Optical Physics (DAMOP) conference at which he helped present a poster on this experiment, while Professor Majumder presented a second poster on the vapor cell experiment mentioned below.

Gabby Vukasin completed her thesis this spring as well. Gabby spent the first part of the year completing an in-depth analysis of the experimental data from a project begun by previous thesis student *David Kealhofer '13*. This work involved using two diode laser systems (IR, UV) to excite thallium atoms contained in a heated (500C) quartz cell in a two-step fashion to measure hyperfine structure and the isotope shift in an excited state of thallium-203 and thallium-205. The results of this work were published in the journal Physical Review A in Jan 2014 with Gabby, David, and Gambhir as co-authors with Professor Majumder.

Both Nathan and Gabby will be studying mechanical engineering next year. Nathan will attend Cambridge University with a Hershel Smith Fellowship, while Gabby will attend Tufts University. We wish them luck! Incoming thesis student Ben Augenbraun, along with summer research students *Talia Calnek-Sugin '15*, and *Saumen Cheng '16* will join Professor Majumder this summer to continue and follow up on both experimental efforts.

Visiting Assistant Professor **Michael Seifert** continued his theoretical work into possible violations of Lorentz symmetry, the symmetry between space and time that underlies Einstein's theory of relativity. His current research deals with structures known as "topological defects" that can arise in these theories, and with their gravitational phenomenology. During the summer and fall of 2013, Seifert worked with *Kamuela Lau '14* to investigate the bending of light rays in the presence of these topological defects, with an eye towards their observational signatures. He also worked with *Brandon Ling '15* during summer 2013 and spring 2014 to identify more generalized models in which these defects can occur.

During the 2013–14 academic year, Professor Seifert taught *Electromagnetic Theory* (PHYS 405T), an advanced tutorial class, and *Electromagnetism and the Structure of Matter* (PHYS 132). He also developed and taught a new course for non-majors, *The Science of Musical Sound* (PHYS 14), during Winter Study 2014.

Professor **Jefferson Strait** and his students build and study optical fiber lasers that produce pulses of light about one picosecond long. Unlike most lasers, which use mirrors to confine light to the laser cavity, an optical fiber laser uses a loop of fiber as its cavity. A section of fiber doped with erbium acts as the gain medium. It lases at 1.55 microns, conveniently the same wavelength at which optical fiber is most transparent and therefore most suitable for telecommunications. This laser functions as a test bed for short pulses of light propagating in fiber.

Max LaBerge '14 worked with Strait on an honors thesis project building and testing a new fiber laser pumped with laser diodes. The new laser produces stable pulses that could be as short as 0.4 picosecond. It uses optical fibers designed for transoceanic communication that have both positive and negative dispersion, giving us control over the overall dispersion in the laser.

Strait serves as pre-engineering advisor and department Webmaster. He completed his seventh and final year as College Marshal, the faculty member responsible for coordinating the college's Convocation and Commencement ceremonies.

Assistant Professor **Frederick Strauch** taught *Seminar in Modern Physics* (PHYS 151) in the fall, while in the spring he taught *Mathematical Methods for Scientists* (PHYS 210) and *Controlling Quanta* (PHYS 314T), each for the first time. The latter was a new tutorial course, taken by first-years through seniors, devoted to modern developments in the control of individual quantum mechanical systems, the topic of the 2012 Nobel Prize in Physics. He also taught a number of students the fundamentals of the Bell Inequality during Winter Study, including an attempted simulation of such experiments using qCraft, a modified version of the popular program MineCraft.

Professor Strauch continued his theoretical work in superconducting quantum circuits, quantum algo-

rithms, and other applications to quantum information processing. He also started a new project, in collaboration with Steven Miller in Mathematics, on the statistical origins of Benford's law. This was studied with thesis student *Joe Iafrate '14*, while *Cesar Melendez '14* studied aspects of the quantum Zeno effect. During Winter Study he worked with *Maria Prado '17*, *Elena Polozova '17*, *Matthew Quinn '17*, and *William McGuire III '17*. During the summer of 2014 he will be working with *Teddy Amdur '15*, *Weng-Him Cheung '15*, *Bijan Mazaheri '16*, and Elena Polozova.

In the fall semester, Associate Professor **Dave Tucker-Smith** taught *Introduction to Mechanics* (PHYS 131), and in the spring, he taught *Gravity* (PHYS 418), an introduction to Einstein's theory of general relativity. Williams students *Weng-Him Cheung '15*, *Isaac Hoenig '14*, and *Gabriel Samach '15* did particle-physics research with Professor Tucker-Smith during the summer of 2013. Weng-Him studied how searches for high-energy photons from dark matter annihilations in our galaxy can be used to test a particular model of dark matter. Isaac and Gabriel studied how results from the Large Hadron Collider constrain a simple extension of the Standard Model of particle physics. Isaac continued the project through the academic year and presented results in his senior honors thesis.

In the summer of 2013, Professor **Bill Wootters** worked with two research students, *Corey Smith '14* and *Kirk Swanson '14*, on a problem in classical information theory inspired by quantum mechanics. Quantum theory has the intriguing property that the number of parameters needed to specify a quantum state is exactly twice the number of independent probabilities associated with the outcomes of a complete, repeatable measurement. Corey and Kirk thoroughly analyzed a classical problem exhibiting a similar factor of two and showed how the classical result differs from the quantum behavior.

Professor Wootters was on sabbatical for the 2013-2014 academic year, during which he attended a number of conferences: the American Physical Society's March Meeting in Denver; a meeting in Puerto Rico sponsored by the Foundational Questions Institute (FQXi); a workshop in Cambridge, UK, celebrating the work of Arthur Eddington and John A. Wheeler; and a symposium in Ottawa, Ontario, on optical approaches to foundational issues in quantum theory. In another visit to Cambridge, he participated in the Isaac Newton Institute's program on mathematical issues in quantum information theory. At the end of the academic year he served as an outside examiner for Swarthmore's honors program.

In Williamstown, Professor Wootters had the pleasure of participating in a few informal physics-related events. In the fall he contributed to an interdisciplinary panel presentation on the subject of light, organized by some of the senior majors in the art department. At Images Cinema, after a showing of "*Gravity*," he led a free-flowing discussion on the physical plausibility of the events depicted in the movie. And at a gathering at the First Congregational Church, he joined Professor Emeritus Stuart Crampton in an exploration of the relation between physics and religion. In another interdisciplinary development, Professor Wootters is excited to be working with philosophy professor Keith McPartland on a new team-taught course, *Philosophical Implications of Modern Physics* (PHYS 312), to be offered for the first time in the spring of 2015.

Class of 1960 Scholars in Physics		
Nathan R. Bricault	Joseph R. Iafrate	Cesar Melendez
Richard P. Eiselen, Jr.	Maxwell C. LaBerge	Gabrielle D. Vukasin
Isaac M. Hoenig		

Physics Colloquia

Kathy Aidala, Mount Holyoke
"Manipulating Magnetic States in Nanorings: The future of data storage?"

Brian Anderson, Joint Quantum Institute, University of Maryland
"Quantum Control and Tomography in a Large Hilbert Space"

Alexi Arango, Mount Holyoke College
"Next-generation photovoltaics utilizing unconventional semiconductors for low-cost, large-scale electricity generation from the sun"

Ashley Carter, Amherst College
"Reshaping our Genetic Future"

Evan Couzo'05, MIT
"Atmospheric Models: Why you should never ever ever trust them, why some people do, and why you will, too"

Eric Heller, Harvard University
"What I Learned About Quantum Mechanics by Studying Acoustics and Vice-Versa"

Paul Hess '08, Harvard University Physics Dept
"How round is the electron? ACME's improved limit on the electron's dipple moment"

Catherine Hirshfeld Crouch '90, Swarthmore College
"Physics and Cell Biology: Physical Models and Techniques for Studying Why Cell Membranes Bend"

Shelby Kimmel '05, MIT
"Problems with Multiple Oracles"

Kamen Kozarev '05, Smithsonian Astrophysical Observatory
"Solar Mass Ejections, Coronal Shock Waves, and Energetic Particle Acceleration"

Catherine McGeoch, Amherst College
"Experimental Evaluation of an Adiabatic Quantum Computer for Combinatorial Optimization"

Paul Schechter, MIT
"The dark matter content of elliptical galaxies measured from the static gravitational micro-lensing of multiply imaged quasars"

Dava Sobel, Smith College
"Copernicus's Search for a More Perfect Heaven"

Joshua Spitz, MIT
"Closing in on the Neutrino"

David Tucker-Smith
"Dark Forces"
Williams College Science Center Forum, March 2014

Jennifer Yee, Harvard Smithsonian Center for Astrophysics
"Extraordinary Extrasolar Planets"

Off-Campus Physics Colloquia

Daniel Aalberts

"Modeling unpairing costs for fast computation of the net binding free energy of an oligo to an mRNA target"
Poster at RNA Finger Lakes Conference, October 2013

"Somewhere over the RNAbow"
Stanford Univ, January 2014

"Modeling unpairing costs for fast computation of the net binding free energy of an oligo to an mRNA target"
Poster at Biophysical Society Meeting, February 2014

"Somewhere over the RNAbow"
Siena College, April 2014

Kevin Jones

"All in good time: molecular spectra, atomic lifetimes and the finite speed of light"
Invited talk at "Frontiers in Cold Matter- A Celebration of the Scientific Life of Paul Julienne," Joint Quantum Institute, University of Maryland, May 2014

David Kealhofer '13, G.D. Vukasin '14, G. Ranjit, and P.K. Majumder

"Precise measurement of the 7P1/2 and 8P1/2 hyperfine splittings and isotope shift in 203Tl and 205Tl using two-step laser spectroscopy"
APS Division of Atomic, Molecular, and Optical Physics Meeting, Madison, WI, June 2014

N. A. Schine '13, N. Bricault '14, B. Augenbraun '15, G. Ranjit, and P.K. Majumder

"High-precision Stark shift measurements using FM spectroscopy in an indium atomic beam"
Contributed poster, APS Division of Atomic, Molecular, and Optical Physics Meeting, Madison, WI, June 2 – June 2014

Frederick Strauch

"Toolbox for resonator-based quantum control"
University of New Mexico Center for Quantum Information and Control, Albuquerque, NM, December 2013

David Tucker-Smith

"A Z' for dark matter at the LHC"
UMass particle theory seminar, University of Massachusetts, February 2014

William Wootters

"What is the origin of complex probability amplitudes?"
Q+ hangout (online presentation), June 2013
Newton Institute, Cambridge, UK, September 2013
University of Bristol, UK, October 2013
University of Calgary, Canada, May 2014

"Why does nature like the square root of negative one?"
RPI, November 2013
Swarthmore College, November 2013

"The ubit model in real-amplitude quantum theory?"
APS March Meeting, Denver, CO, March 2014

"Does nature optimize the transfer of information?"
Symposium: Measuring Photons, Ottawa, Canada, March 2014

"Re-identification as a source of order?"
Workshop: Information and Interactions, Cambridge, UK, March 2014

Postgraduate Plans of Physics Majors

Ilya Amburg	Assistant lab instructor in Physics at Williams
Charles F. Baxter	Junior trader at Oak Hill Advisors in Structured Products Group
Nathan R. Bricault	MPhil in Advanced Computer Science at Cambridge University
Allen B. Davis	Astronomy PhD program at Yale University
Richard P. Eiselen	Seeking employment
Jeremy K. Gold	Managing Member of Alesia Asset Management, San Francisco, CA
Kerrin G. Hensley	NASA/JPL internship (Summer 2014), then Fulbright fellowship teaching in Taiwan
Charles E. Hermann	Studying renewable energy at Shanghai University, China
Isaac M. Hoenig	Teaching Physics and Math at Meridian High School in Meridian, MS
Joseph R. Iafrate	Applied Physics PhD at University of Michigan
Kathryn M. Kistler	Tutoring kids in math and science and applying to grad school in 2015
Henry W. Koster	Coaching a swim team while pursuing employment in social sector, public health
Kamuela N. Lau	JET program, teaching English in Japan
Maxwell C. LaBerge	Research at the University of Puget Sound, applying to PhD programs for 2015
Jacqueline E. Lusardi	Painting by the beach during summer while seeking full time employment
Cesar Melendez	Teaching high school in Minnesota; considering graduate school in Physics or Math
Sarah W. Peters	Clinic work in Chicago, then traveling and volunteering abroad before med school
Nathan Saffold	Backpacking through Europe then research assistant at Pritzker School of Medicine
Corey D. Smith	PhD in Medical Physics at University of Chicago
Kirk Swanson	Trading company in Chicago
Gabrielle Vukasin	Graduate program in Mechanical Engineering at Tufts University

PSYCHOLOGY DEPARTMENT

The psychology major at Williams College attracts a large number of students with diverse interests and aspirations. Our students follow a curriculum that teaches them not only what we know about mind and behavior, but also how we know it, using experiential teaching as our core pedagogy. Students learn how to use the methods of scientific inquiry to critically observe and evaluate behavior, and then construct from experimental evidence the implications for larger questions about human behavior. Students choose from a range of courses spanning the sub-disciplines of neuroscience, cognition, development, education, clinical, and social psychology. Psychology faculty work closely within the Neuroscience and Cognitive Science Programs and the Program in Teaching, as well as with Environmental Studies, Justice and Law, Public Health, and Women's, Gender, and Sexuality Studies.

Psychology students have multiple opportunities to conduct research collaboratively with professors. Some of these are empirical projects within required 300-level lab courses, and others are in work-study or research assistant positions or as more formal independent studies. The culminating research experience is the yearlong senior honors thesis. In 2013-2014 nine students conducted thesis research on a variety of topics. A complete listing can be found in the Student Abstracts section of this report. Some of our majors completed their research experiences by presenting their research at national or international scientific conferences and by co-authoring journal publications. Department events this year included student/faculty/family picnics, evening programs on "Graduate Study in Psychology" and "Careers in Psychology," and a wine and cheese reception to celebrate honors theses presentations in the Psychology Lounge.

We were happy to host two visiting professors this past year, Alison Shawber Sachet from the University of Oregon, and Laura Sockol from the University of Pennsylvania. We are especially pleased that both Laura and Alison will continue to teach here for another year. Next year, we will also have three additional visitors: *Lauren Williamson '07*, of Duke University, Jeff Moher, of Brown University, and Nicole Harrington, a local clinical psychologist. They will enhance our curricular offerings in neuroscience, cognitive, developmental, and clinical psychology. Several new courses were added to the curriculum this year including *Foundations of Cognition* by Mariko Moher, *Imagination* by Alison Sachet, *Gender and Psychopathology* and *Child Psychopathology* by Laura Sockol, and *Progress and Problems in Intergroup Interaction* by Jennifer Randall Crosby.

After 40 years at Williams, including 15 years as the administrative assistant for the Psychology Department, the beloved Lizabeth Stachelek retired at the end of 2013. Beth was absolutely invaluable to faculty, staff, and students in the Psychology Department for all these years, doing more tasks than we could ever hope to quantify, and doing them all with uncompromising skill, patience, and good will. As an indication of Beth's generosity, she agreed to stay on working part-time in the Psychology Department, and she heroically filled in while we were in the process of finding, hiring, and eventually training a new administrative assistant, Christine Russell. We are thrilled with Christine who has already proven to be an outstanding addition to the department since she came aboard in February.

We also are indebted to C.J. Gillig, Psychology Department Technical Assistant, for the many ways in which he helps the Psychology Department. His work ethic and patience and his ability to step in to support our work, often at the last minute, is well-known to students from Introductory Psychology through senior honors theses students. His contributions are deeply appreciated by the faculty. Along with Beth and now Christine, CJ helps keep our large department feeling friendly and accessible.

Professor **Phebe Cramer** was honored at the national meeting of the Society of Personality Assessment as the recipient of the 2014 Bruno Klopfer award. This award is given "in recognition of unique and distinguished contribution to personality assessment" and "unfailing life long support of psychology and psychologists". In this connection, she presented an address *Defense Mechanisms: 40 Years of Empirical Research*. At the meeting, held in March 2014, Professor Cramer also chaired a Symposium *Defense Mechanisms and the TAT: Childhood Pathology, Adult Health*, for which she was the discussant, and presented a paper *Defense Mechanisms Predict Change in Children's Externalizing and Internalizing Behaviors*.

She has continued her work as Associate Editor of the *Journal of Research in Personality* and as Consulting Editor for the *Journal of Personality Assess-*

ment. In addition, she has been an invited ad hoc reviewer for research papers submitted to multiple professional journals. She has also provided consultation to colleagues and graduate students from other educational institutions that wish to use her method to study defense mechanisms.

This past year, **Susan Engel** completed two book manuscripts, *The Hungry Mind: The Development of Curiosity* (Harvard University Press 2015) and *The End of the Rainbow: How the pursuit of money has distorted American education, and how the pursuit of happiness can transform it* (The New Press 2015).

Susan traveled to a variety of professional meetings during the past year: She participated in an international meeting in The Hague Netherlands, sponsored by the Bernard Van Leer Foundation, on teaching people to do participatory research with children in a wide range of cultures and communities. The proceedings of the conference are being made into a book, which will be published in 2015. She gave a talk at the Aspen Ideas Festival on the development of curiosity, and a series of lectures for educators, in Portland Oregon, on educating for curiosity. Susan was the discussant for a symposium on science education at the European Association for Education on Learning and Instruction in Munich Germany, where she was joined by *Madelyn Labella '09*, who presented research based on her honor's thesis. In September she participated in a meeting of early childhood educators, developmental psychologists, and policy makers Palo Alto, organized by Ascend Institute, to discuss educational paths to poverty using two generation approaches.

She received a grant from The Spencer Foundation to begin some new research examining the intellectual impact of college.

She served as a reviewer for manuscripts from the academic journals *Cognitive Development*, and for *Merrill Palmer Quarterly*, and also for grant applications for the Spencer Foundation.

Professor Engel served as director for the *Program in Teaching*. The program lunches included presentations by Lynn Lyons, clinical psychologist titled *Anxious Kids, Anxious Parents*; *Hannah Hausman '12*, titled *Can You Change a Student's Mindset?*; and Stephen DiCarlo, Professor of Physiology, Wayne State University titled *Play in Science*.

Professor **Laurie Heatherington** and her students continued research on change processes in psychotherapy, including therapeutic alliance in couple and family therapy (in collaboration with colleagues at SUNY Albany and Universidad de La Coruña, Spain), the role of social cognitive factors in interpersonal relationship difficulties, and outcomes of residential treatment for major mental illness. They also studied the outcomes of a NAMI-directed training for Berkshire County police officers in handling cases involving emotionally disturbed persons. In the fall semester, Professor Heatherington was on sabbatical leave, finishing several writing projects and developing a new seminar course, *Psychotherapy: Theory and Research* (PSYC 355), which she taught during the spring semester.

In October, Professor Hetherington attended the 2013 NASPR conference in Memphis, TN with her former thesis student *Pacifique Irankunda, '13* where they presented *Burundians' Outcome Expectancies for Various Treatments for Psychological Problems*. At the conference she directed a roundtable discussion titled *The Narrowing of Theoretical Orientations in Clinical Psychology Doctoral Training* and was a panelist in a structured discussion on mentoring. She published, with collaborators, an empirical study of group treatment for anxiety disorders.

Professor Heatherington served on the Editorial Boards of *Psychotherapy Research*; *Journal of Family Psychology*; *Psychotherapy: Theory, Research, Practice, and Applications*; *Journal of Counseling Psychology*; and *Journal of Clinical Psychology: In Session* and did ad-hoc reviewing for several other journals. She served on the Directors and Associates Board of the Gould Farm (Monterey, MA), a treatment center/working farm serving people with schizophrenia and other major mental illnesses, on the Executive Committee of the North American chapter of the Society for Psychotherapy Research (NASPR) and program committee for the International Society for Psychotherapy Research (SPR) Conference in Copenhagen, Denmark.

Professor **Saul Kassin** was on reduced time, in a phased early retirement, while serving as a Distinguished Professor at the John Jay College of Criminal Justice in New York. Focused on policy reform and matters concerning wrongful convictions, Kas-

sin continued working on his 3-year NSF grant to study *The Videotaping of Interrogations: Testing Proposed Effects on Police, Suspects, and Jurors*. In March 2014, Kassin received a lifetime achievement award for Distinguished Contribution from the American Psychology-Law Society (AP-LS). In receipt of this award, he gave an invited lecture entitled *False confessions: Past, present, and future* at the Annual Conference in New Orleans. His work was featured in *The Interview* an article appearing in the *The New Yorker* (12/9/2013) and cited by the U.S. Supreme Court in Salinas v. Texas (6/72013).

This past year, Kassin gave invited speeches at a number of venues, including: at the Annual Meeting of the Association of American Law Schools, in NYC (January 2014), at the Annual Meeting of the American Academy of Forensic Sciences in Seattle (February 2014), at a 50th anniversary Conference on the Legacy of Stanley Milgram at Yale University Law School (October 2014), and at the Annual Federal Bench & Bar Retreat in Lenox, MA (October, 2014). In addition, Kassin spoke at a number of institutions—including Columbia University Law School and Benjamin Cardozo School of Law, in NYC; he gave a half-day workshop on police interrogations and confessions at the Walter Reed National Military Medical Center in Silver Spring, MD; and he participated with Ken Burns in a panel discussion concerning the Central Park Five for The Constitution Project in Washington, DC.

Kassin has continued to serve as a consulting editor of the *Journal of Applied Research on Memory and Cognition* and for *Law and Human Behavior*. He continued to serve on the Research Advisory Board of the Innocence Project, the Advisory Board member of the Social Science Research Network (SSRN), and reviewer for the National Science Foundation. He has also served as a consultant and expert witness in both criminal and civil cases.

Assistant Professor **Nate Kornell** continues his research on cognition, education, and self-regulated learning. He received a $600,000 grant this year from the James S. McDonnell Foundation to study self-regulated learning. He was a consulting editor for five journals: *Archives of Scientific Psychology*; *Educational Psychology Review*; *Journal of Experimental Psychology: Learning, Memory, and Cognition*; *Memory & Cognition*; and *Psychonomic Bulletin & Review*. He continues to write a blog for *Psychology Today*. He published seven journal articles and one book chapter this year. Three articles examined the ability of monkeys to make (metacognitive) judgments about their own memories. Two others examined metacognitive judgments in humans. Two had to do with the benefits of retrieving information from memory when learning. A final article examined the degree to which the fluency with which a teacher explains something can cause students to develop illusions that they understand the material.

Assistant Professor **Mariko Moher** continued her research focusing on the development of memory in infants and young children. This year, she conducted a project with thesis student *Alida Davis '14* with help from *Lauren Glenn '15* and *Jacqueline Lee* '15. This study examined preschoolers' ability to increase the amount of information they can store in memory by grouping items together. In her new course titled *Foundations of Cognition* (PSYC 333), students worked with local preschoolers to examine whether storytelling would influence the children's capacity to reason about other people's emotions and thoughts. In addition, Professor Moher presented her research at the biennial meeting of the Cognitive Development Society and at the annual New England Liberal Arts Colleges Workshop on Cognitive Development (with *Alida Davis '14*), as well as at University of Massachusetts at Amherst and Boston College as part of their developmental psychology colloquia series. Finally, some of her recent work was published in the journal *Cognitive Development*.

The research of Professor **Marlene Sandstrom** focuses on children's social relationships. She is particularly interested in victimization, bullying, bystander behavior, peer rejection, popularity, and social influence. This year, Professor Sandstrom's research focused on developing a better understanding of individual differences in susceptibility to peer pressure. In collaboration with her thesis student *Fanny Mlawer '14*, she explored the extent to which implicit measures of evaluative concern (i.e., low self-esteem, high fear of negative evaluation, high rejection sensitivity) could explain variability in college students' propensity to conform to group opinion on a set of subjective and objective tasks.

In the fall, Professor Sandstrom served as a consultant on an NIH-funded grant entitled *Decreas-*

ing Bullying with Self-Affirmation: A Test of the Compensation Model. Over the past year, Professor Sandstrom has served as an ad hoc reviewer for the academic journals *Child Development*, *Pediatrics*, *Journal of Clinical Child & Adolescent Psychology*, and *Early Adolescence*. Professor Sandstrom was also invited to serve as an external reviewer for the Psychology Departments of Whitman College in Washington state and Occidental College in California.

Associate Professor **Noah Sandstrom** continued his research exploring the role of steroid hormones in shaping outcomes following closed head injury. During the summer, he worked with *Ellen Cook '15* and *Nitsan Goldstein '15* to implement a model of repeated mild head injury and together they explored the behavioral and neuronal effects of this model. During the year, Professor Sandstrom worked with thesis students *Megan Trager '14* and *Jenna Adams '14* to examine how progesterone and estradiol influence outcomes following repeated mild head injuries. This area of investigation complements Professor Sandstrom's service on the Medical Aspects of Sports Committee, a NESCAC Committee exploring medical issues in collegiate sports with a particular focus on concussion prevention and management. In November of 2013, Sandstrom attended the annual meeting of the Society for Neuroscience as well as the annual meeting of Faculty for Undergraduate Neuroscience at which he transitioned from President to Past-President. He also served as Chair of the Behavioral Neuroscience Fellowship study section at the National Institutes of Health and serves as a reviewer for several journals.

Visiting Assistant Professor **Laura Sockol** focuses on mental health during pregnancy and the early postpartum period in her research. She published several articles this year. One paper, published in the *Archives of Women's Mental Health*, found that attitudes toward motherhood predict symptoms of depression and anxiety among pregnant and postpartum first-time mothers. In collaboration with colleagues from the Alpert Medical School of Brown University and Butler Hospital, she published a second article in the *Archives of Women's Mental Health* which investigated factors related to mother-infant bonding among severely psychiatrically ill perinatal women. She published a meta-analysis of preventive interventions for postpartum depression in *Clinical Psychology Review*. She also co-authored a chapter on gender differences in obsessive-compulsive disorder. A poster, *Prenatal risk factors for postpartum symptoms of depression and anxiety among first-time mothers* which Professor Sockol presented at the annual meeting of the Association for Behavioral & Cognitive Therapies, received the ABCT Women's SIG Student Research Award. A talk titled *The relationship between maternal attitudes and symptoms of depression and anxiety among pregnant and postpartum first-time mothers* which Professor Sockol presented at the bi-annual meeting of the North American Society for Psychosocial Obstetrics & Gynecology, received the Steiner Young Investigator Award.

Professor Sockol developed a new upper-level empirical laboratory course this year entitled *Gender & Psychopathology* (PSYC 353). *Rachel Caffey '14*, *Julia Juster '14*, and *Natalie Szykowny '14* conducted a study of gender differences in college seniors' anxiety related to the search for post-graduate employment, and will present findings from their study at the annual meeting of the Association for Behavioral & Cognitive Therapies in November of 2014. At the same conference, Professor Sockol will present a poster of findings from a study of the influence of depressive symptoms on empathetic responses with *Caroline Kaufman '15* and former visiting assistant professor Alicia Hofelich Mohr.

Assistant Professor **Catherine Stroud** is continuing work on her longitudinal research study examining biological, psychological, interpersonal and environmental factors that affect adolescents' response to stressful life events and ultimately confer increased risk for the development of major depression during adolescence. *Emily Norkett '14* and *Elizabeth Albert '14* completed senior honor theses examining diurnal cortisol rhythms, pubertal timing, stress and depression among adolescent girls. Catherine and *Effua Sosoo '13* presented their work on predictors of stress generation at Annual Meeting of the Association of Behavioral and Cognitive Therapies (ABCT) in Nashville, TN. Professor Stroud and *Jessica Fitts '13* also presented their work at ABCT, where Jessica won the student poster award for her work examining parents' contribution to the development of adolescents' coping strategies. Also at ABCT, Stroud, *Stephanie Cardenas '14*, *Elizabeth Greiter '12*, *Nicole Stenquist '12* and *Margaret Richmond '12* presented their work on young adults' sexual behavior, inter-

personal styles and depressive symptoms. In addition, Stroud, Emily Norkett, and Elizabeth Greiter presented their work on adolescents' romantic experiences and depressive symptoms at the biennial meeting of the Society for Research on Adolescence. Catherine and her colleagues also presented work examining interpersonal functioning and personality disorders at the annual meeting of the Society for Research on Psychopathology.

Professor Stroud and her colleagues published a manuscript examining the role of parents' marital functioning and parent-child relationships in young children's adjustment. She also co-authored two chapters on depression and interpersonal relationships. Catherine continued in her role as advisory editor of Family Process and as president of a special interest group promoting research in clinical psychology at liberal arts colleges for the Association of Behavioral and Cognitive Therapies.

Professor **Betty Zimmerberg** continued her service as chair of the Psychology Department in the fall 2013, and was on leave in Spring 2014. Zimmerberg continued her research on the epigenetics of anxiety behavior, investigating the effects of early social enrichment on the developmental trajectory of affective and social behaviors in an animal model of infant temperament. While on leave, she supervised *Amanda Schott '15* in an Independent Study project looking at the role of NK1 receptors in mediating distress calls in neonates.

In the fall, Zimmerberg taught her interdisciplinary seminar *Image, Imaging and Imagining: The Brain and Visual Arts* (PSYC 318). This course examines the literature at the intersection of neuroscience and art. Students studied visual neuroscience – how we see and how our brains organize and perceive what we see. A series of class meetings in the Rose Gallery at WCMA investigated how visual artists used or challenged perceptual cues in their work. Other topics included face perception and portraiture, neuroaesthetics, mirror neurons, and neurological conditions in artists. The course culminated with an exhibit of art created by the students related to the topics of this class. Zimmerberg also participated in developing the new program in public health, and gave a guest lecture titled *Introduction to Public Health on Fetal Alcohol Syndrome*.

In June, Zimmerberg attended the annual meeting of the International Behavioral Neuroscience Society in Las Vegas, where she participated in a symposium on animal models in developmental psychopathologies. Other professional activities included serving on the Editorial Board of *Developmental Psychobiology* as well as reviewing for the academic journals *Neuroscience*, *Frontiers in Neuroscience*, and *Acta Neurobiologiae Experimentalis*.

Class of 1960 Scholars Program

To encourage students to explore careers in psychology, the Class of 1960 Scholars Program brings accomplished researchers from other colleges and universities to campus to give colloquia. In advance of the colloquia, the group of 1960 Scholars read and discuss the speakers' work with a faculty member and then join the speaker and faculty for dinner afterward. The 2013-14 Class of 1960 Scholars are listed below. This year marked the sixth year of the G. Stanley Hall Prize in Psychology, funded by a generous gift from the Chuzi family, parents of Sarah Chuzi '07, and given at graduation to a student who has demonstrated exceptional achievement in psychology. We were happy to award the prize to Alexander (Sandy) LaTourrette for his outstanding thesis.

Class of 1960 Scholars in Psychology

Jenna Adams
Elizabeth Albert
Sivahn Barsade
Katie Berenbaum
Jonathan Brenner
Stephanie Cardenas
Alida Davis
Peter Drews
Nitsan Goldstein
Alexandra Jones
Caroline Kaufman 15
Alexander LaTourrette
Theresa Legan
Eric Liao
Claire Liu
Melissa Martinez
Jelani Medford
Claire Miller
Fanny Mlawer
Narah Moon
Emily Norkett
Alyssa Quann
Sarah Rosemann
Nitza Solis
Sean Sutherland
Megan Trager
Mattia Wruble

Psychology Colloquia

David Huber '91, University of Massachusetts Amherst
"Separating Events in Time Through Perceptual Habituation"

Off-Campus Psychology Colloquia

Phebe Cramer
"Defense Mechanisms Predict Change in Children's Externalizing and Internalizing Behaviors"
Paper presented at the national meeting of the Society of Personality Assessment, Arlington, VA, March 2014

Laurie Heatherington
"Burundians' Outcome Expectancies for Various Treatments for Psychological Problems"
NASPR conference in Memphis, TN, with Pacifique Irankunda '13, October 2013

Saul Kassin
"False Confessions: Past, Present, and Future"
Distinguished Contribution Award Lecture presented at the American Psychology-Law Society, New Orleans, LA, March 2014

"Recanted Corroborations: The Impact of Confessions on Alibi Evidence"
Poster presented at the Meeting of the Association for Psychological Science, San Francisco, CA, with S. Marion, J. Kukucka, C. Collins, & T. Burke, May 2014

"The Effect of Prior False Confession on Guilty Plea Decisions"
Paper presented at the Meeting of the American Psychology-Law Society, New Orleans, LA, with J. Perillo, W. Crozier & C. Pollick, March 2014

"The Impact of Just World Beliefs and Public Self-Consciousness on the Cooperativeness of Innocent Suspects"
Poster presented at the Meeting of the American Psychology-Law Society, New Orleans, LA, with R. Abramowitz & J. Kukucka, March 2014

"Prevalence and Formats of Confessions: Analysis of 772 Closed Crime Cases in the U.S."
Paper presented at the Meeting of the American Psychology-Law Society, New Orleans, LA, with S. Appleby et al., March 2014

"The Forensic Confirmation Bias: How Confessions Corrupt Perceptions and Judgments"
Presented at the Meeting of the American Academy of Forensic Sciences, Seattle, WA, with J. Kukucka, February 2014

"False confessions"
Paper presented at the Annual Meeting of the Association of American Law Schools, New York, NY, January 2014

"The Role of Situational Forces in Shaping Police-Induced False Confessions"
Invited lecture to the Conference on the Legacy of Stanley Milgram, Yale University Law School, New Haven, CT, October 2013

"False Confessions"
Keynote speech to the Federal Bench & Bar Retreat, Lenox, MA, October 2013 .
Walter Reed National Military Medical Center (WRNMMC), Bethesda, MD
Columbia University Law School, New York, NY
Cardozo Law School, New York, NY
The Constitution Project, Washington, DC

Nate Kornell

"The Road Not Taken: Desirable Difficulty as a Path to Learning.
Talk delivered at Dartmouth University, Hanover, NH, October 2013

"Desirable Difficulty as a Path to Learning"
Talk presented at a Pearson Biology Leadership Conference, Amelia Island, Florida, November 2013

"Do Tests Actually Prevent Forgetting?"
Paper presented at the 54th Annual Meeting of the Psychonomic Society, Toronto, ON, November 2013

"Organizing Instruction and Study to Improve Student Learning"
Paper presented as teacher training at The Regional Educational Laboratory (REL) Mid-Atlantic bridge event forum, Ocean City, MD, May 2014

"Mixing Topics While Studying Does Not Enhance Learning"
Poster presented at the 26th Annual Meeting of the Association for Psychological Science, with Hannah Hausman '12, San Francisco, CA, May 2014

"How to Teach an Old Dog New Tricks"
Talk delivered at Staff Lunch, Williams College, September 2013

"Tests Enhance Learning. Do They Prevent Forgetting?"
Talk delivered at Science Lunch, Williams College, October 2013

"Using Tests to Promote Learning"
Talk delivered by Networks for Faculty Development, February 2014

Mariko Moher

"Updating Representations in Infant Working Memory"
Paper presented at the annual New England Liberal Arts Colleges Workshop on Cognitive Development, Northampton, MA, July 2013

"The Fate of Chunked Features in Infant Working Memory"
Poster presented at the annual New England Liberal Arts Colleges Workshop on Cognitive Devel-

opment, Northampton, MA, with Alida Davis '14, M. M. Kibbe & Feigenson, July 2013

"Used Then Lost: Infants use Features to Chunk Objects, But Do Not Store the Features in Memory"
Poster presented at the biennial meeting of the Cognitive Development Society, Memphis, TN, with M. M. Kibbe & L. Feigenson, October 2013

"The Benefits and Costs of Grouping Items in Working Memory"
Paper presented at the University of Massachusetts at Amherst, Amherst, MA, March 2014

"The Benefits and Costs of Grouping Items in Working Memory"
Paper presented as part of the Boston College Current Work in Developmental Psychology Series, Boston, MA, March 2014

Noah Sandstrom

"Faculty for Undergraduate Neuroscience (FUN): Multiple Mechanisms for Supporting the Development of Undergraduate Students and Faculty in the Neurosciences"
Society for Neuroscience, San Diego, CA, with E.R. Reynolds, & S.D. Dickinson, October 2012.

Catherine B. Stroud

"Romantic Experiences and Depressive Symptoms in Adolescents: The Role of Emotion Regulation."
Poster presented at the biennial meeting of the Society for Research on Adolescence, Austin, TX, with Emily Norkett '14, Melody Edwards & Elizabeth Greiter '12, March 2014

"Normal and Abnormal Personality Predictors of Stress Generation among Early Adolescent Girls"
Poster presented at the Annual Meeting of the Association of Behavioral and Cognitive Therapies, Nashville, TN, with Effua Sosoo '13, November 2013

"Understanding the Development of Rumination: The Role of Mothers' Coping Suggestions"
Poster presented at the Annual Meeting of the Association of Behavioral and Cognitive Therapies, Nashville, TN (Poster won Student Poster Award, Association for Behavioral and Cognitive Therapies Clinical Psychology at Liberal Arts Colleges), with Jessica Fitts '13, November 2013

"Depressive Symptoms and Young Adults' Sexual Experiences: Evidence for Attachment as Moderator"
Poster presented at the Annual Meeting of the Association of Behavioral and Cognitive Therapies, Nashville, TN, with R. Hershenberg, Stephanie Cardenas '14, Elizabeth Greiter '12, Nicole Stenquist'12 & Margaret Richmond '12, November 2013

"Interpersonal Dysfunction in Personality Disorders: A Meta-Analytic Review"
Oral symposium presented at the 2013 annual meeting for the Society of Research on Psychopathology, Oakland, CA, with S. Wilson & C.E. Durbin, September 2013

Post-Graduate Plans of Psychology Majors

Name	Plans
Tony W. Ahn	Working in sales and trading at Royal Bank of Scotland (RBS).
Elizabeth B. Albert	Attending the post-baccalaureate premedical program at Goucher College in Baltimore, MD.
Sivahn Barsade	Working in business strategy consulting with a focus on education.
Katie S. Berenbaum	Applying to medical school.
Caitlin F. Bird	Applying to graduate school for a degree in science writing.
Grace D. Bouton	Working as a producer/project manager at Human Care Systems (a health consulting company) in Boston.
Jacob R. Butts	Working as a Dean's fellow at Yale NUS College in Singapore.
Rachel A. Caffey	Unknown
Stephanie A. Cardenas	Working in the Human Genetics Branch as Postbac IRTA fellow for the NIH/NIMH in Washington DC, then graduate school for clinical psychology PhD.
Robert D. Carnes	Working as a paralegal at Cravath, Swaine & Moore LLP in New York City.
Taylor L. Chertkov	Consulting with Booz Allen Hamilton in Washington D.C.
Blair E. Curzi	Unknown
Alida A. Davis	Working as a Research Assistant at Columbia University doing perinatal psychology research.
Peter M. Drews	Teaching English in Thailand.
Demarius D. Edwards	Unknown
Felecia S. Farrell	Attending a two-year master's program at Columbia University's School of Social Work.
Isabella M. Ferre	Unknown
Luigia R. Goodman	Unknown
Michael W. Hanley Jr.	Unknown
Brenda Hernandez	Unknown
Marco J. Hernandez	Unknown
Sanghyun Im	Attending a graduate program at Longy School of Music studying opera performance.
Jennifer Jauregui	Unknown
Alexandra B. Jones	Working as an elementary school teaching intern at The Park School in Brookline, MA.
Julia F. Juster	Working as a Research Assistant in the Child Development Lab at the University of Maryland.
Alexander S. LaTourrette	Pursuing a PhD in Cognitive Psychology at Northwestern University.
Stefan K. Lainovic	Unknown
Anna B. Lau	Unknown
Theresa B. Legan	Planning to attend graduate school for neuroscience.

Eric Y. Liao	Working as a Business Systems Analyst at MetLife in Greenwood Village, CO.
Daniel F. Lima	Teaching in Providence, RI, for Teach for America.
Claire Liu	Unknown
Michael A. Lomio Jr.	Unknown
Marissa B. Lowe	Teaching in Houston for Teach for America.
Mary Margaret MacCallum	Unknown
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ABSTRACTS FROM STUDENT THESES

Astronomy

A Study in Syzygy: Observations and Analyses of Stellar Occultations and the 2013 Total Solar Eclipse

Allen B. Davis

This thesis presents a successful detection and the subsequent analysis of a stellar occultation by the Kuiper Belt Object (50000) Quaoar. Constraints are placed on Quaoar's diameter, density, and albedo. Several other events are discussed, including a possible negative detection of an occultation by KBO 84522, preparations for an occultation of Regulus by the asteroid 163 Erigone that was ultimately clouded out, and a possible transit of the long-period exoplanet candidate KOI 1274. This thesis also discusses the successful observation of the 59-second totality of the 3 November 2013 total solar eclipse from a site in Lopé National Park, Gabon. Flash spectra and hundreds of white-light images of the corona were acquired. Composite images of the white-light corona are presented, revealing the structure of the inner, middle, and outer corona near solar maximum. Features of the corona are discussed, including two coronal mass ejections and an erupting prominence.

Planetary Nebulae as Tracers of the Chemical History of the Andromeda Galaxy

Kerrin G. Hensley

This thesis presents analysis of emission-line spectra of eight outer disk planetary nebulae in the Andromeda Galaxy (M31) obtained with the 10.4-meter Gran Telescopio Canarias. The galactocentric radii of these eight planetary nebulae meet or exceed the radii of previously studied objects in M31. We observe unexpectedly high oxygen abundances of these outer disk objects and a relatively shallow oxygen abundance gradient. Possible reasons for these findings, such as an interaction between M31 and neighboring galaxy M33 about 2-3 billion years ago, are discussed.

Measurement of the Hyperfine Structure of the 7P1/2 state and 8P1/2 state in 205Tl and 203Tl

Gabrielle D. Vukasin

We report a final value of the hyperfine splitting of the 7P1/2 state of 205Tl and 203Tl made using a two-step excitation. Our final values are 2173.3(8) MHz and 2153.2(7) MHz respectively. We also measured the isotope shift of the 7S1/2 → 7P1/2 transition to be 534.4(9) MHz. These experimental hyperfine splitting values are ≈ 20 MHz larger than those measured by another group in 1988 [1]. Our values bring the experimental values closer to the theoretical values published in 2001 [2]. Our data consists of spectra taken by scanning the second-step laser 6 GHz. For precise measurement of these spectra, we stabilize the first-step excitation using a method called laser locking. Using the same experimental layout, we are now working to measure the hyperfine splitting of the 8P1/2 state of both isotopes.

Biology

Effects of Group Housing and Running on Elovl3 Gene Expression and Fatty Acid Profiles in Brown Adipose Tissue of Cold-Stressed Mice

Shayna Barbash

In recent years, studying the activity of brown adipose tissue (BAT) has become a topic of great interest as it serves as a potential therapeutic treatment for obesity and related metabolic disorders. The *Elovl3* gene is induced 200-fold in the brown fat of cold-stressed mice and encodes a condensing enzyme that elongates saturated and monounsaturated very long chain fatty acids (VLCFAs). However, the expression of this gene has not yet been measured under varying housing conditions that might influence an animal's perceived

cold stress. In mice, huddling is a common method of behavioral thermoregulation and wheel running leads to an increase in core body temperature. We hypothesized that group housing and running would reduce brown adipose tissue *Elovl3* expression in relation to singly housed mice. Concurrently, we hypothesized that the BAT fatty acid profiles for group housed and running mice would exhibit increased ELOVL3 product, very long chain fatty acids in the C20-C22 range. Eight week old female mice were housed in one of six conditions for 21 days: 1) singly housed at 20°C, 2) group housed at 20°C, 3) housed with a running wheel at 20°C, 3) singly housed at 30°C, 4) group housed at 30°C, or 6) housed with a running wheel at 30°C. There was a main effect of temperature on *Elovl3* expression in brown fat and at 20°C group housing was associated with decreased *Elovl3* expression. However, running did not influence *Elovl3* mRNA at either temperature. In BAT fatty acid profiles, the 20°C conditions were associated with a decrease in 16:1 and an increase in 18:0, 18:2 and 20:4ω6 compared to 30°C. However, there was no significant effect of group housing or running on the fatty acid profiles at either temperature. Taken together, these results suggest that group housing ameliorates the recruitment of brown adipose tissue in prolonged cold exposure but does not influence brown adipose tissue fatty acid composition.

Short-term ecological responses to an intense storm event in the Hopkins Memorial Forest

Jamie Dickhaus

On 29 May 2012 a storm event occurred that affected the forest dynamics of the Hopkins Memorial Forest by both damaging thousands of trees and creating canopy gaps that allowed more light to reach the understory. A pre-storm survey of the Hopkins Forest Permanent Plot system happened to be completed in 2010-2011 so there was data that allowed the analysis of storm impacts. The present study first examines the storm itself from a meteorological perspective, then attempts to examine the disturbance to the canopy, looking at the type of damage and which trees were most affected. Responses of the forest to such an event were examined by analyzing the responses of the herb and shrub layers to storm-altered light. Red oak and red maple trees had the highest frequency of experiencing some kind of damage. However, quaking aspen trees were most affected relative to the number of trees that were present pre-storm, with over 40% of the trees suffering some kind of damage. In general, far more trees were uprooted than suffering other kinds of disturbance. The most storm-affected trees tended to fall in the middle diameter and height ranges, although there are far fewer larger trees and more medium-sized trees in the Forest. In the herb and shrub layers, there were relatively few species that responded either by expansion or by invasion, likely because this study was conducted only one year after the storm event. Even so, there was a significant increase in total vegetation cover with increasing light levels associated with newly created canopy gaps.

Habitat Selection in the Boreal Chorus Frog (*Pseudacris maculata*)

Luke Faust

I have used the ideal free distribution as an explanatory model of habitat choice to analyze the distribution of the boreal chorus frog (*Pseudacris maculata)* tadpoles in an array of pools in Isle Royale National Park. The model seems to explain much of the pool use of these tadpoles, but a few predictions fail. Significant differences between pools in quality were found. These best pools were used more often, with the low-quality pools used only in years of large population size. There were no effects of density within a pool and the best pools were not occupied first. Also tadpoles did not all have the same fitness at a given time, which suggests that there may be despotic effects within the system. These results also suggest that population regulation occurs in part by pool choice on the part of the frogs rather than through crowding of the tadpoles within pools.

Mapping the Relevant Downstream Pathways of the OVLT

Allison Graebner

Correcting physiological water deficit is a critical part of homeostasis and is carried out by osmoreceptors in the hypothalamus. The organum vasculosum of the lamina terminalis (OVLT) is one purported osmoreceptor. Retrograde neural mapping techniques have shown that it projects to various regions of the brain: to other regions of the hypothalamus to orchestrate hormone release and to the following four regions for presently unknown functions – the anterior cingulate cortex (ACC), the centromedial nucleus of the thalamus (CMt), the paraventricular nucleus of the thalamus (PVNt), and the ventrolateral periaqueductal gray (vlPAG). This study used a different type of retrograde tracing technique (RetroBeads™) to investigate the relative strength and anatomic distribution of connections from the OVLT to these four regions. Results confirmed that all four receive first-order connections from the OVLT. Strength of connection was as follows, in decreasing order: PVNt, ACC, CMt, vlPAG. Anatomical distribution of projections from the OVLT were also determined. The anterior region of the OVLT tended to project more strongly to the ACC and the posterior region of the OVLT tended to project more strongly to the vlPAG. The CMt and PVNt received more evenly distributed projections from the OVLT. A more thorough understanding of these projections can eventually allow us to use optogenetic techniques to stimulate OVLT neurons and unravel the circuitry that controls conscious thirst and water-seeking behavior.

Variation in the benefits of ant-tending to the treehopper *Publilia concava*

Eric Hagen

Mutualism is a widespread phenomenon in nature, but the dynamics are still poorly understood both in general and for specific mutualisms. Here I use model selection to look at how variation in levels of ant tending affects the treehopper *Publilia concava* survivorship. *Publilia concava* is an insect in the family Membracidae which feeds on the phloem of tall goldenrod (*Solidago altissima*) and excretes a sugary waste-product called honeydew. Ants collect this honeydew and in turn provide predator defense, feeding facilitation, and other benefits. Results here show that show that the magnitude of net-benefit to treehoppers varies among study site locations as well as temporally within a single season and across seasons. For treehoppers in 2013 the best model explains these differences with shifts in predation type and pressure.

The Type VI Secretion System as a homeostatic mechanism in A. *tumefaciens* biofilm development

Elizabeth Hart

Biofilms are complex microniches that grow on both biotic and abiotic surfaces. While beneficial for the associated bacteria, biofilms are a serious concern in both agriculture and medicine. Agrobacterium tumefaciens, a gram-negative soil bacterium that infects plants through a unique inter-kingdom genetic transfer, causing crown gall tumors on the infected plants. A. tumefaciens forms biofilms on plant roots and surfaces to better infect host cells. The Type VI secretion system (T6SS) has been broadly implicated in biofilm development through past findings in the Banta Laboratory, with T6SS mutants demonstrating elevated biofilm formation. In this study, we seek to uncover the mechanisms by which the T6SS maintains normal levels of biofilm growth in wild-type bacterial strains. We also examine biotic biofilm formation and the unique inter-bacterial competition function of the T6SS that has been observed in many species, including Pseudomonas aeruginosa and Serratia marcescens. Here, we propose that the T6SS functions as a homeostatic mechanism for biofilm growth, and we provide evidence of the highly variable biofilm growth of the T6SS mutant under altered environmental conditions, while wild-type A. tumefaciens biofilm growth holds steady. We demonstrate that high concentrations of bacteria inhibit seedling growth, a common result of plant PAMP-triggered immunity, and that recalcitrant lines of Arabidopsis thaliana show enhanced sensitivity to T6SS-containing bacterial strains. Additionally, we show that A. tumefaciens does not take part in T6SS-mediated intra-species competition. This thesis contributes to the growing base of knowledge regarding the type VI secretion system and its many functions.

Genomic Adaptation and Molecular Acclimation to Light Stress in *Prochlorococcus*

Kathleen Higgins

The marine cyanobacterium Prochlorococcus is the most numerous photosynthetic organism on Earth (Partensky, 1999). In order to thrive in a wide variety of environments it has diverged genetically, structurally, and physiologically, forming distinct populations called "ecotypes." Different ecotypes dominate different depths in the ocean (Johnson et al., 2006), at least partially reflecting adaptations to high and low light stress.

Here, we test the ability of two strains to grow under a range of light levels between 2 and 40 μmol photons m-2 s-1, corresponding to about 85 - 170 m in the oceanic water column (Sigman and Hain, 2012). MIT9312 is representative of the ecotype eMIT9312, which lives throughout the oceanic water column but reaches the highest concentrations between 0 - 120 m (Johnson, 2006). SS120 is representative of eSS120, which is most abundant between 70 – 180 m (Johnson, 2006). Our lab hypothesizes that each strain's optimal light level will fall within the irradiance levels experienced by its ecotype in the open ocean.

We found that SS120 grows faster, reaches higher cell densities, and has a higher photosynthetic efficiency at 2 μmol photons m-2 s-1, while MIT9312 prevails at 10 μmol photons m-2 s-1and above. Between 5 and 8 μmol photons m-2 s-1 the strains should exhibit similar growth rates and photosynthetic efficiencies. This corresponds to a light level where both ecotypes can be found in comparable concentrations (Johnson et al., 2006). Interestingly, MIT9312 consistently showed a greater change between low and high light conditions, which suggests that it cannot acclimate enough to prevent inhibition at these light levels.

We also investigated the genetic and physiological mechanisms that might explain the differences between the two strains. Pigment extractions and spectral deconvolutions suggest that MIT9312 produces more Chlorophyll a at all light levels, while SS120 produces more Chlorophyll b. Comparative genomics studies revealed differences in the alternative electron transport pathways available to different strains, which may affect their ability to live under high light or low nutrient conditions. Members of the large clade of recently differentiated lineages, such as MIT9312, are more likely to contain plasotquinone terminal oxidase (PTOX), while members of the deeply branched lineages, such as SS120, are much more likely to contain PetJ, an electron carrier that may replace plastocyanin under low copper conditions (Bialek, 2008). All strains contain the ndh genes necessary for the formation of a complex involved in cyclic electron transport. Though all of these genes are generally well conserved, the proteins in some strains have differences in mutation rate and isoelectric point that suggest that they are diverging in structure and function.

Characterizing the Role of von Hippel-Lindau in *Helobdella robusta* Embryonic Development

Nina B. Horowitz

Helobdella robusta, a species of freshwater glossiphoniid leech, reliably exhibit the highly unusual presence of two distinct blastocoels during the process of embryonic development. The first appears during the first asymmetrical division but then disappears entirely before reappearing at stage four. The function of these fluid-filled cavities may be to ensure proper positioning of cells during early stages or to prevent or enable signaling between cells located across from or adjacent to each other, respectively.

Here we examine the von Hippel-Lindau protein, which localizes to the blastocoel during its two early appearances and may be mediating its formation in some way. This examination is two-fold: we investigated both the mRNA and the protein itself in order to elucidate the mechanisms that may be enabling its function. The mRNA was analyzed through comparisons of multiple sequences, searches for known localization sequences in the 3'UTR, and creation of models that predicted the secondary structure of the 3'UTR across species. The protein-coding sequence was used to create several phylogenies and the presence of a highly conserved region across species was investigated as well. We also injected embryos with alpha-amanitin and Rhodamine B isothiocyanate-dextran to determine the effects of VHL knockdown on blastocoel formation and the position of the DM cells relative to the blastocoel, respectively.

Identification of discrete, intermingled hypocretin neuron subpopulations

Manasi Iyer

Hypocretins (Hcrts) are neuropeptides exclusively expressed in a population of neurons in the hypothalamus. Hcrt neurons have been shown to play a role in both addiction and arousal behaviors. Recently, it has been hypothesized that there are actually two distinct subpopulations of Hcrt neurons that each project to downstream nuclei that either affect addiction or arousal. However, direct anatomical proof of the existence of these two subpopulations remains elusive. Manasi's thesis directly tested the hypothesis that Hcrt neurons differentially project to either addiction or arousal neurons using injections of fluorescent retrograde tracers in mice. She found that there was no overlap between Hcrt neurons that projected to arousal centers versus Hcrt neurons that projected to addiction centers. Interestingly, she also found that these subpopulations of Hcrt neurons are intermingled and are not biased in the medial/lateral or anterior/posterior direction. This research suggests a mechanism by which Hcrt neurons can influence both addiction- and arousal-related behaviors.

Relative Efficacies of Alternate Day Fasting vs. Caloric Restriction in Reducing Chronic Disease Risk Factors in Obese, Male C57BL-6 Mice

Patrick Joslin

While caloric restriction (CR) is known to increase both longevity and overall health in mice, the effects of alternate day fasting (ADF) remain to be shown. This study tested the relative efficacies of CR and ADF in improving general health and reducing chronic disease risk factors in obese, male C57BL/6 mice. Mice were maintained on either a high-fat (5.2 kcal/g) or chow (3.7 kcal/g) diet beginning at 5 weeks of age, maintained throughout the study. The CR group was pair-fed with the ADF group so that each group consumed the same total average calories. We hypothesized that ADF would decrease body weight, improve glucose tolerance, and lead to higher mean body temperatures and heart rates relative to CR mice. On the final fast day of the study, 42 days from the onset of treatment, ADF mice had significant reductions in weight relative to both CR and high fat (HF)-Ad Lib. mice (9.2±1.3 vs. CR: 4.7±0.5 grams lost). ADF and CR animals consumed significantly less total calories than the Ad Lib. cohort in the study (ADF:427.5±19.3 kcal vs. Ad Lib.:635.5±31.3 kcal). ADF mice fluctuated significantly in body temperature between fast and fed days, oscillating from being the warmest animals during feeding days (37.1±0.1°C), to being the coolest animals during fast days (36.0±0.1°C); this trend in ADF animals is also observed in mean heart rates between fed (515.5±10.4 bpm) and fast (425.3±5.46 bpm) days during the light cycle. ADF mice sacrificed during their final fast day show significant differences in relative plasma concentrations of free fatty acids (FFAs) (0.416±0.111 nmole) and leptin (5547.6±295.6 pg/mL) when compared to the other treatments. Area under the curve analysis of glucose tolerance tests show significant improvements to glucose tolerance for both ADF and CR mice when compared to the HF-Ad Lib. group (CR:5546±284.9 AUC vs. Ad Lib.: 9480±1196 AUC). We observe substantial correlations between body weight and AUC, and body weight and leptin concentration, indicating that increases in body weight increase FFA and leptin concentrations. These results collectively suggest that the ADF regimen causes significant fluctuations in the physiology of the mouse, while reducing chronic-disease risk factors to a degree similarly seen in CR.

Abnormalities in Mauthner axons may cause lateralization of startle response in *Poecilia reticulate*

Kelsey McDermott

When confronted with predator cues, Trinidadian guppies elicit a startle response in the form of a C-start, which is an extremely fast bend of the body and subsequent swimming away from the source of danger. This escape response is facilitated by the Mauthner cells. The Mauthner cells are a pair of large, identifiable neurons in the hindbrains of many fish and amphibians, with axons crossing the midline and projecting the length of the spinal cord. These cells initiate escape responses in these organisms by stimulating the musculature on the side of the body of the activated axon.

Here we describe abnormalities in the Mauthner axons of Trinidadian guppies that to our knowledge have not been witnessed before. On their way down the spinal cord from the hindbrain, some axons project into the IVth ventricle for part of their trajectory, and then return to the brain. They also sometimes branch and lose parts of their myelin. We believe this aberrant morphology may cause a failure in axon potential on the affected axon, thus making the fish less likely to startle on that side. This could lead to individuals within a population that are lateralized in their escape responses. The presence of lateralized organisms within a prey population could enhance the unpredictability of the guppies, increasing their chances of survival in the presence of predators. Therefore, the presence of abnormal Mauthner cells in some guppies has potential implications for survival both on the individual and population level.

Weight based discrimination of *Cornus candadensis* in a generalist pollination network

Molly McEntee

Taxonomic specificity in plant–pollinator relationships can confer an adaptive advantage by ensuring pollen transfer to conspecific flowers. However, generalist pollination networks where multiple taxa provide pollination services are also common in floral communities and the adaptive advantage of generalist systems needs further testing. Here we use studies of the boreal shrub, Cornus canadensis, to test the hypothesis that weight-based discrimination in pollen placement is an adaptation to a taxonomically generalist pollination network. The flowers of C. canadensis open explosively when triggered by insects that weigh over 0.01 g, preferentially placing pollen on large visitors. First, to document visitors to C. canadensis over the entire duration of their bloom we filmed time-lapse video at four different sites for the duration of the bloom period. Our data clearly demonstrate a generalist system that is highly variable among sites. We recorded 33,818 visits from over 50 taxa belonging to six different insect orders. Furthermore, there are significant differences in visitor taxa over the bloom period and between sites even though sites were no more than 333 m apart. Second, we use a full factorial randomized block design of 4 individually caged inflorescences and one uncaged inflorescence (control) to test the effect of pollinator size on female fitness (seed set). We introduced large insects (> 0.01g), small insects (<0.01g), both large and small insects, or no insects, to the 4 cage treatments. Visits by large insects or large and small insects resulted in significantly higher seed set, demonstrating the adaptive value of selecting large insect pollinators. Together these studies show that in this generalist pollination system, weight based discrimination enhances female fitness and allows C. canadensis to draw on local insect populations and utilize a variety of large insect taxa as effective pollinators.

Dopaminergic regulation of sleep and arousal in the Mushroom Body of Drosophila.

Zachary McKenzie

The dopaminergic circuits within the brain regulate a variety of primitive and higher-order functions. Gaining an understanding of how dopaminergic circuits come together and are regulated provides invaluable information into how the nervous system functions and dysfunctions. In the Drosophila brain, the mushroom bodies and the fan-shaped body provide an ideal system to probe dopaminergic circuits and their role in sleep/endogenous arousal as well as exogenous arousal. Proper understanding of these circuits has implications in learning and memory as well as arousal disorders. Their current implication in regulating different aspects of sleep along with past thesis students' results makes these regions interesting targets. By understanding how dopamine regulates arousal and modulates circuits, a better understanding of arousal in general can be obtained. The prevalence of sleep throughout the animal kingdom requires that sleep be better understood. An organism's interpretation of the external world allows for it to respond when arousal circuits are function or have anxiety if arousal circuits are dysfunctional. I hypothesize that the mushroom body will use dopaminergic signaling to regulate sleep patterns in Drosophila. Our results show that restoration of dopamine in specific subsets of the mushroom body shows rescue of daytime activity and daytime sleep whereas global rescue does not show similar rescue of activity or sleep patterns. These results support the model of antagonistic sleep-promoting and inhibiting neurons in the mushroom body regulating sleep and that at least a subset of these neurons are dopaminergic.

The Role of *dfoxo* in Fat Body of *Drosophila*

Stephanie Nguyen

Epilepsy, a common disorder of the brain function that is characterized by periodic and unpredictable occurrences of seizures, affects about one percent of the US population and about 50 million people worldwide. Seizure activity has been associated with type 1 diabetes mellitus through the insulin signal transduction pathway. Drosophila have bang-sensitive mutations, such as slamdance (sda), that are phenotypically similar to seizures in humans, as well as a conserved insulin pathway, providing a genetic model for how insulin signaling might affect seizure sensitivity. One key component of the insulin pathway is dfoxo, which encodes a protine homolgous to the FOXO transcription factor in humans. Because loss of function in dfoxo reduces the sda phenotype, we asked how misexpression of dfoxo in various patterns within the fat body might affect the seizure sensitivity of sda mutants. To explore other functions of the insulin signal transduction pathway, we performed an array of behavioral assays on dfoxo mutants as well as on flies misexpressing dfoxo in the fat body. Viability and starvation resistance were also assed at various points of the life cycle. Together these studies provide deeper understanding of dfoxo functioning in the fat body in relation to behavior and physiology.

Investigating the role of dfoxo in affecting the central nervous system, bang-sensitivity, foraging, and starvation in Drosophila

Rahul Sangar

Current models support an interaction between seizure sensitivity and the insulin pathway. For example, the seizure-like phenotype of Drosophila slamdance (sda) mutants can be rescued by knocking out function of dfoxo or inversely enhanced by misexpressing dfoxo throughout the nervous system. However, it is unknown which neuronal subpopulations misexpressed dfoxo acts in to affect the sda phenotype. dfoxo is also known to affect foraging behavior and the starvation response, but the roles of specific neuronal subpopulations in these processes are poorly understood. Using classical mutations in dfoxo, as well as the GAL4-UAS system to misexpress dfoxo in glutaminergic, dopaminergic or cholinergic neuronal cell populations, we assessed sda seizure sensitivity, foraging behavior, and the response to starving conditions. This study aims to 1) identify whether glutaminergic, dopaminergic or cholinergic neuronal populations can possibly recreate the bang sensitivity enhancement of effect seen with misexpressing dfoxo throughout the nervous system of sda mutants and to 2) clarify the foraging and starvation-associated behavioral consequences of knocking out dfoxo function.

Physiological and Molecular Characterization of Light Acclimation Responses of the Marine Cyanobacterium *Prochlorococcus*

Catherine Pang

Climate change directly affects biogeochemical cycles and open ocean environments. *Prochlorococcus*, an ecologically important marine cyanobacterium, dominates subtropical and tropical oceans, and is found in the water column from the surface to depths of 200 m. As the smallest and most abundant marine cyanobacterium, *Prochlorococcus* contributes to as much as half of global net primary production. Twelve strains are used to represent the various *Prochlorococcus* ecotypes, which exhibit distinctive physiological, molecular, and genomic characteristics. Such differences directly influence the adaptive capabilities of the *Prochlorococcus* ecotypes, and contribute to the ability of *Prochlorococcus* to acclimate to changing environmental conditions. In this study, I specifically investigated the differential responses of two *Prochlorococcus* strains, MED4 and MIT9313, to changing light levels, and the presence of molecular chaperones and small heat shock proteins in the *Prochlorococcus* lineage. Comparative analyses of light acclimation strategies are particularly important due to the abundance of *Prochlorococcus* in the open oceans, their role in global primary production, and the potential effects that climate change may have on the adaptive capabilities of *Prochlorococcus*.

MED4 and MIT9313 had differential physiological responses when grown under medium and high light levels. More specifically, I observed that MED4 has a faster growth rate, higher overall and maximal cell yields, lower Chlorophyll *a* content, and greater photochemical efficiency of Photosystem II than MIT9313 when grown in high irradiance levels. These differences were consistent with the molecular, physiological, and genomic differences previously found between MED4 and MIT9313. In addition, these findings support our hypothesis that *Prochlorococcus* ecotypes have evolved different strategies to acclimate to high light conditions.

Many marine cyanobacteria also contain molecular chaperones and small heat shock proteins that aid in protecting the cell from protein misfolding and protein aggregation under environmental stress. Hsp33, a redox-regulated chaperone, acts as a molecular chaperone "holdase" that holds the misfolded protein in place before other chaperone "foldases," such as GroEL and DnaK, acts to fold the misfolded protein back into a functional state. On the other hand, Hsp17 is a small heat-shock protein found in distantly related *Synechocystis* PCC6803 that functions to maintain membrane stability under conditions of heat stress. Through using bioinformatics and genomic databases and tools, I characterized the Hsp33 protein in the majority of *Prochlorococcus* strains and confirmed the absence of Hsp17 in all *Prochlorococcus* strains. In addition, the chromosomal organization and protein sequences of Hsp33 are highly conserved among *Prochlorococcus* strains, with the exception of strains MIT9313 and MIT9303, from which Hsp33 is absent. The absence of Hsp33 in MIT9313 and MIT9303 and the lack of Hsp17 in all *Prochlorococcus* strains suggest differential capabilities of *Prochlorococcus* strains to adapt to a variety of environmental stresses.

More information about the ability of *Prochlorococcus* to acclimate to changes in light stress at the molecular and biochemical levels can be determined through gene expression analyses of genes encoding photosynthetic apparatus proteins and molecular chaperones under varying light levels. Findings from such experiments may provide a better understanding of how *Prochlorococcus* can adapt to climate change and continue to contribute effectively to global primary production.

Hspb7 **Localization in Kupffer's Vesicle in developing Zebrafish**

John Sanderson

Morpholino (MO) knockdown of the small heat shock protein *hspb7* causes laterality defects in developing zebrafish embryos. On an organismal level, *hspb7* knockdown causes aberrant cardiac formation and migration: specifically, embryos injected with *hspb7* MO display both rightward-jogging hearts and cardia bifida (Lahvic et al., 2013). The specific mechanism of this aberrant development is tied to disruptions of the structure and function of Kupffer's Vesicle (KV), a transient organ that begins developing at the 1000-cell stage (3hpf) and disappears by the 10-somite stage (14hpf). In KV, motile cilia generate a unidirectional fluid flow that triggers downstream expression of side-specific genes in the lateral plate mesoderm. MO knockdown of *hspb7* decreases the volume and directionality of this unidirectional flow (Lahvic et al., 2013) and disrupts proper ciliogenesis in KV, as indicated by the loss of the central microtubule pair (Lahvic et al., 2013) and a decrease in length of KV cilia (Rosenfeld et al., 2013). Despite these effects, the exact function of *hspb7* is not known.

Based on its ability to associate with Filamin A (FlnA), a structural protein, we attempted to rescue *hspb7* function by injecting FlnA mRNA at the 1-2 cell stage, leading to gene overexpression. The native translation machinery failed at translating the injected FlnA mRNA, so we turned our attention to the subcellular localization of *hspb7* in the area around KV. Using a Sigma-Aldrich anti-*hspb7* antibody, we successfully stained *hspb7* around KV. Examination of *hspb7* localization patterns led us to two conclusions. First, between the bud stage (10hpf) and the 10-somite stage (14hpf), *hspb7* localization in KV decreases significantly, but remains in large deposits outside of KV. Second, unlike previous research in human cell lines that concluded that *hspb7* is a nuclear speckle protein (Vos et al., 2009), we found *hspb7* to be located outside of cell nuclei, supporting the possibility that it may function as a structural protein involved in ciliogenesis. These novel discoveries should help direct future research on the function of *hspb7*.

Host defenses modulate expression of *A. tumefaciens* Type VI secretion system needed for full virulence

Melinda B. Wang

Like a variety of mammalian pathogens, *A. tumefaciens* possesses a functional Type VI Secretion System (T6SS) that has been implicated in virulence. T6SS proteins are encoded on the 14-gene imp operon and the divergently transcribed hcp operon. We have obtained evidence that the *Agrobacterium* T6SS both triggers and dampens host defense responses. A key determinant of infection success for *A. tumefaciens* is the pathogen-associated molecular pattern EF-Tu, which upon perception by the host receptor Efr, triggers innate defenses. We have proposed that defenses elicited by EF-Tu, common to both WT and T6SS-deletion mutant bacteria, mask T6SS-triggered defenses in WT plants, but that in an *efr-* mutant plant, the absence of a functional EF-Tu receptor allows for the T6SS-elicited responses to become apparent. To further characterize T6SS-modulated defenses, we explored their relationship to ethylene- and salicylic acid (SA)-dependent defense pathways. We hypothesize that if the T6SS increases *A. tumefaciens* virulence as an effector, it might affect the ethylene and salicylic acid hormonal pathways crucial to global plant immunity, and might alter circadian or light-regulated defenses. Our data indicate that under some conditions the bacterial T6SS attenuates negative regulators of host defense pathways. Unlike many canonical pathways of host defense, T6SS-triggered responses are SA-independent and light-, rather than circadian-, regulated. Intriguingly, we also found that T6SS gene expression is itself modulated by hormonal-dependent defenses. Together, these results reveal a sophisticated regulatory interplay between host defense status and the bacterial T6SS.

Expression of small heat shock protein *hspb7* in the zebrafish heart is essential to valvulogenesis

Kaijie Zheng

Regulation of zebrafish cardiogenesis involves the interplay of a complex network of genetic pathways and various epigenetic factors. Small heat shock protein (sHsp) *hspb7* is essential for proper cardiac development in zebrafish. *hspb7* is expressed in the heart, yolk syncytial layer (YSL), and Kupffer's vesicle. Proper expression of *hspb7* has been shown to be important for establishment of left-right heart asymmetry, development of the ventricle, and formation of atrioventricular valve leaflets. Morpholino knockdown of *hspb7* leads to cardiac migration defects, aberrant ventricular morphology, and hyperplastic valve leaflets. However, whether valve formation is dependent upon *hspb7* expression in the YSL remains unknown. Previous results suggested that valve formation may be partially dependent on *hspb7* expression in the YSL, but they were inconclusive due to unavailability of the proper antibodies and transgenic fish line. Here we show that *hspb7* expression in the YSL is not necessary for proper valve development. We found that targeted knockdown of *hspb7* in the YSL did not result in structural changes of the valve leaflets. In contrast, global knockdown of *hspb7* at the 1-cell stage recapitulated the hyperplastic valves seen before. Our results show that valve development is dependent only on the expression of *hspb7* in the heart, likely the myocardium. This finding allows further experimentation to investigate how knockdown of *hspb7* in the heart results in valvular overgrowth.

Chemistry

Carbon Mitigation Potential of Solar Ovens in Nicaragua

Gordon Bauer

Solar ovens hold the potential to mitigate climate change while reducing deforestation and respiratory illness in the developing world by providing a sustainable source of cooking energy. The carbon credit market offers a possible avenue for funding solar ovens on a large scale, but this will require the development of a rigorous yet simple method for quantifying the carbon mitigation potential of solar oven distribution projects. For this thesis project I traveled to Condega, Nicaragua, from June to August 2013, to study the carbon

mitigation potential of solar ovens previously distributed there. Through cooking surveys and temperature dataloggers I explored the nature of solar oven usage, and through measurements of cookstove emissions, fuelwood consumption, and solar irradiance I studied the connection between solar oven usage and greenhouse gas emissions reductions. I found solar oven usage on 40.1% of days surveyed, and oven temperature elevation on 36.0% of days with temperature records. However, largely due to the nature of the cooking tasks commonly performed in the solar ovens, I did not find any significant wood savings connected to this usage. I used considerations of the nature and duration of solar oven usage to predict a carbon mitigation savings of approximately 0.2 tons of CO2/year per solar oven, approximately one order of magnitude too low for full funding through the carbon credit market.

Polymeric Carriers for Small Molecule Antioxidant Delivery

Todd A. Brenner

Reactive oxygen species (ROS) are mediators of a variety of disease states, causing damage to macromolecules and acting as signaling ligands in pro-inflammatory and proliferative pathways. Human cells have evolved defenses that quench or scavenge ROS, and the literature has turned to these antioxidants, especially polyphenols antioixdants, for putative therapeutics. This work uses gallic acid (GA) as a model for the development of antioxidant-polymer conjugates and presents two strategies towards the synthesis of GA-polymer conjugates via post-polymerization and pre-polymerization methods. Both approaches yield water-soluble conjugates when copolymerized with N,N-dimethylacrylamide (DMA).

To establish the features of a GA-polymer conjugate, the post-polymerization GA-p(Gly-HEMA)0.5-co-DMA0.5 product was characterized using both in vitro and in vivo methods. Folin-Ciocalteu and radical-scavenging assays showed that the GA-p(Gly-HEMA)0.5-co-DMA0.5 conjugate delivers a 20.7 wt% antioxidant load and that the GA moieties retained their antioxidant properties after coupling to the polymer. In vivo studies in RAW264.7 murine macrophages revealed that the GA-conjugate is non-toxic up to 30 μM and that p(Gly-HEMA)-co-DMA-based polymers associated with RAW cells at 1 h. Finally, intracellular staining of the pro-inflammatory cytokine TNF-α showed that cells dosed with GA-p(Gly-HEMA)0.5-co-DMA0.5 are resistant to pro-inflammatory lipopolysaccharide stimulation. These preliminary tests demonstrate the potential value of GA-polymer conjugates in the development of polymeric therapies and delivery systems.

Towards The Synthesis of Enigmazole A: Efforts Towards a C1–C12 Fragment

Craig Burt

Enigmazole is a phosphorylated 18-membered macrolide natural product first isolated from the sponge Cinachyrella Enigmatica. The molecule exhibits potent cytotoxic activity, although its cellular mechanism of action remains unclear. Enigmazole's biological activity and unique architecture have both drawn significant interest as a synthetic target. This unique architecture also includes a 2,4-substituted oxazole moiety as well as eight stereocenters. The original plan for the synthesis of enigmazole envisioned the use of Evans β-ketoimide aldol chemistry to generate asymmetry in the C1–C4 dipropionate unit efficiently. However, this approach failed due to the inability to remove the superfluous C3 hydroxyl, and was redesigned to establish the configuration at the C2-position through a Myers alkylation. Herein we report on continued efforts to generate the C1–C12 fragment of enigmazole A using this synthetic approach. In particular, we focus on the generation of the C7–C11 pyran system and attempted selective conjugate reduction of the enone.

Synthesis and Characterization of Phenylenevinylene Oligomers and Functionalized Aromatic Systems

Peter L. Clement

Our group has synthesized a library of phenylenevinylene oligomers and functionalized anthracenes, perylenes, and pyrenes. While functionalization in previous work was centered on the incorporation of electron-withdrawing moieties (Br, CN, CHO, BMes2) to conjugated systems, this year's work incorporates

electron-donating moieties, in the form of diphenylamine groups, into conjugated systems. Diphenylamine functionalized anthracene, perylene and pyrene were all synthesized. Additionally, the characterization of the library of compounds synthesized was expanded from UV/Vis and fluorescence spectroscopies to include characterization by cyclic voltammetry (CV). Using a combination of UV/Vis and CV, electron-withdrawing groups were shown to primarily decrease the energy of the LUMO energy while electron-donating groups were shown to primarily increase the energy of the HOMO energy.

Activation of σU and the Putative Role of PrsU in *Streptomyces coelicolor*

Jessica Monterrosa Mena

Streptomyces coelicolor is a model species of gram positive-soil dwelling bacteria, with a complex life cycle and multicellular differentiation. This study focused on the role of stress response sigma factor σU, in the life cycle of Streptomyces coelicolor. Disruption of the gene encoding RsuA, a protein believed to be a negative regulator of the sigma factor of σU, inhibits development and antibiotic production in S. coelicolor. Due to homology between the B. subtilis σW regulon and σU, and observations about acidic environmental stressors activating σU, the PrsU protein is hypothesized to be part of the SigU system. Prsu is hypothesized to be involved in detecting acid or comparable environmental stressors and respond by degrading RsuA, thereby activating σU to participate in gene transcription. To investigate whether PrsU is involved in regulating the σU system, we used mutant strains to determine how mutations of the SigU system affect antibiotic synthesis, strain sensitivity to acid, and σU activation by acid stressors.

In this study we found differences in acid sensitivity and antibiotic production between sigU, rsuA, and prsU mutants. In antibiotic assays, Bld, sigU-rsuA and prsU mutants demonstrated different secretion of undecylprodigiosin and actinorhodin antibiotics compared to the WT strain. In acid sensitivity assays, sigU-rsuA and prsU mutants showed increased sensitivity to a variety of organic acids including acetic acid and oxalic acid, but diminished sensitivity to citric acid as compared to the WT. Finally, luciferase reporter assays suggested that σU activity in WT strains can be induced by acid, but results are inclusive due to methodological problems with control strains. The results of this study support the hypothesis that PrsU is involved in activation of the SigU system, but suggests that complicated mechanisms are at work in σU activation.

The Atom Transfer Radical Polymerization of Acrylated Methyl Oleate

Lilliana Morris

Plant-based feedstocks offer a wide range of substrates. Previous work has shown acrylated methyl oleate as a promising material for pressure sensitive adhesive applications. However, there has been no exploration of solution or controlled polymerization of acrylated methyl oleate. Therefore, this thesis explored the plausibility of polymerizing of acrylated methyl oleate in solution. Previously published protocols were followed to yield methyl oleate epoxide in 97% yield. While problems with the acrylation of methyl oleate epoxide were encountered when acrylic acid underwent polymerization, complete exclusion of formic acid from the system prevents this side reaction from occurring. The synthesis was further optimized by varying work up procedure, reagent ratios, and temperature until acrylated methyl oleate was successfully synthesized in 92% yield at a 10 g scale. Free radical polymerization yielded poly(acrylated methyl oleate) with degree of polymerization up to 19 and 27 for toluene and anisole, respectively. While ATRP of acrylated methyl oleate occurred, it was plagued by low molecular weights and degree of polymerization was limited to 15 even after variation of solvent, reaction ratios, or reaction temperature. Block copolymers of poly(acrylated methyl oleate) and polystyrene were successfully synthesized.

Synthesis of Amino Acid Containing Block Copolymers by ATRP

Julia H. Nguyen

Homopolymers of the amino acid based monomers Boc-L-alanine methacryloyloxyethyl ester (Boc-Ala-HEMA), Boc-Ile-HEMA, Boc-Phe-HEMA, Boc-Pro-HEMA, and Boc-Val-HEMA were synthesized by traditional free radical polymerization. The monomers, homopolymers, and deprotected homopolymers were

characterized by specific rotation measurements and circular dichroism spectroscopy. These analyses provided evidence of the formation of secondary structure for the Phe and Val homopolymers. Block copolymers were also synthesized for each of these monomers using methyl methacrylate (MMA) as the comonomer by atom transfer radical polymerization. Block copolymers with low ratios of amino acid monomer to MMA monomer (0.14-0.53) were found to be insoluble in water, while block copolymers with higher ratios of amino acid monomer to MMA monomer (1-1.8) were found to soluble in water. Of these water soluble block copolymers, the Val block copolymer exhibited a critical pH of 7.2 while the Phe block copolymer exhibited a critical pH of 5.9. The Val block copolymer, Phe block copolymer and Pro block copolymer all exhibited temperature responsiveness, with LCST values of 75, 81, and 78˚C, respectively. UV-vis provided evidence of micelle formation due to the presence of critical micelle concentrations, with the Val block copolymer and the Phe block copolymer having CMC values of 0.54 and 0.45 mg/mL, respectively. Self assembly and stimuli responsiveness make these polymers attractive candidates for drug delivery vehicles.

SCO6672 in *Streptomyces coelicolor* A3(2): Defining Its Role as a Carrier Protein Phosphodiesterase in Antibiotic Production

Georgiana Salant

In Streptomyces coelicolor A3(2), the biosynthesis of one of its naturally occurring antibiotics, calcium-dependent antibiotic (CDA), occurs on a large enzymatic complex called a nonribosomal peptide synthetase (NRPS). In order for CDA biosynthesis to occur, the peptidyl carrier domain of the NRPS responsible for producing CDA must undergo a posttranslational modification: the addition of a 4'-phosphopantetheine (Ppant) group from coenzyme A catalyzed by a phosphopantatheinyl transferase (PPTase), SCO6673. Previous studies identified a phosphodiesterase, SCO6672, which can cleave the Ppant group from CDA peptide synthetase peptidyl carrier protein substrates. SCO6672 also demonstrates in vitro phosphodiesterase activity towards the general phoshphodiesterase synthetic substrate bis-pNPP.

In this study, the in vitro phosphodiesterase activity of SCO6672 was further characterized by site-directed mutagenesis of putative manganese binding residues (D16, H18) resulting in a loss of enzymatic function towards hydrolysis of bis-pNPP. In addition, Zn2+ could strongly inhibit the SCO6672-catalyzed reaction of bis-pNPP hydrolysis with an IC50 of approximately 15 μM. However, when trying to determine if zinc's mode of inhibition was competitive, non-competitive, or mixed, the data showed inconclusive results.

The in vivo biological function of SCO6672 was assessed by assaying the amount of CDA produced by SCO6672 deletion mutants compared to wild-type (WT). It is possible that these mutants could affect CDA biosynthesis in the organism as SCO6672 is implicated in the CDA biosynthetic pathway with its ability to cleave the Ppant group from CDA peptide synthetase peptidyl carrier protein substrates. A standard CDA assay demonstrated that three deletion mutant candidates produced what qualitatively seemed to be the same amount of CDA as WT, indicating that SCO6672 does not seem to be essential for CDA biosynthesis. Whether SCO6672 deletion mutants quantitatively alter CDA production in the organism has yet to be determined.

Electron Spin Resonance (ESR) Dating and Homo sapiens Evolution:Evolutionary Significance of >200,000 Year Old Homo sapiens Teeth Found in Tanzania

Kassandra Spiller

In 2006 several Homo sapiens teeth were found in the Magubike rockshelter, Iringa region, Tanzania, with hundreds of flaked stone tools. Also in the site were other mammalian teeth and numerous samples of the land snail Achatina sp. Both materials are in principle suitable for electron spin resonance (ESR) dating, although Achatina has not been fully tested for this purpose. ESR dating measures the accumulation of radiation-induced damage and can date materials as young as 30 ka and as old as several million years with a precision of 10-15%. In the summer of 2013, additional shells and teeth were collected from the MSA levels. The teeth ages show good stratigraphic consistency, with those 50-60 cm below the surface dating to around

100 ka, and those from depths conforming to the H. sapiens finds dating around 200 ka. The ages of the Achatina shells were much less promising, but the tooth ages suggest strongly that the Iringa specimens are among the oldest known examples of Homo sapiens.

Polymeric Micelles with Varying Hydrophobic Blocks for Delivery of Therapeutics

Bianca A. Ulloa

Drug delivery of hydrophobic therapeutics is limited by their insolubility in aqueous media. Micelles formed from self-assembling amphiphilic block copolymers provide a means by which to enhance the solubility and the transport of these drugs within the body. In an effort to optimize micelle stability and drug loading efficiency, block copolymers were created by copolymerizing the hydrophilic monomer, poly(ethylene glycol) methyl ether methacrylate (PEGMA), with the hydrodophobic monomer of methyl methacrylate, styrene, or tert-butyl acrylate. These particular hydrophobic blocks were chosen because of their varying identity and different glass transition temperatures. Thus, our long-term objective for this study is to analyze micelle composition, stability, and drug loading efficiency in relation to different hydrophobic segments of varying block lengths.

The homopolymerization of these monomers demonstrated to have a good level of control via atom-transfer radical polymerization (ATRP). The diblocks copolymers with PEGMA exhibited a range of critical micelle concentrations (CMCs) from 0.40 to 2.85 mg/mL, where a larger hydrophilic to hydrophobic ratio correlated with an increase in CMC values. By transmission electron microscopy (TEM), the block copolymers were shown to be mainly spherical in shape and between 100 to 200 nm in diameter, although some aggregates were present. Glass transition temperatures (Tg), measured by differential scanning calorimetry, did not depend on either the hydrophilic to hydrophobic ratio or the actual size of the copolymer. Further research into drug-loading studies may lead to a conclusive determination of whether modifying hydrophobic block identity and Tg optimizes micelle stability and drug-loading efficiency.

Developing Novel Non-heme Iron Catalytic Systems Using Amino Acid and Ester Derived Ligands for Olefin Epoxidation

Areli Valencia

Non-heme iron catalysts are effective olefin epoxidation catalysts and addition of acetic acid has been shown to enhance epoxide selectivity and yield through previous work by the Que, Jacobsen, and White group. This thesis aimed at incorporating this acid additive into non-heme catalytic systems by synthesizing a series of ligands derived from amino ester and amino acids. It was hypothesized that amino acid derived catalysts would be more effective compared to their amino ester catalyst counterparts. The ester derived ligands were successfully synthesized. Isolated yields varied from 58-87%. Results from in situ epoxidations of octene, decene, cyclooctene using the amino ester based catalysts showed no oxidation activity, which was consistent with our hypothesis. Furthermore, zinc complexes were synthesized to probe whether ester derived ligands coordinated to the metal. Preliminary work has shown that the acid derived ligand could be obtained through the hydrolysis of the ester counterpart, but only the anionic species was isolated. Future work needs to be conducted to isolate the neutral species for the acid derived ligands.

Development of Biochemical and Chemical Systems for Novel Antibiotic Discovery

Chau Vo

The urgent need for new antibiotics has pointed to the investigation of new targets for antibacterial action. Histidine kinases—mediators of two-component signaling path- ways—are a promising target. We are interested in regulating CckA, an essential histi- dine kinase in Caulobacter crescentus that is essential for normal cell division. CckA provides an ideal platform for studying pharmacological inhibition of histidine kinases.

The catalytic and ATP-binding domain of histidine kinases is conserved with the ATP-binding domain of Hsp90, an ATP-dependent chaperone in mammalian cells against which many inhibitors have been devel-

oped as an anticancer therapy. The lab successfully demonstrated CckA inhibition effects of CCT 018159, a 3,4-diarylpyrazole Hsp90 inhibitor. To derivatize this chemical scaffold with hopes of improving inhibitor potency, I synthesized a small library of six 3,4-diarylpyrazoles. I tested these molecules for inhibitory potency against CckA using an ATP-coupled assay, the results of which have revealed initial structure-activity relationships. My work has prepared the lab to move forward with diversification of the compound library and screening for inhibitory effects, further realizing our ultimate goal of verifying histidine kinase inhibition as a po- tential new mode of antibiotic action.

Synthesis and Modeling of Diaryl Pyrazole and Diaryl Isoxazole Compounds for CckA and PhoQ Inhibition

Anna Zhou

The need for new antibiotics cannot be understated. Resistance is quickly developing to current antibiotic modes of action. Perhaps the best way to develop new antibiotics is to develop drugs that target new mechanisms controlling bacterial growth and survival. We reason that inhibiting Histidine kinases (HKs), a class of enzymes in cellular signaling, is sufficient enough to kill off bacteria, as HKs control cellular growth and response to environmental stimuli. Molecules that inhibit HKs have been developed and we have found a potential class of molecules that inhibit HKs in vitro, but deeper understanding about how these molecules bind to the HKs is still elusive.

To test the viability of HK-mediated signaling pathways as antibacterial targets, we must find a lead molecule and build a molecular library. Two potential inhibitors of CckA, an essential HK in Caulobacter crescentus that mediates the Caulobacter cell cycle, have been discovered in our lab. These molecules share a common chemical scaffold and our molecular library will be based on this scaffold. Herein, we report building derivative molecules using a three-step synthetic scheme.

To further understand how these molecules interact with HKs, we modeled PhoQ, a structurally similar HK from Salmonella, in Molecular Dynamics (MD) simulations. The simulations allow us to understand distinct hydrogen bonding and energetic of these protein-ligand interactions and potentially make predictions about important structural features and key amino acid residues in the binding pocket. Hence, we also report the energy of interactions obtained from these simulations.

Computer Science

Decoupling and Coalescing Race Checks

Parker S. Finch

Much of our computing infrastructure utilizes multicore processors and multiprocessor hardware. Such systems can concurrently execute many software threads of control to improve responsiveness and performance, but the potential for unintentional interference between concurrent threads makes it difficult to ensure the reliability of multithreaded software. Automated tools to identify concurrency errors have the potential to make this task easier.

Perhaps the most fundamental concurrency error is a race condition. A race condition consists of two threads accessing (and at least one modifying) the same piece of data at the same time. While dynamic data race detection algorithms have improved in recent years, the overhead of race detection in array-intensive programs remains prohibitive. One promising insight is that arrays are often accessed via common patterns that enable compression of the information maintained by a dynamic race detector, as well as a reduction in the number of checks performed. However, a purely dynamic implementation of this compression technique failed to realize a corresponding decrease in run-time overhead due to the cost of inferring those

access patterns at run time. We explore statically annotating programs with the array access patterns that appear at run time to eliminate the need to infer them. Our results show that this can effectively reduce the run-time overhead of race detection on programs with identifiable array access patterns.

Multi-Class Feature Selection

Joshua E. Geller

Feature selection involves identifying an "optimal" set of features in order to make a classification task more efficient or effective. There are three major approaches to feature selection in the context of classifier learning. One of these - the wrapper method - is a general class of algorithms that can be applied to any underlying classifier, but the choice of the classifier learner impacts the features selected. An interesting issue arises when the goal is multi-class classification but the underlying classifier learner is fundamentally designed for two-class problems, as is the case for support vector machines (SVMs). These types of classifiers handle multi-class tasks with an ensemble of binary classifiers. Current multi-class feature selection approaches operate on the black box level, using one uniform feature set for all underlying binary classifiers. I propose a framework for multi-class feature selection wrapper methods that includes the black box approach, but also introduces two additional multi-class feature selection approaches: the composite individual and the composite summed. I investigate a number of properties of this three-fold framework as well as multi-class feature selection in general.

Building Sum-Product Networks

Daniel T. Seita

Probabilistic inference is the process of determining the probability of an event given some evidence. While techniques based on probabilistic graphical models have been used in practical settings, exact inference can still be intractable. Sum-Product Networks (SPNs) were recently invented to address this deficiency. SPNs are trees formed from sum and product nodes, and they can model a probability distribution while allowing inference to be done in time linear in the number of edges. In this thesis, we give an introduction to SPNs and investigate different procedures to construct them given observed data. Specifically, we modify a current implementation of SPN learning in two ways. In the first, we incorporate the Independent Variable Grouping Analysis (IVGA) method for grouping variables based on dependency relationships. In the second, we use Density-Based Spatial Clustering of Applications with Noise (DBSCAN) to cluster similar instances. We analyze the performance of the SPN learning algorithm with these modifications and compare it to the original implementation that uses pairwise comparisons and Expectation-Maximization (EM) for variable grouping and instance clustering, respectively. We find that for grouping variables, IVGA appears to be worse than pairwise comparisons, but that for clustering instances, DBSCAN is a viable alternative to EM, and may even result in SPNs that can better tolerate noise in data.

Geosciences

The Eruptive History of Strawberry Crater, San Francisco Volcanic Field, Northern Arizona

Eloise C. Andry

Strawberry Crater is a ~50 ka cinder cone located in the eastern portion of the intra-plate, monogenetic San Francisco Volcanic Field north of Flagstaff, Arizona. This volcanic field contains over 600 scoria cones and stratovolcanoes that range in age from 6 Ma to ~900 ybp. Scoria cone formation is usually modeled as an explosive cone-building phase followed by a lava flow and occasional breaching of the cone. Strawberry Crater deviates from this model with a complex eruption history reflecting changes in vent conditions.

Facies analysis of the cone and lava flows shows three lava flows, each with an associated breaching and rafting event, directed rootless flow and agglutinate deposition on the rim, and rootless flows that acted as slip-surfaces for fallen blocks inside the crater. The eruption began with a scoria-producing Strombolian

eruption that was followed by eruption of a lava flow that breached the eastern section of the cone. Vertical eruptions continued, but the height of the eruptive column decreased and overall, Hawaiian-style eruptions became predominant, depositing rootless flow and agglutinate on the inside and outside of the crater. A second lava flow breached the cone, emplacing rafted blocks against the first lava flow. Unstable blocks of agglutinate and rootless flow slipped from the rim, creating unconformities with younger deposits. The vent became directional, causing thick agglutinate layers to be deposited on the northwestern section of the crater. A final lava flow breached the cone, again rafting out blocks and forming a dam against the second flow. This forced the lava to flow to the east and south of previous flows, weakening the southern portion of the crater. This breaching caused the unstable agglutinate to slip in large blocks from the rim, leaving slickensides along the interior rootless flows. A landslide to the west removed a portion of the southern crater rim, leaving a pronounced topographic saddle.

Geochemical analysis correlated with the eruptive history shows that the eruption became increasingly more silicic as it progressed. This was likely caused by magma mixing of a mantle-derived basaltic melt and melted continental crust, according to the model of Bloomfield and Arculus (1989). Disequilibrium from the magma mixing produced zoned pyroxenes and sieve-textured plagioclase.

The eruptive history of Strawberry Crater demonstrates that cinder cone formation can be a highly complex process, consisting of multiple eruptive styles with various depositional products, small scale landslides, and changing vent conditions. Unique to Strawberry Crater is that evidence for these events has been preserved, primarily due to the prominence of resistant rootless flow and agglutinate layers.

A Radiocarabon Reconstruction of the Deglacial Bering Sea

Paul De Konkoly Thege

Ocean and atmospheric circulation modulates global and regional climate by distributing heat poleward. 25% of this heat is associated with deep ocean circulation, which transports twice as much heat as the Gulf Stream in the modern North Atlantic (Talley, 2003). Deglacial deep ocean circulation history is relatively well-understood for the North Atlantic but remains uncertain for the North Pacific. It has been proposed that circulation in these two basins was "antiphase" (Ahagon et al., 2003) wherein deep water might form in the North Pacific during a shutdown of AMOC (Okazaki et al., 2010). The Bering Sea is a site where deep water may have formed in the past (Ohkushi et al., 2003). To test these hypotheses, I reconstructed ocean circulation in the Bering Sea from the Last Glacial Maximum to the Early Holocene using radiocarbon analysis of benthic-planktonic foraminiferal pairs from ocean sediments in HLY02-02-51JPC (1467 m water depth). My record is based on a radiocarbon-independent age model constructed using tephrochronology and stable isotope geochemistry that allows for reconstruction of the offset between the radiocarbon age of the atmosphere and the ocean surface through time (ΔR). Deglacial ventilation is strongest during H1. Water at 1500 m appears younger than the surface ocean, which is a potential signal for convection that began elsewhere in the North Pacific. Apparent ventilation decreases by the Oldest Dryas while ΔR reaches a deglacial minimum, implying minimal export of surface water to greater depths. ΔR and apparent ventilation age reach a deglacial maximum during the Younger Dryas, most likely due to some combination of sea ice growth (Caissie et al., 2010) and a coeval decline in atmospheric radiocarbon (Reimer et al., 2013). By the Early Holocene, the apparent age of water at ~1500 m is equal to modern water from the same depth in the Bering Sea (McCorkle, 2002). These results suggest that deglacial Bering Sea circulation was not antiphase with the North Atlantic.

A Paleoclimate Reconstruction of Lake Linné: Interpreting the Influence of Sediment Sources Through Time

Johanna S. Eidmann

As part of a Keck project I travelled to Lake Linné, a proglacial lake located in Svalbard, in an effort to improve the understanding of climatic changes in the Linné Valley throughout the Late Holocene. To pro-

duce a longer climate reconstruction than previous studies from the southern basin of the lake, I analyzed sediment core JE3 from the distal northern basin of the lake, where I expected sedimentation rates to be lower. The age model from visually counting sediment laminations does not match the results of plutonium analyses, suggesting that JE3 does not contain annual varves and can therefore not be used to produce an independent age model. High-resolution XRF analysis, however, enables the correlation between JE3 and well-dated cores from previous studies. Using the age model of a core located at Site H (LH-Long), JE3 is estimated to span approximately 1,600 years. Through SEM analyses, I distinguished the elemental signatures of laminae found in the core, and compared the SEM analyses to the XRF analyses to conclude that the tan and pink laminae found in the cores throughout the lake are associated with mass depositional events from the eastern carbonate formations. Therefore carbonate-rich laminae should be taken out of future varve analyses and age models. The same pattern in calcium and manganese abundance is found in multiple cores across the lake, suggesting that this mechanism affects both the southern and northern basins. The increased frequency of calcium peaks, change in the calcium-manganese ratio, and change in stratigraphy within a 100-year time period may be due to a climatological shift at this time. I propose that a shift in the NAO between 13000 and 1400 AD may have caused an increase in precipitation and/or a rapid glacial advance that led to more erosion from the eastern carbonate formations in the Linné Valley.

The Sedimentology of Storm-Emplaced Coastal Boulder Deposits in the Northeastern Atlantic Region

Kalle L. Jahn

Northeastern Atlantic coasts exposed to the open ocean have coastal boulder ridges formed and modified by storm waves, providing an opportunity to examine the sedimentology of these understudied deposits. This study documents the morphology and sedimentology of boulder ridges through surveying and systematic grain size measurements. A number of interesting conclusions were reached: some intuitively obvious, others surprising. It makes sense that ridge size and largest clast sizes tend to decrease as ridge height above high water increases. It is surprising then, that there is a significant trend showing larger ridges and clast sizes correlated with distances further inland. Noise in the data inhibits prediction of ridge morphology and sedimentology, but a low coastal slope appears to be a criterion for the transport of large boulders far inland. A mass-based analysis was performed in addition to direct measurements of transect population statistics, because most grain size analyses are performed with mass-based sieving. When a large proportion of the population's total mass is located in a few large clasts, mass-based population statistics deviate strongly from statistics calculated directly from clast measurements. Mass-based statistics are therefore not a good proxy for direct measurements of boulder ridge clast populations, which tend to contain several outsized clasts. The literature lacks other systematized studies of ridge sedimentology, so the ridges of this study are compared to the most analogous deposits: boulder beaches. The rarity of fine-tailed grain size distributions among boulder ridges distinguishes them from boulder beaches, which tend to be fine-tailed. The morphology and sedimentology of boulder ridges are inherently variable, but this study represents a first step in expanding our understanding of these deposits.

Sulfate Reduction at Deep Springs Lake, California: Applicability to the "Dolomite Problem"?

Michelle Paradis

Dolomite is an abundant sedimentary rock found throughout much of geologic history, yet there are few environments where it forms today. This discrepancy, often known as the dolomite problem, is poorly understood and has long plagued carbonate sedimentologists seeking to understand carbonate depositional systems. Deep Springs Lake, California is one of the few places where dolomite is actively forming; thus, a better understanding of how dolomite forms here may provide insight into the dolomite problem.

One mechanism linked to dolomite formation in modern systems is microbial sulfate reduction, which may promote dolomite formation by concentrating the requisite ions. Geochemical proxies for sulfate reduction

include decreasing sulfate concentration with depth and increasing δ34S with depth. At Deep Springs Lake, these two parameters were measured in both spring water and porewater to determine whether sulfate reduction was occurring at the time of sample collection. They were also measured in sediment from the lake basin to determine long-term trends in sulfate reduction.

Data provide equivocal evidence for sulfate reduction in at least one location within the lakebed, but it is insufficient in magnitude to affect dolomite precipitation on a large scale. Therefore, more work is needed to determine the causes of dolomite formation at Deep Springs Lake.

Mathematics and Statistics

Explicit Forms For and Some Functional Analysis Behind a Family of Multidimensional Continued Fractions -- Triangle Partition Maps -- and Their Associated Transfer Operators

Ilya D. Amburg

The family of 216 multidimensional continued fractions known as known as triangle partition maps (TRIP maps for short) has been used in attempts to solve the Hermite problem [3], and is hence important in its own right. This thesis focuses on the functional analysis behind TRIP maps. We begin by finding the explicit form of all 216 TRIP maps and the corresponding inverses. We proceed to construct recurrence relations for certain classes of these maps; afterward, we present two ways of visualizing the action of each of the 216 maps. We then consider transfer operators naturally arising from each of the TRIP maps, find their explicit form, and present eigenfunctions of eigenvalue 1 for select transfer operators. We observe that the TRIP maps give rise to two classes of transfer operators, present theorems regarding the origin of these classes, and discuss the implications of these theorems; we also present related theorems on the form of transfer operators arising from compositions of TRIP maps. We then proceed to prove that the transfer operators associated with select TRIP maps are nuclear of trace class zero and have spectral gaps. We proceed to show that select TRIP maps are ergodic while also showing that certain TRIP maps never lead to convergence to unique points. We finish by deriving Gauss-Kuzmin distributions associated with select TRIP maps.

Geosciences students in the senior seminar examine an outcrop along the Deerfield River in Shelburne Falls, Massachusetts. The igneous rocks formed in the deep crust 475 million years ago in an island arc that collided with Ancient North America during the Taconic orogeny.

Resampling Methods With Applications in Variance Estimation

Shiwen Chen

In point estimation, the true parameter of interest theta of the population distribution F is often estimated by a functional of the empirical distribution of n observations, denoted as $\theta_n = \theta(F_n)$. In statistical practice, it is important to learn about the sampling distribution and assess the precision of a point estimator by estimating its variance. For many functionals, closed form expression of the sampling distribution is not available. Resampling schemes reproduce samples from the original set of observations. With the help of these reproduced samples, the sampling distribution of $_n$ can be estimated. This thesis explores a set of topics related to resampling schemes. We make contributions in two directions: the proposal of a general class of linearly extrapolated variance estimators as a generalization of the delete-one jackknife variance estimator, and the investigation of resampling schemes for dependent data, in particular, spatial data.

Completions of Unique Factorization Domains with Unique Factorization Modulo a Principal Prime Ideal

Craig Matthew Corsi

We present new work in the theory of complete local rings. Given a complete local ring T with maximal ideal M, and given $p \in R$, we conjecture that a set of weak conditions is necessary and sufficient to ensure the existence of a local unique factorization domain R such that $p \in R$ and R/pR is also a unique factorization domain. We make significant progress toward proving this claim. Then, given a complete local ring T with maximal ideal M, C a countable set of nonmaximal, pairwise incomparable set of prime ideals of T, and $p \in \bigcap_{P \in C} P$, we give necessary and sufficient conditions for T to be the completion of a local integral domain A such that $p \in A$, and pA is a prime ideal whose formal fiber has maximal elements the elements of C. We also give conditions under which A can be constructed to be excellent.

A Characterization of Trees With Convex Obstacle Number 1 or 2

Philippe Demontigny

A convex obstacle representation of a tree T is a drawing of the vertices of T in the plane with a set of convex polygons so that two vertices are connected by an edge if and only if that edge does not intersect any of the polygons. The minimum number of obstacles required to represent a tree in this way is called the convex obstacle number of the tree. This new description of a graph has steadily gained popularity since its introduction in 2009, and is particularly interesting because of its relationship to visibility graphs, which have been studied extensively and have applications in robot motion planning and architecture. So far, it is known that a representation using only 5 convex obstacles exists for all trees, which implies that the upper bound for the convex obstacle number of any given tree is five. However, not much is known about which trees have a convex obstacle number that is less than 5. In this thesis, we begin to fill this gap by providing necessary and sufficient conditions for a tree to have convex obstacle number 1 or 2. We also provide insights into how one could approach the problem of finding all trees with convex obstacle number 3 or 4.

Modelling and Improving Pitching Strategies in Major League Baseball

Carson Eisenach

In Major League Baseball, the bullpen is perhaps the most poorly utilized of a teams resources. Finding better strategies for using the bullpen is very valuable. In this senior thesis, I explore a framework for analyzing pitching strategies in Major League Baseball. The main contributions of this thesis are (1) the development of an extensive set of tools to create the game state data needed to analyze pitching strategies and (2) using the data discovered to develop several models for pitching strategies as well as metrics by which to assess model fit.

A Practical Review of Time-Series Forecasting Using A Large Number of Predictors

Vu Le

Time-series forecasting using a large number of predictors has received increasing attention in recent years. Stock and Watson (1999), Bai and Ng (2002, 2007), among others, have developed techniques to extract relevant information from a large set of forecasting variables with promising results. In this paper, we first study the main theory behind this topic, the diffusion index forecasting model (Stock and Watson, 1999). It estimates unobserved factors nonparametrically by principal components of existing predictors. We have confirmed that the model outperforms the benchmark alternatives in terms of mean squared forecasting error (MSFE). We then explore and present the empirical efficacy of proposed refinements to the model. These include the determination of the number of factors and predictor selection using soft and hard thresholding (Bai and Ng, 2007). Along the way, we will propose and test some potential refinements to the existing methodologies.

Benford's Law and Fraud Detection

Yang Lu

Benford's Law describes the situation in which the frequency distribution of the first digits in a real-life data set does not follow a uniform distribution. Rather, the probability of a digit d occurring as the leading digit of a data point is the difference between d+1 and d on a logarithmic scale with base 10. This phenomenon has been regularly used by auditors as a tool to detect fraud. The bootstrap is a resampling method which can be used to estimate the sampling distribution of an estimator, first proposed by Efron in 1979.

We apply the bootstrap method to find a way to reduce the number of data points required for effective fraud detection based on Benford's Law. Oftentimes an auditor may not have access to all the data; a method using a subset of the data for fraud detection makes the auditor's job possible and potentially saves both human and computational resources. We have found that assuming that a data set of size 5000 or more is either free of manipulation or a result of summing the original values and some values following either a normal distribution or a uniform distribution, we only require 5% of the data to detect potential data manipulation.

Relieving and Readjusting Pythagoras: Improving the Pythagorean Formula

Victor Dan Luo

The Pythagorean expectation was invented by Bill James in the late 70's as a way of calculating how many wins a baseball team should have by utilizing just runs scored and runs allowed. His original formula predicts a winning percentage of RS^2/(RS^2+RA^2), where RS stands for runs scored and RA stands for runs allowed. Although the simplicity of the formula is a thing of beauty, with the development of more advanced baseball statistics it should be possible to enhance the formula such that it gives a more accurate prediction of a team's wins. Implementing statistics such as ballpark effect as well as accounting for game state factors, we will test to see if it is indeed the case that adjusting the Pythagorean expectation formula gives a statistically significantly better prediction for a team's wins than the unadjusted formula.

In order to test these adjusted formulas, we will be culling data from the internet, specifically from http://www.retrosheet.org/gamelogs/index.html and espn.com. We will then import this data into R and use our code to manipulate the data, calculating the new adjusted Pythagorean expectation and old Pythagorean expectation by year for each team. Then, using different regression models, we will determine which expectation formula is more accurate.

In addition, it has been shown that we can use a Weibull distribution in order to model run production. The versatility of the distribution is due to the fact that it accounts for three parameters that can be varied to adjust the spread, shift, and scale of the distribution. We will explore whether a linear combination of Weibulls is able to more accurately determine a team's run production.

Completions of Reduced Local Rings with Prescribed Minimal Prime Ideals

Byron J. Perpetua

A central question in commuta**tive algebra asks when a complet**e local ring T is the completion of a local subring A, subject to a given set of conditions on A. Arnosti et al. answer the question when T is assumed to contain the rationals and A is required to be a reduced local ring with a finite number of maximal elements in the formal fiber at each of its minimal prime ideals. In this thesis, we construct A so that the number of maximal elements in the formal fiber at each minimal prime ideal is countable instead of finite, and we introduce a new set of necessary and sufficient conditions for T to be the completion of such a ring A, which weaken the requirement that T contain the rationals.

Simultaneous Inference on Margins of Binary Data

Faraz Wasiur Rahman

Simultaneous inference deals with testing several hypotheses that might be related. Techniques in this field control the chances of rejecting one or more of the true hypotheses at a low value like 5%, and then try to reject the remaining false hypotheses with high probability. We will develop and evaluate the performance of a closed testing procedure to analyze the margins of binary data, and explore some applications of the technique in a clinical trial scenario.

Testing Benford's Law

Jirapat Samanvedhya

Benford's Law, a phenomenon of the first-significant bias, is often used in fraud and data integrity detection. The application of Benford's Law uses goodness-of-fit test which typically involves the chi-square, the Kolmogorov-Smirnov, or the Kuiper's tests. There are some issues with the comparison of these tests: 1) the latter two are designed to test continuous distributions and they are found to be too conservative for discrete distributions 2) we must compare both Type I error and power. This thesis aims to address those issues by using a simulation-based approach to normalize Type I error and bypass the complication with continuity.

We use the Monte Carlo method to compare powers of the Kolmogorov-Smirnov test, the Kuiper's test and the power-divergence test, which is a family of test statistics that generalizes the chi-square test. We test Benford's Law against five major discrete distributions (uniform, linear, Poisson, geometric and binomial distributions) and generalize to 2-digit Benford's Law. We find that the Kuiper's test is one of the most powerful tests in general. However, when the alternative distribution is very similar to the Benford distribution, the power-divergence test has more power. We then test two real data sets whose distribution of first significant digits visually exhibits Benford behavior. For the AAPL daily trading volume dataset, all tests reject the null hypothesis that it obeys Benford's Law. For the streamflow dataset, the power-divergence tests rejects the null hypothesis at 95% confidence level, whereas the other tests do not.

A Novel Model for White-Nose Syndrome in Little Brown Bats

David F. Stevens

Bats are important reservoirs for emerging human and wildlife diseases. Certain pathogens that are highly virulent to humans are able to persist in healthy bats and little is known about the mechanisms by which bat immune systems are able to cope with these diseases. White nose syndrome (WNS) is a devastating emerging infectious disease in North American bat populations. In 2006, the first incidence of bats infected with WNS was discovered in a cave near Albany, New York. It has since spread rapidly across eastern North

America. WNS is caused by a newly described fungus, Geomyces destructans, that grows on the exterior of hibernating bats. The infection is thought to rouse infected bats from hibernation, depleting essential fat stores and resulting in death by starvation. This disease is forecasted to cause the regional extinction of little brown bats in the northeastern United States, with the potential for serious consequences for ecosystem integrity. In this paper we outline disease control strategies for WNS with the aim of preventing the regional extinction of *Myotis lucifugus*. For this purpose, we develop a mixed-time SEI model for WNS in *Myotis lucifugus* broken into three stages: (1) roosting, (2) swarming, and (3) hibernation.

Maximal Bipartite Subgraphs of Special 4-Regular Planar Graphs

Sean Sutherland

Graph theorists have long been interested in determining the number of edges included in the largest bipartite subgraph of a given graph. We first provide a simple proof to show that every 4-regular planar graph has a maximal bipartite subgraph containing at least 2/3 of its edges. By applying Hadlock's [3] procedure for determining bipartite subgraphs of planar graphs, we provide the exact size of the maximal bipartite subgraphs of two special classes of 4-regular planar graphs. We conclude by outlining our attempt to prove that the only graphs for which the maximal bipartite subgraph realizes the 2/3 ratio are the triangular checkerboard graphs.

Limiting Spectral Measures of Random Matrix Ensembles With a Polynomial Link Function

Kirk Swanson

Given an ensemble of N by N random matrices, an interesting question to ask is: do the empirical spectral measures of typical matrices converge to some limiting measure as N tends to infinity? The limiting measures of several canonical matrix ensembles have been well-studied, such as the symmetric Wigner, Toeplitz, and Hankel matrices. It is known that in the limit, the Wigner matrices have a semicircular distribution, the Toeplitz have a near-Gaussian distribution, and the Hankel have a non-unimodal distribution. Although it is not fully understood why, these ensembles exhibit the interesting property that as more constraints are introduced to a patterned random matrix, new limiting measures other than the semicircle can arise. It is natural, then, to explore the question: to what extent will a patterned random matrix continue to have a semicircular limiting eigenvalue distribution? In the following, we explore this question by generalizing the Toeplitz and Hankel ensembles. The resulting matrix ensembles with bivariate polynomial link functions have unique limiting spectral distributions. In specific cases, we establish that when the variables in the polynomial are raised to the same power the limiting measure becomes non-semicircular, but when the variables are raised to different powers the limiting measure remains semicircular.

Primes in Arithmetic Progressions of Polynomials

Samuel Tripp

Dirichlet's Theorem on Primes in Arithmetic Progressions states that if a and b are coprime, there are infinitely many primes congruent to a modulo b. The proof, however, is quite analytic. Murty and Thain ask for which pairs of integers a and b this can be proved algebraically. They prove that if the square of a is congruent to 1 modulo b, there is an algebraic proof that there are infinitely many primes congruent to a modulo b.

Knowing that the analogue of Dirichlet's Theorem holds in the function field case, we present results establishing an analogue of the results of Murty and Thain in the function field case as well.

Neuroscience

Exploring the Potential Neuroprotective Effects of Estradiol in a Mouse Model of Repetitive Mild Traumatic Brain Injury

Jenna Adams

Traumatic brain injury (TBI) is a major health concern in the United States. In particular, mild TBIs (mTBI), or concussions, are difficult to diagnose and may result in unresolved symptoms up to one year following the injury. Sustaining multiple concussions increases the risk of poor outcomes, which had raised attention specifically within athletics where mTBIs can be unreported. Clinical observations and experiments using animal models of TBI suggest that there are sex differences in outcomes of brain injury that may be mediated by endogenous levels of steroid hormones, including 17b-estradiol (estradiol) and progesterone. While estradiol has demonstrated neuroprotective effects in clinical models of neurodegeneration, rodent models of ischemic stroke, and in vitro models of neuronal insult, its effects on behavioral and physiological outcomes of TBI remain controversial. The aim of the current study was to investigate the potential neuroprotective effects of estradiol in a mouse model of repetitive mTBI (rmTBI) by evaluating motor performance using the rotarod test, spatial learning and memory using the Morris Water Maze (MWM), and microglia activation in the dentate gyrus (DG) following repeated closed head injuries (CHIs) in ovariectomized female mice treated with estradiol. The 2x2 experimental design yielded four treatment groups: Vehicle (V) + Sham, Estradiol (E) + Sham, V + CHI, and E + CHI. Estradiol treatment impaired motor performance, but no effect of CHI was found. Estradiol-treated mice and sham-injured mice performed better, on average, on the hidden platform MWM than vehicle-treated and injured mice, respectively. However, these differences were largely due to better performance on the initial training trials and were not due to more rapid acquisition. This unexpected pattern of results makes interpretation of theses findings in the context of learning difficult. A probe trial indicated that all groups had similar performance, although there was a trend for sham-injured mice to spend more time in the immediate vicinity of the previous platform location compared to injured mice. The visible platform MWM testing further suggested that the hippocampus wasn't vulnerable to deficits in spatial learning and memory following rmTBI, as performance on this task was correlated to performance on the hidden platform MWM. Microglia activation in the DG was similarly unaffected by injury or hormone treatment. These results suggest that the rmTBI protocol utilized, despite its similarity to other effective protocols described in the literature, produced an injury that was too mild to be detected by the outcomes measured, and thus prevented the investigation of whether estradiol could protect against deficits produced by rmTBI.

Examination of the Protective Effects of Progesterone in a Mouse Model of Repetitive Mild Traumatic Brain Injury

Megan Trager

Traumatic Brain Injury (TBI) is a widespread cause of death and disability throughout the world. Mild Traumatic Brain Injuries (mTBI) constitute 75% of TBIs and are common sports related injuries. Recent studies have shown that repetitive mTBI (rmTBI) within a critical time window can lead to deleterious effects on motor function, learning and memory, and depression that are not found after a single injury. While the effects of repeated mTBI are long lasting, currently there is not a standard treatment in order to prevent long-term consequences. The finding that females have better predicted outcomes compared to males has led to interest in the role of progesterone in the treatment of mTBI. In the current study, I used a repetitive mild closed head injury model in mice to examine the effects of progesterone on neural and behavioral outcomes described below. I hypothesized that the rmTBI would cause deficits in motor function and learning which would be alleviated by progesterone treatment immediately following injury. The Rotorod test was used to measure motor function, the Morris Water Maze determined spatial learning and memory, and the Sucrose Preference Test assessed depression. As an indicator of the inflammatory response to brain injury, microglia were stained in the hippocampal dentate gyrus with Iba-1 immunohistochemistry. Results showed that

rmTBI impaired motor performance compared to sham-injured mice, led to increased latency to right, and increased microglial proliferation in the hippocampal dentate gyrus. However, rmTBI did not impair spatial learning or increase depressive behavior compared to vehicle treated sham-injured mice. The proliferation of microglia correlated with impaired Rotorod performance on the final day of rmTBI and both rate of learning and performance on the final testing session in the Morris Water Maze. While rmTBI impaired performance on these tests, progesterone was not sufficient to protect against the deleterious behavioral effects or microglial proliferation. In uninjured mice, but not mice that underwent repeated weight drop, progesterone was found to have a beneficial effect on spatial learning and memory.

Physics

Towards a Precision Measurement of the Stark Shift in the Indium $5P_{1/2} \rightarrow 6S_{1/2} \rightarrow 6P_{1/2}$ Transition

Nathan R. Bricault

We have made progess towards a precise measurement of the Stark shift in the $5P_{1/2} \rightarrow 6S_{1/2} \rightarrow 6P_{1/2}$ two-step transition in atomic indium. We have demonstrated the ability of two-tone frequency modulation spectroscopy to resolve a signal from this two step transition, and found good agreement with the predicted lineshape. Frequency Modulated spectroscopy of the $5P_{1/2} \rightarrow 6S_{1/2}$ transition has been used to verify the functioning of the atomic beam source. A new design for the electric field plates has been formalized which has the potential to significantly reduce measurement uncertainty over previous work. With this groundwork in place, we are well positioned to complete a measurement of the Stark shift and put *ab initio* atomic theory calculations of Group IIIA atoms to the test.

Beating the Standard: Improved Hologram Calculation for Highly Symmetric Holographic Optical Trapping

Richard P. Eiselen

In this thesis I experimentally characterize the holographic optical trapping performance of 3x3 holograms created by J,an iterative algorithm designed by Skitka to overcome the particular challenges of calculating holograms for highly symmetric trapping configurations. As a benchmark I compare the performance of J's holograms to those created by Weighted Gerchberg- Saxton, a standard iterative algorithm for creating symmetric trapping con- figurations. J resulted in holograms that were approximately as stiff, 10% more uniform in stiffness, and 20% less variable in stiffness (as measured by their fractional standard deviation) than those produced by Weighted Gerchberg-Saxton.

Previous attempts were made by thesis students of the Lopes Lab to characterize J. In addition to being the first thesis to characterize J and Weighted Gerchberg-Saxton at serval iteration values, the performance of algorithms described bythis thesis is most consistent with the theoretical performance of the algorithms. Better agreement with predictions was achieved through nu- merous changes to the trapping apparatus and hologram generation scheme. Generally, the changes to the system resulted in optical traps that were up to 8 times as stiff and 3 times as uniform as those created before.

A Kinetically Mixed Z' Gauge Boson at the LHC

Isaac M. Hoenig

We investigate the sensitivity of the Large Hadron Collider (LHC) to a hypothetical Z' gauge boson. This particle is a manifestation of a $U(1)'$ gauge symmetry added to the Standard Model gauge group. By kinetic mixing of the $U(1)'$ with the SM $U(1)$ gauge group, the Z' inherits couplings to SM fermions and therefore has the potential to be detected in particle collider experiments. We explore Z' particles with mass below the Z boson mass, a region in which precision electroweak measurements provide the strongest current constraints. By estimating the bounds on the Z' model from an analysis of the $\

sqrt{s}=7\ $TeV $pp\rightarrow\mu^+\mu^-$ data carried out by the CMS collaboration; and by using Monte Carlo simulations to study the potential sensitivity of $\sqrt{s}=7\ $TeV and $\sqrt{s}=8\ $TeV data under different analysis conditions, we show that the LHC is considerably more sensitive to Z' than the current constraints. This study should serve as impetus for further analysis of $pp\rightarrow\mu^+\mu^-$ data produced at the LHC, as there is potential for fruitful results in the dimuon mass range below the Z mass..

Benford's Law and Power Law Behavior in Fragmentation Processes

Joseph R. Iafrate

We construct and analyze models for the fragmentation of a conserved quantity. Using a statistical model, we derive an approximation as well as bounds for the restricted partitioning problem, which we apply to the distribution of fragments. We also modify the canonical ensemble from statistical physics. Taken together, we set a threshold on the magnitude of the conserved quantity needed to result in power law behavior, as well as a threshold on the number of possible piece sizes in a special case. We also investigate variations on two specific fragmentation procedures, the directed and undirected fragmentations, for power law behavior. Calculations show that the undirected fragmentation exhibits power law behavior. We consider small perturbations to process rates and find that the multi-path fragmentation is affected less as the number of piece sizes grows. We confirm this numerical result using first-order perturbation theory.

A New All-Fiber Pulsed Laser: Continued Study of the Nonlinear Optical Loop Mirror

Maxwell C. LaBerge

This thesis discusses the building and operation of a passively mode-locked, picosecond pulsed, all-telecommunication-grade optical fiber laser. The laser takes advantage of a nonlinear optical loop mirror (NOLM), along with other nonlinear effects innate in single-mode optical fiber to create these pulses. It was built to continue research on the NOLM, and is greatly improved over the previous laser. Some of these many improvements include the use of incredibly stable diode lasers, and the deliberate use of specific types of specialized fiber that allow us to control the overall dispersion in the laser cavity. When pulsing, the laser's spectral bandwidth is wide enough to support pulses as short as 0.2 ps.

Timescales for the Quantum Zeno Effect

Cesar Melendez

We studied two types of quantum decay in the presence of repeated measurements. We first studied a quantum particle capable of tunneling through a potential barrier subjected to pulsed measurements. Its survival probability indicated that the system exhibits the Quantum Zeno Effect when the initial wavefunction is allowed to exist in the classically forbidden region. We also considered the continuous and pulsed measurements on a model of an excited atom that spontaneously decays while emitting a photon. The survival probability was analyzed in the regimes of large and small measurements rates. These results may be of use in future efforts to observe the Quantum Zeno Effect in decaying systems.

Psychology

Predictors of Pubertal Timing Among Adolescent Girls: The Roles of Interpersonal Stress and Diurnal Cortisol Rhythms

Elizabeth Albert

Research has evidenced a relationship between interpersonal stress and early pubertal timing. However, prior work has not examined whether different domains of adolescent interpersonal stress (e.g., family, marital and romantic stress) uniquely predict pubertal timing and/or changes in the rate of pubertal timing. Moreover, little research as explored the role of hypothalamic-pituitary-adrenal (HPA) axis in this relationship. Guided by the Biological Sensitivity to Context theory, the present study examined adolescent chronic interpersonal stress, pubertal timing and diurnal cortisol rhythms in a one-year longitudinal study. Partici-

pants were 72 adolescent girls (M = 12.54 years) and their maternal caregivers. Findings supported BSC and indicated that distinct domains of interpersonal stress uniquely predict pubertal timing and changes in the rate of pubertal timing, and that this relationship is moderated by diurnal cortisol rhythms. First, increased romantic stress uniquely predicted early pubertal timing. Second, among girls with flatter slopes from wake up to bedtime (Slope A) and peak to wakeup (Slope B), increased romantic stress predicted accelerations in the rate of pubertal timing. Third, increased family stress uniquely predicted decelerations in rate of pubertal timing and AUC, Slopes A and B moderated this association. Fourth among girls with steeper Slopes A and B, greater family stress predicted deceleration in the rate of pubertal timing. Fifth, CAR moderated the relationship between marital stress and pubertal timing. These findings underscore the importance of teaching adolescent girls how to cope with chronic family and romantic stress in order to prevent early pubertal timing.

Chunking in Preschoolers: The Effects of Conceptual and Spatial Organizational Cues on Young Children's Recall

Alida Davis

We rely on working memory all the time: when we need to remember the steps of a recipe, for example, or when we have to hold a phone number in mind before we can dial it. However, working memory has a severely limited capacity; we can only hold a few units of information in mind at one time. One way that we can cope with this small capacity is by "chunking": increasing the amount of information that can count as a single unit in working memory. Chunking is a flexible strategy, and age-related abilities including metamemory and long-term knowledge can affect the ways in which and success with which we chunk. Previous results indicate that infants, toddlers and adults can chunk using a variety of organizational cues such as spatial, perceptual or conceptual cues. It is particularly interesting to understand how young children might chunk, as they are in a stage of rapid metamemory development. Existing evidence suggests that young children may be able to utilize conceptual, but not spatial, cues to chunk information on a recall task, but inconsistencies between study designs render these findings difficult to interpret or compare. The present study directly investigated and compared the effects of conceptual and spatial cues on preschool-aged children's chunking abilities and subsequent memory in a serial probed recall task. We did not find that conceptual, spatial or combined conceptual-spatial cues increased children's performance on the working memory task. However, a qualitative analysis of errors indicated that children might have been sensitive to the chunking cues. The role of metamemory in this type of task is discussed.

For Meat's Sake: Anticipated Hypocrisy and Environmental Information Avoidance

Peter Drews

Information avoidance has long been a topic of study in the health domain, yet it has rarely been applied to environmental psychology. In three studies, I examine whether feelings of anticipated hypocrisy may lead to avoidance of environmental information, in the form of meat-eating's negative consequences for the environment. In Study 1, participants rated either images of appealing meat, disgusting meat, or cookies, and then read a paragraph about either meat's negative environmental consequences or a control paragraph. I then had participants rate their preferences for viewing four videos, one of which related to environmental issues. In Study 2, participants rated either pictures of nature or of meat, and then either advocated for the environment or did nothing. They were then asked whether or not they wished to view a video linking meat-eating to environmental devastation. In Study 3, participants either advocated for the environment or did nothing. Then, some were asked whether they wished to see the same meat-eating video as in Study 2, while others were asked whether or not they wished to view a video about the damage international corporations do to the environment. These findings suggest that anticipated feelings of hypocrisy may lead people away from information about the environment.

When Moving Gets You Nowhere: Investigating the Limits of the Dynamic Superiority Effect

Alexander LaTourrette

Video is well on its way to establishing itself as dominant form of media in modern society: as computers, cameras and phones become more powerful, video becomes increasingly easy to both produce and consume. Additionally, video is intuitively superior to the alternative mediums: it provides more content, does so more quickly, and often presents itself in a very life-like fashion. However, the present research indicates that at least in the domain of recognition memory, this may be an overly enthusiastic view. In my first two experiments, I demonstrate that while videos may be more memorable than still images arbitrarily selected from videos, videos are not more memorable than pictures selected independently but according to the same criteria as the videos. In my final experiment, I demonstrate that videos may benefit substantially more than pictures from being repeated during the learning phase. This result is consistent with an evanescence account of video recognition memory: videos contain more (or more memorable) content but are harder to encode and so benefit more from an extended encoding process than the more easily encoded pictures. Thus, while dynamic stimuli do not seem to be inherently more memorable than static stimuli, the high levels of memorability which both types of stimuli display may result from somewhat different encoding processes.

Sharing is Caring: Adult Prosocial Behavior and Emotional Responses to Real and Fictional Social Interactions

Eric Liao

Adult prosocial behavior and emotional reactions were measured in response to a computerized ball-tossing game involving social exclusion of another individual in real and fictional interactions. College student (N = 53; Mage = 19.09, SDage = 1.18; nmale = 24, nfemale = 29) participants filled out questionnaires online regarding individual differences before playing the ball-tossing game. Participants showed no significant differences in prosocial behavior between conditions, but were significantly more empathic and happier when playing with other perceived real people. Additionally, participants' pulse rate increased when playing with real co-players. Findings suggest that individuals may prefer human-to-human interaction, as indicated by the changes in emotional and physiological reaction.

Fitting in to Feel Good: Explicit & Implicit Predictors of Conformity

Fanny Mlawer

The present study examined the unique and joint contributions that implicit and explicit measures of self-esteem (SE), need to belong (NTB), fear of negative evaluation (FNE), rejection sensitivity (RS) and importance of popularity (IMP) make to the prediction of behavioral conformity. In an initial testing session, participants completed explicit measures of the five constructs in addition to providing preliminary answers on a comic rating task and a dot discrimination task. In the second session, participants rerated a subset of the comics and dot discrimination items in the presence of supposed "prior peer ratings" before completing implicit tasks measuring the five constructs. Results revealed a significant three-way interaction between implicit FNE, explicit FNE and gender on self-reported conformity, as well as a two-way interaction between implicit and explicit self-esteem on behavioral conformity in the comic rating task. Specifically, we found that among males high in implicit FNE, those with corresponding high explicit FNE were significantly more likely to report succumbing to peer pressure than those with low social avoidance, and, among females low in implicit FNE, participants with high explicit FNE reported higher susceptibility to peer pressure. We also found that on the comic rating task among those low in implicit SE, individuals with correspondingly low explicit SE conformed significantly more to false peer feedback than those with higher levels of explicit SE. Future research in this area should explore additional areas of evaluative concern, other types of behavioral conformity, and situational factors that may complicate these relationships.

Examining the Association between Diurnal Cortisol Rhythms, Subjective Appraisals of Stress, and Depressive Symptoms in Adolescent Girls

Emily Norkett

Research has evidenced a relationship between HPA axis functioning and depression. However, prior work is mixed regarding what types of diurnal cortisol profiles confer greater risk to depression. Moreover, research has not examined if and how perceptions of stress serve to influence that relationship, especially in the context of other known vulnerabilities to depression such as personality. Finally, no studies have examined to what extent these associations may be bidirectional in nature. Guided by a biopsychosocial theory of depression (Schotte, Van Den Bossche, De Doncker, et al., 2006), the present study examined adolescent diurnal cortisol rhythms, perceptions of stress, personality, and depression in a one-year longitudinal study. Participants were 73 sixth and seventh grade adolescent girls (mean age 12.55 years) and their maternal caregivers. Findings supported a bidirectional relationship between diurnal cortisol rhythms and depression, and between diurnal cortisol rhythms and increased perceptions of stress. First, greater overestimations of stress predicted higher AUC, which in turn predicted greater overestimations of stress among girls low in neuroticism and girls high in aggression. Second, greater overestimations of stress also predicted flatter slopes across the day, whereas steep slopes predicted greater overestimations of stress. Third, higher levels of depressive symptoms predicted lower AUC and steeper slopes across the day, whereas higher CAR and flatter slopes predicted increases in depressive symptoms, especially for girls who exhibited greater overestimations of stress. These findings underscore the importance of early intervention and prevention efforts to teach adolescents better coping skills to deal with stress, thereby helping to prevent first onsets of and reoccurrences of depression.

Was that a Good Performance?: The Effect of Visual Information on Judgments of Music Performance Quality

Sarah Rosemann

The present research explored the effect of visual cues on judgments of musical performance quality. I start by examining a previous study that showed that judgments of audio quality were strongly affected by visual cues. I hypothesized that while visual cues have an affect on any performance judgment, they are not the primary source of information. I present a series of experiments designed to test the hypothesis that judgments of audio quality are affected by visual cues. Experiments 1, 2 and 3 presented two audio tracks with a video or the performer or no visual cues and ask the participants to make a judgment of auditory performance quality. Between the Video+Audio condition and AudioOnly condition, the addition of the visual component made no difference to participants. We found that in Experiment 1 and 3 the participants were significantly higher than chance at picking the correct audio performance. In Experiment 2, the participants were at chance both with visual cues and without visual cues. Experiment 4 present used the same procedure but instead used Youtube videos. There were three conditions, one condition, Agree, where the visual cues and audio cues agreed which performance was better. The second condition, Disagree, where visual cues and audio cues were better in opposite videos. The third condition, Same Video, where the video was the same quality in both videos but the audio quality differed. We found that across conditions, the participants were significantly better than chance at picking the better audio performance but were not significantly influenced by the different visual qualities.

Bias in Student Evaluations of Female Instructors: An Examination of the Influence of Grade Leniency and Student Gender in Traditional and Online Classes

Mattia Wruble

The present research examines the effect of two potential biases – grade leniency and student gender – on student evaluations of female instructors in tradition and online classroom settings. Analyses failed to find a difference between male and female students' evaluations of female instructors, or between manipulated quiz feedback's effects on their evaluations. However, analyses did reveal a strong main effect of feedback,

dubbed "the grade leniency bias," on student evaluations: participants who were randomly assigned to the positive feedback condition evaluated the female instructor more positively than participants who were randomly assigned to the negative feedback condition did. Findings indicate that while this bias persists across traditional and online settings, it may produce slightly stronger effects in online classes. By identifying a bias that unfairly benefits some instructors and disadvantages others, this series of experiments challenges the reliability of student evaluations of female instructors. Accordingly, these findings have significant implications for the widespread use of student evaluations of instructors in academic institutions, and for their consideration in important administrative decisions.

ABSTRACTS FROM FACULTY PUBLICATIONS AND PRESENTATIONS

Astronomy

The Cosmos: Astronomy in the New Millennium

Pasachoff, Jay M., and Alex Filippenko

Cambridge University Press, 2014

Preface; About the authors; 1. A grand tour of the heavens; 2. Light, matter and energy: powering the Universe; 3. Light and telescopes: extending our senses; 4. Observing the stars and planets: clockwork of the Universe; 5. Gravitation and motion: the early history of astronomy; 6. The terrestrial planets: Earth, Moon, and their relatives; 7. The Jovian planets: windswept giants; 8. Pluto, comets, and space debris; 9. Our Solar System and others; 10. Our star: the Sun; 11. Stars: distant suns; 12. How the stars shine: cosmic furnaces; 13. The death of stars: recycling; 14. Black holes: the end of space and time; 15. The Milky Way: our home in the Universe; 16. A Universe of galaxies; 17. Quasars and active galaxies; 18. Cosmology: the birth and life of the cosmos; 19. In the beginning; 20. Life in the Universe; Epilogue; Appendices; Selected readings; Glossary; Index.

Nearest Star: The Surprising Science of the Sun, 2nd ed.

Golub, Leon, and Jay M. Pasachoff

Cambridge University Press, 2014

Preface; Acknowledgments; 1. The Sun; 2. The once and future Sun; 3. What we see: the solar disk; 4. What we don't see; 5. Eclipses; 6. Space missions; 7. Between fire and ice; 8. Space weather; Bibliography; Glossary; Index

The 2011 June 23 Stellar Occultation by Pluto: Airborne and Ground Observations

Person, M. J., E. W. Dunham, A. S. Bosh, S. E. Levine, A. A. S. Gulbis, A. M. Zangari, C. A. Zuluaga, J. M. Pasachoff, B. A. Babcock, S. Pandey, D. Amrhein, S. Sallum, D. J. Tholen, P Collins, T. Bida, B. Taylor, J. Wolf, A. Meyer, E. Pfueller, M. Widemann, H.-P. Roeser, R. Lucas, M. Kakkala, J. Ciotti, S. Plunkett, N. Hiraoka, W. Best, E. J. Pilger, M. Miceli, A. Springmann, M. Hicks, B. Thackeray, J. Emery, S. Rapoport, I. Ritchie, M. Pearson, A. Mattingly, J. Brimacombe, D. Gault, R. Jones, R. Nolthenius, J. Broughton, T. Barry

Astron. J. ***146*** *83 (15pp), October, doi:10.1088/0004-6256/146/4/83*

On 2011 June 23, stellar occultations by both Pluto (this work) and Charon (future analysis) were observed from numerous ground stations as well as the Stratospheric Observatory for Infrared Astronomy (SOFIA). This first airborne occultation observation since 1995 with the Kuiper Airborne Observatory resulted in the best occultation chords recorded for the event, in three visible wavelength bands. The data obtained from SOFIA are combined with chords obtained from the ground at the IRTF, the U.S. Naval Observatory Flagstaff Station, and Leeward Community College to give the detailed state of the Pluto-Charon system at the time of the event with a focus on Pluto's atmosphere. The data show a return to the distinct upper and lower atmospheric regions with a knee or kink in the light curve separating them as was observed in 1988,

rather than the smoothly transitioning bowl-shaped light curves of recent years. The upper atmosphere is analyzed by fitting a model to all of the light curves, resulting in a half-light radius of 1288 ± 1 km. The lower atmosphere is analyzed using two different methods to provide results under the differing assumptions of particulate haze and a strong thermal gradient as causes for the lower atmospheric diminution of flux. These results are compared with those from past occultations to provide a picture of Pluto's evolving atmosphere. Regardless of which lower atmospheric structure is assumed, results indicate that this part of the atmosphere evolves on short timescales with results changing the light curve structures between 1988 and 2006, and then reverting these changes in 2011 though at significantly higher pressures. Throughout these changes, the upper atmosphere remains remarkably stable in structure, again except for the overall pressure changes. No evidence of onset of atmospheric collapse predicted by frost migration models is seen, and the atmosphere appears to be remaining at a stable pressure level, suggesting it should persist at this full level through New Horizon's flyby in 2015.

Air-cooling mathematical analysis as inferred from the air temperature observation during the 1st total occultation of the Sun of the 21st century in June 21, 2001, at Lusaka, Zambia

Peñaloza-Murillo, Marcos A., and Jay M. Pasachoff

Journal of Atmospheric and Solar-Terrestrial Physics, 2013, submitted.

In an attempt to analyze mathematically air temperature measurements made near the ground by the US Williams College during its expedition to observe the first total occultation of the Sun (TOS) of the 21st century in Lusaka, Zambia, in the afternoon of June 21, 2001, we have revisited some earlier and contemporary methods to test their usefulness in performing this analysis. Two of them based on a radiative scheme for solar radiation modeling and that has been originally applied for a morning occultation, have successfully been combined to obtain the delay function for an afternoon occultation, via derivation of the so-called instantaneous temperature profiles. For this purpose, we have followed the suggestion given by the third of these methods to calculate this function although by itself it has failed to do so at least for this occultation. The analysis has taken into account the limb-darkening, occultation and obscuration functions. The delay function obtained describes quite fairly the lag between the solar radiation variation and the delayed air temperature measured. Also, in this investigation, a statistical study has been carried out to get information on the convectional activity produced during this event. For that purpose, the fluctuations generated by turbulence has been studied by means of an analysis of variance and residuals calculation. The results, indicating an irreversible steadily decreasing of this activity, are consistent with those published by other different studies. At the end the air temperature drop due to this event is well estimated by applying the empirical scheme given by the fourth of these methods, based on the daily amplitude temperature and the standardized middle time of the occultation. It is demonstrated then that by using a simple set of air temperature measured during solar occultations, along with some supplementary data, a simple mathematical analysis can be achieved by the application of the four methods reviewed here. However it is recommended more investigation in order to improve the performance of them. For those seeking to do further research, the paper includes a chronological bibliography or historical resource letter of publications reporting ambient temperature measurements made during solar occultations by the Moon. From this information it can be inferred that only five of these studies has been published up to date on TOS occurred over Africa [Mauritania (1973), Zimbabwe (2001) and Nigeria (2006)].

The Planetary and Eclipse Oil Paintings of Howard Russell Butler

Pasachoff, Jay M., and Roberta J. M. Olson

Bull Am. Astron. Soc. 45, #9, 23, 2013

The physics-trained artist Howard Russell Butler (1856-1934) has inspired many astronomy students through his planetary and eclipse paintings that were long displayed at the Hayden Planetarium in New York, the Fels Planetarium at the Franklin Institute in Philadelphia, and the Buffalo Museum of Science.

We discuss not only the eclipse triptychs (1918, 1923, and 1925) at each of those institutions but also his paintings of Mars as seen from Phobos and from Deimos (with landscapes of those moons in the foreground depicted in additional oils hung at Princeton University) and the Earth from our Moon. We also describe his involvement with astronomy and his unique methodology that allowed him to surpass the effects then obtainable with photography, as well as his inclusion in a U.S. Naval Observatory eclipse expedition in 1918, as well as his auroral, solar-prominence, and 1932-eclipse paintings.

Metal-Rich Planetary Nebulae in the Outer Reaches of M31

B. Balick, K.B. Kwitter, R.L.M. Corradi, & R.B.C. Henry

Astrophysical Journal, v. 774, p. 3, September 2013

Spectroscopic data of two relatively [O III]-luminous planetary nebulae (PNe) have been obtained with the 10.4 m Gran Telescopio Canarias. M174 and M2496 are each ~1 degree from the center of M31 along opposite sides of its minor axis. The ensemble of these 2 distant PNe plus 16 similarly luminous outer-disk PNe published previously by Kwitter et al. (2012) forms a homogeneous group in luminosity, metal content, progenitor mass, age, and kinematics. The main factual findings of our work are (1) O/H (and other low-mass α elements and their ratios to O) is uniformly solar-like in all 18 PNe ({12 + log(O/H)} = 8.62 ± 0.14); (2) the general sky distribution and kinematics of the ensemble much more closely resemble the rotation pattern of the classical disk of M31 than its halo or bulge; (3) the O/H gradient is surprisingly flat beyond Rg ~ 20 kpc. The PNe are too metal-rich to be bona fide members of M31's disk or halo, and (4) the abundance patterns of the sample are distinct from those in the spiral galaxies M33, M81, and NGC 300. Using standard PN age diagnostic methods, we suggest that all of the PNe formed ~2 Gyr ago in a starburst of metal-rich interstellar medium that followed an M31–M33 encounter about 3 Gyr ago. We review supporting evidence from stellar studies. Other more prosaic explanations, such as dwarf galaxy assimilation, are unlikely.

First Results from HST19 GO 12600: CNO Abundances in Seven Milky Way Planetary Nebulae

K.B. Kwitter, R.J. Dufour, R.A. Shaw, R.B.C. Henry, B. Balick, & R.L.M. Corradi

Presented at 224th meeting of the American Astronomical Society in Boston, MA, June 2014

We were awarded 32 orbits with HST to observe a sample of Galactic planetary nebulae from 1150–10270 Å with STIS. The ultimate goal of the project is to obtain accurate abundances of carbon, nitrogen and oxygen so that we can assess carbon production in the low-to-intermediate-mass (LIMS) progenitors of PNe with near-solar metallicity (~0.5-1.2 x solar), but varying N/O (~0.1-3), comparing observational data with theoretical models of carbon yields. We report here on the first global abundances derived from these spectra.

Abundances in Eight Outer M31 Planetary Nebulae

K.G. Hensley ('14), K.B. Kwitter, R.L.M. Corradi, R. Galera-Rosillo, B. Balick, & R.B.C. Henry

Presented at 224th meeting of the American Astronomical Society in Boston, MA, June 2014

We have observed eight planetary nebulae in the outer reaches of M31 using the OSIRIS spectrograph on the 10.4-m Gran Telescopio Canarias. The projected distances from the center of M31 range between 1.3 and 2.8 degrees. From these spectra we have determined the PNe chemical abundances; despite their galactocentric distances, all exhibit oxygen abundances above 1/3 solar.

Observations of Planetary Nebula NGC 3242 Using STIS from HST19 GO 12600

T.R. Miller, R.J. Dufour, R.B.C. Henry, K.B. Kwitter, R.A. Shaw, B. Balick, & R.L.M. Corradi

Presented at 224th meeting of the American Astronomical Society in Boston, MA, June 2014

During HST Cycle 19, we obtained long-slit spectra using STIS of the planetary nebula NGC 3242 with higher spatial resolution than previously published. The full wavelength range is around 1100-10200Å, covering many nebular lines for determining numerous ionic abundances and electron densities and temperatures. In this work, we first analyze the low- and moderate-resolution UV emission lines of carbon, nitrogen and

oxygen. In particular, the resolved lines of C III] 1907 and C III] 1909 have yielded a direct measurement of one of the dominant ionic species for carbon and a determination of the density occupied by doubly-ionized carbon and other similar ions. Next, the spatial emission profile of these lines reveals variations in the inferred density along the line of sight from about 2800-11500 cm-3, compared with a value ~3800 cm-3, when averaged over the entire slit. Similarly, the electron temperature is around 12000K for the entire slit and ranges from about 11400-14000K when the slit is divided into smaller sub-regions. Lastly, these sub-regions of the nebula have been modeled in detail with the photoionization code CLOUDY. This modeling will assess the density profile that produces the observed density variation, reproduce the temperature fluctuations, and constrain the central star temperature.

Using PNe to Explore the History of M31's Extended Disk

K.B. Kwitter, B. Balick, R.L.M. Corradi, K.G. Hensley ('14), & R.B.C. Henry

Presented at 224th meeting of the American Astronomical Society in Boston, MA, June 2014

The results of O/H abundances derived from PNe in M31 (accompanying poster by Hensley et al.) have extended the radius coverage of our previous gradient studies out to projected disk distances of 100 kpc. The PNe are drawn from the peak of the [O III] PNLF which suggests that their progenitor stars are more massive than about 1.5 $M_{0}$with evolution lifetimes less than ~2 billion years. However, many of the PNe in this sample are located in regions without gas and other signatures of recent star formation. Here we investigate how the measured O/H abundances of PNe beyond the classical disk of M31 correlate within stellar groupings that are defined in various ways (region, disk radius, kinematic deviations from a thin disk model, and proximity to known stellar streams). The goal is to determine the relationships of the M31 PN sample to any H I and the other stellar populations associated with the evolution of M31's outer environment.

Photometry and Spectroscopy of BD+35 1111 in M38

S.P.Souza, K.B. Kwitter, M. Sami ('16), & G. Beltz-Mohrmann (Wellesley '15)

Presented at 224th meeting of the American Astronomical Society in Boston, MA, June 2014

BD+35 1111 is a ~10.5-magnitude star in the field of M38, an open cluster that has been a target of our ongoing study of Hα emission variability in massive stars via narrowband CCD photometry (e.g. Souza, Davis, and Teich 2013, BAAS. 45, PM354.22). BD+35 1111 has no MKK classification in the literature, and is not listed as variable in GCVS, VSX, or NSVS. It is included, with no further characterization, in both the Vatican and Kohoutek catalogs of emission line stars. Using inhomogeneous ensemble photometry (e.g. Bhatti, Richmond, Ford, and Petro 2010, ApJ Supp., 186, 233), we find it to be an irregular variable with a range of ~0.15 mag. To further understand this star we obtained a medium-resolution spectrum using the DIS spectrograph on the ARC 3.5-meter telescope at Apache Point Observatory. We classify BD+35 1111 as B2Ve, the only confirmed Be star in the field of M38. This raises the question of membership, since the age of M38 is likely 250 Ma or greater (Pandey et al. 2007, Publ. Astron. Soc. Japan 59, 547). From published B and V magnitudes we find a nominal distance to BD+35 1111 of 1.6 kpc, but with a range of 1.3 to 2.0 kpc, marginally consistent with distance estimates for M38 ranging from 1.0 to 1.4 kpc. If a member, BD+35 1111 is a candidate blue straggler. If not, it may have escaped from a nearby younger cluster, possibly Kronberger 1 (Kronberger et al. 2006, A&A 447, 921), which has the right heliocentric distance and age. The notion that BD+35 1111 is behind M38 is supported by its reddening of EB-V ~ 0.5, significantly higher than for M38 itself (~ 0.24). We gratefully acknowledge support for student research from NSF grant AST-1005024 to the Keck Northeast Astronomy Consortium, Williams College, and NASA via an American Astronomical Society Small Research Grant.

The Light Curve and Period of MT696

S.P.Souza, M. Sami, ('16), & G. Beltz-Mohrmann (Wellesley '15)

J. Amer. Assoc. Var. Star Obs., **42**, (2014)

We have obtained 4-year narrowband light curves at 645nm and 656nm of the massive eclipsing binary star #696 in the Massey and Thompson (1991) study of massive stars in the Cygnus OB2 association. MT696 is a near-contact binary with components of near-equal temperature. We refine its orbital period to 1.46919 ± 0.00006 days. There is no convincing evidence of a change in period, and the 645-nm and 656-nm light curves are indistinguishable.

Photometry and Spectroscopy of BD+35 1111 in M38

S. P. Souza, K. B. Kwitter, M. Sami ('16), G. Beltz-Mohrmann (Wellesley '15)

*BAAS. **46**, PM291.05, 224th Meeting of the American Astronomical Society, Boston, MA, June 2014*

BD+35 1111 is a ~10.5-magnitude star in the field of M38, an open cluster that has been a target of our ongoing study of Hα emission variability in massive stars via narrowband CCD photometry (e.g. Souza, Davis, and Teich 2013, BAAS. 45, PM354.22). BD+35 1111 has no MKK classification in the literature, and is not listed as variable in GCVS, VSX, or NSVS. It is included, with no further characterization, in both the Vatican and Kohoutek catalogs of emission line stars. Using inhomogeneous ensemble photometry (e.g. Bhatti, Richmond, Ford, and Petro 2010, ApJ Supp., 186, 233), we find it to be an irregular variable with a range of ~0.15 mag. To further understand this star we obtained a medium-resolution spectrum using the DIS spectrograph on the ARC 3.5-meter telescope at Apache Point Observatory. We classify BD+35 1111 as B2Ve, the only confirmed Be star in the field of M38. This raises the question of membership, since the age of M38 is likely 250 Ma or greater (Pandey et al. 2007, Publ. Astron. Soc. Japan 59, 547). From published B and V magnitudes we find a nominal distance to BD+35 1111 of 1.6 kpc, but with a range of 1.3 to 2.0 kpc, marginally consistent with distance estimates for M38 ranging from 1.0 to 1.4 kpc. If a member, BD+35 1111 is a candidate blue straggler. If not, it may have escaped from a nearby younger cluster, possibly Kronberger 1 (Kronberger et al. 2006, A&A 447, 921), which has the right heliocentric distance and age. The notion that BD+35 1111 is behind M38 is supported by its reddening of EB-V ~ 0.5, significantly higher than for M38 itself (~0.24). We gratefully acknowledge support for student research from NSF grant AST-1005024 to the Keck Northeast Astronomy Consortium, the Office of the Dean of Faculty and the DIII Research Funding Committee of Williams College, and NASA via an American Astronomical Society Small Research Grant.

Biology

CelR, an ortholog of the diguanylate cyclase PleD of *Caulobacter*, regulates cellulose synthesis in *Agrobacterium tumefaciens*. *Appl. Environ. Microbiol.*79:7188-7202

Barnhart, D.M., S. Su, B. E. Baccaro '09, L. M. Banta, and S. K. Farrand. 2013.

*Appl. Environ. Microbiol.*79:7188-7202

Cellulose fibrils play a role in attachment of Agrobacterium tumefaciens to its plant host. While the genes for cellulose biosynthesis in the bacterium have been identified, little is known concerning the regulation of the process. The signal molecule cyclic di-GMP (c-di-GMP) has been linked to the regulation of exopolysaccharide biosynthesis in many bacterial species, including A. tumefaciens. In this study, we identified two putative diguanylate cyclase genes, *celR* (*atu1297*) and *atu1060*, that influence production of cellulose in A. tumefaciens. Overexpression of either gene resulted in increased cellulose production, while deletion of *celR*, but not *atu1060*, resulted in decreased cellulose biosynthesis. *celR* overexpression also affected other phenotypes, including biofilm formation, formation of a polar adhesion structure, plant surface attachment, and virulence, suggesting that the gene plays a role in regulating these processes. Analysis of *celR* and Δ*cel* mutants allowed differentiation between phenotypes associated with cellulose production, such as biofilm

formation, and phenotypes probably resulting from c-di-GMP signaling, which include polar adhesion, attachment to plant tissue, and virulence. Phylogenetic comparisons suggest that species containing both *celR* and *celA*, which encodes the catalytic subunit of cellulose synthase, adapted the CelR protein to regulate cellulose production while those that lack *celA* use CelR, called PleD, to regulate specific processes associated with polar localization and cell division.

Genetic Identification of a Neural Circuit that Suppresses Appetite

Carter, ME, Soden, ME, Zweifel, LS, Palmiter, RD.

Nature (2013). doi:10.1038/nature12596.

Appetite suppression occurs after a meal and in conditions when it is unfavourable to eat, such as during illness or exposure to toxins. A brain region proposed to play a role in appetite suppression is the parabrachial nucleus[1, 2, 3], a heterogeneous population of neurons surrounding the superior cerebellar peduncle in the brainstem. The parabrachial nucleus is thought to mediate the suppression of appetite induced by the anorectic hormones amylin and cholecystokinin[2], as well as by lithium chloride and lipopolysaccharide, compounds that mimic the effects of toxic foods and bacterial infections, respectively[4, 5, 6]. Hyperactivity of the parabrachial nucleus is also thought to cause starvation after ablation of orexigenic agouti-related peptide neurons in adult mice[1, 7]. However, the identities of neurons in the parabrachial nucleus that regulate feeding are unknown, as are the functionally relevant downstream projections. Here we identify calcitonin gene-related peptide-expressing neurons in the outer external lateral subdivision of the parabrachial nucleus that project to the laterocapsular division of the central nucleus of the amygdala as forming a functionally important circuit for suppressing appetite. Using genetically encoded anatomical, optogenetic[8] and pharmacogenetic[9] tools, we demonstrate that activation of these neurons projecting to the central nucleus of the amygdala suppresses appetite. In contrast, inhibition of these neurons increases food intake in circumstances when mice do not normally eat and prevents starvation in adult mice whose agouti-related peptide neurons are ablated. Taken together, our data demonstrate that this neural circuit from the parabrachial nucleus to the central nucleus of the amygdala mediates appetite suppression in conditions when it is unfavourable to eat. This neural circuit may provide targets for therapeutic intervention to overcome or promote appetite.

Barriers to gene exchange in hybridizing field crickets:
the role of male courtship effort and cuticular hydrocarbons

Maroja, L.S., McKenzie, Z.M. '14, Hart, E. '14, Jing, J. '13, Larson, E.L. and Richardson, D.P.

BMC Evolutionary Biology 2014,14:65

Pre-zygotic barriers often involve some form of sexual selection, usually interpreted as female choice, as females are typically the choosier sex. However, males typically show some mate preferences, which are increasingly reported. Here we document previously uncharacterized male courtship behavior (effort and song) and cuticular hydrocarbon (CHC) profiles in the hybridizing crickets Gryllus firmus and G. pennsylvanicus. These two species exhibit multiple barriers to gene exchange that act throughout their life history, including a behavioral barrier that results in increased time to mate in heterospecific pairs.

Development And Characterization Of 10 Microsatellite Markers In
Sagina Nodosa (Caryophyllaceae)

Singh, T. '12, Edwards, J. and Maroja, L.S. In Print.

Applications in Plant Sciences 2(1): 1300064, 2014

Premise of the study: We developed 10 novel microsatellite loci for Sagina nodosa, a diploid perennial arctic-alpine herb. To our knowledge, these are the first microsatellite loci for a Sagina species. Methods and Results: We performed a low-coverage 454 next-generation sequencing of enriched genomic fragments derived from one individual to generate a massive library of contigs containing potential polymorphic microsatellites. We present data for 10 novel polymorphic microsatellite loci containing di-, tri-, tetra-, and

hexanucleotide repeats with two to nine alleles per locus assessed in 29 individuals. Conclusions: These polymorphic microsatellite loci in S. nodosa will provide insights on the population structure and life history of S. nodosa in Isle Royale and other North American populations.

Barriers to Gene Exchange in Hybridizing Field Crickets:
The Role of Male Courtship Effort and Cuticular Hydrocarbons

Luana S. Maroja, *Zachary.M. McKenzie '14*, *Elizabeth Hart '14*, *Joy Jing '13*,
Erica L. Larson, and *David P. Richardson*

BMC Evolutionary Biology, **14**:65, 2014.

Pre-zygotic barriers often involve some form of sexual selection, usually interpreted as female choice, as females are typically the choosier sex. However, males typically show some mate preferences, which are increasingly reported. Here we document previously uncharacterized male courtship behavior (effort and song) and cuticular hydrocarbon (CHC) profiles in the hybridizing crickets Gryllus firmus and G. pennsylvanicus. These two species exhibit multiple barriers to gene exchange that act throughout their life history, including a behavioral barrier that results in increased time to mate in heterospecific pairs.

Small heat shock proteins are necessary for heart migration and
laterality determination in zebrafish Jamie

L. Lahvic '10, Yongchang Ji, *Paloma Marin '12, Jonah P. Zuflacht '11, Mark W. Springe '12, Jonathan E. Wosen '13,* Leigh Davis, Lara D. Hutson, Jeffrey D. Amack, *Martha J. Marvin*

Developmental Biology. 384 (2013) 166180.

Small heat shock proteins (sHsps) regulate cellular functions not only under stress, but also during normal development, when they are expressed in organ-specific patterns. Here we demonstrate that two small heat shock proteins expressed in embryonic zebrafish heart, hspb7 and hspb12, have roles in the development of left–right asymmetry. In zebrafish, laterality is determined by the motility of cilia in Kupffer's vesicle (KV), where hspb7 is expressed; knockdown of hspb7 causes laterality defects by disrupting the motility of these cilia. In embryos with reduced hspb7, the axonemes of KV cilia have a 9þ0 structure, while control embyros have a predominately 9þ2 structure. Reduction of either hspb7 or hspb12 alters the expression pattern of genes that propagate the signals that establish left–right asymmetry: the nodal-related gene southpaw (spaw) in the lateral plate mesoderm, and its downstream targets pitx2, lefty1 and lefty2. Partial depletion of hspb7 causes concordant heart, brain and visceral laterality defects, indicating that loss of KV cilia motility leads to coordinated but randomized laterality. Reducing hspb12 leads to similar alterations in the expression of downstream laterality genes, but at a lower penetrance. Simultaneous reduction of hspb7 and hspb12 randomizes heart, brain and visceral laterality, suggesting that these two genes have partially redundant functions in the establishment of left–right asymmetry. In addition, both hspb7 and hspb12 are expressed in the precardiac mesoderm and in the yolk syncytial layer, which supports the migration and fusion of mesodermal cardiac precursors. In embryos in which the reduction of hspb7 or hspb12 was limited to the yolk, migration defects predominated, suggesting that the yolk expression of these genes rather than heart expression isresponsible for the migration defects.

Oxyntomodulin increases intrinsic heart rate through the glucagon receptor

Mukharji, A. '07, Drucker, DJ., Charron, MJ., *Swoap, SJ.*

Physiological Reports (2013). doi: 10.1002/phy2.112

Two hormones from the gastrointestinal tract, glucagon and oxyntomodulin (OXM), vigorously elevate the intrinsic heart rate (I_{HR}) of mice. We have previously shown that OXM influences murine heart rate (HR) independent of the glucagon-like peptide 1 (GLP-1) receptor. Here, we demonstrate using radiotelemetry in mice deficient in the glucagon receptor (*Gcgr* –/–) that both OXM and glucagon require the glucagon receptor for their chronotropic effects on the heart. Furthermore, we found that other hormones associated with hunger and satiety (ghrelin, leptin, and PYY_{3-36}) had no effect on I_{HR}, while cholecystokinin moderately

elevated the I_{HR}. Finally, the resting HR of *Gcgr* −/− mice was higher than in control mice (*Gcgr* +/+ and *Gcgr* +/−) at thermal neutral temperature (30°C). Using atropine, we demonstrated that *Gcgr* −/− mice have diminished parasympathetic (PNS) influence of the heart at this temperature. *Gcgr* −/− mice displayed a normal bradycardia as compared to controls in response to administration of either methacholine (to activate the muscarinic acetylcholine receptor) or methoxamine (to activate the baroreflex through agonism of the α1 adrenergic receptor agonist) suggesting that vagal pathways are intact in the *Gcgr* −/− mice. As OXM is an agonist of the GLP-1 receptor and Gcgr with antidiabetic activity, we suggest OXM may be an alternative to glucagon in the treatment of overdose of beta-blockers to elevate HR in clinical conditions.

A hindbrain segmental scaffold specifying neuronal location in the adult goldfish, Carassius auratus

E. Gilland, H. Straka, *T.W. Wong '07*, R. Baker, *S.J. Zottoli*

Journal of Comparative Neurology 522:2446–2464

The vertebrate hindbrain develops as a series of well-defined neuroepithelial segments or rhombomeres. While rhombomeres are visible in all vertebrate embryos, generally there is not any visible segmental anatomy in the brains of adults. Teleost fish are exceptional in retaining a rhombomeric pattern of reticulospinal neurons through embryonic, larval, and adult periods. We use this feature to map more precisely the segmental imprint in the reticular and motor basal hindbrain of adult goldfish. Analysis of serial sections cut in three planes and computer reconstructions of retrogradely labeled reticulospinal neurons yielded a segmental framework compatible with previous reports and more amenable to correlation with surrounding neuronal features. Cranial nerve motoneurons and octavolateral efferent neurons were aligned to the reticulospinal scaffold by mapping neurons immunopositive for choline acetyltransferase or retrogradely labeled from cranial nerve roots. The mapping corresponded well with the known ontogeny of these neurons and helps confirm the segmental territories defined by reticulospinal anatomy. Because both the reticulospinal and the motoneuronal segmental patterns persist in the hindbrain of adult goldfish, we hypothesize that a permanent "hindbrain framework" may be a general property that is retained in adult vertebrates. The establishment of a relationship between individual segments and neuronal phenotypes provides a convenient method for future studies that combine form, physiology, and function in adult vertebrates.

Chemistry

Physical Chemistry for the Chemical Sciences

Raymond Chang and John W. Thoman, Jr.

University Science Books, Mill Valley, CA, 2014.

(2*S*,5*R*)-2,5-Dimethyl-1,4-bis(pyridin-2-ylmethyl)piperazine

Christopher Goh, *Lilliana Morris '14*, *Michael Girouard '13*, *Tamuka Chidanguro '15*, and J.P. Jasinski

Acta Crystallographica Section E, Structure Reports Online, E69m o1101, 2013.

Multidentate ligands containing pyridine and amine donor moieties have applications in metal-catalyzed oxidations and in the design of macrocyclic metal-binding receptors. Our group has been interested in the use of neutral tetradentate hetero-aromatic-amine ligands in metal-catalyzed oxidations. Here we report the synthesis and crystal structure of the meso form of the tetradentate ligand (2*S*,5*R*)-2,5-dimethyl-1,4-bis(pyridin-2-ylmethyl)-piperazine.

Epoxidation of Alkenes Bearing a Carboxylic Acid Group by Iron Complexes of the Tetradentate Ligand N,N'-dimethyl-N,N'-bis(2-pyridylmethyl)-1,2-diaminoethane and its Derivatives

Lilliana Morris '14, *Michael Girouard '13*, *Matthew Everhart '11*, *William McClain '10*, J.A. van Paridon, R.D. Pike, and *Christopher Goh*

Inorganica Chimica Acta, 413C, 149-159, 2014.

The addition of carboxylic acids enhances the rate and selectivity of alkene oxidations catalyzed by [(bpmen)Fe(OTf)$_2$] (bpmen = *N*,*N*'-dimethyl-*N*,*N*'-bis(2-pyridylmethyl)-1,2-diaminoethane). The syntheses and characterizations of four derivatives of this iron complex with varying substitutions on the pyridine ring and with a substituted piperazine backbone are reported. These [(L)Fe(OTf)$_2$] complexes and [(bpmen)Fe(OTf)$_2$] are employed as catalysts for the oxidation of alkenes bearing a carboxylic acid functional group, namely oleic acid, undecylenic acid, 5-hexenoic acid and 4-pentenoic acid, with hydrogen peroxide as the oxidant. Comparisons with the analogous ester substrates demonstrate the beneficial impact of the acid functional group on conversion and selectivity when using [(bpmen)Fe(OTf)$_2$] as a catalyst. For the oleic and undecylenic acids, epoxide product is formed with moderate to high conversions and high selectivities. Under the conditions employed, 4-pentenoic acid is oxidized to a γ-lactone, most likely via the epoxide intermediate, and 5-hexenoic acid to a mixture of epoxide and δ-lactone. Of the iron complexes with bpmen derivatives as ligands, only the *N*,*N*'-dimethyl-*N*,*N*'-bis(5-chloropyridin-2-ylmethyl)-1,2-diaminoethane variant shows appreciable activity. The effect of solvent choice is also investigated.

Polymer Chemistry in an Undergraduate Curriculum

Sarah L. Goh

ACS Symposium Series, 1151, 113-127, 2013.

The multi-disciplinary applications that polymers have in biology, chemistry, medicine, and materials science make them ideal vehicles for teaching. They serve as familiar, real-world examples and help to reinforce concepts and reaction mechanisms while introducing developments in current chemical research. Examples of polymer-related topics and concepts are presented for use in introductory and intermediate organic courses.

Reconstructing Paleoenvironments in the Western Desert, Egypt: ESR Dating Freshwater Molluscs from Kharga Oasis

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Archaeological Chemistry VII, ACS Symposium Series, 321-364, 2013.

At Kharga Oasis in Egypt's hyperarid Western Desert, the escarpment today lacks naturally occurring surface water. Near Kharga, large tufa deposits ranging from a few hectares to more than 10 km^2 in area, such as Midauwara, Matana, and Bulaq, dot the edge of the Libyan Plateau. The tufas and lacustrine sediment record several moist intervals during the Pleistocene, when wetlands, ponds, and small freshwater lakes provided water to enable herbivore and human habitation. Along with Pleistocene fossils, archaeological finds in the area include artifacts from Early Stone Age, Middle Stone Age, Aterian, Later Stone Age, and younger cultures lying in gravel lags, within sedimentary deposits, and on the older geomorphic surfaces. Standard ESR analysis was used to date freshwater mollusc shells (*Melanoides tuberculata* and *Gyraulus*) found in tufas and lake silts at Wadi Midauwara, Metana, and Bulaq. In some units, multiple gastropod populations from different times have been preserved as a mixed deposit, while several others appear to only preserve a single population. Snail dates suggest that fresh water existed sporadically at Bulaq and Matana during Marine (Oxygen) Isotope Stages (MIS) 2 and 4, and at Midauwara during MIS 7 and 5-2, as well as during the earliest Pleistocene, at ~ 2.4 ± 0.4 Ma, which could have enabled the first hominin migration out of Africa via the Western Desert.

Computer Science

Combined Heat and Privacy: Preventing Occupancy Detection from Smart Meters

Dong Chen, David Irwin, Prashant Shenoy, and *Jeannie Albrecht*

Proceedings of the Twelfth IEEE Conference On Pervasive Computing and Communications (PerCom), March 2014.

Electric utilities are rapidly deploying smart meters that record and transmit electricity usage in real-time. As prior research shows, smart meter data indirectly leaks sensitive, and potentially valuable, information about a home's activities. An important example of the sensitive information smart meters reveal is occupancy -whether or not someone is home and when. As prior work also shows, occupancy is surprisingly easy to detect, since it highly correlates with simple statistical metrics, such as power's mean, variance, and range. Unfortunately, prior research that uses chemical energy storage, e.g., batteries, to prevent appliance power signature detection is prohibitively expensive when applied to occupancy detection. To address this problem, we propose preventing occupancy detection using the thermal energy storage of large elastic heating loads already present in many homes, such as electric water and space heaters. In essence, our approach, which we call Combined Heat and Privacy (CHPr), controls the power usage of these large loads to make it look like someone is always home. We design a CHPr-enabled water heater that regulates its energy usage to mask occupancy without violating its objective, e.g., to provide hot water on demand, and evaluate it in simulation and using a prototype. Our results show that a 50-gallon CHPr-enabled water heater decreases the Matthews Correlation Coefficient (a standard measure of a binary classifier's performance) of a threshold-based occupancy detection attack in a representative home by 10x (from 0.44 to 0.045), effectively preventing occupancy detection at no extra cost.

Prototype Support Vector Machines: Supervised Classification in Complex Datasets

April Shen '13 and *Andrea Danyluk*

COPEM at ECML/PKDD, 2013.

Classifier learning generally requires model selection, which in practice is often an ad hoc and time-consuming process that depends on assumptions about the structure of data. To avoid this difficulty, especially in real-world data sets where the underlying model is both un-known and potentially complex, we introduce the ensemble of prototype support vector machines (PSVMs). This algorithm trains an ensemble of linear SVMs that are tuned to different regions of the feature space and thus are able to separate the space arbitrarily, reducing the need to decide what model to use for each dataset. We present experimental results demonstrating the efficacy of PSVMs in both noiseless and noisy datasets.

Computer Science Curricula 2013

ACM/IEEE-CS Joint Task Force on Computing Curricula (17 authors including *Andrea Danyluk*)

ACM Press and IEEE Computer Society Press, 2013.

ACM and IEEE-Computer Society have a long history of sponsoring efforts to establish international curricular guidelines for undergraduate programs in computing on roughly a ten-year cycle, starting with the publication of Curriculum 68 over 40 years ago. This volume is the latest in this series of curricular guidelines and represents a comprehensive revision. The CS2013 guidelines include a redefined body of knowledge, a result of rethinking the essentials necessary for a Computer Science curriculum. It also seeks to identify exemplars of actual courses and programs to provide concrete guidance on curricular structure and development in a variety of institutional contexts.

RedCard: Redundant Check Elimination for Dynamic Race Detectors

Cormac Flanagan and *Stephen N. Freund*

European Conference on Object-Oriented Programming, 2013.

Precise dynamic race detectors report an error if and only if an observed program trace exhibits a data race. They must typically check for races on all memory accesses to ensure that they catch all races and generate no spurious warnings. However, a race check for a particular memory access is guaranteed to be redundant if the accessing thread has already accessed that location within the same release-free span. A release-free span is any sequence of instructions containing no lock releases or other "release-like" synchronization operations, such as wait or fork.

We present a static analysis to identify redundant race checks by reasoning about memory accesses within release-free spans. In contrast to prior whole program analyses for identifying accesses that are always race-free, our redundant check analysis is span-local and can also be made method-local without any major loss in effectiveness. RedCard, our prototype implementation for the Java language, enables dynamic race detectors to reduce the number of run-time checks by close to 40% with no loss in precision.

We also present a complementary shadow proxy analysis for identifying when multiple memory locations can be treated as a single location by a dynamic race detector, again with no loss in precision. Combined, our analyses reduce the number of memory accesses requiring checks by roughly 50%.

Planar and Plane Slope Number of Partial 2-Trees

William Lenhart, Giuseppe Liotta, Debajyoti Mondal, and Rahnuma Islam Nishat

Twenty-First International Symposium on Graph Drawing, Bordeaux, France, September 2013

We prove tight bounds (up to a small multiplicative or additive con- stant) for the plane and the planar slope numbers of partial 2-trees of bounded degree. As a byproduct of our techniques, we answer a long standing question by Garg and Tamassia about the angular resolution of the planar straight-line drawings of series-parallel graphs of bounded degree.

Bar 1-Visibility Graphs and their relation to other Nearly Planar Graphs

W. Evans, M. Kaufmann, *W. Lenhart*, G. Liotta, T. Mchedlidze, and S. Wismath

Submitted for publication

A graph is called a strong (resp. weak) bar 1-visibility graph if its vertices can be represented as horizontal segments (bars) in the plane so that its edges are all (resp. a subset of) the pairs of vertices whose bars have a ε-thick vertical line connecting them that intersects at most one other bar. We explore the relation among weak (resp. strong) bar 1-visibility graphs and other nearly planar graph classes. In particular, we study their relation to 1-planar graphs, which have a drawing with at most one crossing per edge; quasi-planar graphs, which have a drawing with no three mutually crossing edges; the squares of planar 1-flow networks, which are upward digraphs with in- or out-degree at most one. Our main results are that 1-planar graphs and the (undirected) squares of planar 1-flow networks are weak bar 1-visibility graphs and that these are quasi-planar graphs.

A Survey of Efficient Representations for Independent Unit Vectors

Z. Cigolle '12, *S. Donow '16*, *D. Evangelakos '15*, *M. Mara '12*, *M. McGuire*, and Q. Meyer

The Journal of Computer Graphics Techniques, 3(2), 2014, http://jcgt.org/published/0003/02/01/

The bandwidth cost and memory footprint of vector buffers are limiting factors for GPU rendering in many applications. This article surveys time- and space-efficient representations for the important case of non-register, in-core, statistically independent unit vectors, with emphasis on GPU encoding and decoding. These representations are appropriate for unit vectors in a geometry buffer or attribute stream - where no correlation between adjacent vectors is easily available - or for those in a normal map where quality higher than that

of DXN is required. We do not address out-of-core and register storage vectors because they favor minimum-space and maximum-speed alternatives, respectively.

We evaluate precision and its qualitative impact across these techniques and give CPU reference implementations. For those methods with good quality and reasonable performance, we provide optimized GLSL GPU implementations of encoding and decoding.

Order-Independent Blended Transparency

M. McGuire and L. Bavoil

The Journal of Computer Graphics Techniques, 2(2), 2013, http://jcgt.org/published/0002/02/09/
(1st Place, I3D 2014 Best Presentation Awards)

Many rendering phenomena can be modeled with partial coverage. These include flames, smoke, hair, clouds, properly-filtered silhouettes, non-refractive glass, and special effects such as forcefields and magic. A challenge in rendering these is that the value of pixel partly covered by multiple surfaces depends on the depth order of the surfaces. One approach to avoid the cost of storing and sorting primitives or fragments is to alter the compositing operator so that it is order independent, thus allowing a pure streaming approach.

We describe two previous methods for implementing blended order-independent transparency, and then introduce two new methods derived from them. Both new methods guarantee correct coverage of background and strictly improve color representation over the previous methods. Because these require only classic OpenGL-style blending and bounded memory, they may be preferred to A-buffer like methods for mobile devices, consoles, and other constrained rendering environments. They are attractive for all platforms for models such as particle systems and hair, where discrete changes in surface ordering that will be perceived as popping are undesirable and a soft transition between surfaces is preferred.

A Fast and Stable Feature-Aware Motion Blur Filter

J. Guertin, *M. McGuire*, and D. Nowrouzezahrai

ACM SIGGRAPH / Eurographics High Performance Graphics, June, 2014

High-quality motion blur is an increasingly important and pervasive effect in interactive graphics that, even in the context of offline rendering, is often approximated using a post process. Recent motion blur post-process filters (e.g., [MHBO12, Sou13]) efficiently generate plausible results suitable for modern interactive rendering pipelines. However, these approaches may produce distracting artifacts, for instance, when different motions overlap in depth or when both large- and fine-scale features undergo motion. We address these artifacts with a more robust sampling and filtering scheme that incurs only small additional runtime cost. We render plausible,
temporally-coherent motion blur on several complex animation sequences, all in just 3ms at a resolution 1280x720. Moreover, our filter is designed to integrate seamlessly with post-process anti-aliasing and depth of field.

Geosciences

The Early Rhuddanian Survival Interval in the Lower Silurian of the Oslo Region: A Third Pulse of the End-Ordovician Extinction

B. G. Baarli

Palaeogeography, Palaeoclimatology, Palaeoecology 395, 29-41, 2014

Ordovician/Silurian boundary layers with Rhuddanian strata are exposed as a long, continuously fossiliferous sequence in the Solvik Formation in the Asker area, central Oslo Region, Norway. Brachiopods belonging to Benthic Assemblage 5 are preserved in the lower parts of the formation. This level is investigated for the presence of a survival interval after the last end-Ordovician extinction event. The criteria for a survival

interval include taxa that are dwarfed, long ranging, eurytopic, often opportunistic, as well as assemblages that show low density and diversity. Four species, *Isorthis prima*, *Leangella scissa*, *Dicoelosia osloe*nsis and *Eoplectodonta duplicata*, were collected and measured. The three former were dwarfed compared to a younger Aeronian fauna belonging to the same Benthic Assemblage. Detailed investigations showed a statistically significant two-step reduction in size for all but *D. osloensis*. The first interval, immediately above the last end-Ordovician extinction event, displays dwarfed brachiopods, but diversity is high and the number of long-ranging and eurytopic species is low due to the presence of globally and locally "relict" Ordovician species. The second interval, the upper parts of lower Rhuddanian, shows all the characteristics of a survival interval in which the sizes are statistically significantly smaller than both those in the interval below and those in the Aeronian interval above. No lithological change within lower Rhuddanian strata could be linked to the pronounced reduction in size. The second step in size reduction may be related to global occurrence of anoxia in the deep oceans with a pulse of anoxic water pushed onto the shelf at that time. It is coeval with a short negative $\partial_{13}C$ excursion found in some locales, signifying a brief period of global warming. The results suggest a protracted extinction event through parts of the early Rhuddanian and a third and final extinction event followed by a clear survival interval.

Embankment of Middle Miocene Carbonates on an Active Volcanic Slope: Ilhéu de Baixo, Madeira Archipelago, Eastern Atlantic

B. G. Baarli, M. Cachão, C.M. da Silva, *Markes E. Johnson*, E.J. Mayoral, and A. Santos

Geological Journal 49, 90-106, 2014

Carbonate factories on insular oceanic islands in active volcanic settings are poorly explored. This case study illuminates marginal limestone deposits on a steep volcanic flank and their recurring interruption by deposits linked to volcaniclastic processes. Historically known as Ilhéu da Cal (Lime Island), Ilhéu de Baixo was separated from Porto Santo, in the Madeira Archipelago, during the course of the Quaternary. Here extensive mines were tunneled in the Miocene carbonate strata for the production of slaked lime. Approximately 10,000 m^3 of calcarenite (-1 to 1ø) was removed by hand labour from the Blandy Brothers mine at the south end of the islet. Investigations of two stratigraphic sections at opposite ends of the mine reveal that the quarried material represents an incipient carbonate ramp developed from east to west and embanked against the flank of a volcanic island. A petrographic analysis of limestones from the mine shows that coralline red algae from crushed rhodoliths account for 51% of all identifiable bioclasts. This material was transported shoreward and deposited on the ramp between normal wave base and storm wave base at moderate depths. The mine's roof rocks are formed by Surtseyan deposits from a subsequent volcanic eruption. Volcaniclastic density flows also are a prevalent factor interrupting renewed carbonate deposition. These flows arrived downslope from the north and gradually steepened the debris apron westwards. Slope instability is further shown by a coral rudestone density flow that followed from growth of a coral reef dominated by Pocillopora madreporacea (Lamarrck), partial reef collapse, and transport from a more easterly direction into a fore-reef setting. The uppermost facies represents a soft bottom at moderate depths in a quiet, but shore-proximal setting. Application of this study to a broader understanding of the relationship between carbonate and volcaniclastic deposition on oceanic islands emphasizes the susceptibility of carbonates to dilution and complete removal by density flows of various kinds, in contrast to the potential for preservation beneath less-disruptive Surtseyan deposits.

Progress And Challenges In Assessing Proterozoic Eukaryotic Diversity

Phoebe Cohen

Geological Society of America Abstracts with Programs 45 (7),185, 2013

Over the past half-century, the number of fossils described from Proterozoic rocks has increased exponentially. These discoveries have occurred alongside an increased understanding of the dynamics of the rest of Proterozoic Earth system. The fleshing out of the Proterozoic record has allowed us to begin to form hypoth-

esis about the relationships between abiotic and biotic events, including "Snowball Earth", dramatic changes in the redox state of global oceans, and the rise of metazoans. However, these efforts are hampered by our lack of an adequate understanding of the myriad factors that lead to fossil diversity in the Proterozoic rock record. Here, I will attempt to quantitatively and qualitatively address the biases present in the Proterozoic fossil record of eukaryotes and present new data compilations of eukaryotic fossil diversity.

The past decades have seen significant progress towards a view of Phanerozoic marine diversity that takes into consideration various potential biases such as sampling, rock volume, and preservation, enabling us to begin to answer essential questions about the Earth-life system. Such interpretations are not yet possible in the Proterozoic, where we face specific challenges when attempting to analyzing diversity, including the relative paucity of exposed strata, the lack of a large amount of fossil data to create statistically significant correlations, fossil specimens with few taxonomically meaningful character traits, and the challenges of "telling time" in a world with little meaningful biostratigraphy.

In order to move towards a more comprehensive view of the Proterozoic Earth system, I have dissected the current Proterozoic fossil record of eukaryotes in an attempt to account for major biases. Initial analyses show that assemblage changes through Proterozoic are robust, as is an increase in the number of functional groups and modes of recalcitrance. Overall, there is an increasea in both alpha and beta diversity through the Proterozoic, however, smaller-scale patterns are difficult to discern through the lens of lithological, taphonomic, and geographic biases. Further quantifying and addressing these biases will be an essential step towards future paleontological and geobiological work in the Proterozoic.

Productivity, Ventilation and Oxygenation in the North-Central Bering Sea During the Last Deglaciation

Mea S. Cook, A. Christina Ravelo, Beth E. Caissie, Jason A. Addison, and Jennifer E. Kusler

American Geophysical Union Meeting Online, 2013

During the last deglaciation, the oxygen minimum zone (OMZ) in the North Pacific intensified, resulting in laminated and dysoxic continental margin sediments at intermediate depths from the Gulf of California to Japan. The ventilation of North Pacific Intermediate Water can cause basin-wide changes in OMZ intensity, but increased export productivity near intermediate-water formation areas can also affect the North Pacific OMZ by decreasing oxygen concentrations of recently-formed water, decoupling ventilation from oxygenation. There is evidence that both productivity and ventilation of the subarctic Pacific changed at millennial time scales during the deglaciation. Both processes could have impacted the oxygenation of subsurface water originating in the North Pacific and the basin-wide OMZ. We studied IODP Site U1345, from 1000 meters water depth on the continental slope of the Bering Sea, and a nearby piston core, HLY02-02- 3JPC. High terrigenous sediment fluxes result in an expanded deglacial sequence, with millimeter-scale annual laminations during the Bolling-Allerod (BA) and early Holocene. We measured benthic and planktonic foraminiferal radiocarbon, paleoproductivity proxies, and bulk sediment δ15N to reconstruct the local production and ventilation history in this marginal sea. During the early deglaciation, there is a convergence of benthic and planktonic radiocarbon ages, accompanied by a minimum of d15N and increasing productivity. This suggests there were episodes of convection to at least 1000 m, accompanied by greater major nutrient supply to the surface ocean and lower utilization. During the BA, the water column at 1000 m was enriched in radiocarbon compared to today, but with no evidence of local convection. From the BA through the early Holocene, laminated, high productivity, high δ15N sediments alternate with massive, lower productivity, low δ15N sediments, but the benthic-planktonic radiocarbon age differences are stationary. If we assume that changes in surface reservoir age are not masking ventilation-driven changes in radiocarbon at 1000 m, then it appears that ventilation is not a major driver of oxygenation. Rather, the subarctic Pacific OMZ appears strongly linked to stratification, surface nutrient supply and productivity.

Movie "Man of Aran" as a Documentary Source for Studying Boulder Transport by Storm Waves

Rónadh Cox

Geological Society of America Abstracts with Programs 45 (7), 52, 2013

The Aran Islands, off Ireland's west coast, are exposed to strong Atlantic storms but have not been subject to tsunami activity in recent centuries. Their coastal boulder deposits therefore preserve an excellent record of the effects of large storm waves on decadal to millennial timescales. But although regional studies show large-scale patterns of sedimentation, it is difficult to pinpoint specific transportation events, and in particular to document the motions of very large boulders (masses several 10s of tonnes). Archival imagery can help bridge that gap.

Between 1931 and 1933 Robert Flaherty shot the classic film "Man of Aran" on Inishmore, the largest of the three Aran Islands, depicting island life and showcasing the rocky Atlantic coast with its battering storm waves. Eighty years later, his footage provides a documentary pinning point for analysing large-boulder movements. Fifteen minutes into the film, Flaherty shows his characters working their way homeward across a coastal limestone platform among the boulder piles. The area is identifiable as being near the Grí Óir at the western end of Inishmore. In 2012 it was possible to find the exact location where Flaherty positioned his camera and re-take the same shots. Comparison of photographs taken in June 2012 with frames from the movie reveals substantial rearrangement of the coastal boulder clusters and addition of new blocks.

Boulders up to 61 tonnes weight have been added to the coastal boulder deposit since 1933, at 6 m above highest high tide (11.2 m o.d.), and 45 m inland from the high water mark. The minimum force required to transport rocks of this mass (based on equations of Hansom et al. 2008, *Marine Geology* v. 253, p. 36-50) would be provided by a bore 7.5 m thick travelling at 8.6 m/s.

This result underscores the usefulness of historical imagery in chronicling the effects of storms on decadal to centennial time scales. It dovetails with previous work showing that Aran Islands boulder ridges have migrated since the mid-19th C, but is the first photo-documentation of specific coarse-boulder movements in Ireland in the 20th century.

Through the Ice, Exposing the Ocean: Impact Breakthrough Parameters for Europa

Rónadh Cox and Aaron Bauer '11

Large Meteorite Impacts and Planetary Evolution V Conference (hou.usra.edu/meetings/sudbury2013/pdf/3091.pdf), 2013

The idea that impacts could deposit organic and other compounds on Europa's surface is well established, but whether and how these materials might be transported to a subsurface ocean remains in question. Previous studies have shown that Europa's ice shell is vulnerable to impact breaching, and this analysis quantifies the conditions under which impacts might penetrate to water. Impact exposure of the ocean would provide a conduit for surface-subsurface exchange of biogenic materials. We used the iSALE hydrocode to model ice overlying water. We simulated ice thicknesses (T) from 1-40 km to cover the range of likely values for Europa. Impactors were ice spheres of density 910 kg/m^3. Median impact velocity at Europa is about 26 km s^{-1}, but since high impact velocities require smaller time steps, we ran simulations at lower velocity (15 km s^{-1}) and scaled projectile size to produce the energies of interest. Impactor diameters (26 km s^{-1} equivalent) ranged from 200-5000 m. Craters form when the ratio between impact energy and ice thickness is small (in thick ice or for small impactors). But as energy increases, transient crater depths (d_t) approach the ice-water contact. Surface-to-ocean communication occurs when the full ice thickness is melted or vapourised. The transition from non-penetrating craters to ocean-exposing melt-through events comes at $d_t \approx 0.8T$, where post-impact melting and rebound of the sub-crater ice combine to produce a surface-to-ocean water column; so we take $d_t = 0.8T$ AS the breakthrough criterion. The upper limit on crater size at Europa depends on ice thickness. For ice 40 km thick, the largest possible non-penetrating crater has transient diameter (D_t)

≈80 km, which would produce a final diameter ≈160 km: there are no craters of this size on Europa. For 20 km ice, the upper limit for a crater-producing event is $D_t \approx 40$ km, which is close to the estimated D_t for Europa's largest mapped craters. This may be telling us that the likely ice thickness on Europa is in the 15-20 km range, which lines up with results from other lines of evidence. All ice thicknesses tested are subject to full penetration by impactors with geologically short return times at Europa. The return time for a 5-km diameter cometary impact (100-km crater) is about 50 m.y. Such an object impacting 40 km-thick ice at 26.5 km s^{-1} produces d_t 38 km deep, with subsequent melt-through to ocean. For ice 10-20 km thick, the breakthrough criterion is met by impactors 0.8-2 km diameter (return times 3-15 million years). Most estimates for Europa's ice thickness are in the 10-20 km range, so we expect that Europa's ice can be breached on timescales of 10^6- 10^7 m.y. Impact penetration to liquid has been proposed to explain features of Callanish and Tyre, Europa's largest craters; and also as a mechanism for forming chaos terrane. Our numerical models support these interpretations and suggest a need to consider impact breakthrough as a geomorphic process on Europa. Exposure of the ocean via impact represents a protracted opportunity for transfer of materials into the subsurface realm because refreezing is estimated to take 10^5-10^6 years. Although mass delivered by the hole-forming impactor is unlikely to end up in the ocean, ejecta from subsequent impacts might well land on its receptive, still molten surface. Cometary organic matter can survive and be retained by Europa's gravity field; such material, released and impelled by subsequent impacts elsewhere on the moon, might fall onto older but incompletely frozen impact sites, and thence into the subsurface ocean.

Basins and Bedrock: Spatial Variation in ^{10}Be Erosion Rates and Increasing Relief in the Southern Rocky Mountains, USA

David P. Dethier, William B. Ouimet '01, Paul R. Bierman '85, Dylan H. Rood, *Greg Balco '92*

Geology 42 (2) 167–170, 2014

We used measurements of cosmogenic ^{10}Be in alluvium to estimate erosion rates on a 10^3-10^4-year timescale for small (0.01-47 km^2), unglaciated basins in northern Colorado, southern Wyoming and adjacent western Nebraska. Basins formed in Proterozoic cores of Laramide ranges are eroding more slowly (23 ± 7 mm kyr^{-1}, n = 20) than adjacent basins draining weakly lithified Cenozoic sedimentary rocks (69 ± 31 mm kyr^{-1}, n = 20). Erosion rates show a relationship to rock resistance and, for a given rock type, to basin slope, but not to mean annual precipitation. We also sought to estimate longer-term (> 10^5-year time scale) erosion rates for the granitic core of the Front Range by measuring the concentration of ^{10}Be and ^{26}Al produced mainly by muon interactions at depths 1.7-10 m below the surface. Concentrations imply erosion rates of 10-40 mm kyr^{-1}, similar to shorter-term erosion rates inferred from surface sediment. The spatial distribution of erosion rates taken with stratigraphic evidence imply that relief in the southern Rocky Mountains increased in the late Cenozoic; modern relief probably dates from post-middle Miocene time.

Critical Zone Evolution: Climate and Exhumation in the Colorado Front Range

Anderson, S.P., R. S. Anderson, G.E. Tucker, and *D. P. Dethier*

Geological Society of America Field Guide 33, 1–18, 2013

The architecture of the critical zone—the distribution of mobile regolith, the thickness of weathered rock, and their characteristics, as well as the topography of the land surface—is shaped by erosion and weathering processes that depend upon both lithology and climate. In this trip we explore the Boulder Creek watershed, a landscape that juxtaposes uplifted Precambrian crystalline rocks of Colorado's Front Range against Mesozoic marine sedimentary rocks underpinning the western edge of the High Plains. The landscape is strongly shaped by Quaternary climate cycles operating on this template inherited from the Laramide orogeny. Stop 1 will provide an overview of the abrupt topographic step at the Front Range–High Plains join, where we will discuss fluvial strath terraces on the Plains. At Stop 2 in Betasso Preserve, we will discuss the impact of the canyon cutting set off by late Cenozoic exhumation of the High Plains on the hillslopes and groundwater systems lining the master stream. At Stop 3, we will hike 2 miles down Gordon Gulch, a focus

site in the Boulder Creek Critical Zone Observatory. At stops on the hike, we will discuss exhumation rates, climate-modulated weathering, hillslope hydrology and hillslope sediment transport, and the influence of slope aspect on these processes. Our goal is to focus on the history of climate-driven erosion and weathering processes, and how to incorporate these processes into quantitative models of landscape evolution.

Transient Hillslopes and the Legacy of Climate in the Colorado Front Range

Neil Shea, *William B. Ouimet '01, David P. Dethier, Paul R. Bierman '85*, and Dylan H. Rood

Geological Society of America Abstracts with Programs 45 (7), 409, 2013

Hillslope regolith cover provides direct insight to the balance between weathering, sediment production, and the downslope transport of mobile material. Climate plays a crucial role in the regulation of this balance by mediating the vegetative cover of hillslopes and influencing sediment transport processes such as rainsplash and frost heave. Here, we present the results of a systematic study that documents basin-wide variation in mobile regolith thickness and uses inventories of meteoric ^{10}Be to assess the mechanisms and time scales of sediment transport and storage in Gordon Gulch, a mid-elevation watershed in the Colorado Front Range. Gordon Gulch lies within the unglaciated topography of the Front Range believed to be in long-term steady state, despite the current warm climate regime being representative of just 20% of the past 65 ka. This 3.7 km^2 watershed is characterized by soil mantled hillslopes with prominent bedrock outcrops (tors) on ~10% of slopes and intermittent gullying. Analysis of over 200 soil pits indicates mobile regolith thickness, which is defined as the depth to immobile weathered bedrock and/or saprolite, averages 39 cm but displays a wide range (10-200 cm). Mobile regolith cover, meteoric ^{10}Be inventories and soil residence times all increase downslope on north-facing hillslopes, but this trend is absent on south-facing slopes. Meteoric ^{10}Be inventories on low-slope ridgetop locations within Gordon Gulch indicate soil residence times <21 ka. Regolith thickness patterns and meteoric ^{10}Be inventories thus support efficient transport of hillslope material prior to and during the colder climates associated with the end of the last glacial maximum (~21 ka), with transported regolith stored at the bottom of hillslope transects, yet to be excavated by the Gordon Gulch stream. This transient state of hillslope deposition and hillslope-channel decoupling is supported by the presence of alluvial fans and toe-slopes at the base of north-facing slopes, as well as terraces adjacent to the modern stream course. Carbon-14 dates confirm that these features represent Holocene sediment redistribution in the basin (~5-10 ka), most likely the result of hillslope sediment transport associated with episodic events such as wildfire and short-intervals of colder climate.

Fallout Radionuclides in Critical Zone Studies, Front Range, Colorado

William B. Ouimet '01, David P. Dethier, Hannah Mondrach, Neil Shea, James Kaste, and *Paul Bierman '85*

Geological Society of America Abstracts with Programs 45 (7), 409, 2013

Fallout radionuclides meteoric ^{10}Be, ^{137}Cs and ^{210}Pb adhere strongly to mineral and organic matter and are useful for studying sediment transport on hillslopes. Different half-lives and depth-dependent distributions of these isotopes make them useful over different timescales in critical zone studies. Meteoric ^{10}Be is a tracer for late Pleistocene to Holocene processes whereas ^{137}Cs and ^{210}Pb are useful for measuring sediment movement over the past century. Given that these nuclides have different affinities for soil organic material near the soil surface, different depth dependent processes can be evaluated. Here, we discuss meteoric ^{10}Be, ^{137}Cs and ^{210}Pb analyses from over 20 hillslope pits and valley deposits in the Boulder Creek Critical Zone Observatory, Front Range, Colorado. Inventories of meteoric ^{10}Be, ^{137}Cs and ^{210}Pb along steep, hillslope catenas in forested, unburned areas highlight the mobility of soil at both short and long timescales. Meteoric ^{10}Be inventories on hillslope transects increase downslope and highlight the redistribution of the entire mobile regolith column (40 cm, on average) over the last 21 ka. ^{137}Cs and ^{210}Pb data exhibit lower concentrations and inventories within the steepest or foot-slope locations on individual hillslope transects, indicating surface erosion of the upper 5 cm over the last 50 years. The sensitivity of ^{137}Cs and ^{210}Pb concentrations and inventories to shallow soil disturbance is well illustrated by examining soil profiles on burned hillslopes and valley

deposits associated with post-fire erosion and flooding of the 2010 Fourmile Fire. A pair of adjacent, steep hillslope pits, where one represents a location protected from post-fire erosion, shows ~3 cm of truncation in the ^{137}Cs and ^{210}Pb profile and removal of ash-rich surface material enriched in these isotopes. Furthermore, analysis along Fourmile Canyon below these hillslope sites demonstrates that overbank fine grained, ash-rich organic material within post-fire floods deposits is enriched in ^{137}Cs and ^{210}Pb indicating that high levels of these isotopes are being washed far downstream. While the short-lived radionuclides demonstrate that fires trigger sediment transport over the last century, we will use meteoric ^{10}Be analyses to evaluate the role of wildfires in longer-term hillslope evolution.

Soil Geomorphology: Where We Started, What We've Learned and Where We are Headed

David P. Dethier and Peter Birkeland

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Soil geomorphology (SG) and weathering studies in North America probably started with the late 1800s to early 1900s work on mid-continent tills, where soils recorded nonglacial intervals. During WW II, the USGS Military Geology Unit had both geologists and soil scientists working on military problems. Their research after the war, along with that of mid-continent workers, helped define modern SG. In the 1960s, some geology and geography departments added SG. Jenny's 1941 book on soil-forming factors (ClORPT) formed the template for SG. The 1965 USA INQUA meeting showcased SG well. Soil geomorphologists identified geologic vs. pedologic layering (P) in soil profiles, and recognized dust input in all environments. Soil chronosequences (T) have been studied in most climatic regions, so we know how most soils develop with time, climate (Cl), and paleoclimate. Soil catenas (R) also have been studied in many environments, and are useful to assess slope stability. Workers in other fields (neotectonics, archaeology) find SG valuable. New analytical and monitoring techniques over the past 30 years have produced quantitative advances and modeling of soil-forming factors, as well as challenges to SG paradigms. Microbes (O) are far more important in weathering than previously recognized. Laboratory studies of chemical weathering have narrowed the gap between measured field and laboratory rates. Cosmogenic dating, luminescence studies and the ability to analyze milligram quantities of carbon have led to new ways of characterizing soil age. Short-lived isotopes such as ^{137}Cs and ^{210}Pb allow better measurement of soil mixing and erosion rates. Mass spectrometers have improved climate change interpretation using ^{18}O and clumped isotope studies of soil carbonate and organic matter. Application of steady-state functions to soils on slopes has returned a focus to long-term SG studies and generates considerable discussion. One paradigm change is that some soils in arid and semiarid landscapes grow upward by dust accretion, protected by desert pavements. And Arctic and peatland soils are globally significant for terrestrial carbon and CH4 budgets.

SG has moved in the direction that Jenny would be proud to have influenced; it will continue to focus on reconstructing the past and guide short-term studies in the critical zone.

Spatial Variation in ^{10}Be Erosion Rates and Increasing Relief in the Southern Rocky Mountains

David P. Dethier, William B. Ouimet '01, Paul R. Bierman '85, Dylan H. Rood, and *Greg Balco '92*

Geological Society of America Abstracts with Programs 45 (7), 189, 2013

Measurements of cosmogenic ^{10}Be in alluvium imply erosion rates on a 10^3-10^4-year timescale for small (0.01-47 km^2), unglaciated basins in northern Colorado, southern Wyoming and adjacent western Nebraska. Basins that formed in Proterozoic cores of Laramide ranges are eroding more slowly (23 ± 7 mm kyr^{-1}, n = 20) than adjacent basins draining weakly lithified Cenozoic sedimentary rocks (69 ± 31 mm kyr^{-1}, n = 20). Erosion rates are correlated with rock resistance and, for a given rock type, to basin slope, but not to mean annual precipitation. We also estimated longer-term (> 105-year time scale) erosion rates for the granitic

core of the Front Range by measuring the concentration of ^{10}Be and ^{26}Al produced mainly by muon interactions at depths 1.7 to 10 m below the surface. Concentrations imply erosion rates of 10-40 mm kyr^{-1}, similar to shorter-term erosion rates inferred from surface sediment. The spatial distribution of erosion rates taken with stratigraphic evidence imply that relief in the southern Rocky Mountains increased in the late Cenozoic; modern relief probably dates from post-middle Miocene time.

Spatial Variations in Mobile Regolith Thickness, Meteoric ^{10}Be Concentration, and Sediment Storage in the Boulder Creek Critical Zone Observatory: Implications for Landscape Evolution and Hillslope Sediment Transport

Neil Shea, *William B. Ouimet '01, David P. Dethier, Paul R. Bierman '85*, and Dylan H. Rood

Geological Society of America Abstracts with Programs 45 (1), 101, 2013

The Boulder Creek Critical Zone Observatory (BcCZO) aims to understand the history, architecture, and evolution of hillslopes found within the diverse topography and climate regimes of the Colorado Front Range. Here, we present the results of a systematic study which aims to document spatial patterns of mobile regolith thickness, meteoric ^{10}Be concentrations, and sediment storage in the Gordon Gulch watershed of the BcCZO. Gordon Gulch lies within the unglaciated portion of the BcCZO and is hypothesized to be in long-term steady state evolution. This small, 3.7 km^2 watershed is characterized by mixed bedrock-soil mantled hillslopes, with intermittent bedrock outcrops (tors) on ~10% of slopes. Varying fracture spacing and rock strength of the local bedrock, topographic slope and curvature, and hillslope aspect provide distinctive lenses to interpret the evolution of the hillslopes. Our analysis of over 200 soil pits reveals high variability in mobile regolith thickness, which we define as the depth to immobile weathered bedrock and/or saprolite. In general, the mobile regolith cover is thinner on the south-facing slopes than on the north, and a thickening of mobile regolith occurs on the toes of steep north-facing slopes. Furthermore, the upper portion of Gordon Gulch has, on average, greater thicknesses than the lower portions of the watershed. We combine our analysis of regolith thicknesses on hillslopes with mapping of toe-slopes, alluvial fans, stream terraces, and gulley fills to build a sediment budget for the watershed. In addition, meteoric ^{10}Be analysis and carbon-14 dating provide constraints of the age, rates, and timing of sediment transport, storage, and removal from the watershed. Initial meteoric ^{10}Be results indicate that total pit inventories are higher on south-facing hillslopes than on north-facing hillslopes, implying longer residence times on the south-facing hillslopes. These data suggest that erosion and hillslope sediment transport are more efficient on north-facing slopes. This conclusion is supported by our mapping within the lower Gordon Gulch stream valley, which indicates a larger volume of sediment is stored within Holocene alluvial fans and toe-slopes at the base of north-facing slopes than within similar features at the base of south-facing slopes.

Examining the Roles of instructor Pedagogy and Student Motivation and Self-regulation on Student Learning

Katrien van der Hoeven Kraft, *Lisa Gilbert*, Megan Jones, and Jonathan Hilpert

www.narst.org/annualconference/2014_Abstracts.pdf, 8, 2014

Reformed instructional practices clearly provide evidence for learning gains at both the primary, secondary level (National Research Council [NRC], 2005; NRC, 2007) and the post-secondary (Ambrose et al., 2010). And yet, the role the instructor plays in these gains is not well understood, particularly aspects that may not specifically pertain to the content itself. What does the instructor contribute to student learning? Our research has quantified the amount that an instructor contributes to student performance in introductory geology courses, as measured by grades and conceptual learning gains by specifically examining the relationship between student motivation and self-regulation, and classroom pedagogy, something that has received little consistent attention at the college level, and no broad analysis within a single discipline.

Motivation, Classroom Environment, and Learning in Introductory Geology: A Hierarchical Linear Model

Lisa Gilbert, Jonathan Hilpert, Katrien van der Hoeven Kraft, Davide Budd, Megan Jones, Ronald Matheney, David McConnell, Dexter Perkins, Jennifer Stempien, and Karel Wirth

American Geophysical Union Fall Meeting, http://abstractsearch.agu.org/meetings/2013/FM/sections/ED/sessions/ED31C/abstracts/ED31C-0755.html, 2013

Prior research has indicated that highly motivated students perform better and that learning increases in innovative, reformed classrooms, but untangling the student effects from the instructor effects is essential to understanding how to best support student learning. Using a hierarchical linear model, we examine these effects separately and jointly. We use data from nearly 2,000 undergraduate students surveyed by the NSF-funded GARNET (Geoscience Affective Research NETwork) project in 65 different introductory geology classes at research universities, public masters-granting universities, liberal arts colleges and community colleges across the US. Student level effects were measured as increases in expectancy and self-regulation using the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991). Instructor level effects were measured using the Reformed Teaching Observation Protocol, (RTOP; Sawada et al., 2000), with higher RTOP scores indicating a more reformed, student-centered classroom environment. Learning was measured by learning gains on a Geology Concept Inventory (GCI; Libarkin and Anderson, 2005) and normalized final course grade. The hierarchical linear model yielded significant results at several levels. At the student level, increases in expectancy and self-regulation are significantly and positively related to higher grades regardless of instructor; the higher the increase, the higher the grade. At the instructor level, RTOP scores are positively related to normalized average GCI learning gains. The higher the RTOP score, the higher the average class GCI learning gains. Across both levels, average class GCI learning gains are significantly and positively related to student grades; the higher the GCI learning gain, the higher the grade. Further, the RTOP scores are significantly and negatively related to the relationship between expectancy and course grade. The lower the RTOP score, the higher the correlation between change in expectancy and grade. As such, students with low motivation show higher grades and greater learning gains in high RTOP (student-centered) classrooms than in low RTOP ones. These results support the recommendation of student-centered practices in the classroom and consideration of student motivation in our approach to the future of geoscience education.

Geoscience Learning For A Sustainable Future: InTeGrate Hurricane Hazards Module

Lisa Gilbert, Joan Ramage, Joshua Galster, Mary Savina, and David McConnell

Geological Society of America Abstracts with Programs 45(7), 68, 2013

Making the difficult decision to evacuate before a hurricane makes landfall can save lives and property, but unnecessary evacuations can be expensive and cause evacuation fatigue. As part of a national NSF-funded effort to increase interdisciplinary learning for a sustainable future (InTeGrate), we have created a two-week module to help introduce students to the scientific and societal challenges associated with hurricanes. This module explores how hurricanes connect the ocean-atmosphere-terrestrial systems and society. Students evaluate how hurricane hazards and risks have changed with coastal development. In particular, recent data from Hurricanes Sandy, Irene, Katrina, and others are used in the module. Students use data and deal with issues of uncertainty to track historic hurricanes and compare the impacts from different hurricanes. The module culminates in a role-playing activity in which students identify and represent stakeholders facing hypothetical evacuation in their town. While addressing key science literacy principles, the module includes a variety of teaching strategies and is adaptable to a variety of class sizes, course levels, and learning environments.

Developed and tested at three different undergraduate institutions (public research university, private research university, and private liberal arts college), this module is one of many being developed as part of

the InTeGrate project. The InTeGrate project (http://serc.carleton.edu/integrate/index.html) has designed a new model for the development, testing, and dissemination of free, customizable, modular geoscience educational resources that have undergone rigorous testing and can be readily incorporated into a variety of introductory geoscience courses. Over two years, teams develop modules that explicitly address geoscience-related societal challenges, build interdisciplinary problem-solving skills, make use of real geoscience data, and incorporate geoscientific and systems thinking. Modules are reviewed against the InTeGrate design rubric, and piloted and assessed by the module authors in their classrooms.

The Interplay Between Student, Instructor, Motivation And Performance: How Does It All Relate?

Katrien van der Hoeven Kraft, Jonathan Hilpert, David Budd, *Lisa Gilbert*, David McConnell, Dexter Perkins, Karl Wirth, Ann Bykerk-Kauffman, Jennifer Stempien, and Ronald Matheney

Geological Society of America Abstracts with Programs 45 (7), 733, 2013

Two decades of discipline-based education research have consistently shown that learning gains are typically greater in student-centered classrooms than in classes emphasizing traditional lectures. But why? Is it the classroom teaching style or might there also be accompanying changes in student affect (e.g., motivation, learning strategies, metacognition, etc.) that impact learning? To address this question, we applied a hierarchical linear modeling method to a data set of ~1800 student participants across multiple institution types in the NSF-funded GARNET (Geoscience Affective Research NETwork) project. We focused on quantified measures of classroom teaching practices (Reformed Teaching Observation Protocol; RTOP) and students' motivation (value and expectancy) and metastrategies (as measured by the Motivation Strategy and Learning Questionnaire; MSLQ).

With these variables, we determined that 9% of a student grade is attributable to the instructor's classroom pedagogy and 91% to the student. There is a strong correlation between a student's grade and their learning gains on a modified version of the Geoscience Concept Inventory. Factors that influence variation in a student's grade include the expectancy a student has for his/her success in the course, the amount s/he values the content (both of which impact motivation), and effective employment of learning strategies (metastrategies). The teacher's influence on student grades is directly related to how student-centered the classroom is (as measured by the RTOP), and influences almost half of the 9% variance in students' grade. In addition, a student's expectancy for success is less likely to impact their grade in a more student-centered classroom. As such, students who may have low expectations of success still have an equal opportunity to achieve. These results indicate that we need to include consideration of how to support student motivation when we consider how to approach the future of student-centered practices in the classroom.

Stalking The Second Tier: Strategies To Attract And Retain More Majors And Improve Student Learning

Dexter Perkins, Karl Wirth, David McConnell, Ann Bykerk-Kauffman, *Lisa Gilbert*, Jennifer Stempien, Ronald Matheney, David Budd, Katrien van der Hoeven Kraft, and Jaakko Putkonen

Geological Society of America Abstracts with Programs 45 (7), 61, 2013

In 1990, Sheila Tobias published They're Not Dumb, They're Different. The subtitle was Stalking the Second Tier. Tobias observed that many students (first tier) will succeed no matter how we teach, but many others will only succeed if we adjust our approach to teaching. This second group, the second tier, is a student population that could be a key part of our futures. Unless we adjust and teach for them, we do not meet our obligations as teachers, we lose potentially excellent students, our programs do not thrive as they might, and we don't produce necessary professionals for the geoscience workforce.

We studied 4064 students taking intro geology at 14 schools (community colleges, small liberal arts colleges, and large MS and PhD granting colleges and universities). Although talking about good and bad teaching is common, our data show that instructor characteristics only directly account for <10% of student learning. Student characteristics, both cognitive and affective (especially motivation), are much more significant. The

importance of motivation is greatest for second tier students. We used SAT/ACT scores as proxies to divide students into tiers of cognitive ability and found that motivated second tier students perform as well as first tier students. SAT/ACT scores predict 20% of the variance in student grades, student expectancy predicts 5%, and student value another 2%.

Instructors have only limited impact on student cognitive skills, but have potentially huge impacts on student motivation. Indirectly, we can improve student learning and retention by improving student motivation. Most importantly, we must help students: 1) value what they are learning, 2) have confidence in their abilities to do well, and 3) develop self-reflection and other metacognitive skills. Traditional classrooms do not promote these desirable characteristics, but innovative, student-centered classrooms do. Average students in intro geology classes lose motivation during a semester. First tier students lose less than second tier students, no matter what the teaching approach. The difference is stark in instructor-centered classrooms but significantly less in student centered classrooms. The impacts of student-centered instruction multiply -- for maximum effect, students must encounter reformed teaching in multiple classrooms.

Off-Trail Adventures in Baja California:
Exploring Landscapes and Geology on Gulf Shores and Islands

Markes E. Johnson, Emeritus

University of Arizona Press, 272 p. Tucson (2014)

From "Advice to the Reader": This book describes a sampling of places on islands in the Gulf of California and related shores of Mexico's Baja California peninsula. It is meant to celebrate spots where the intersection of geography, geology, and ecology meet to instill in the observer a deep understanding of place and time. We humans have many peculiarities that set us apart, but our innate curiosity is surely among our most definitive traits. We want to know what makes a thing go, how a system functions, and where we might fit into the bigger picture. Whole years may be devoted to reaching but a few "ah-ha" moments, when the clarity of a particular setting strikes a chord within us and we come to know something that occupies more space and meaning than found in our small, personal lives. I am never more alive than when one of those flashes of insight strikes. Months, maybe even years, of normal living stretch between such moments. To some extent, however, the special moments can be anticipated and actively cultivated.

For 25 years, I have returned on an annual basis (mostly during the month of January) to explore the wild landscapes and little-known geology of the Baja California peninsula. Foremost, I am a teacher. My work is confined to the classroom most of the year, where I try to interest college students in the story of our planet's development. During the summers, I am free to conduct field studies that have taken me to other destinations such as Western Australia, south China, Inner Mongolia, Siberia, northern Norway, and parts of Canada. But at least once a year for several weeks at a time, I am lured back to Baja California like a moth drawn to the light. Not that the geology of other places is less exciting, but the atmosphere of Baja California is a deep-soothing balm that restores my physical and intellectual energy. Perhaps I find it so, because students usually join me on my travels there. The lines between teaching and research become blurred. I revel in sharing new insights with them just as much as with my research colleagues. More to the point, seeing the place through the eyes of novitiates has a rejuvenating power.

Turnover from Mollusk-Dominated Depauperate Zone (Late Ordovician) to Brachiopod-Dominated (Early Silurian) Faunas in central North America

Markes e. Johnson, Emeritus

GFF (Geologiska Föreningens Förhandlingar) 136, 130-135, 2014

The Depauperate Zone from the base of the Ordovician (Katian) Maquoketa shale in Dubuque, Iowa, features a range of diminutive infaunal, epifaunal, nektonic, and planktonic members with multiple growth stages. Fossils are preserved as phosphatized internal molds. In rare cases, shell replacement conserves growth lines. Sixteen species were recovered, including three-dimensional graptolites (*Rectograptus peos-*

ta). The bivalves *Palaeoneilo fecunda* and *Nuculites neglectus* are most abundant, but the orthid brachiopod *Plaesiomys subquadrata* also is common. Bivariate analyses were conducted on the bivalve and brachiopod species, two gastropods (*Liospira micula* and *Cyrtolites carinatus*), a reputed sponge (*Hindia sphaeroidalis*), and the graptolite. All mollusks follow an isometric growth pattern and the same is especially characteristic of the orthid brachiopod. Winnowing by waves or bottom currents was minimal. Pene-contemporaneous replacement of fine details was due to concentrations of P_2O_5 in seawater intermittently brought from the shelf margin through upwelling. Paedomorphosis was likely, because the brachiopod *P. subquadrata* shows a record of individuals 150% larger in adult size elsewhere in North America. In contrast, populations of Silurian *Pentamerus oblongus* preserve a full range of immature to adult individuals with a curvi-linear growth pattern. Clear-water deposition under conditions of good marine circulation prevailed during much of the Silurian, although secondary silicification of original $CaCO_3$ shells was common. The muddy Maquoketa substrate vanished due to sea-level rises that flooded all clastic sediment sources.

Geomorphology and Coastal Erosion of a Quartzite Island:
Hongdo in the Yellow Sea off the SW Korean Peninsula

Markes E. Johnson, Emeritus and B. G. Baarli

Journal of Geology 121, 503-516, 2013

As a dense metamorphic rock with silica grains that are strongly fused, quartzite exposed on rocky shores is generally resistant to marine erosion. The longevity of quartzite coasts compared to those formed by other rock types is underscored by the preservation of many former islands that retain notable topographic relief as inliers of Archean and Proterozoic quartzite surrounded by Paleozoic marine strata in North America and Western Australia. Among the few places where modern rocky shores composed principally of quartzite may be studied with regard to marine erosion, Hongdo in the Yellow Sea off the southwestern Korean peninsula is a natural laboratory where intersection of structural geology, coastal geomorphology, oceanography, sedimentology, and climate converge to demonstrate how a quartzite island evolves through time. Although small in size (6.87 km^2), Hongdo is open to the ocean on all sides. The island's structure as an asymmetrical anticline permits a wide range of attack angles for seasonal storms to work against variable thicknesses in bedding as well as intervals of rock cleavage perpendicular to original bedding. Along the island's 20.8-km perimeter, Mongdol Beach on the west side is the only place where eroded clasts accumulate, typically as quartzite cobbles. Size and shape analyses on multiple samples show that rock partings of both kinds (bedding and cleavage) play a roll in contemporaneous clast development. All clasts are elongate in shape, but many clasts that originate from zones where cleavage is predominant tend to be less ellipsoidal in form. Orientation of Mongdol Beach indicates that the principal agent of coastal erosion relates to the frequent monsoonal storms that reach the island from the Asian continent in the northwest during the late fall and winter months of November through March. Fewer but more intense, typhoons may arrive from the southeast during August and September. The island's eastern coast is better shielded against wave surge coming from this direction by the steeply dipping eastern limb of the anticline.

Upper Devonian Shoal-Water Delta integrated with Cyclic Back-reef facies off the
Mowanbini Archipelago (Canning Basin), Western Australia

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Facies 59, 991-1009, 2013

The Oscar Range in Western Australia's Canning Basin exhibits folded Proterozoic, quartzite, quartzite conglomerate, phyllite and metavolcanic rocks that survive with positive relief. Facies of the Pillara Limestone were deposited around this relief during Late Devonian (Frasnian) time. A segment of the Great Devonian Barrier Reef with a linear reef margin strikes parallel to the outer palaeoislands in the Mowanbini Archipelago. A more sheltered strait separates inner islands from the cratonic Devonian mainland on the Kimberley Block. Large fan-deltas emanated from the craton, but locally small shoal-water deltas prograded from a

drainage basin on one of the larger palaeoislands in the Oscar Range. That island is expressed today by local topography exhumed from beneath a cover of former Devonian, Carboniferous and Permian strata. The Devonian shoal-water delta rests unconformably on tilted Proterozoic phyllite and incorporates abundant phyllitic debris accumulated under fluvial to shoreface conditions. Some quartzite pebbles and hydrothermal quartz were derived from a source more than a kilometre away. Rare gastropods and stromatoporoid fragments in the deltaic sediments were abraded from the adjacent reef margin. The clast-supported conglomerate in the exposed shoal-water delta is mapped over a distance of 130 m to within 15 m of the inner reef margin, exposed nearby on steeply dipping phyllite. A cyclic succession of mixed clastic and carbonate parasequences, 31.5 m in thickness, follows above a disconformity surface on the delta-top facies. The overall succession represents a minor fall in relative sea level associated with erosion of delta facies and a major transgression characterized by a retrograde parasequence stacking pattern. The succession shifts through siliciclastic-rich shoreface to intertidal distal back-reef facies, ending with a subtidal, siliciclastic-poor proximal back-reef facies. The study demonstrates how variability in sedimentary cycles is influenced by local palaeogeographic constraints in an island system dominated by quartzite highlands and phyllite lowlands.

Miocene-Pliocene Rocky Shores on São Nicolau (Cape Verde Islands): Contrasting Windward and Leeward Biofacies on a Volcanically Active Oceanic Island

Markes E. Johnson, Emeritus, R. S. Ramalho, *B. G. Baarli*, M. Cachão, C. M. Silva, E. J. da Mayoral, and A. Santos

Palaeogeography, Palaeoclimatology, Palaeoecology 395, 131-143, 2014

North Atlantic islands in the Cape Verde Archipelago off the coast of West Africa commonly feature an elongated N–S shape in which reduced northern coasts and longer eastern shores absorb the brunt of wave activity and long-shore currents generated by prevailing North East Trade Winds. Located in the middle windward islands, São Nicolau is unusual in profile with an elongated E–W configuration that offers a broad target against high-energy, wind-driven waves. Conversely, the south shore of São Nicolau provides relatively wide shelter in a leeward setting. Reconstruction of the proto-island prior to the onset of the Main Eruptive stage during the Late Miocene at ~5.1 Ma reveals a moderately smaller island with essentially the same E–W orientation. This study combines previous data with results from a detailed stratigraphic log based on Upper Miocene limestone deposits on the island's south flank for comparison with stratigraphic profiles of Upper Miocene limestone from the island's northeast quarter. Logs from a Pliocene sandy limestone outcropping on the south-central coast of São Nicolau give added context to the diversity of marine invertebrates, including branching coral colonies and delicate ramose bryozoans that found shelter in a leeward setting. Whole rhodoliths contribute the main fabric of carbonates deposited against rocky shores on the northern, exposed side of the Miocene island, whereas only traces of worn rhodoliths and rhodolith sand occur as in finer Miocene grainstone on the island's southern, protected side. Miocene and Pliocene carbonate deposits were terminated by submarine flows on an actively growing volcanic island. The passage zone from submarine to subaerial flows on the island's flanks makes a useful meter-stick to gauge absolute water depth at the moment of local extinction by volcanic activity.

Staircase Sequences Reflecting Sea-Level Oscillations and Tectonic Uplift During the Quaternary and Neogene

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Earth Science Reviews 132, 13-38, 2014

Many coasts feature sequences of Quaternary and Neogene shorelines that are shaped by a combination of sea-level oscillations and tectonics. We compiled a global synthesis of sea-level changes for the following highstands: MIS 1, MIS 3, MIS 5e and MIS 11. Also, we date the apparent onset of sequences of paleoshorelines either from published data or tentatively extrapolating an age for the uppermost, purported oldest

shoreline in each sequence. Including the most documented MIS 5e benchmark, we identify 926 sequences out of which 185 also feature Holocene shorelines. Six areas are identified where elevations of the MIS 3 shorelines are known, and 31 feature elevation data for MIS 11 shorelines. Genetic relationships to regional geodynamics are further explored based on the elevations of the MIS 5e benchmark. Mean apparent uplift rates range from 0.01 ± 0.01 mm/yr (hotspots) to 1.47 ± 0.08 mm/yr (continental collision). Passive margins appear as ubiquitously uplifting, while tectonic segmentation is more important on active margins. From the literature and our extrapolations, we infer ages for the onset of formation for ~ 180 coastal sequences. Sea level fingerprinting on coastal sequences started at least during mid Miocene and locally as early as Eocene. Whether due to the changes in the bulk volume of seawater or to the temporal variations in the shape of ocean basins, estimates of eustasy fail to explain the magnitude of the apparent sea level drop. Thus, vertical ground motion is invoked, and we interpret the long-lasting development of well identified strandlines that are distinct from one another. Pliocene and Lower Pleistocene strandlines associated with faster cyclicity (40,000 yrs) are more compact and easily merge into rasas, whereas older Cenozoic low-frequency eustatic changes generally led to widespread flat-lying coastal plains.

Creating and Disseminating Interactive 3D Geologic Models

Paul Karabinos

Geological Society of America Abstracts with Programs 45, 504, 2013

Many fundamental geologic concepts are rooted in 3D spatial relationships. Well-crafted 2D perspective diagrams illuminate such relationships for some students, but interactive 3D models help a much wider range of students visualize complex geometries. In particular, students commonly learn how to solve specific problems using 2D projections but many fail to link the solution to the underlying 3D geometry. Trimble SketchUp is a particularly useful program for creating 3D models because it is relatively easy to learn and a free version exists. I have created interactive 3D models with SketchUp that illustrate how the stereographic projection works and how geologic maps and cross-sections are used to summarize the geology of an area. I also created a sequence of models showing how structure contours can help test if a contact is planar, determine the strike and dip of planar beds, find the true thickness of stratigraphic units, solve the 3-point problem, determine the depth of a target unit, estimate displacement across faults, and create cross-sections. SketchUp Pro offers the ability to create dynamic components, which can be used in the free version, and add another level of interactivity to SketchUp models. For example, models illustrating how the stereographic projection works can incorporate dynamic components so that the user can specify any values of strike and dip or trend and plunge to explore how planes and lines will plot on the stereonet.

Creating effective 3D models is, however, only the first step. Only motivated users will download a new program or plugin and take the time to learn how to use it. The models must, therefore, be easily accessible to instructors and students and be intuitive to use. The second challenge, then, is to provide interactive 3D models in a familiar format. SketchUp models can be exported as COLLADA digital asset exchange (.dae) files, and incorporated into an iBook as interactive 3D models using iBooks Author for IOS devices. The .dae files can also be uploaded to Sketchfab, a web service designed to publish and display 3D models. Once uploaded to Sketchfab, the models may be embedded in a webpage where anyone with a Web Graphics Library enabled browser can view them. A third promising approach is to export SketchUp models as 3D PDFs and incorporate them in digital instructional materials.

Interactive 3D Geologic Models Created with SketchUp

Paul Karabinos

Geological Society of America Abstracts with Programs 45, 147, 2013

Trimble SketchUp is a useful program for creating interactive 3D models that illustrate fundamental geologic concepts. It is relatively easy to learn and a free version exists. SketchUp Pro adds the ability to create dynamic components, which are available to users of the free version. Dynamic components add greater

interactivity to a 3D model because users can modify some elements of the model using a simple dialog box. The free version of SketchUp can be used to import USGS DEM and DDF format files to portray topographic surfaces that can be draped with geological maps and coupled with accurately located cross-sections. Cross-sections and topographic models can be geolocated and exported to Google Earth as Collada digital asset exchange (.dae) files to give the 3-D models greater geographic context. This poster will highlight several different kinds of interactive 3D SketchUp models and explain how they are made. Examples will include block diagrams of geologic maps and cross-sections, digital terrane models that show how structure contours are used to solve many geologic problems, and models with dynamic components that illustrate how the stereographic projection works. SketchUp models also help show how cross-sections are created from geologic maps. SketchUp offers instructors a valuable teaching resource for engaging students in the challenge of 3D visualization in such a way that success is almost certain.

Interactive 3D models are more valuable to instructors and students unfamiliar with SketchUp if they are easily accessible and intuitive to use. There are three promising strategies for packaging interactive 3D models in a familiar format so that more time can be devoted to learning. SketchUp models can be exported as COLLADA files, and incorporated into an iBook as interactive 3D models using iBooks Author for IOS devices. The COLLADA files can also be uploaded to Sketchfab, a web hosting service designed to publish and display 3D models. Once uploaded to Sketchfab, the models may be embedded in a webpage where anyone with a Web Graphics Library enabled browser can view them. A third approach is to export SketchUp models as 3D PDFs and incorporate them seamlessly in digital instructional materials.

Terrane Accretion and Foreland Basin Formation in the Northern Appalachians

F. A. Macdonald, J.L. Crowley, and *Paul Karabinos*

Geological Society of America Abstracts with Programs 45, 740, 2013

Differences in the style and timing of Ordovician foreland subsidence between Newfoundland and New England may reflect first-order variations in the accretion of peri-Laurentian and peri-Gondwanan arcs and terranes during the Taconic orogeny. Detrital zircon in metasediments of the Late Cambrian to Early Ordovician Moretown Formation in western MA and southern VT was derived from a Gondwanan protolith, with prominent peaks between ca. 500 and 600 Ma, similar to those previously reported from the Moretown in northern VT. These data suggest that the Red Indian Line, which separates peri-Laurentian and peri-Gondwanan terranes, lies between the ultramafic-rich Rowe Schist and the Moretown, farther west than previously suspected. The suture predated the Late Ordovician Middlefield granite, which stiched the Rowe and Moretown. Importantly, metasediments in the structurally higher Ordovician Hawley Formation contain distinctly Grenvillian detrital zircon. The Hawley is interpreted to be a forearc to the Early to Middle Ordovician Shelburne Falls arc. If this is correct, the provenance of Hawley metasediments suggests that the Shelburne Falls arc developed on the Moretown after it was proximal to Laurentia. However, the age of the heterogeneous Hawley is poorly constrained; it may post-date the Shelburne Falls arc. The location of the Red Indian Line indicates that the peri-Laurentian Dashwoods terrane, which accreted to the Newfoundland Laurentian margin in the Middle Ordovician, is absent in MA and VT. This is consistent with differences in the subsidence history of the foreland basins on the autochthon. In Newfoundland, the Table Head and Goose Tickle groups record the development of a large Middle Ordovician foreland basin with the obduction of Dashwoods, whereas in New York, Middle Ordovician subsidence and deposition are meager. New CA-ID-TIMS dating of ashes in the Utica shale in New York demonstrates that it formed rapidly in the Katian stage of the Late Ordovician, and is equivalent with the Long Point Group in Newfoundland, both of which formed as foredeeps in the final closure of the Iapetus ocean. Thus, we suggest that differences in the foreland basins record first-order variations in the history of terrane accretion between Newfoundland and New England, in particular the absence of Dashwoods to the south.

Linked Histories of Allochthon Emplacement, Pulsed Subsidence and Faunal Evolution in the Taconic Foreland Basin

C. E. Mitchell, F. A. Macdonald, J.L. Crowley, and *Paul Karabinos*

GAC-MAC-AMC Abstract 34, 193, 2014

Previous interpretations of Taconic foreland basin evolution in New England have emphasized a gradual westward migration of facies in which the Utica Shale and related flysch deposits prograded over the drowned Trenton shelf in response to a gradual subduction of the Laurentian plate and subsequent basin filling. Recent work on the tectonic setting suggests instead that the Utica Shale formed in a retro-arc basin with two episodes of accelerated foreland subsidence and facies response. The first occurred within the latest C. bicornis Zone, between 452.8-452.3 Ma (bracketed by the Millbrig and Sherman Falls K-bentonites) and lead to deposition of the Utica Shale above an abrupt drowning surface that is essentially synchronous from Ballston Spa to Little Falls NY.

The second event took place at ~451.65 Ma, bracketed by the Manheim and Ostquago Kbentonites. That event emplaced O. ruedemanni Zone age, shelly greywackes onto the Vischer Ferry-Cohoes mélange belt, and produced soft sediment and thrust deformation in lower D. spiniferus Zone rocks west of the Vischer Ferry mélange zone (on the up-thrown side of the Saratoga-McGregor Fault), as well as extensional fault-block rotation and sediment slides (Thruway Disconformity) in the central Mohawk Valley. The Thruway event terminated deposition of the Dolgeville Formation and abruptly spread Utica Shale yet farther west. These events affected basin hydrography and faunal evolution as well. The initial Utica onlap event was accompanied by the immigration of a modest graptolite fauna and a unique set of geochemical conditions. The graptolite fauna became more species poor and more endemic as the basin became restricted during local base level fall in O. ruedemanni Zone time. The Thruway event was accompanied by abrupt shifts in $\delta^{13}C$ and $\delta^{18}O$ values, and by immigration of a new tropical oceanic graptolite fauna. Simultaneously, the endemic trilobite Triarthrus beckii underwent a basin-wide shift in morphology. These faunal responses suggest that thrust emplacement in the retroarc foreland and the ensuing basin-wide subsidence lead to rapid changes in local basinal conditions, probably including changes in current circulation, water temperature and productivity.

A Newly Identified Gondwanan Terrane in the Northern Appalachian Mountains: Implications for the Taconic Orogeny and Closure of the Iapetus Ocean

F. A. Macdonald, J. Ryan-Davis, R. A. Coish, J. L. Crowley, and *Paul Karabinos*

Geology 42, 539-542, 2014

The Taconic and Salinic orogenies in the northern Appalachian Mountains record the closure of the Iapetus Ocean, which separated peri-Laurentian and peri-Gondwanan terranes in the early Paleozoic. The Taconic orogeny in New England is commonly depicted as an Ordovician collision between the peri-Laurentian Shelburne Falls arc and the Laurentian margin, followed by Silurian accretion of peri-Gondwanan terranes during the Salinic orogeny. New U-Pb zircon geochronology demonstrates that the Shelburne Falls arc was instead constructed on a Gondwanan-derived terrane preserved in the Moretown Formation, which we refer to here as the Moretown terrane. Metasedimentary rocks of the Moretown Formation were deposited after 514 Ma and contain abundant ca. 535–650 Ma detrital zircon that suggest a Gondwanan source. The Moretown Formation is bound to the west by the peri-Laurentian Rowe belt, which contains detrital zircon in early Paleozoic metasedimentary rocks that is indistinguishable in age from zircon in Laurentian margin rift-drift successions. These data reveal that the principal Iapetan suture in New England is between the Rowe belt and Moretown terrane, more than 50 km farther west than previously suspected. The Moretown terrane is structurally below and west of volcanic and metasedimentary rocks of the Hawley Formation, which contains Laurentian-derived detrital zircon, providing a link between peri-Laurentian and peri-Gondwanan terranes. The Moretown terrane and Hawley Formation were intruded by 475 Ma plutons during peak

activity in the Shelburne Falls arc. We propose that the peri-Laurentian Rowe belt was subducted under the Moretown terrane just prior to 475 Ma, when the trench gap was narrow enough to deliver Laurentian detritus to the Hawley Formation. Interaction between peri-Laurentian and peri-Gondwanan terranes by 475 Ma is 20 m.y. earlier than documented elsewhere and accounts for structural relationships, Early Ordovician metamorphism and deformation, and the subsequent closure of the peri-Laurentian Taconic seaway. In this scenario, a rifted-arc system on the Gondwanan margin resulted in the formation of multiple terranes, including the Moretown, that independently crossed and closed the Iapetus Ocean in piecemeal fashion.

Mathematics

A classification of spanning surfaces for alternating links

Colin Adams with *Thomas Kindred '07*

Algebraic and Geometric Topology 13, 2967-3007, 2013.

A classification of spanning surfaces for alternating links is provided up to genus, orientability, and a new invariant that we call aggregate slope. That is, given an alternating link, we determine all possible combinations of genus, orientability, and aggregate slope that a surface spanning that link can have. To this end, we describe a straightforward algorithm, much like Seifert's algorithm, through which to construct certain spanning surfaces called state surfaces, obtained by splitting each crossing one of the two ways, filling in the resulting circles with disks and connecting these disks with half twisted bands at the crossings. A particularly important subset of these will be what we call basic state surfaces. We can alter these surfaces by performing the entirely local operations of adding handles and/or crosscaps, each of which increases genus.

The main result then shows that if we are given an alternating projection P(L) and a surface S spanning L, we can construct a surface T spanning L with the same genus, orientability, and aggregate slope as S that is a basic state surface with respect to P, except perhaps at a collection of added crosscaps and/or handles. Furthermore, S must be connected if L is nonsplittable.

This result has several useful corollaries. In particular, it allows for the determination of nonorientable genus for alternating links. It also can be used to show that mutancy of alternating links preserves nonorientable genus. And it allows one to prove that there are knots that have a pair of minimal nonorientable genus spanning surfaces, one boundary-incompressible and one boundary-compressible.

Unknotting Tunnels, Bracelets and the Elder Sibling Property for Hyperbolic 3-Manifolds

Colin Adams and K. Knudson '09

Journal of the Australian Mathematical Society, 95, 1–19, 2013.

An unknotting tunnel in a 3-manifold with boundary is a properly embedded arc, the complement of an open neighborhood of which is a handlebody. A geodesic with endpoints on the cusp boundary of a hyperbolic 3-manifold and perpendicular to the cusp boundary is called a vertical geodesic. Given a vertical geodesic \$\alpha \$ in a hyperbolic 3-manifold \$M\$, we find sufficient conditions for it to be an unknotting tunnel. In particular, if \$\alpha \$ corresponds to a 4-bracelet, 5-bracelet or 6-bracelet in the universal cover and has short enough length, it must be an unknotting tunnel. Furthermore, we consider a vertical geodesic \$\alpha \$ that satisfies the elder sibling property, which means that in the universal cover, every horoball except the one centered at \$\infty \$ is connected to a larger horoball by a lift of \$\alpha \$. Such an \$\alpha \$ with length less than \$\ln (2)\$ is then shown to be an unknotting tunnel.

Quadruple Crossing Number of Knots and Links
Colin Adams

Mathematical Proceedings of the Cambridge Philosophical Society, Vol. 156, No. 2, 241-253, 2014.

A quadruple crossing is a crossing in a projection of a knot or link that has four strands of the knot passing straight through it. A quadruple crossing projection is a projection such that all of the crossings are quadruple crossings. In a previous paper, it was proved that every knot and link has a quadruple crossing projection and hence, every knot has a minimal quadruple crossing number. In this paper, we investigate quadruple crossing number, and in particular, use the span of the bracket polynomial to determine quadruple crossing number for a variety of knots and links.

A Grader's Dream
Colin Adams

Mathematical Intelligencer, Vol. 35, No. 3, 34-35, 2013.

Math is Everywhere
Colin Adams

Mathematical Intelligencer, Vol. 35, No. 4, 39-42, 2013.

The Pi Day Massacre
Colin Adams

Mathematical Intelligencer, Vol. 36, No. 1, 61-63, 2014.

On-Line Edutainment
Colin Adams

Mathematical Intelligencer, Vol. 36, No. 2, 15-17, 2014.

Resolving the Roles of Immunity, Pathogenesis and Immigration for Rabies Persistence in Vampire Bats
Julie C. Blackwood, DG Streicker, S. Altizer, and P. Rohani

Proceedings of the National Academy of Sciences, 110, 9595-9600, 2013.

Bats are important reservoirs for emerging infectious diseases, yet the mechanisms that allow highly virulent pathogens to persist within bat populations remain obscure. In Latin America, vampire-bat-transmitted rabies virus represents a key example of how such uncertainty can impede efforts to prevent cross-species transmission. Despite decades of agricultural and human health losses, control efforts have had limited success. To establish persistence mechanisms of vampire-bat-transmitted rabies virus in Latin America, we use data from a spatially replicated, longitudinal field study of vampire bats in Peru to parameterize a series of mechanistic transmission models. We find that single-colony persistence cannot occur. Instead, dispersal of bats between colonies, combined with a high frequency of immunizing nonlethal infections, is necessary to maintain rabies virus at levels consistent with field observations. Simulations show that the strong spatial component to transmission dynamics could explain the failure of bat culls to eliminate rabies and suggests that geographic coordination of control efforts might reduce transmission to humans and domestic animals. These findings offer spatial dynamics as a mechanism for rabies persistence in bats that might be important for the understanding and control of other bat-borne pathogens.

Skeletal Configurations of Ribbon Trees
Satyan Devadoss with H. Cheng, B. LI, A. Risteski

Discrete Applied Mathematics, 170, 46-54, 2014.

The straight skeleton construction creates a straight-line tree from a polygon. Motivated by moduli spaces from algebraic geometry, we consider the inverse problem of constructing a polygon whose straight skeleton is a given tree. We prove there exists only a finite set of planar embeddings of a tree appearing as straight

skeletons of convex polygons. Computational issues are also considered, uncovering ties to a much older angle bisector problem.

Business Statistics, 3rd Edition
Richard De Veaux with Norean Sharpe and Paul Velleman

Pearson, January 2014.

Follow the Fundamentals: Four Data Analysis Basics Will Help You Do Big Data Projects the Right Way
Richard De Veaux with Ron Snee and R.W. Hoerl

Quality Progress, 24-28, January 2014.

A Multi-dimensional Continued Fraction Generalization of Stern's Diatomic Sequence
Thomas Garrity

Journal of Integer Sequences, Vol. 16, 2013

Continued fractions are linked to Stern's diatomic sequence 0,1,1,2,1,3,2,3,1,4,… (given by the recursion relation a{2n}=a(n) and a(2n+1} = a(n) + a(n+1) where a(0)=0 and a(1)=1), which has long been known. Using a particular multi-dimensional continued fraction algorithm (the Farey algorithm), we will generalize the diatomic sequence to a sequence of numbers that quite naturally should be called Stern's triatomic sequence (or a two-dimensional Pascal's sequence with memory). As continued fractions and the diatomic sequence can be thought of as coming from a systematic subdivision of the unit interval, this new triatomic sequence will arise by a systematic subdivision of a triangle. We will discuss some of the algebraic properties for the triatomic sequence.

Longitudinal Cluster Analysis With Applications to Growth Trajectories
Brianna Heggeseth

UC Berkeley Electronic Theses and Dissertations, 1-130, 2013.

Longitudinal studies play a prominent role in health, social, and behavioral sciences as well as in the biological sciences, economics, and marketing. By following subjects over time, temporal changes in an outcome of interest can be directly observed and studied. An important question concerns the existence of distinct trajectory patterns. One way to discover potential patterns in the data is through cluster analysis, which seeks to separate objects (individuals, subjects, patients, observational units) into homogeneous groups. There are many ways to cluster multivariate data. Most methods can be categorized into one of two approaches: nonparametric and model-based methods. However, the bulk of the available clustering algorithms are not appropriate to be directly applied to repeated measures with inherent dependence and do not clustering according to change over time, the key feature measured by longitudinal data.

Multivariate Gaussian mixtures are a class of models that can be adapted to longitudinal data, but simplifying assumptions about the dependence structure are often made. I study, through asymptotic bias calculations and simulation, the impact of covariance misspecification in multivariate Gaussian mixtures. Although maximum likelihood estimators of regression and prior probability parameters are not consistent under misspecification, they have little asymptotic bias when mixture components are well separated or if the assumed correlation is close to the truth even when the covariance is misspecified. I also present a robust standard error estimator and show that it outperforms conventional estimators in simulations and can provide evidence that the model is misspecified.

To fulfill the need for clustering based explicitly on shape, I propose three methods that are adaptations of available algorithms. One approach is to use a dissimilarity measure based on estimated derivatives of functions underlying the trajectories. One challenge for this approach is estimating the derivatives with minimal bias and variance. The second approach explicitly models the variability in the level within a group of similarly shaped trajectories using a mixture model resulting in a multilayer mixture model. One diffi-

culty with this method comes in choosing the number of shape clusters. Lastly, vertically shifting the data by subtracting the subject-specific mean directly removes the level prior to modeling. This non-invertible transformation can result in singular covariance matrixes, which makes parameter estimation difficult. In theory, all of these methods should cluster based on shape, but each method has shortfalls. I compare these methods with existing clustering methods in a simulation study and apply them to a real data set of childhood growth trajectories from the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) study.

The Impact of Covariance Misspecification in Multivariate Gaussian Mixtures on Estimation and Inference: An Application to Longitudinal Modeling

Brianna Heggeseth and Nicholas Jewell

Statistics in Medicine 32 (16) 2790-2803, 2013.

Multivariate Gaussian mixtures are a class of models that provide a flexible parametric approach for the representation of heterogeneous multivariate outcomes. When the outcome is a vector of repeated measurements taken on the same subject, there is often inherent dependence between observations. However, a common covariance assumption is conditional independence—that is, given the mixture component label, the outcomes for subjects are independent. In this paper, we study, through asymptotic bias calculations and simulation, the impact of covariance misspecification in multivariate Gaussian mixtures. Although maximum likelihood estimators of regression and mixing probability parameters are not consistent under misspecification, they have little asymptotic bias when mixture components are well separated or if the assumed correlation is close to the truth even when the covariance is misspecified. We also present a robust standard error estimator and show that it outperforms conventional estimators in simulations and can indicate that the model is misspecified. Body mass index data from a national longitudinal study are used to demonstrate the effects of misspecification on potential inferences made in practice.

Parity and Body Mass Index in U.S. Women: A Prospective 25-Year Study

Brianna Heggeseth, Barbara Abrams, David Rehkopf, and Esa Davis

Obesity 21 (8) 1514-1518, 2013.

The objective of this paper was to investigate long-term body mass index (BMI) changes associated with childbearing. Adjusted mean BMI changes were estimated by race-ethnicity, baseline BMI, and parity using longitudinal regression models for 3,943 young females over 10 and 25 year follow-up from the ongoing 1979 National Longitudinal Survey of Youth cohort. Estimated BMI increases varied by group, ranging from a low of 2.1 BMI units for white, non-overweight nulliparas over the first 10 years to a high of 10.1 BMI units for black, overweight multiparas over the full 25-year follow-up. Impacts of parity were strongest among overweight multiparas and primaparas at 10 years, ranges 1.4-1.7 and 0.8-1.3 BMI units, respectively. Among non-overweight women, parity-related gain at 10 years varied by number of births among black and white but not Hispanic women. After 25 years, childbearing significantly increased BMI only among overweight multiparous black women. Childbearing is associated with permanent weight gain in some women, but the relationship differs by maternal BMI in young adulthood, number of births, race-ethnicity, and length of follow-up. Given that overweight black women may be at special risk for accumulation of permanent, long-term weight after childbearing, effective interventions for this group are particularly needed.

Adiponectin and Leptin Trajectories in Mexican-American Children from Birth to 9 Years of Age

Brianna Heggeseth, Vitaly Volberg, Kim Harley, Karen Huen, Paul Yousefi, Veronica Davé, Kristin Tyler, Michelle Vedar, Brenda Eskenazi and Nina Holland.

PLoS ONE 8 (10):e77964, 2013.

The objective of this paper was to address molecular mechanisms underlying obesity development, we examined patterns of critical metabolism-related hormones, adiponectin and leptin (adipokines), over childhood. Plasma adiponectin and leptin were measured in 80 Mexican-American children at birth and again

at 2, 5, and 9 years from the ongoing prospective cohort followed by the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS). We used a mixture modeling approach to identify patterns in adipokine trajectories from birth to 9 years. Leptin was positively related to child body size within all ages, however adiponectin had inverse and weaker associations with BMI at 2, 5, and 9 years. Correlations between adipokine levels over the 0–2, 2–5, and 5–9-year periods increased for both leptin (r = 0.06, 0.31 and 0.62) and adiponectin (r = 0.25, 0.41 and 0.46). Our mixture modeling approach identified three trajectory clusters for both leptin (1L [slowly-rising], 2L [rapidly-rising], and 3L [stable]) and adiponectin (1A [steep-dropping and rebounding], 2A [moderately-dropping], and 3A [stable]). While leptin groups were most separated over the 2–9-year period, adiponectin trajectories displayed greatest heterogeneity from birth to 2 years. Children in the rapidly-rising 2L group had highest BMI and waist circumference at 9 years. Further, children with greater birth weight had increased odds of belonging to this high risk group (OR = 1.21 95% CI 1.03, 1.43, compared to stable group 3L). Children whose mothers consumed more sugar-sweetened beverages during pregnancy were at risk of being in the steep-dropping 1A group (OR = 1.08, 95% CI 1.01, 1.17, compared to stable group 3A). Our results highlight developmental differences in leptin and adiponectin over the childhood period. Leptin closely reflects child body size however factors affecting adiponectin and long-term consequences of its changes over infancy need to be further explored.

Development and Validation of a Questionnaire to Measure Serious and Common Quality of Life Issues for Patients Experiencing Small Bowel Obstructions

Bernhard Klingenberg, Amanda D. Rice, Leslie B. Wakefield, Kimberley Patterson, Evette D'Avy Reed, Belinda F. Wurn, C. Richard King, III and Lawrence J. Wurn

Healthcare 2, doi:10.3390/healthcare2010139, 139-149, 2014.

A validated questionnaire to assess the impact of small bowel obstructions (SBO) on patients' quality of life was developed and validated. The questionnaire included measurements for the impact on the patients' quality of life in respect to diet, pain, gastrointestinal symptoms and daily life. The questionnaire was validated using 149 normal subjects. Chronbach alpha was 0.86. Test retest reliability was evaluated with 72 normal subjects, the correlation coefficient was 0.93. Discriminate validity was determined to be significant using the normal subject questionnaires and 10 questionnaires from subjects with recurrent SBO. Normative and level of impact for each measured domain were established using one standard deviation from the mean in the normal population and clinical relevance. This questionnaire is a valid and reliable instrument to measure the impact of SBO on a

patient's quality of life related to recurrent SBOs; therefore establishing a mechanism to monitor and quantify changes in quality of life over time.

A New and Improved Confidence Interval for the Mantel-Haenszel Risk Difference

Bernhard Klingenberg

Statist. Med., doi:10.1002/sim.6122, 2014.

Writing the variance of the Mantel–Haenszel estimator under the null of homogeneity and inverting the corresponding test, we arrive at an improved confidence interval for the common risk difference in stratified 2 times 2 tables. This interval outperforms a variety of other intervals currently recommended in the literature and implemented in software. We also discuss a score-type confidence interval that allows to incorporate strata/study weights. Both of these intervals work very well under many scenarios common in stratified trials or in a metaanalysis, including situations with a mixture of both small and large strata sample sizes, unbalanced treatment allocation, or rare events. The new interval has the advantage that it is available in closed form with a simple formula. In addition, it applies to matched pairs data.We illustrate the methodology with various stratified clinical trials and a meta-analysis. R code to reproduce all analysis is provided in the Appendix.

Completions of Hypersurface Domains

Susan Loepp, *J. Ahn '12*, E. Ferme, F. Jiang, and G. Tran

Communications in Algebra no. 12, 4491-4503, 2013.

Given a complete local ring T, the authors find necessary and sufficient conditions for there to exist a hypersurface domain whose completion is T.

The Low-Lying Zeros of Level 1 Maass Forms

Steven Miller with Levent Alpoge

Int Math Res Notices 24, pages doi:10.1093/imrn/rnu012, 2014.

The Katz-Sarnak density conjecture states that the scaling limits of the distributions of zeroes of families of automorphic L-functions agree with the scaling limits of eigenvalue distributions of classical subgroups of the unitary groups U(N). This conjecture is often tested by way of computing particular statistics, such as the one-level density, which evaluates a test function with compactly supported Fourier transform at normalized zeroes near the central point. Iwaniec, Luo, and Sarnak studied the one-level densities of cuspidal newforms of weight k and level N. They showed in the limit as kN tends to infinity that these families have one-level densities agreeing with orthogonal type for test functions with Fourier transform supported in (-2,2). Exceeding (-1,1) is important as the three orthogonal groups are indistinguishable for support up to (-1,1) but are distinguishable for any larger support. We study the other family of GL_2 automorphic forms over Q: Maass forms. To facilitate the analysis, we use smooth weight functions in the Kuznetsov formula which, among other restrictions, vanish to order M at the origin. For test functions with Fourier transform supported inside (-2 + 3/(2(M+1)), 2 - 3/(2(M+1))), we unconditionally prove the one-level density of the low-lying zeros of level 1 Maass forms, as the eigenvalues tend to infinity, agrees only with that of the scaling limit of orthogonal matrices.

The n-Level Density of Zeros of Quadratic Dirichlet L-Functions

Steven Miller with *Jake Levinson '11*

Acta Arithmetica 161, 145-182, 2013.

Previous work by Rubinstein and Gao computed the n-level densities for families of quadratic Dirichlet L-functions for test functions where the sum of the supports is less than 2, and showed agreement with random matrix theory predictions in this range for n < 4 but only in a restricted range for larger n. We extend these results and show agreement for n < 8, and reduce higher n to a Fourier transform identity. The proof involves adopting a new combinatorial perspective to convert all terms to a canonical form, which facilitates the comparison of the two sides.

The Limiting Spectral Measure for Ensembles of Symmetric Block Circulant Matrices

Steven Miller with *Murat Kologlu '12*, Gene S. Kopp, *Frederick W. Strauch,* Associate Professor of Physics and *Wentao Xiong '11*

Journal of Theoretical Probability 26, no 4, 1020-1060, 2013.

Given an ensemble of N x N random matrices, a natural question to ask is whether or not the empirical spectral measures of typical matrices converge to a limiting spectral measure as N tends to infinity. While this has been proved for many thin patterned ensembles sitting inside all real symmetric matrices, frequently there is no nice closed form expression for the limiting measure. Further, current theorems provide few pictures of transitions between ensembles. We consider the ensemble of symmetric m-block circulant matrices with entries i.i.d.r.v. These matrices have toroidal diagonals periodic of period m. We view m as a ``dial'' we can ``turn'' from the thin ensemble of symmetric circulant matrices, whose limiting eigenvalue density is a Gaussian, to all real symmetric matrices, whose limiting eigenvalue density is a semi-circle. The limiting eigenvalue densities f_m show a visually stunning convergence to the semi-circle as m tends to infinity, which we prove. In contrast to most studies of patterned matrix ensembles, our paper gives explicit closed form

expressions for the densities. We prove that f_m is the product of a Gaussian and a certain even polynomial of degree 2m-2; the formula is the same as that for the m x m Gaussian Unitary Ensemble (GUE). The proof is by derivation of the moments from the eigenvalue trace formula. The new feature, which allows us to obtain closed form expressions, is converting the central combinatorial problem in the moment calculation into an equivalent counting problem in algebraic topology. We end with a generalization of the m-block circulant pattern, dropping the assumption that the m random variables be distinct. We prove that the limiting spectral distribution exists and is determined by the pattern of the independent elements within an m-period, depending on not only the frequency at which each element appears, but also the way the elements are arranged.

Coordinate Sum and Difference Sets of d-Dimensional Modular Hyperbolas

Steven Miller with Amanda Bower, *Victor Luo '14* and Ron Evans

INTEGERS #A31, 16 pages, 2013.

Many problems in additive number theory, such as Fermat's last theorem and the twin prime conjecture, can be understood by examining sums or differences of a set with itself. A finite set A of the integers is considered sum-dominant if |A+A|>|A-A|. If we consider all subsets of {0, 1, ..., n-1}, as n tends to infinity it is natural to expect that almost all subsets should be difference-dominant, as addition is commutative but subtraction is not; however, Martin and O'Bryant in 2007 proved that a positive percentage are sum-dominant as n tends to infinity.

(WS) Generalizing Zeckendorf's Theorem to f-Decompositions

Steven Miller with *Philippe Demontigny '14*, Thao Do, Archit Kulkarni and Umang Varma

Journal of Number Theory 141, 136-158, 2014.

A beautiful theorem of Zeckendorf states that every positive integer can be uniquely decomposed as a sum of non-consecutive Fibonacci numbers $\{F_n\}$, where $F_1 = 1$, $F_2 = 2$ and $F_{\{n+1\}} = F_n + F_{\{n-1\}}$. For general recurrences $\{G_n\}$ with non-negative coefficients, there is a notion of a legal decomposition which again leads to a unique representation, and the number of summands in the representations of uniformly randomly chosen m \in $[G_n, G_{\{n+1\}})$ converges to a normal distribution as n tends to infinity. We consider the converse question: given a notion of legal decomposition, is it possible to construct a sequence $\{a_n\}$ such that every positive integer can be decomposed as a sum of terms from the sequence? We encode a notion of legal decomposition as a function f from the non-negative integers to non-negative integers and say that if a_n is in an "f-decomposition", then the decomposition cannot contain the f(n) terms immediately before a_n in the sequence; special choices of f yield many well known decompositions (including base-b, Zeckendorf and factorial). We prove that for any such f, there exists a sequence $\{a_n\}$ such that every positive integer has a unique f-decomposition using $\{a_n\}$. Further, if f is periodic, then the unique increasing sequence $\{a_n\}$ that corresponds to f satisfies a linear recurrence relation. Previous research only handled recurrence relations with no negative coefficients. We find a function f that yields a sequence that cannot be described by such a recurrence relation. Finally, for a class of functions f, we prove that the number of summands in the f-decomposition of integers between two consecutive terms of the sequence converges to a normal distribution.

(S) Sets of Special Primes in Function Fields

Steven Miller with Julio Andrade, Kyle Pratt, and Minh-Tam Trinh

INTEGERS 14, #A18, 2014.

When investigating the distribution of the Euler totient function, one encounters sets of primes P where if p is in P then r is in P for all r|(p-1). While it is easy to construct finite sets of such primes, the only infinite set known is the set of all primes. We translate this problem into the function field setting and construct an infinite such set in $F_p[x]$ whenever p is equivalent to 2 or 5 modulo 9.

The Pythagorean Won-Loss Formula and Hockey: A Statistical Justification for Using the Classic Baseball Formula as an Evaluative Tool in Hockey

Steven Miller with Kevin Dayaratna

The Hockey Research Journal: A Publication of the Society for International Hockey Research, 193-209, 2012/2013.

Originally devised for baseball, the Pythagorean Won-Loss formula estimates the percentage of games a team should have won at a particular point in a season. For decades, this formula had no mathematical justification. In 2006, Steven Miller provided a statistical derivation by making some heuristic assumptions about the distributions of runs scored and allowed by baseball teams. We make a similar set of assumptions about hockey teams and show that the formula is just as applicable to hockey as it is to baseball. We hope that this work spurs research in the use of the Pythagorean Won-Loss formula as an evaluative tool for sports outside baseball.

(WS) The Pi Mu Epsilon 100th Anniversary Problems: Part 1

Steven Miller with James M. Andrews, Avery T. Carr and many students

The Pi Mu Epsilon Journal 13, no. 9, 513-534, 2013.

(WS) The Pi Mu Epsilon 100th Anniversary Problems: Part 2

Steven Miller with James M. Andrews, Avery T. Carr and many students

The Pi Mu Epsilon Journal 13, no. 10, 577-608, 2014.

As 2014 marks the 100th anniversary of Pi Mu Epsilon, we thought it would be fun to celebrate with 100 problems related to important mathematics milestones of the past century. The problems and notes below are meant to provide a brief tour through some of the most exciting and influential moments in recent mathematics. No list can be complete, and of course there are far too many items to celebrate. This list must painfully miss many people's favorites. As the goal is to introduce students to some of the history of mathematics, accessibility counted far more than importance in breaking ties, and thus the list below is populated with many problems that are more recreational. Many others are well known and extensively studied in the literature; however, as our goal is to introduce people to what can be done in and with mathematics, we've decided to include many of these as exercises since attacking them is a great way to learn. We have tried to include some background text before each problem framing it, and references for further reading. This has led to a very long document, so for space issues we split it into four parts (based on the congruence of the year modulo 4). That said: Enjoy!

Note: I also edited the problem section for these two issues and contributed original problems.

The Mathematics of Encryption: An Elementary Introduction

Steven Miller with Midge Cozzens

AMS Mathematical World Series 29, Providence, RI, 332 pages, 2013.

This book is the outgrowth of introductory cryptography courses for nonmath majors taught at Rutgers University and Williams College. It is a pleasure to thank our colleagues and our students for many helpful conversations that have greatly improved the exposition and guided the emphasis, in particular *Elliot Schrock '11* (who helped write the Enigma chapter) and *Zane Martin '13* and Qiao Zhang (who were the TAs for the 2013 iteration at Williams College, and helped guide the class in writing the solutions manual for teachers).

The Isoperimetric Problem in Higher Codimension

Frank Morgan and Isabel M.C. Salavessa

Manuscripta Mathematica 142, 369-382, 2013.

We consider three generalizations of the isoperimetric problem to higher codimension and provide results on equilibrium, stability, and minimization.

Town Hall Meeting: Minority Participation in Math

Alissa S. Crans, *Frank Morgan* and Talithia Williams

MAA Focus, December 2013/January 2014.

Report on the 2013 MathFest Town Hall Meeting on minority participation in mathematics.

Dark Matter and Worst Packings

Frank Morgan

Huffington Post Blog, 28 May 2013.

A report on the annual Geometry and Topology conference at Lehigh University.

Are Smaller College Classes Really Better?

Frank Morgan

Huffington Post Blog, 26 August 2013.

A study shows that larger classes are often just as good.

Adding Fractions

Frank Morgan

Huffington Post Blog, 14 March 2014.

A suggestion that we start by teaching that fractions cannot be added.

Measurable Time-Restricted Sensitivity

Cesar E Silva with *Domenico Aiello '11,* Hansheng, Diao, Zhou Fan, Daniel O. King, Jessica Lin

Nonlinearity, 25, 3313-3325, 2012.

We develop two notions of sensitivity to initial conditions for measurable dynamical systems, where the time before divergence of a pair of paths is at most an asymptotically logarithmic function of a measure of their initial distance. In the context of probability measure-preserving transformations on a compact space, we relate these notions to the metric entropy of the system. We examine one of these notions for classes of non-measure-preserving, nonsingular transformations.

Precalculus

Edward Burger, Contributing Authors: Sarah Flood-Ryland, Douglas Quinney, and *Allison Pacelli*

Thinkwell, 2013.

Variance Estimation of a General U-Statistic With Application to Cross-Validation

Qing Wang

*Statistica Sinica,*24(3), 2014.

This paper addresses the problem of variance estimation for a general U-statistic. U-statistics form a class of unbiased estimators for those parameters of interest that can be written as E(ϕ (X1,…,Xn)) where ϕ is a symmetric kernel function with *k* arguments. Although estimating the variance of a U-statistic is clearly of interest, asymptotic results for a general U-statistic are not necessarily reliable when the kernel size *k* is not negligible compared with the sample size *n*. Such situations arise in cross-validation and other non-parametric risk estimation problems. On the other hand, the exact closed form variance is complicated in form, especially when both *k* and *n* are large. We have devised an unbiased variance estimator for a general U-statistic. It can be written as a quadratic form of the kernel function ϕ and is applicable as long as $k<=n/2$. In addition, it can be represented in a familiar analysis of variance form as a contrast of between-class and

within-class variation. As a further step to make the proposed variance estimator more practical, we developed a partition resampling scheme that can be used to realize the U-statistic and its variance estimator simultaneously with high computational efficiency. A data example in the context of model selection is provided. To study our estimator, we construct a U-statistic cross-validation tool, akin to the BIC criterion for model selection. With our variance estimator we can test which model has the smallest risk.

Physics

Quantum mutual information of an entangled state propagating through a fast-light medium
Kevin M. Jones, McElfresh Professor of Physics, and others

Nature Photonics (May 25, 2014)

It is widely accepted that information cannot travel faster than c, the speed of light in vacuum. Here, we investigate the behavior of quantum correlations and information in the presence of dispersion. To do so we send one half of an entangled state of light through a gain-assisted slow- or fast-light medium and detect the transmitted quantum correlations and quantum mutual information. We show that quantum correlations can be advanced by a small fraction of the correlation time, even in the presence of noise added by phase-insensitive gain. Additionally, although the peak of the quantum mutual information between the modes can be advanced, we find that the degradation of the mutual information due to added noise appears to prevent an advancement of the leading edge. In contrast, we demonstrate a significant delay of both the leading and trailing edges of the mutual information in a slow-light system.

Measurement of $7p_{1/2}$-state hyperfine structure and $7s_{1/2}$-$7p_{1/2}$ transition isotope shift in ^{203}Tl and ^{205}Tl
G. Ranjit, *D. Kealhofer ('13)*, *G.D. Vukasin ('14)*, and *P.K. Majumder*

Phys. Rev. **A 89**, 012511 (2014)

A two-step, two-color laser spectroscopy technique has been used to measure the hyperfine splitting of the $7p_{1/2}$ excited state in ^{203}Tl and ^{205}Tl, as well as the isotope shift within the $7s_{1/2}$-$7p_{1/2}$ transition. Our measured values for the hyperfine splittings, 2153.2(7) MHz (in 203Tl) and 2173.3(8) MHz (in 205Tl), each differ by 20 MHz from previously published values which quoted comparable precision. The transition isotope shift of ^{203}Tl relative to ^{205}Tl was measured to be 534.4(9) MHz. In our experiment, one laser was locked to the thallium $6p_{1/2}$-$7s_{1/2}$ 378-nm transition, while a second, spatially overlapping laser was scanned across the $7s_{1/2}(F = 1)$-$7p_{1/2}(F = 0,1)$ infrared transitions. To facilitate accurate frequency calibration, radio-frequency modulation of the laser was used to create sidebands in the absorption spectrum.

Lorentz violation and topological defects
M. Seifert

Proceedings of the Sixth Meeting on CPT and Lorentz Symmetry (V. A. Kostelecký, ed.)

If Lorentz symmetry is broken, it must have occurred dynamically, via a vector or tensor field whose potential energy forces it to take on a non-zero background expectation value "in vacuum". If the set of minima of this potential (the vacuum manifold) has a non-trivial topology, then there can arise topological defects: stable solutions in which the field approaches different potential minima as we go to infinity in different directions. I discuss the current status of research into these topological defects in the context of Lorentz symmetry breaking, including recent results concerning the birefringent light-bending of monopole solutions, and the search for models supporting cosmic-string and domain-wall defects.

Direct-coupling lensing by antisymmetric tensor monopoles
K. Lau and *M. Seifert*

*Phys. Rev. **D**, in review*; arXiv/1309.2241

We discuss the effects of a direct coupling between a rank-two antisymmetric tensor field and the Maxwell field. The coupling we consider leads to vacuum birefringence, allowing us to place constraints on the magnitude of the tensor field and the strength of its coupling to the Maxwell field via cosmological birefringence

measurements. For light propagating in the presence of a topological defect solution, we find that light rays with different polarizations will follow different trajectories; the magnitude of this deflection is predicted to be extremely small (on the order of 10^-10 arcseconds). We discuss the plausibility of this phenomenon as a method for detection of these monopoles, along with the applicability of our methods to other possible couplings between the tensor field and the Maxwell field.

Communicating through Probabilities:
Does Nature Optimize the Transfer of Information?
William K. Wootters

Entropy **15**, 3130 (2013)

A quantum measurement can be regarded as a communication channel, in which the parameters of the state are expressed only in the probabilities of the outcomes of the measurement. We begin this paper by considering, in a non-quantum-mechanical setting, the problem of communicating through probabilities. For example, a sender, Alice, wants to convey to a receiver, Bob, the value of a continuous variable θ, but her only means of conveying this value is by sending Bob a coin in which the value of θ is encoded in the probability of heads. We ask what the optimal encoding is when Bob will be allowed to flip the coin only a finite number of times. As the number of tosses goes to infinity, we find that the optimal encoding is the same as what nature would do if we lived in a world governed by real-vector-space quantum theory. We then ask whether the problem might be modified, so that the optimal communication strategy would be consistent with standard, complex-vector-space quantum theory.

Unextendible mutually unbiased bases from Pauli classes
Prabha Mandayam, Somshubhro Bandyopadhyay, Markus Grassl, and *William K. Wootters*

Quantum Information and Computation **14**, 823 (2014)

We provide a construction of sets of d/2+1 mutually unbiased bases (MUBs) in dimensions d=4,8 using maximal commuting classes of Pauli operators. We show that these incomplete sets cannot be extended further using the operators of the Pauli group. Moreover, specific examples of sets of MUBs obtained using our construction are shown to be strongly unextendible; that is, there does not exist another vector that is unbiased with respect to the elements in the set. We conjecture the existence of such unextendible sets in higher dimensions (d=2n, n>3) as well. Furthermore, we note an interesting connection between these unextendible sets and state-independent proofs of the Kochen-Specker theorem for two-qubit systems. Our construction also leads to a proof of the tightness of an H2 entropic uncertainty relation for any set of three MUBs constructed from Pauli classes in d=4.

Psychology

Systém Hodnocení Obranných Mechanismů v TAT Podle Phebe Cramerové
(Defense Mechanisms Assessment in TAT According to Phebe Cramer)
T. Soukupová, P. Goldmann, *Phebe Cramer*

In I. Čermák, T. Fikarová (Eds.), *Tematicko-apercepční test: interpretační perspektivy* (*Thematic Apperception Test: Interpretative Perspectives*) (pp. 401–420). Nové Zámky: Psychoprof, spol. s.r.o.

Applying Group Cognitive Behavior Therapy for Anxiety Disorders in Community Settings:
Retention, Outcome, and Clinical Considerations
Laurie Heatherington, N.T. Harrington, J.J. Harrington, K.F. Niemeyer, S.C. Weinberg, & M.L. Friedlander

Journal of Cognitive Psychotherapy, 28, 2014.

The efficacy, and to a lesser extent, effectiveness, of individual CBT for anxiety disorders has been demonstrated, but whether manualized treatments work in a group format in community settings is less established. We investigated the predictors of retention and outcome in 26 groups (11 GAD, 11 Panic, 4 Social Phobia groups), conducted over 10 years in a semi-rural community mental health center by 19 therapists. Members of the Anxiety Disorders Treatment Team delivered manualized group CBT treatments. Analysis

of standard symptom measures at pre- and post-treatment and archival data revealed significant pre-post decreases in anxiety, retention rates comparable to past findings on group retention, and several significant predictors of retention and outcome. Manualized group CBT for anxiety appears to be a viable treatment in community settings. Limitations of the study as well as related practice-research implications of the findings are discussed.

Does Video Recording Alter the Behavior of Police During Interrogation?:
A Mock Crime-and-Investigation Study

Saul Kassin, J. Kukucka, V. Lawson, J. DeCarlo

Law and Human Behavior, 38, 73-83, 2014.

A field study conducted in a mid-sized city police department examined whether video recording alters the process of interrogation. Sixty-one investigators inspected a staged crime scene and interrogated a male mock suspect in sessions that were surreptitiously recorded. By random assignment, half the suspects had committed the mock crime; the other half were innocent. Half the police participants were informed that the sessions were being recorded; half were not. Coding of the interrogations revealed the use of several common tactics designed to get suspects to confess. Importantly, police in the camera-informed condition were less likely than those in the -uninformed condition to use both maximization and minimization tactics; they were also perceived by suspects—who were all uninformed of the camera manipulation—as trying less hard to elicit a confession. Unanticipated results indicated that camera-informed police were better able to discriminate between guilty and innocent suspects in their judgments and behavior. The results as a whole indicate that video recording can affect the process of interrogation—notably, by inhibiting the use of certain tactics. It remains to be seen whether these findings generalize to longer and more consequential sessions and whether the camera-induced differences found are to be judged as favorable or unfavorable.

Do Confessions Taint Perceptions of Handwriting Evidence?
An Empirical Test of the Forensic Confirmation Bias

J. Kukucka, *Saul Kassin*

Law and Human Behavior, 38, 2014.

Citing classic psychological research and a smattering of recent studies, Kassin, Dror, and Kukucka (2013) proposed the operation of a forensic confirmation bias, whereby pre-existing expectations guide the evaluation of forensic evidence in a self-verifying manner. In a series of studies, we tested the hypothesis that knowing that a defendant had confessed would taint people's evaluations of handwriting evidence relative to those not so informed. In Study 1, participants who read a case summary in which the defendant had previously confessed rated handwriting samples from the defendant and perpetrator as more similar, were more likely to conclude that the samples were authored by the same person, and were more likely to judge the defendant guilty, compared to those in a no-confession control group. Study 2 replicated these findings using a within-subjects design in which participants rated the same samples both before and after reading a case summary. These findings underscore recent critiques of the forensic sciences as subject to bias, and suggest the value of insulating forensic examiners from contextual information.

Attempting to Answer a Meaningful Question Enhances Subsequent Learning
Even When Feedback is Delayed

Nate Kornell

Journal of Experimental Psychology: Learning, Memory, and Cognition, 40, 106-114, 2014.

Attempting to retrieve information from memory enhances subsequent learning even if the retrieval attempt is unsuccessful. Recent evidence suggests that this benefit materializes only if subsequent study occurs immediately after the retrieval attempt. Previous studies have prompted retrieval using a cue (e.g.,

whale–???) that has no intrinsic answer. Experiment 1 replicated prior word pair studies, but in Experiment 2, when participants learned meaningful trivia questions, testing enhanced learning even when subsequent study was delayed. Even in Experiment 3, when subsequent study was delayed by up to 24 hr, tests enhanced learning on a final test another 24 hr later. These findings may give comfort to educators who worry that asking a question or giving a test, on which students inevitably make mistakes, impairs learning if feedback is not immediate. They also suggest that there is a consensus in the literature thus far: Questions with rich semantic content enhance subsequent learning even when feedback is delayed, but less meaningful questions without an intrinsic answer enhance learning only when feedback is immediate.

Where is the "Meta" in Animal Metacognition?

Nate Kornell

Journal of Comparative Psychology, 128, 143-149, 2014.

Apes, dolphins, and some monkeys seem to have metacognitive abilities: They can accurately evaluate the likelihood that their response in cognitive task was (or will be) correct. These certainty judgments are seen as significant because they imply that animals can evaluate internal cognitive states, which may entail meaningful self-reflection. But little research has investigated what is being reflected upon: Researchers have assumed that when animals make metacognitive judgments they evaluate internal memory strength. Yet decades of research have demonstrated that humans cannot directly evaluate internal memory strength. Instead, they make certainty judgments by drawing inferences from cues they can evaluate, such as familiarity and ease of processing. It seems likely that animals do the same, but this hypothesis has not been tested. I suggest two strategies for investigating the internal cues that underlie animal metacognitive judgments. It is possible that animals, like humans, are capable of making certainty judgments based on internal cues without awareness or meaningful self-reflection.

Where to Draw the Line on Metacognition: A Taxonomy of Metacognitive Cues

Nate Kornell

Journal of Comparative Psychology, 128, 160-162, 2014.

This response to commentaries describes 4 kinds of cues that could guide metacognitive judgments. The cues are classified based on 2 factors: whether they are direct assessments of the information being judged (direct) or involve drawing inferences from other information (inferential), and whether they are observable to outsiders (public) or not (private). There is a consensus that using private-direct cues requires metacognition and public-direct cues does not. I argue that private- inferential cues such as familiarity qualify as metacognitive because they are internal cognitive states, but public-inferential cues such as reaction time do not qualify because they are behaviors, not cognitions. Contemplating this framework can inspire a healthy skepticism about what it is, exactly, that makes metacognition different from other situations in which animals respond based on complex cues.

The Effects of Memory Retrieval, Errors and Feedback on Learning

Nate Kornell, J. Metcalfe

In V. A. Benassi, C. E. Overson, & C. M. Hakala (Eds.). *Applying Science of Learning in Education: Infusing Psychological Science into the Curriculum* (pp. 225-251), 2014.

In recent years, a great deal of cognitive science research has focused on principles of learning that can be used to enhance education. And yet these principles have rarely been tested in real-world educational settings. For example, asking students to retrieve answers from memory enhances learning in laboratories—but what happens when a student fails to answer, or makes an error, or gets distracted? Can feedback compensate for such errors? We implemented a computer-based study program to help children learn, and

in doing so assessed three cognitive principles: Does retrieving answers help? Do errors hurt, if they are corrected? And what is the effect of feedback? We found that retrieval helped, though less robustly than we expected; making errors, if they were corrected, caused no measurable harm; and feedback was unconditionally beneficial.

Retrospective and Prospective Metacognitive Judgments in Rhesus Macaques (Macaca Mulatta)

G. Morgan, *Nate Kornell*, T. Kornblum, H.S. Terrace

Animal Cognition, 17, 249-257, 2014.

A growing body of research suggests that some non-human animals are capable of making accurate metacognitive judgments. In previous studies, non-human animals have made either retrospective or prospective judgments (about how they did on a test or how they will do on a test, respectively). These two types of judgments are dissociable in humans. The current study tested the abilities of two rhesus macaque monkeys to make both retrospective and prospective judgments about their performance on the same memory task. Both monkeys had been trained previously to make retrospective confidence judgments. Both monkeys successfully demonstrated transfer of retrospective metacognitive judgments to the new memory task. Furthermore, both monkeys transferred their retrospective judgments to the prospective task (one, immediately, and one, following the elimination of a response bias). This study is the first to demonstrate both retrospective and prospective monitoring abilities in the same monkeys and on the same task, suggesting a greater level of flexibility in animals' metacognitive monitoring abilities than has been reported previously.

Appearances can be Deceiving: Instructor Fluency Increases Perceptions of Learning Without Increasing Actual Learning

S. K. Carpenter, M. M. Wilford, *Nate Kornell*, K. M.Mullaney

Psychonomic Bulletin & Review, 20, 1350-1356, 2013.

The present study explored the effects of lecture fluency on students' metacognitive awareness and regulation. Participants watched one of two short videos of an instructor explaining a scientific concept. In the fluent video, the instructor stood upright, maintained eye contact, and spoke fluidly without notes. In the disfluent video, the instructor slumped, looked away, and spoke haltingly with notes. After watching the video, participants in Experiment 1 were asked to predict how much of the content they would later be able to recall, and participants in Experiment 2 were given a text-based script of the video to study. Perceived learning was significantly higher for the fluent instructor than for the disfluent instructor (Experiment 1), although study time was not significantly affected by lecture fluency (Experiment 2). In both experiments, the fluent instructor was rated significantly higher than the disfluent instructor on traditional instructor evaluation questions, such as preparedness and effectiveness. However, in both experiments, lecture fluency did not significantly affect the amount of information learned. Thus, students' perceptions of their own learning and an instructor's effectiveness appear to be based on lecture fluency and not on actual learning.

Feedback Reduces the Metacognitive Benefit of Tests

Nate Kornell, M.G. Rhodes

Journal of Experimental Psychology: Applied, 19, 1-13, 2013.

Testing long-term memory has dual benefits: It enhances learning and it helps learners discriminate what they know from what they do not know. The latter benefit, known as delayed judgment of learning (dJOL) effect, has been well documented, but in prior research participants have not been provided with test feedback. Yet when people study they almost universally (a) get feedback and (b) judge their learning subsequent to receiving the feedback. Thus, in the first three experiments, participants made JOLs following tests with feedback. Adding feedback significantly decreased the dJOL effect relative to conditions taking a test without receiving feedback. In Experiment 4, participants made decisions about which items to restudy (without actually restudying); adding feedback also decreased the accuracy of these decisions. These findings suggest

that, in realistic situations, tests enhance self-monitoring, but not as much as previously thought. Judging memory based on prior test performance and ignoring the effects of feedback appears to produce an "illusion of not knowing."

Phrasing Questions in Terms of Current (Not Future) Knowledge Increases Preferences for Cue-Only Judgments of Learning

I. Todorov, *Nate Kornell*, M.L. Sundqvist, F.U. Jönsson

Archives of Scientific Psychology, 1, 7-13, 2013.

Effective learning demands knowledge about what learning strategies are most effective. Much research has addressed what students' know about how to improve memory. However, to effectively study it is also important to accurately feel (i.e., monitor) how well or poorly you have learned; for example, a glossary list, because such monitoring is closely related to the decisions students make about what to restudy. Such monitoring, termed judgments of learning (JOLs), predict later recall of glossaries (i.e., word pairs) more accurately when they are made after a delay, while viewing the first word only (cue) compared with both words in a word pair (cue and target). We investigated whether people recognize the benefit of cue-only responses when making JOLs and whether their preferences depend on how JOL prompts are phrased. Forty participants studied glossaries and then made delayed cue-only and cue-target JOLs. When the JOL prompts were phrased as predictions of future memory performance, only 15% of the participants preferred the better cue-only strategy. When JOLs were instead phrased as assessments of the current state of learning, 55% preferred the cue-only strategy. To conclude, students do not seem to recognize the value of cue-only JOLs, but they picked the superior JOL strategy more often when the JOL phrasing focused their attention on their knowledge state at the time of the JOL, rather than on a future state. This indicates that study-advice to students should not only include information about how to improve memory, but also about how to improve monitoring.

Factors Influencing Infants' Ability to Update Object Representations in Memory

Mariko Moher, L. Feigenson

Cognitive Development, 28(3), 272-289, 2013.

Remembering persisting objects over occlusion is critical to representing a stable environment. Infants remember hidden objects at multiple locations and can update their representation of a hid- den array when an object is added or subtracted. However, the factors influencing these updating abilities have received little systematic exploration. Here we examined the flexibility of infants' ability to update object representations. We tested 11-month-olds in a looking-time task in which objects were added to or subtracted from two hidden arrays. Across five experiments, infants successfully updated their representations of hidden arrays when the updating occurred successively at one array before beginning at the other. But when updating required alternating between two arrays, infants failed. However, simply connecting the two arrays with a thin strip of foam-core led infants to succeed. Our results suggest that infants' construal of an event strongly affects their ability to update memory representations of hidden objects. When construing an event as containing multiple updates to the same array, infants succeed, but when construing the event as requiring the revisiting and updating of previously attended arrays, infants fail.

From Classroom to Dyad: Actor and Partner Effects of Aggression and Victimization

T.A.M. Lansu, A.H.N. Cillessen & *Marlene J. Sandstrom*

Social Development, in press.

This study examined whether early adolescents' classroom aggression predicted their aggression in a one-on-one dyadic setting, and whether early adolescents' classroom victimization predicted their victimization in the dyadic setting. After completing peer nominations for aggression and victimization, 218 early adolescents (*M* age = 11.0 years) participated in a dyadic paradigm in which they were led to believe that they

played against a same-sex classmate for whom they could set the intensity of noise blasts. Analyses with the actor–partner interdependence model by Olsen and Kenny showed that peer-nominated physical aggression for boys and relational aggression for girls predicted noise blast aggression in the dyadic setting. For girls but not boys, peer-nominated victimization predicted victimization in the dyadic setting.

Elevated Risk of Adverse Obstetric Outcomes in Pregnant Women with Depression

D. R. Kim, *Laura E. Sockol*, M. Sammel, C. Kelly, M. Moseley & C.N. Epperson

Archives of Women's Mental Health, 16, 475-482, 2013.

In this study, we evaluated the association between prenatal depression symptoms adverse birth outcomes in African–American women. We conducted a retrospective cohort study of 261 pregnant African–American women who were screened with the Edinburgh Postnatal Depression Scale (EPDS) at their initial prenatal visit. Medical records were reviewed to assess pregnancy and neonatal outcomes, specifically preeclampsia, preterm birth, intrauterine growth retardation, and low birth weight. Using multivariable logistic regression models, an EPDS score ≥10 was associated with increased risk for preeclampsia, preterm birth, and low birth weight. An EPDS score ≥10 was associated with increased risk for intrauterine growth retardation, but after controlling for behavioral risk factors, this association was no longer significant. Patients who screen positive for depression symptoms during pregnancy are at increased risk for multiple adverse birth outcomes. In a positive, patient-rated depression screening at the initial obstetrics visit, depression is associated with increased risk for multiple adverse birth outcomes. Given the retrospective study design and small sample size, these findings should be confirmed in a prospective cohort study.

Correlates of Impaired Bonding in a Partial Hospital Program for Perinatal Women

Laura E. Sockol, C.L. Battle, M. Howard & T. Davis

Archives of Women's Mental Health, 2014.

Maternal psychopathology is a risk factor for impaired mother-infant bonding, but not all women with this illness experience impaired bonding. This study investigated correlates of mother-infant bonding among 180 postpartum women treated in a psychiatric partial hospitalization program. Women completed self-report measures of depressive symptoms and mother-infant bonding, and a retrospective chart review assessed demographic characteristics, clinician-rated diagnoses, and obstetric factors. Symptoms of depression, self-reported suicidality, demographic characteristics, and mode of delivery were significantly associated with impaired bonding.

The Relationship Between Maternal Attitudes and Symptoms of Depression and Anxiety Among Pregnant and Postpartum First-Time Mothers.

Laura E. Sockol, C.N. Epperson & J.P. Barber

Archives of Women's Mental Health, 17, 199-212, 2014.

Two studies examined the relationship between maternal attitudes and symptoms of depression and anxiety during pregnancy and the early postpartum period. In the first study, a measure of maternal attitudes, the Attitudes Toward Motherhood Scale (AToM), was developed and validated in a sample of first-time mothers. The AToM was found to have good internal reliability and convergent validity with cognitive biases and an existing measure of maternal attitudes. Exploratory and confirmatory factor analyses determined that the measure comprises three correlated factors: beliefs about others' judgments, beliefs about maternal responsibility, and maternal role idealization. In the second study, we used the AToM to assess the relationship between maternal attitudes and other psychological variables. The factor structure of the measure was confirmed. Maternal attitudes predicted symptoms of depression and anxiety, and these attitudes had incremental predictive validity over general cognitive biases and interpersonal risk factors. Overall, the results of these studies suggest that maternal attitudes are related to psychological distress among first-time mothers during the transition to parenthood and may provide a useful means of identifying women who may benefit

from intervention during the perinatal period.

Preventing postpartum depression: A meta-analytic review.
Laura E. Sockol, C.N. Epperson & J.P. Barber

Clinical Psychology Review, 33, 1205-1217, 2013.

This meta-analysis assessed the efficacy of a wide range of preventive interventions designed to reduce the severity of postpartum depressive symptoms or decrease the prevalence of postpartum depressive episodes. A systematic review identified 37 randomized or quasi-randomized controlled trials in which an intervention was compared to a control condition. Differences between treatment and control conditions in the level of depressive symptoms and prevalence of depressive episodes by 6 months postpartum were assessed in separate analyses. Depressive symptoms were significantly lower at post-treatment in intervention conditions, with an overall effect size in the small range after exclusion of outliers (Hedges'g = 0.18). There was a 27% reduction in the prevalence of depressive episodes in intervention conditions by 6 months postpartum after removal of outliers and correction for publication bias. Later timing of the postpartum assessment was associated with smaller differences between intervention and control conditions in both analyses. Among studies that assessed depressive symptoms using the EPDS, higher levels of depressive symptoms at pre-treatment were associated with smaller differences in depressive symptoms by 6 months postpartum. These findings suggest that interventions designed to prevent postpartum depression effectively reduce levels of postpartum depressive symptoms and decrease risk for postpartum depressive episodes.

Marital Quality Spillover and Young Children's Adjustment:
Evidence for Dyadic and Triadic Parenting as Mechanisms
*Catherine B. Stroud***,** K. Meyers, S. Wilson & C.E. Durbin

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Research has evidenced support for the spillover model, which posits that parents' marital functioning influences child adjustment by eroding parenting and co-parenting in dyadic (mother-child and father-child) and triadic (mother-father-child) contexts. However, prior work has not simultaneously investigated dyadic and triadic parenting as mechanisms of spillover. Furthermore, although evidence indicates that the marital system affects child adjustment by influencing parents' behavior, research has not explored whether child behaviors in parent-child interactions also serve as mechanisms. To address these gaps, we examined the spillover model using observational measures of parent and child behavior in parent–child dyadic interactions as well as co-parenting in triadic interactions. We also explored parent and child gender differences in spillover effects. Participants were families with children aged 3 to 6 years (n = 149; 62% Caucasian). Findings indicated that marital functioning influences child adjustment by disrupting parent-child interactions in dyadic and triadic contexts, although results differed by child/parent gender and outcome examined. First, children's responsiveness to their mothers emerged as a significant mechanism of spillover effects for boys' internalizing and girls' externalizing behavior. Second, for girls and boys, marital functioning was indirectly related to children's internalizing and externalizing behavior through reductions in co-parenting warmth. Finally, there was little evidence that parent gender moderated the indirect effect of dyadic parenting, except that child responsiveness to mothers (versus to fathers) was more strongly related to child adjustment. These findings underscore the need for interventions targeting dyadic and triadic parent-child interactions in the face of marital distress.

Depression in Couples and Families
J. Davila, *Catherine B. Stroud* & L.R. Starr

In I. Gotlib & C. Hammen (Eds.), *Handbook of Depression, 3rd Ed.* New York: Guilford Press (in press)

As other chapters in this book also attest, depression is associated with significant interpersonal impairment, both as a cause and a consequence of the disorder. This is particularly evident than in the context of couple

and family relationships. This chapter provides an overview of the literature on depression in these contexts, highlights conceptual themes, and provide directions for future research.

Intimate Relationships

Catherine B. Stroud, B.A. Feinstein, V. Bhatia, R. Hershenberg, & J. Davila

In Richards, S. & O'Hara, M. (Eds.), *The Oxford Handbook of Depression and Comorbidity*. New York: Oxford University Press (in press)

The concurrent and longitudinal association between intimate relationship dysfunction and depression is well-established in both adolescents and adults. This association can be best understood as a bi-directional, transactional one, such that intimate relationship dysfunction and depression reciprocally influence one another over time. This chapter will review the existing research in this area, focusing on the main components and processes of intimate relationships (including how they start, function, and end) in relation to depression. Adolescent research has also focused on how romantic and sexual experiences relate to depression, which will also be reviewed. Finally, couple therapy, particularly Cognitive Behavioral Couple Therapy, will be discussed as an efficacious treatment for comorbid intimate relationship dysfunction-depression. Future directions for research are also suggested.