Report of Science

at

Williams College

2014-2015

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

Williamstown, Massachusetts

Front Cover Image:

This composite figure of M31 (the Andromeda Galaxy) demonstrates the wide-ranging locations of its planetary nebulae. Each dot, color-coded by brightness, represents one of the more than 3000 of these glowing gas shells powered by UV photons from the dying stars at their centers. Many are hidden by the inset, which shows, to scale, the familiar inclined galactic spiral of M31, located 2 million light-years away. Karen Kwitter (Astronomy) and her students study these planetary nebulae to determine their evolutionary histories and chemical compositions. With *Emma Lehman '10*, she co-authored a paper on the 16 labeled planetary nebulae shown here (http://iopscience.iop.org/0004-637X/753/1/12/pdf/0004-637X_753_1_12.pdf). And with *Kerry Hensley '13*, she co-authored a paper on eight more planetary nebulae even farther from the center of M31 (http://iopscience.iop.org/article/10.1088/0004-637X/807/2/181/pdf).

One puzzling result: the oxygen abundance in these planetary nebulae remains almost constant regardless of their distance from M31's center, contrary to the fall-off at larger distances seen in most other spiral galaxies. An intriguing possibility involves the aftermath of a close passage from M31's neighboring spiral galaxy, M33, about 3 billion years ago, which may have stirred up enriched material from which the currently-observed planetary nebulae formed.

Figure compiled by K. Kwitter (M31 image source: Bill Schoening,Vanessa Harvey/REU program/NOAO/AURA/NSF)

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.

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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, modern laboratory space, shared instrumentation, and technical support. The relatively large number of faculty in all the science departments promotes breadth and depth in both research activities and curricular scope.

In 2000, a $47 million science facility was completed to unify all science departments in a single complex surrounding a central science library. Our model of the entire science division as a cohesive programmatic unit has flourished. 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 2015 had 522 graduates, with 222 majors in a science or mathematics discipline. Approximately 25% of students in 2015 have expressed interest in careers in scientific research. The quality of the College's science programs has nurtured this interest and this year 53 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. Many students conducted independent research projects during the academic year with 72 completing theses and 180 were engaged in fulltime research with Williams science faculty during the summer of 2015. Dozens of Williams students participated in conferences where they presented the results of their research, and at least 50 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. Emphasizing close student-faculty interactions, the opportunities in undergraduate science education at Williams are exciting, diverse, and forward-looking.

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 to purchase new equipment, to support maintenance contracts and the repair of existing instruments, and also to support 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 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 College that are equal in quality to those they might experience 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 the physical sciences (astrophysics, computer science, geosciences, mathematics/statistics, and physics) and will increase the proportion of women in these fields conducting honors thesis research and pursuing doctoral degrees and careers in science. The Clare Boothe Luce research grant supports cohorts, of eight women each year for three years, 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; to include discussion sessions with Williams alumnae currently in graduate school.

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 28th 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, and 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) and 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 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 400level 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 bio logical 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 and computation are pervasive in our society. They play enormously important roles in areas as diverse as education, business, industry, and the arts. The **Computer Science Department** seeks to provide students 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 the non-major who wants a more extensive introduction to computer science in general or who seeks 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, digital media revolution, 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 program and the major 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 2600acre Hopkins Memorial Forest and its Rosenburg Center Field Station, 1.5 miles from campus, and is in the final phase of adding land from the old Wire Bridge Farm

along the Hoosic River near the Vermont border. The Environmental Science Laboratory in the Morley Science 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 their physical and biological evolution and how the planet 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 development of energy or mineral resources, or simply an appreciation of our 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 **Mathematics** major is designed to meet two goals: to introduce some of the central ideas in mathematics and to develop problem-solving ability by teaching students to combine creative thinking with rigorous reasoning. The new **Statistics** major is designed to meet three goals: to introduce some of the central ideas of information and data science, to develop problem-solving ability by teaching students to combine creative thinking with rigorous reasoning, and to develop interdisciplinary skills by applying statistics to an application area of interest. Both majors include participation in the undergraduate colloquium and opportunities for original research. Majors typically go on in mathematics, statistics, economics, other sciences, engineering, law, medicine, business, finance, consulting, teaching, and other careers.

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 Physics 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 educations. 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. Students may then take the 300 level courses, which include lab courses in which students do an original empirical study, discussion seminars, and 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 capstone 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 student 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 **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 1975-1976 the Williams faculty and the Mystic Seaport's board of directors voted to establish the Williams Mystic Program in American Maritime Studies. In 2002-2003 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 2015 Offerings

BIOL 14 Biology and Psychology of Food Intake and Taste

Examining the biological and psychological factors that influence how we consume and experience food. Topics covered include: sensory experience of various tastes, the role of olfaction, hunger and cravings, and developmental or environmental influences. We combine class lectures & discussions with kitchen- or lab-based activities that allow students to experience or experiment with tastants and ingredients.

CHEM 16 Glass and Glassblowing

We look at the theoretical consideration of the glassy state of matter and the practical manipulation of glass. We do flameworking with hand torches for at least 12 hours per week. While no previous experience is required, students with patience, good hand-eye coordination, and creative imagination find the course most rewarding. The class is open to both artistically and scientifically oriented students.

CHEM 24 Introduction to Research in Physical Chemistry

An independent experimental project in physical chemistry is carried out in collaboration with a member of the Department with expertise in physical chemistry. Current research projects in the Department include computer modeling of non-linear, chaotic chemical and biochemical systems, molecular modeling of water clusters, laser spectroscopy of chlorofluorocarbon substitutes, and observing the dynamics in glasses using single molecule spectroscopy and molecular dynamics simulations.

CSCI 12 Stained Glass Tiling

A combination of medieval craftsmanship and contemporary geometry. Each student builds a piece of stained glass using colored glass tiles that fit together to form two or three-dimensional tiling patterns. Students learn how to cut glass; to paint and print on glass with kiln-fired enamels; and to assemble and solder a stained glass window. Assignments require both artistic decision-making and practical problem-solving in figuring out ways to support, connect and assemble the tiles into a unique work of art. Instructional sessions on the use of tools and safe handling of materials are included where necessary.

CSCI 13/PSYC 13: Designing for People

Many technologically-innovative and aesthetically-beautiful products fail because they are not sensitive to the attitudes and behaviors of the humans who interact with them. The field of Human Factors combines aspects of psychology and sociology with information technology, education, architecture, and physiology, to design objects and information that are easy for people to learn and easy for people to use. The course provides students with a theoretical framework for analyzing ease-of-learning and ease-of-use, as well as practical knowledge of a variety of human factors testing methodologies. The course examines usability of a wide variety of designed objects, including buildings, publications, websites, software applications, and consumer electronics gadgets. Students demonstrate their understanding of human factors theory through a short paper and participation in class discussion. Students identify a

usability problem and design a solution which they evaluate by heuristic analysis and a usability test with 8-10 human test subjects. Findings are presented to the class. Books used in the class are: The Design of Everyday Things by Donald Norman and The Inmates are Running the Asylum by Alan Cooper.

CSCI 23: Introduction to Research and Development in Computing

An independent project is completed in collaboration with a faculty advisor from the Computer Science Department. The projects undertaken involve either the exploration of a research topic related to the faculty member's work or the implementation of a software system that extends the students design and implementation skills. Students spend 20 hours per week working on the project. At the completion of the project, each student submits a 10-page written report or the software developed together with appropriate documentation of its behavior and design. In addition, students are expected to give a short presentation or demonstration of their work. Students must consult with the instructor before the beginning of the Winter Study registration period to determine details of projects that might be undertaken.

Geos 10: Coastal Destruction: Were People Meant to Live along the Coast?

Can people live safely and permanently along the coast? The answer depends on who you ask, and where along the coast you are standing. Yet, regardless of the actual answer, people continue to flock to the coast even as the shoreline recedes and destructive storms and tsunamis occur with alarming regularity. There are underlying social, political and economic factors that draw people toward the coast which amplifies the destruction caused by natural processes and events. For example, the magnitude of destruction caused by a hurricane that blows across a deserted island is very different from that of a hurricane that hits New York City. Rising sea levels associated with climate change and rapidly growing coastal cities exacerbates the situation. During this class, students gain a basic understanding of the physical processes (e.g., coastal erosion) and events (e.g., storms, tsunamis) that dominate changes in and destruction to the coastal environment. Students the investigate how the effects of these physical processes and events can be amplified (or mitigated) by social, political and economic realities, especially those that promote continued coastal development. By the end of the class students will have a greater appreciation for the complex processes that dominate the coastal-human environment, as well as how science can inform policy decisions.

MATH 12 The Mathematics of LEGO Bricks

Since their introduction in 1949, LEGO bricks have challenged and entertained millions. In this course we explore some of the connections between LEGO bricks, 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 discuss the general theory of such computations and its effect on attacking important problems. We 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! We tried to do it in

under 10 minutes last year and just failed at 10:21; save me from doing this course three years in a row!

STAT 10 Data Visualization

Through modern technology, our world is becoming increasingly quantifiable, and it is now easier than ever to collect accurate and timely data from sources of myriad variety. Data visualization provides one means to detect patterns and structure in "big data" which can translate into accessible information to further scientific knowledge and improve decision making. In this course, we study techniques for creating effective visualizations based on principles from graphic design, visual art, perceptual psychology, and neuroscience. The class meet about 8 hours a week for lecture and discussion. In addition to participating in class discussions, students areexpected to keep a daily journal, complete short programming and data analysis exercises as well as a final data visualization project. Students write up their process and present their final visualization to the class.

PHYS 10 Holography

Examine the art and science of holography. It will introduce modern optics at a level appropriate for a non-science major, giving the necessary theoretical background in lectures and discussion. Demonstrations will be presented and students make several kinds of holograms in the lab. Thanks to a grant from the National Science Foundation, we have 7 well-equipped holography darkrooms available for student use. At the beginning of WSP, the class meets for lecture and discussion three mornings a week and for lab 2 afternoons a week. The later part of the month will be mainly open laboratory time during which students, working in small groups, conducts an independent project in holography approved by the instructor.

PHYS 13 Loop d' Loop d' Loop d' Loop d' Loop d' Loop...

This class is about music, but you don't have to be a musician to take it. It is about recursion, but you don't have to be a computer scientist to get it. We play with the subjective and social meanings of sound-art, but you don't have to be an artist to play along.

Imagine that you record yourself speaking in a room; You record the sound of that recording as it plays back in that same room; You record the recording of the recording; You sit back and let this loop repeat and repeat. Eventually your words are smoothed out by the resonances of the room into a rich melody.

Explore the world of sound-art. We transmute audio samples by harnessing the resonances of architectural spaces in Williamstown, from dorm room to theater. Emphasizing hands-on projects, students create, listen, read, and field trip their way to a new understanding of sound and recursion.

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. Where is the line between fun and danger? This course examines the realities of the role of alcohol in the social lives of college students. Students engage in active discussions of outside readings, in-class videos, and myths vs. facts, as well as personal observations and opinions. Class structure involves 3-hour classes that meet twice weekly. Participants 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 include evocative footage and interviews, such as "College Binge Drinking and Sober Reflections." We 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 is reviewed, including survey results from the Core Institute and the Harvard School of Public Health Alcohol study.

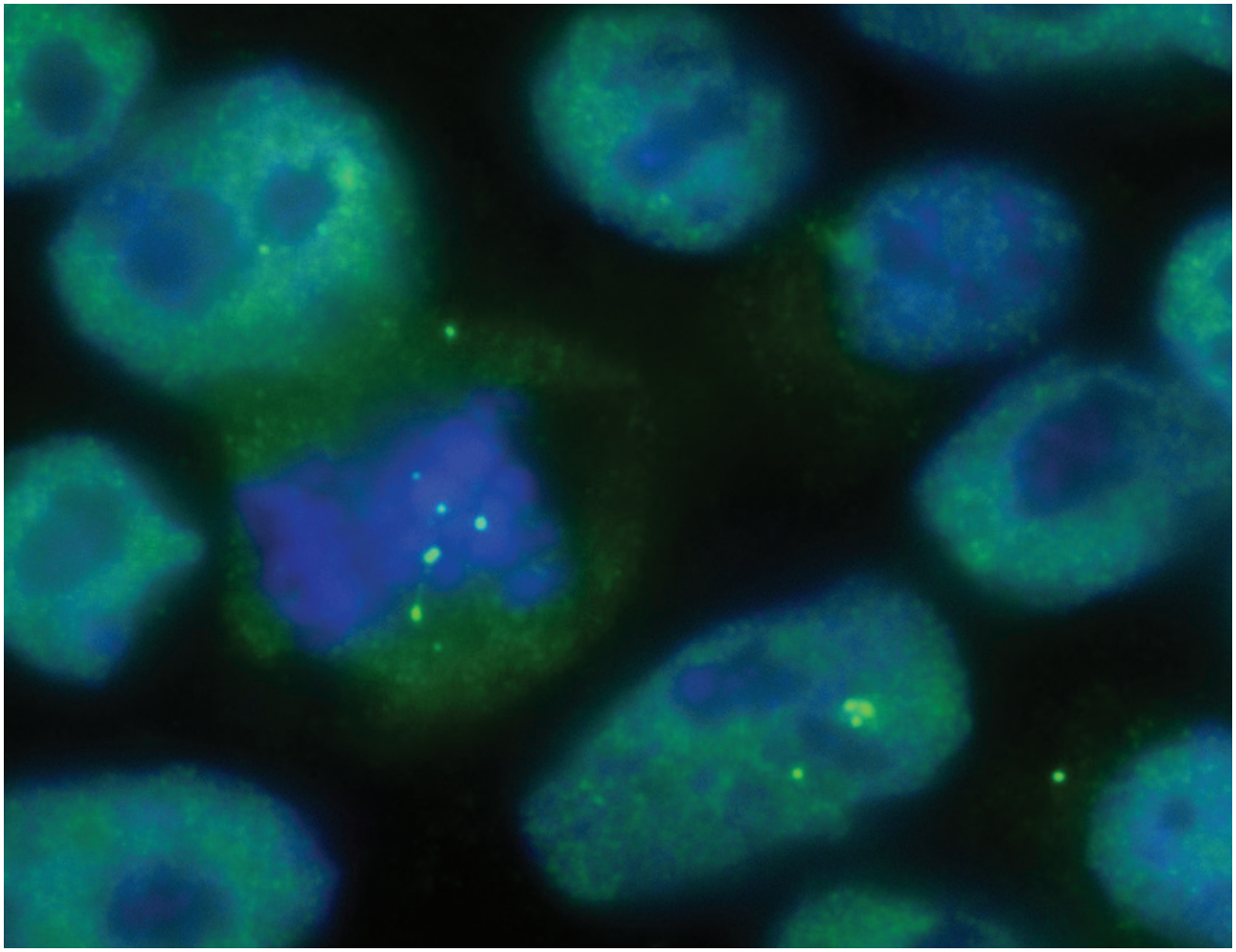
PSYC 15 Ephquilts: An Introduction to Traditional Quilting

This studio course leads the student through various piecing, appliqué and quilting styles and techniques, with some non-traditional methods included. Samples are be made of techniques learned, culminating in the completion of a sizeable project of the student's choosing (wall quilt or lap-size quilt). There is an exhibit of all work (ephquilts), at the end of winter study. "Woven" into the classes are discussions of the history of quilting, the controversy of "art" quilts vs. "traditional" quilts, machine vs. hand-quilting and the growing quilting market. The reading list includes: Pieces of the Past by Nancy J. Martin; Stitching Memories: African-American Story Quilts by Eva Ungar Grudin; Sunshine and Shadow: The Amish and Their Quilts by Phyllis Haders; A People and Their Quilts by John Rice Irwin; Treasury of American Quilts by Cyril Nelson and Carter Houck; The Quilt:

New Directions for an American Tradition, Nancy Roe, Editor.

PSYC 18 Knocking on Heaven's Door: Thanatology 101

Of the two great themes that peoples of all cultures have reflected upon since the dawn of time, love and death, the latter has only been recently addressed in undergraduate curricula. In this important and ground-breaking class, we attend to central issues dealing with the experiences of dying people; decision-making at the end of life; challenges for the care-givers; manifestations of grief as a healing process; and, that which constitutes a "death system." Our sources and materials are drawn from literature, film, psychology, philosophy, religion, ethics and the law. Some of our sessions feature first-person narratives of individuals discussing real-world scenarios.



Repeat sequences comprise half of the human genome. While this half of the genome was previously considered to be silent (not transcribed into RNA), abundant RNA is detected by RNA fluorescence in situ hybridization using a probe to specifically detect repeat sequences (bright spots), suggesting that repeats are not silent. Pictured here are human pluripotent stem cells. In the center of the image is a cell undergoing cell division that has released repeat RNA in large, bright foci. This image was taken on a Zeiss Axiovision epiflourescence microscope using a 100X objective.

photo credit: Dawn Carone, Biology

Science Center Programs

The Science Center links the Bronfman Science Center with the Thompson Biology, Chemistry, and Physics Laboratories, Schow Library, and the Morley Science Laboratory wing; 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 members of all Science diciplines. 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 lectures sponsored each semester by the local Sigma Xi chapter.

Through government agencies and private foundations, the science center oversees the distribution of more than $650,000 of research funds annually. In 2014-2015, there were thirteen individual Williams College science faculty members with active NSF grants totaling more than $3.5 million for the purchase of equipment and support of research projects.

Student Summer Science Research

The summer is a relaxed, yet focused time for research, without the competition of course work to interrupt collaborative efforts between students and faculty. 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.

Summer Research Fellowships were awarded to 180 individuals at Williams during the summer of 2015. Many of the summer research students entering their senior year are beginning work that will lead to senior honors research. A three year grant from the Sherman Fairchild foundation awarded fellowships to twelve rising sophomores and juniors who were engaged in independent research for the first time. This summer was the second year of a three year grant from the Clare Boothe Luce Foundation that funds up to eight sophomore women majoring in one of the six physical science disciplines. 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 included students from outside Williams. Students from a number of other institutions were sponsored by an NSF/REU site grant to the mathematics and statistics department.

Support for summer research, a $4000 stipend for 10 weeks, plus housing, comes from a variety of sources including 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.

2015 Summer Science Research Funding Sources

Contributors:	Number of Students Supported
Arnold Bernhard Foundation Summer Fellowships	24
Astronomy Department	1
Bronfman Science Center Fund	7
Camille & Henry Dreyfus Foundation	1
Center for Environmental Studies Department	2
Clare Boothe Luce Scholarships for Women in Science	8
Class of 1951	5
Computer Science Department	1
Freeman Foote Fund - Geosciences	1
Geology Summer Internship Program	1
Keck Northeast Astronomy Consortium	1
Lowe 1973 Chemistry Fellowships	10
Markgraf JH 1952 Fellowships	5
NASA	1
NSF/NIH grants to individual faculty	20
NSF/Small Program Mathematics	16
Petroleum Research Corporation - Chemistry	1
Research Corporation for Science Advancement - Physics	2
Science Center funds (SO & DISC)	32
Sherman Fairchild Foundation	15
Somers B & L 1948 Physics Internships	3
Sperry Family Fund - Geosciences	1
Summer Science Program Alums	8
Synott TW 3rd 1958 Physics Internships	1
Wege Markgraf Chemistry Fellowships	5
Williams Bicentennial Psychology Scholarship	1
Whitehead Scholars Program - Biology	2
William C. Grant Scholarship	1
Additional internal funding	4
Total number of 10 week stipends	**176**

2015 Summer Science Students and their Faculty Advisors

Astronomy

Rebecca Durst	Jay Pasachoff
Aylin Garcia Soto	Steve Souza
Meilu McDermott	Karen Kwitter
Tim Nagle-McNaughton	Karen Kwitter
Hallee Wong	Steve Souza

Biology

Maria Vincent Allende	Dan Lynch
Josselyn Barahona	Damian Turner
Katherine Bennett	Luana Maroja
Bethany Berry	Steven Zottoli
Osama Brosh	Luana Maroja
Graham Buchan	Manuel Morales
Gabriella Carmona	Steven Zottoli
Julia Carroll	Claire Ting
Mike Chen	Manuel Morales
Ivy Ciaburri	Heather Williams
Ellie Deveaux	Manuel Morales
William Duke	Joan Edwards
Rachel Essner	Matt Carter
Daniel Patrick Gainey	Luana Maroja
Yanira Guerra	Dan Lynch
William Hardesty-Dyck	Hank Art
Patricia Ho	Damian Turner
Intekhab Hossain	Dan Lynch
Adam Jamnik	Ben Carone
Carolina Jaramillo	Damian Turner
Aubrey Kenefick	Lois Banta
Soomin Kim	Tim Lebestky
Moon-Hyung (Jacob) Kim	Lois Banta
Catherine Landers	Dawn Carone
Brian Levine	Matt Carter
Peter Lugthart	David Smith
Natalia Miller	Dan Lynch
Conor Mook	Matt Carter
Breanna Nguyen	Lois Banta
Laura Partida	Luana Maroja
Nicole Perez	Steven Zottoli
Elise Pitmon	Tim Lebestky
Christine Reed	Alex Engel
Adam Resnick	Lois Banta
Dave Ronak	Ben Carone
Anna Ryba	Heather Williams
Lacey Serletti	Dawn Carone
Amin Seema	Dan Lynch
Penny Sun	Claire Ting
Hallie Walker	Manuel Morales
Margaret Whitney	Alex Engel

Biology-Mystic

Molly Weiner	Lisa Gilbert

Center for Environmental Sciences

Christine Pash	J. Racela/D. Dethier

Computer Science

Amelia Archer	Tom Murtagh
Gordon Finnie	A. Danyluk/J. Albrecht
Nola Gordon	Brent Heeringa
Devin Gardella	J. Albrecht/A. Danyluk
Russell (Kenny) Jones	Brent Heeringa
Jamie Lesser	Morgan McGuire
Alexander Marjercik	Sephen Freud
Dong Hwan (David) Moon	Stephen Freund
Nathan Perry	Duane Bailey
Riwaz Poudyal	Duane Bailey
Kaleb Yitong Tseo	Stephen Freund
Kai Wang	Andrea Danyluk

Chemistry

Jackson Barber	Chris Goh
Katherine Cavanaugh	Thomas Smith
Melissa Cendejas	Patrick Barber
Hannah Cole	Sarah Goh
Alexandra DeSousa	Amy Gehring

Elizabeth Gootkind	Charles Lovett
Matthew Goss	D.Richardson/J.Thoman
Ron Govin	Anne Skinner
Garrick Gu	Thomas Smith
Jacques Guyot	Patrick Barber
Taylor Jackvony	Charles Lovett
Luis (David) Jaramillo	Patrick Barber
Elizaveta Lavrova	E.Peacock-Lopez/A. Gehring
Dongheon Lee	Anne Skinner
Lia Lee	Amy Gehring
Brian Leland	Amy Gehring
Jose Lopez	Chris Goh
Stephen Mayfield	John Thoman
Alexi McAdams	Patrick Barber
Lauren Moseley	Enrique Peacock-Lopez
Jessica O'Brien	Sarah Goh
Alonso Villasmil Ocando	Charles Lovett
Carly Schissel	Thomas Smith
Emily Silva	Enrique Peacock-Lopez
Linda Shin	J.Thoman/D.Richardson
Uygar Sozer	Enrique Peacock-Lopez
Galen Squiers	Charles Lovett
Megan Steele	Amy Gehring
Young Sun Lee	Charles Lovett
Samuel Swire	Enrique Peacock-Lopez
Lindsey Vandergrift	Sarah Goh
Miranda Villanueva	Charles Lovett
Douglas Wassarman	Jimmy Blair

Geosciences

Caroline Atwood	David Dethier
Henry Barker	Pheobe Cohen
Jordon Fields	Ronadh Cox
Joshua Harrington	Ronadh Cox
Mary Ignatiadis	David Dethier
Spencer Irvine	Pheobe Cohen
Abigail Kelly	Pheobe Cohen
Kaitlyn Kelma	Lisa Gilbert
Ezekiel King Phillips	Ronadh Cox
Jeffrey Rubel	Mea Cook
Christina Seeger	Ronadh Cox
Laura Stamp	Paul Karabinos
Molly Weiner	Lisa Gilbert
Caroline White-Nockleby	Mea Cook

Mathematics & Statistics

Alvaro Aleman	Brianne Heggeseth
Megumi Asada	S. Miller/A. Palsson
Owen Barrett	S. Miller/A. Palsson
Jonathan Berry	Frank Morgan
Phillip Brockman	Bernhard Klingenberg
Paula Burkhardt	S. Miller/A. Palsson
David Burt	S. Miller/A. Palsson
Aaron Calderon	Colin Adams
Matthew Dannenberg	Frank Morgan
Sophia Dever	Leo Goldmakher
Jonathan Dewitt	S. Miller/A. Palsson
Robert Doward	S. Miller/A. Palsson
Michael Druker	Leo Goldmakher
Xixi Edelsbrunner	S. Miller/A. Palsson
Sarah Fleming	Susan Loepp
Eva Fourakis	S. Miller/A. Palsson
Eli Goldstein	S. Miller/A. Palsson
Lena Ji	Susan Loepp
Xinyi Jiang	Colin Adams
Alexander Kastner	Colin Adams
Gregory Kehne	Colin Adams
Jason Liang	Frank Morgan
Isaac Loh	Cesar Silva
Sarah Manski	S. Miller/A. Palsson
Nathaniel Mayer	Colin Adams
Peter McDonald	Susan Loepp
Alexander Meyer	Julie Blackwood
Gwyneth Moreland	S. Miller/A. Palsson
Nina Pande	Susan Loepp
Huy Pham	Leo Goldmakher
David Schwein	Susan Loepp
Mia Smith	Colin Adams
Gabriel Staton	S. Miller/A. Palsson
Hong Suh	S. Miller/A. Palsson
Blaine Talbut	S. Miller/A. Palsson

Kevin Yang	S. Miller/A. Palsson
Vidya Venkatesh	Leo Goldmakher
Yingyi Zeng	Frank Morgan

Neuroscience

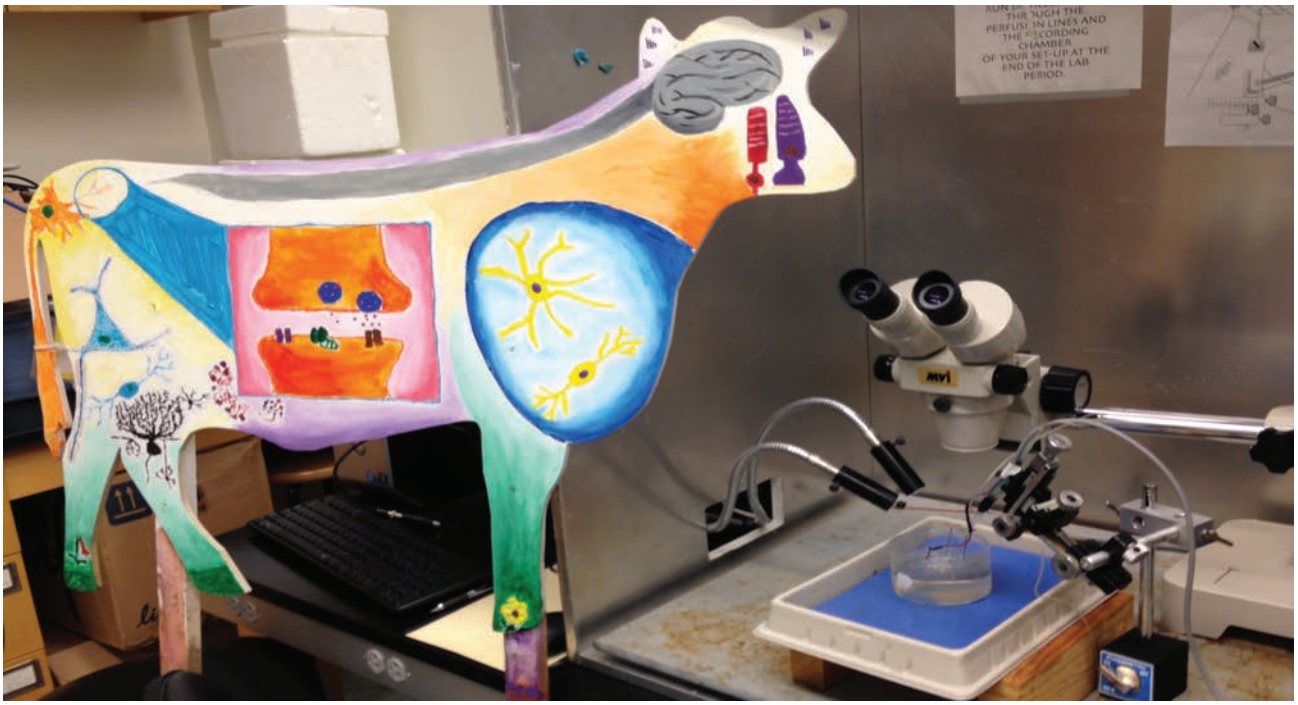
Naomi Currimjee	Martha Marvin
Jacqueline Harris	Martha Marvin
Tracey Kim	Martha Marvin

Physics

Michael Flynn	Daniel Aalberts
Allison Carter	Protik Majumder
Sau Man Cheng	Protik Majumder
Jaeho Choi	Bill Wootters
Brian Cintron	Jeff Strait
Sierra Jubin	Charles Doret
Owen Kay	Charles Doret
Will Kirby	Bill Wootters
Bijan Mazaheri	Daniel Aalberts
Ashay Patel	Jeff Strait
Matt Radford	Dave Tucker-Smith
Anneliese Rilinger	Kevin Jones
John Russell	Dave Tucker-Smith
Ariel Silbert	Charles Doret
Sam Steakley	Bill Wootters
Nathaniel Vilas	Protik Majumder
Daniel Wong	Daniel Aalberts

Psychology

Claire Bergey	Safa Zaki
Rebecca Dunwoody	Mariko Moher
Candice Dyce	Alex Engel
Syed Fareed (Bukhari)	Lauren Williamson
Amelia Hidalgo	Lauren Williamson
Sarah Lehman	Lauren Williamson
Benjamin Lin	Moher J./Moher M
Carey Marr	Kate Stroud
Mai Mitsuyama	Amie Hane
Abigail Pugh	Safa Zaki
Stephanie Stacy	Safa Zaki
Lauren Steele	Betty Zimmerberg
Keiana West	Laura Sockol
Sarah Wieman	Amie Hane
Charley Wyser	Laura Sockol



Summer Science Research Poster Session: August 14, 2015

At the end of the summer, individual students (or teams) who were engaged in Summer Science Research can choose to present a poster highlighting the research they had been working on. Posters are reviewed by their peers, faculty and visitors. Student posters are listed below with their faculty advisor(s) by department.

Team	Advisor(s)	Title
MeiLu McDermott and Timothy Nagle-McNaughton	Karen Kwitter	Modeling Planetary Nebulae in the Outer Disk of M31
Rebecca Durst	Jay Pasachoff	Observation of the 2015 June 29 Pluto Occultation
Hallee Wong, Aylin Garcia Soto	Steve Souza	Short Term Variability in NGC 1960
Jacob Kim, Adam Resnick, Breanna Nguyen, Aubrey Kenefick	Lois Banta	A. tumefaciens T6SS elicits host defences that limit transformation and subsequent pathogen infection
Ronak Dave, Adam Jamnik	Ben Carone	Comparing Nucleosome Mapping Efficiency of Bleomycin vs. Micrococcal Nuclease
Kiki Landers, Lacey Serletti	Dawn Carone	In Situ Analysis of Repeat RNA Structure
Christine Reed, Margaret Whitney	Alex Engel	Immune sensing and membrane trafficking: Intracellular TLRs localize to late compartments
Elise Pitmon and Soomin Kim	Tim Lebestky	Role of Dopamine Receptor in Grooming, Sleep, and Visuolocomotor Arousal
Natalia Miller, Seema Amin	Daniel Lynch	Effects of Boron Deficiency on Physcomitrella patens sphingolipids
Yanira Guerra	Daniel Lynch	sphingolipid long-chain bases are required for physcomitrella growth and viability
Daniel Patrick Gainey	Luana Maroja	Mapping of reduced introgression loci on X chromosome of Gryllus firmus and Gryllus pennsylvanicus
Katie Bennett	Luana Maroja	Genetic structure of Sagina nodosa populations on Isle Royale, Michigan
Laura Partida	Luana Maroja	The Role of Female Cuticular Hydrocarbons in the Male Courtship Behavior of Hybridizing Crickets G. firmus and G. pennsylvanicus
Osama Brosh	Luana Maroja	Where Do Frogs Lay Their Eggs?
Graham Buchan, Michael Chen, Eleanor Deveaux, Reena Walker	Manuel Morales	Mutualism dynamics of P. Concava across loci and host plant choice as a metric of simulated herbivory on S. Altissima.
Julia Carroll, Penny Sun	Claire Ting	A Prokaryote's Guide to Survival in the Oceans: How to Thrive in a Sea of Microbes

Patricia Ho, Carolina Jaramillo, Josselyn Barahona	Damian Turner	Investigating the Mechanism of Tolerance Induction through Allergen-Specific Immunotherapy
Douglas Wassarman	Jimmy Blair	Evaluating small molecule inhibitors of CckA
Alexandra DeSousa & Lia Lee	Amy Gehring	Assaying the Role of SCO6672 in S. coelicolor Antibiotic Production
Brian Leland and Megan Steele	Amy Gehring	Characterization of the Streptomyces coelicolor Life Cycle
Dylan M. Barber	Sarah L. Goh	Concentration-Dependent Morphologies
Emily Silva	Enrique Peacock-Lopez	Twelve-Month Seasonality in the Logistic Map
Lauren Moseley	Enrique Peacock-Lopez	Catalytic Dimer on Chemical Self-Replication
Samuel Swire	Enrique Peacock-López	Chaos in Treehopper-Ant Mutualism: Ecological Reality or Mathematical Phenomena?
Uygar Sozer	Enrique Peacock-López	Pattern formation in ecological reaction-diffusion systems and the effects of cross-diffusion
Elizaveta Lavrova	Enrique Peacock-Lopez and Amy Gehring	Construction of a Minimal 2-Gene Oscillator
Elizabeth Gootkind, Taylor Jackvony, Young Sun Lee, Galen Squiers	Chip Lovett	Identifying and characterizing inhibitors of the bacterial SOS system
Matthew Goss, Linda Shin	D Richardson, J Thoman	PCB Analysis in Hoosic River Trout
Dongheon Lee	Anne Skinner	Comparing ESR and OSL dates of fossil teeth from Affad 23, Sudan
Ronald Govin	Anne Skinner	ESR Dating of Teeth from Mumba Cave
Linda Shin	Jay Thoman	Analysis of PCB contamination
Devin Gardella	Jeannie Albrecht	Visualizing Energy Usage in the Kellogg House
Nathan Perry	Duane Bailey	FPGA Fabric and the Linux Kernel
Riwaz Poudyal	Duane Bailey	Curling Number of Sequences
Kai Wang	Andrea Danyluk	Unsupervised Salamander Matching With Stacked Denoising Autoencoders
Gordon Finnie	A Danyluk, J Albrecht	Machine Learning and Energy Disaggregation
Alexander Majercik, Yitong Tseo	Stephen Freund	Überlock
David Moon	Stephen Freund	Optimizing Dynamic Race Detection With Hash Consing
Kenny Jones and Nola Gordon	Brent Heeringa	Using Visual Memory to Encode Sensitive Information
Jamie Lesser	Morgan McGuire	Blue Noise Dithering

Abby Kelly	Phoebe Cohen	Microfossil Assemblage Variation Across the Late Devonian Mass Extinction Event
Caroline White-Nockleby and Akuku Makori	Mea Cook	Tephrachronology as a tool to constrain reservoir age in the deglacial Bering Sea
Aaron Calderon, Xinyi Jiang, Alex Kastner, Gregory Kehne, Nathaniel Mayer, Mia Smith	Colin Adams	Hyperbolic links: tilings and densities
Vidya Venkatesh	Leo Goldmakher	Additive decompositions of dense sets
Alvaro Aleman	Brianna Heggeseth	Effect of Baseline Characteristics on Longitudinal Growth Patterns: A Comparison of Statistical Methods
Phil Brockman	Bernard Klingenberg	Statistics Android Application
Sarah Fleming, Lena Ji, Peter McDonald, Nina Pande, David Schwein	Susan Loepp	Unexpected Spectral Connections Between Rings
Megumi Asada, Eva Fourakis, Eli Goldstein, Sarah Manski, Gwyneth Moreland	N. McNew, S. Miller	A Ramsey Theoretic Approach to Function Fields, Quaternions, and Free Groups
Megumi Asada, Paula Burkhardt, Jonathan DeWitt, BobbyDorward, Eva Fourakis, Gwyneth Moreland, Blaine Talbut, Kevin Yang	O. Barrett, S. Miller, C. Turnage-Butterbaugh	From Analysis to Arithmetic: An Investigation of L-Functions
David Burt, Blaine Talbut	S. Miller, E. Palsson	Benford's Law of Digit Bias
Megumi Asada, Bobby Dorward, Eva Fourakis, Sarah Manski, Hong Suh	S. Miller, E. Palsson	Zeckendorf Decompositions and More Sums Than Differences Sets
David Burt, John Dewitt, Eli Goldstein, Sarah Manski, Gwyneth Moreland, Hong Suh	S. Miller, E. Palsson	Problems and Applications of Combinatorial Geometry and Analysis
John Berry	Frank Morgan	Optimal Pentagonal Tilings
Bijan Mazaheri	Daniel Aalberts	Clustering RNA Secondary Structures into Macrostates
Ariel Silbert, Sierra Jubin, Owen Kay	Charlie Doret	It's a Trap! Preparing to Trap and Cool Ca+
Elena Polozova	C. Doret, M. Taylor	Making Dreams into Reality: Machining a Vacuum Chamber to Stabilize a Laser
Allison Carter	Tiku Majumder	Precise Measurement of the Stark Shift in the Indium 6P1/2 State Using Two-Step Laser Spectroscopy
Sauman Cheng and Nathaniel Vilas	Tiku Majumder	Precise measurement of the 8P1/2 hyperfine splitting in Tl-203 and Tl-205 using two-step laser spectroscopy
John Russell	Dave Tucker-Smith	Search for a Heavy Top Quark at the LHC
Matthew Radford	Dave Tucker-Smith	New Physics at the LHC: Searching Beyond the Standard Model

Brian Cintron & Ashay Patel	Jefferson Strait	Nonlinear Optical Loop Mirror (NOLM) Fiber Laser
Sam Steakley and Jaeho Choi	William Wootters	Classical Approximation of Quantum Systems of Many Spin-1/2 Particles
William Kirby	William Wootters	Quantum Entanglement as a Resource
Rebecca Dunwoody and Benjamin Lin	J. Moher, M. Moher	Can Kids Chunk? The Role of Spatial and Categorical Cues in Children's Memory

Summer Science Research Colloquia 2015

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.

Speaker	Title
Norman Bell	Lab Safety
Ben Carone, Biology	Transgenerational Epigenetics: You are what your Grandparents ate
Steven Miller, Math	Extending Pythagoras
David Dethier, Geosciences	Using Lidar to help see the forest, the trees and the ground
Sarah Goh, Chemistry	Polymers for [oxidative] stress relief
Jay Pasachoff, Astronomy	Observing the 2015 and 2017 total solar eclipses
David Tucker Smith, Physics	After the Higgs
Brent Heeringa, Computer Science	Using Recognition Memory to Encode Information
Mea Cook, Geosciences	Radiocarbon dating and ocean circulation

Pre-First Year Summer Science Program

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.

In its twenty-eighth summer in 2015, twenty-five 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 performance at the Williamstown Theater Festival and a weekend trip to Mystic Seaport.

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 the sciences. And several 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 Cassandra Cleghorn (English), and Professor Ronadh Cox conducted the geology field laboratory.

The Summer Science Program has been funded primarily by Williams College as part of its commitment to encourage the participation of traditionally underrepresented 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 students 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.

Grace Sullivan '17 assists 5th and 6th grade participants in the Summer Science Lab Program with their experiment.

2015 Pre-First Year Summer Science Program Participants

Students

Chinonso Anokwute
David Ariyibi Jr.
Mikhayla Armstrong
Alexia Barandiaran
Katherine Blake
Iliana Cobos
Quinnton Cooper
William Fung
Christian Holway
Si Hou Lon
Alejandra Magana
Oscar Merino
Esmeralda Navarro
Melani Ortega
Dawn Penso
Cielo Perez
Cecilia Pou Jove
James Rasmussen
Daniel Russell
Aesha Siddiqui
Larissa Silva
Josemaria Silvestrini
Anthony Simpson
Brandon Vuong
Alison Wong

Faculty

Cassandra Cleghorn
Ronadh Cox
Charles Lovett, Director
Dan Lynch
David Richardson
Cesar Silva
Mihai Stoiciu

Tutors

Malcolm Singleton
Miranda Villanueva
Alonso Villasmil
Stella Worters

Students and faculty advisors from the Summer Science Program 2015

Summer Science Lab Program

For the last seventeen years Williams College Summer Science Lab has brought science alive for local elementary students. Summer Science Lab is an amazing science experience for children entering 5th or 6th grade. Elementary students in groups of four, experiment with a variety of substances in Williams College laboratories. Each Lab group is guided by a Williams College or Massachusetts College of Liberal Arts undergraduate and investigates a variety of chemical reactions relating to solids, liquids and gasses. Williams College chemistry professors David Richardson and Charles Lovett present chemical mysteries to the young scientists and explain, through demonstrations and experiments, the chemistry behind those mysteries.

The mission of Summer Science Lab is to get elementary students more engaged with and educated in the scientific process and how things work at the molecular level, and to help undergraduates, who are aspiring scientists and educators, understand how to teach science.

Two lab weeks are offered in late June and early July. In 2015 five Williams College and three MCLA students taught elementary students through hands-on experiments, which explore scientific processes. Hailing from eighteen different towns, forty-six elementary students attended Summer Science Lab.

This model science teaching experience for undergraduates places them alongside college faculty as well as two local high school science teachers, who act as director and assistant director, for Summer Science lab.

Historically Summer Science Lab began in 1999 with funding from the Howard Hughes Medical Institute. Over the years additional support has also come from Williams College Olmsted funding. Currently elementary student fees fund Summer Science Lab, as well as a National Science Foundation grant, Teaching to Learn. Teaching to Learn funds Williams College and MCLA student stipends for their leadership and teaching during Summer Science Lab. Also Williams College generously sponsors elementary student scholarships to make this opportunity widely available.

We are grateful for the continuing support of science faculty, Summer Science Lab director and assistant director, Williams and MCLA undergraduates, the Center for Learning in Action, and Williams College in providing this valuable learning experience to the children of our community.

Summer Science Lab Program Participants

Students

Seema Amin '18
Dylan Caples (MCLA)
Greg Ferland '16
Yanira Guerra '17
Michael Smith (MCLA)
Grace Sullivan '17
Darla Torres '18
Jessica Wojcik (MCLA)

Williams Faculty

Dave richardson
Chip Lovett

Local teachers

Stephen Bechtel - Director
Tim Herrman - Asst. Director

And 46 Elementary School Students!

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 2014 -15 were Professor Jay Pasachoff of the Astronomy Department, President, and Professor Lois Banta of the Biology Department, Secretary/Treasurer.

This year, as usual, the local Sigma Xi chapter sponsored two excellent talks directed to broad community audiences. In October, Matt Carter, Assistant Professor of Biology, presented, "The Neuroscience Behind A Good Night's Sleep." In April, Marek Demianski, visiting Professor of Astronomy, presented "How Did the Universe Come In to Existence?" The lectures were followed by lively and well-attended receptions 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 Melissa Swann.

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 53 newly elected associate members from the class of 2015 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 induction ceremony, graduation 2015
Photo by: Charles Augenbraun

2015 Associate Sigma Xi Inductees

Biology
Achala Chittor
Emily Gaddis
Nitsan Goldstein
Amir Hay
Elissa Hult
Julie Jung
Daeun Kang
James Marvel-Coen
Alexandra McInturf
Adrian Mitchell
Alice Stears
Gabriel Stephens
Kiah Walker
Daniela Zarate

Chemistry
Dylan M. Barber
Tamuka Chidanguro
Ivan J. Huerfano
Salmaan A. Karim
Ashley A. Kim
Claire A.L. Lidston
Lillian Ma
Linamarie Miller
Alexander J. Silver
Katherine J. Susa

Computer Science
Sarah M. Abramson
Gregory B. Becker
Daniel Evangelakos
Emma K. Harrington
Isaiah H. Leonard

Geosciences
Alice U. Chapman
Nell E. Davis
Victor W. Major
Oona G. Watkins
Will J. Wicherski

Mathematics & Statistics
Wyatt B. Boyer
Benjamin H. Demeo
Jesse B. Freeman
Nicholas K. Gardner
Isaac C. Loh
Samantha N. Petti
Eric G. Schneider

Neuroscience
Anuj Shah

Physics
Samuel T. Amdur
Benjamin L. Augenbraun
Weng-Him Cheung
Julia R.K. Cline
Michael J. Flynn
Brandon V. Ling
Cole M. Meisenhelder
Gabriel O. Samach

Psychology
Caroline C. Kaufman
Raea E. Rasmussen

Psychology/Neuroscience
Amanda L. Schott

Academic Year Science Lunch Colloquia 2015

In an effort to foster collaboration between the various science departments, the science center sponsors a luncheon for faculty and staff of the sciences to meet and descuss current topics in their research. Each week a faculty member presents findings and progress in their research. below are the presenters and topics from the 2014-2015 academic year.

Presenter	**Title**
Tiku Majumder, Physics	Welcome and Introductions
Thomas Garrity, Mathematics	On novel ways for thinking about numbers
Alex Engel, Biology	Fighting pathogens and tolerating self: Immune sensors and subcellular organization
Manuel Morales, Biology	Mutualism: the long and short of it.
Enrique Peacock Lopez, Chemistry	Spatial patterns in mutualism
Brent Heeringa, Computer Science	"Using Recognition Memory to Encode Information"
Colin Adams, Math/Stats	Zombies & Calculus; A Survival Guide
Steven Miller, Math/Stats	From Fibonacci Quilts to Benford's Law through Zeckendorf Decompositions
Alex Apotsos, Geosciences	"Turbulence in the Water: Mixing Science and Policy"
Allison Pacelli, Math/Stats	Common Core Math
Steve Swoap, Biology	Sugar, Sugar, Sugar…
Luana Maroja, Biology	Genes with restricted interspecific gene flow between cricket species are concentrated on the X-chromosome.
Robert Volz, Chapin Library	Rare books
David Dethier, Geosciences	Using Lidar to help geoscientists see the ground!
Anne Skinner, Chemistry	Immigration to the Americas: Who were the 'real' first Americans?
Jennifer Swoap, Ctr for Learning in Action	Center for Learning in Action
Laurie Heatherington, Psychology	Studying Mental Health Outcomes in the Field
Lisa Gilbert, Mystic-Williams	Citizen science inspired by Moby-Dick
Michael Taylor, Science Shop	Not Your Run of the Mill Machine Shop
Jay Pasachoff, Astronomy	March 20's total solar eclipse in Svalbard

Astronomy Department

Faculty of the Astronomy Department included Jay Pasachoff, Chair, Field Memorial Professor of Astronomy, and Director of the Hopkins Observatory; Karen Kwitter, Ebenezer Fitch Professor of Astronomy (on leave, spring semester); Marek Demianski (Visiting Professor of Astronomy, spring semester); and Steven Souza, Senior Lecturer in Astronomy. Bryce Babcock, who retired as Staff Physicist and Coordinator of Science Facilities, has continued at Williams as Associate of the Hopkins Observatory. The summer 2014 planetarium teaching assistants were Teddy Amdur '14, Allison Carter '16, Muzhou Lu '13 and visiting Keck Northeast Consortium Summer Fellow, Adam Schiff. The summer 2014 observatory teaching assistants were Michael May '17, Christina Seeger '16, and Sarah Stevenson '17.

Marek Demianski has been visiting professor at Williams more than a dozen times, replacing Profs. Pasachoff and Kwitter during their leaves. While here, he continued his work on the early epoch of the Universe, especially through observations of the cosmic background radiation with the European Space Agency's Planck Mission. He taught a 200-level course (ASTR 221) on compact stellar objects (white dwarfs, neutron stars/pulsars, black holes) and an advanced, 400-level course (ASTR 420) on cosmology.

Prof. Demianski gave the Sigma Xi lecture in the spring semester on the topic of the early Universe.

Professor **Karen Kwitter** continues 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 has observed 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). Our latest paper on this work was published in the Astrophysical Journal in June 2015, with Kerry Hensley '14, Kwitter's thesis student, as co-author. Williams is part of a consortium of small colleges that has entered into a three-year agreement for purchasing telescope time at APO, and she will continue to observe remotely from campus with students.

With colleagues, Kwitter continued work 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 PN parent stars. The first paper from this collaboration was published in the Astrophysical Journal in April 2015.

Kwitter serves on the International Astronomical Union's Working Group on Planetary Nebulae (now reconstituted as Commission C.H.3 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; this was published in 2014. She continued as the coordinator for the summer intern program of the Keck Northeast Astronomy Consortium (KNAC). In November 2014, she attended the KNAC Student Research Symposium at Swarthmore College, and in July 2015 she attended the KNAC faculty meeting at Wesleyan University. In January 2015 she attended the 225th meeting of the American Astronomical Society in Seattle, where she gave an invited talk at a special session on "The Emerging Multiwavelength View of Planetary Nebulae," and co-authored four posters on her group's Hubble Space Telescope ultraviolet data.

In the spring 0f 2015 Kwitter began serving on the Van Biesbroeck Prize Committee of the American Astronomical Society; the committee awards this prize to a member who has a longstanding history of substantial service to the astronomical community, often beyond the scope of his or her paid position.

Professor **Jay Pasachoff** with Allison Carter '16 and colleagues observed the total solar eclipse of March 20, 2015, from Svalbard, at latitude 78° in the Arctic, with support from the Committee on Research and Exploration of the National Geographic Society.

The Pasachoff team was studying especially the solar corona, which is now past its appearance that corresponded to the maximum of the solar-activity cycle. They made high-resolution imaging of the corona, which has been assembled into various compound images, including joint work with D*an Seaton '99*, who is now director of the SWAP (Sun-Watcher with Active Pixels) telescope on the European Space Agency's PROBA2 spacecraft. Other compound images have been made in collaboration with a large number of other eclipse-expedition members.

Other observations at the Svalbard eclipse included spectra taken with an instrument built and then operated on site by Aristeidis Voulgaris in collaboration with John Seiradakis of the Aristotle University of Thessaloniki, Greece.

Work was completed on analyzing the imaging data from the 2012 eclipse, and is continuing with analyzing the imaging data from 2012 and the spectral data from the 2012 and 2013 eclipses. Work was carried on during the summer of 2014 with *Tina Seeger '16* and Keck Northeast Astronomy Consortium Summer Fellow Adam Schiff of Middlebury College. The studies of the annular and total eclipses of 2012 are supported by a grant from the National Science Foundation's Atmospheric Sciences Division's Solar Research Program.

Pasachoff continued working with Dale Gary of the New Jersey Institute of Technology and his student Shaheda Begum Shaik on high-resolution observations of the sun made with the Jansky Very Large Array outside Socorro, New Mexico, as part of the NSF-sponsored project to study the 2012 annular solar eclipse

Pasachoff observed the partial solar eclipse of October 23, 2014, from the Sacramento Peak Observatory at Sunspot, New Mexico. It was his 60th solar eclipse observation. See http://totalsolareclipse.org. He then participated in a Solar Eclipse Conference in neighboring Cloudcroft.

Pasachoff continued his solar-system work, together with Bryce Babcock and MIT colleagues including Michael Person, Amanda Bosh, and Carlos Zuluaga as well as Southern African Astronomical Observatory colleague Amanda Gulbis, on studying the atmosphere of Pluto and other aspects of the outer solar solar system through the method of stellar occultations. The teams published two articles in the journal Icarus (1) about the analysis of their observations of a double occultation by Pluto and its largest moon, Charon, in 2011 and (2) about a study of Pluto atmosphere that concludes that Pluto will still have an atmosphere in 2015 when the NASA New Horizons spacecraft arrives. They observed several Pluto occultation events during the summer of 2014 from the Mt. John University Observatory in Tekapo, New Zealand, with Pasachoff and Schiff on site, with coordinated observations from Australia and Chile. This effort included attempts at observing Pluto's moon *Nix* and the Kuiper Belt object *Quaoar* in addition to their Pluto successes. 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. The team prepared an expedition for Pasachoff, Babcock and *Rebecca Durst '16* to the Mt. John Observatory, to be joined there with junior-semester-abroad-in-New-Zealand *Christina Seeger '16*, for observing an especially bright star being occulted on June 29, 2015, coordinated with colleague Michael Person on NASA's instrumented airplane, Stratospheric Observatory for Infrared Astronomy (SOFIA) flying nearby out of Christchurch.

Pasachoff continued his work on studying the 2012 transit of Venus and the relation of the observations to in situ observations at Venus from the European Space Agency's Venus Express spacecraft. Most of the observations had been made at the Haleakala Observatory of the University of Hawaii on Maui together with Bryce Babcock and Muzhou Lu '13, with support from the Committee on Research and Exploration of the National Geographic Society. Ron Dantowitz of the Clay Center Observatory in Brookline, Massachusetts, was a key member of the team and brought his RED Epic IMAX-quality cameras. Coordinated observations were made in collaboration with Kevin Reardon '91 at the Sacramento Peak Observatory; Reardon joined the National Solar Observatory staff, which has moved to Boulder, Colorado. Pasachoff is studying such effects in collaboration with Glenn Schneider of the University of Arizona's Stewart Observatory and with Dr. William Sheehan of Minnesota.

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. He was Chair (2013-2015) of the Historical Astronomy Division of the American Astronomical Society, and is now Past Chair (2015-2017) and chair of the prize committee. He was involved in planning a Historical Astronomy Division session at Seattle for the January 2015 meeting, and a Historical Astronomy Division session jointly with the Division of Planetary Sciences at their Tucson meeting in November 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. These IAU commissions are being revised in a new Union-wide structure, including C.C1 for Historical Astronomy and C.C3 for Education and Development, and Pasachoff is preparing papers to be delivered at the the General Assembly of the IAU to be held in Honolulu in August 2015. See http://www.eclipses.info and http://www.transitofvenus.info. Pasachoff continues as representative of the American Astronomical Society to the American Association for the Advancement of Science's Astronomy Division

He attended the AAS's Division of Planetary Sciences meeting in November 2014 in Tucson, and the Solar Physics Division's May 2015 meeting in Indianapolis, as part of the first Triennial Earth-Sun Summit (TESS). Pasachoff, summer student Schiff, and the occultation team presented Pluto studies in Tucson and in Seattle; Pasachoff and Carter presented their eclipse results in Indianapolis.

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 in total intensity 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. Pasachoff and Olson had an article on solar eclipses in art, the cover story in Nature for April 17, 2014, and they continue discussing the eclipse paintings of Howard Russell Butler and others.

Pasachoff continued his work on the history of astronomy with a paper at the January AAS meeting, with a full version published in the May 2015 issue of the Journal for the History of Astronomy about the independent discovery of the four major moons of Jupiter by Simon Marius in 1610 (Gregorian calendar), one day after Galileo's famous discovery. In honor of the opening of the new Williams College library facility, and the Year of the Book at Williams, Pasachoff gave a seminar on Great Astronomers and their Original Publications, crosslisted in History of Science and in Leadership Studies, with guest speakers from all over the U.S. and in coordination with Wayne Hammond, Assistant Librarian of Williams College's Chapin Library. Two of the speakers' expenses were supported in part by the NASA Massachusetts Space Grant Consortium. Other parts of the speakers' expenses were supported in part by the Williams College Lecture Committee. Contributions were made by the Astronomy, Physics, History of Science, and History Departments. Pasachoff's Astronomy 101 and 104 lecture classes also visited the Chapin Library to see original books by Copernicus, Galileo, Kepler, Newton, Fraunhofer, and others.

Pasachoff continued as President of Williams College's Sigma Xi chapter and as the Williams College representative to the NASA-sponsored Massachusetts Space Grant.

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*.

Pasachoff, a Fellow of the Society for Skeptical Inquiry, is on the editorial board of the *Skeptical Inquirer*.

Steven Souza conducts and supervises the astronomy observing program, indoor labs, and daytime observing. He hosted numerous observatory visitors, including: planetarium groups, Summer Science Program particpants, alumni, Family Days attendees, Mt. Greylock HS students, MCLA students, Berkshire Community College students, Arlington VT middle school students, Ciao Italia participants, Prof.

Laleian's photography class, and student previews and prospectives. In November 2014 he presented a guest lecture "Magnetic Resonance Imaging" in CHEM 364. He continues to maintain and improve the observatory, and has begun planning for a major upgrade, which includes adding remote/robotic operation. He also maintains department computer systems, and once again upgraded the astronomy department server with new hardware and software. He acts as department liaison with OIT and Facilities, and worked with Facilities, WCMA and Athletics regarding campus light pollution issues. Souza served as a first-year/sophomore advisor, and as a facilitator for Williams Reads: "The Immortal Life of Henrietta Lacks."

Souza continued his research effort to monitor variations in H-alpha emission in massive stars in young open star clusters. He served as summer research advisor for Sarah Stevenson '17 and Michael May '17, whose research work resulted in a presentation entitled "Narrowband Color-Magnitude Diagrams for Young Open Clusters" at the Keck Northeast Astronomy Consortium (KNAC) Student Symposium at Swarthmore College in November 2014. He continued research observations locally, and began remote observations using the 0.5-m ARCSAT telescope at Apache Point Observatory in New Mexico. He also began a major rework of the computing resources used in this work. Souza attended the KNAC Faculty Meeting at Haverford College in June 2014, and the KNAC Student Symposium in November.

Astronomy Colloquia

[Colloquia are held jointly with the Physics Department. See Physics section for listings.]

Marek Demianski
"The New View of the Universe"
Sigma Xi Lecture, April 2015

Karen B. Kwitter
"The Lives of Stars"
Faculty Research Luncheons for Staff, April 2015

Jay Pasachoff
"March 20's total solar eclipse in Svalbard"
Science Center Lunch Talk, May 2015

Off-Campus Astronomy Colloquia

Karen B. Kwitter

"What Are M31 Disk Planetary Nebulae Trying to Tell Us?"
invited talk at a Special Session on The Emerging Multiwavelength View of Planetary Nebulae at the 225th American Astronomical Society meeting in Seattle, WA, January 2015

Jay M. Pasachoff

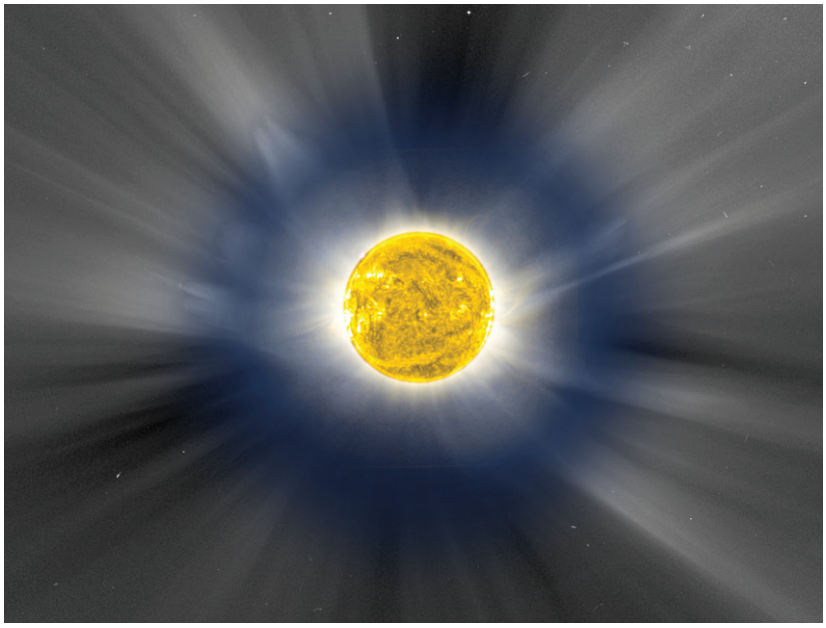
"Observing Solar Eclipses"
UNIS/Norwegian Space Centre, University Center, Svalbard, March 2015

"Galileo Galilei and Simon Marius: Their 1609 and 1610 Discoveries about our Moon and Jupiter's Moons"
Society for the History of Astronomy, Greenwich, U.K., March 2015

"Coronal Dynamics at Recent Solar Eclipses"
Catholic University, Washington, DC, April 2015

Post-Graduation Plans of Astronomy Majors

Name	Plans
Jacob A. Goldenring	Greylock McKinnon Associates, consulting firm in Boston
Austin K. Shea	Unknown
Avishek K. Shrestha	Unknown



A composite made of dozens of solar-eclipse coronal images by Allison Carter '16 and Prof. Jay Pasachoff in Svalbard on March 20, 2015, surrounded by a space image of the outer corona and with a near-simultaneous image (pasted onto the lunar silhouette) taken in the ultraviolet of million-degree coronal gas with a spacecraft's telescope supervised by Daniel B. Seaton '01, who also made the composite.

Biology Department

Working closely with 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, one-on-one research with a professor in addition to offering state of the art academic courses. To that end the department had 27 honors students working in faculty labs this past year. Of these, 16 were inducted into the Sigma Xi Honors Society. For the 2015-2016 academic year, there will be 26 students conducting honors work. Several of our students were awarded grants or fellowships to pursue their studies after graduation. The department also has over 40 students conducting summer research, either at Williams or off campus during Summer '15 including *Intekhab Hossain '16* and *Maria Vincent Allende '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 received funding from NSF or NIH. This funding allows many students to travel to professional meetings throughout the year presenting posters on their research at Williams.

Each year at graduation, the Biology Department awards prizes to several outstanding majors. Nitsan Goldstein and Alison Smith each received the Benedict Prize in Biology. Alice Stears received the Dwight Botanical Prize. James Marvel-Coen received the Conant-Harrington Prize for exemplary performance in the biology major, and Adrian Mitchell received the William C. Grant, Jr. Prize for demonstrating excellence in a broad range of areas in biology.

This year the biology department welcomes **Damian Turner** as a new Assistant Professor. Damian starts in the Fall 2015 semester following his post-doctoral research at Columbia University Medical Center in the laboratory of Donna Farber. His research has examined the establishment of tissue resident memory cells in the lungs following influenza infection as well as examined lung T cells in a mouse model of allergic asthma. He did his graduate work at the University of Connecticut Health Center in the laboratory of the late Leo Lefrançois. His graduate work focused on the induction of T cell memory to respiratory viral and bacterial infections. At Williams his research will focus on understanding how resident immune cell populations are established and maintained within the lung and their contribution to the development and chronicity of allergic asthma.

Additionally, **Anne Farewell** joined us as a STINT Fellow for one semester in the Fall of 2014. Anne is an Associate Professor in the Department of Chemistry and Molecular Biology-Microbiology at Göteborg University, Göteborg, Sweden. She taught *Microbiology* (BIOL 315) while she was here.

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 students *Adrienne Strait '15* and *Achala Chittor '15*, along with independent study student *Isaiah Clark '15* and post-doctoral fellow Janis Bravo, pursued this line of investigation. They were joined in the lab over the summer by *Raza Currimjee '16* and *Zihan Su '17* who also contributed to this project. This research is funded by a three-year individual research grant to Professor Banta totaling $462,000 from the National Science Foundation. Research assistants *Naomi Patterson '15* and *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 bleach. At the annual international Crown Gall Conference, held this year in West Lafayette, IN, Janis Bravo, Achala Chittor, and Isaiah Clark presented a poster, and Lois Banta presented a talk on this research. In October, Professors Banta and Alex Engel also took nine students to an all-day Life Sciences Symposium on the Cell Biology of Microbial-Host Interactions at Dartmouth Medical School.

During the fall semester, Professor Banta taught the lab-intensive capstone course for the Genomics, Proteomics, and Bioinformatics program. The course focuses on one model system, the Ras/MAPK signal

transduction pathway, and its role in the development of colon cancer. Highlights of the course this year included using quantitative real-time PCR to probe the contributions of inflammation to human colon cancer. A new aspect of the course this year was the switch to next-generation sequencing for the dog olfactory receptor polymorphism project that has been a part of this course for the past several years. In the spring, Professor Banta taught the sophomore tutorial "Dangerous Exposure: Environment, Immunity, and Infectious Disease". Students in this course read primary literature on the ecology and evolution of several recently (re-)emergent diseases such as influenza, Ebola hemorrhagic fever, and AIDS. Topics included transmission dynamics, epidemiological modeling of vaccination strategies, and wildlife reservoirs that contribute to human virus exposure. The course examined progress in preventing the parasitic disease malaria, as well as cholera and Dengue fever, and why these diseases have proven so refractory to effective containment. Students also discussed the science behind the recent development of the vaccine against the human papillomavirus, which causes cervical cancer, and the intriguing and highly unusual transmissible cancers in dogs and Tasmanian devils. Finally, they explored the contributions of inadequate diagnostic capacities world-wide and broader issues of resource shortages in driving the global emergence of drug resistance in tuberculosis and other diseases. One common theme in each of these case studies was the interplay between the host immune response and the evolution of the pathogen.

Professor Banta is the current Gaudino Scholar for the College. In that capacity, among many other programming events, she was deeply involved in the College-wide "Why Liberal Arts? Challenging, Transforming, Connecting" initiative. She also helped organize much of the programming around the Williams Reads book for this year, *The Immortal Life of Henrietta Lacks*. During this academic year, Professor Banta was a reviewer for the National Science Foundation, *Journal of Bacteriology, Plant Journal, Plant Physiology, BMC Plant Biology* and *PLoSOne*. Within Williams, she served on the Faculty Steering Committee, the Advisory Committees for Public Health, Biochemistry/Molecular Biology, Bioinformatics/Genomics/Proteomics, and Environmental Studies. Finally, she is Secretary/Treasurer of the Williams College Chapter of the national science honor society Sigma Xi.

Ben Carone began teaching and research at Williams College in the fall of 2014 as Visiting Assistant Professor. During the course of this past year he taught lab sections of Introduction to Biology, Biochemistry II, as well as a Senior Seminar in his area of specialty, Epigenetics. Ben comes to us following his post-doctoral research at the University of Massachusetts Medical School. His research interests are primarily molecular biology with extensive training in functional chromatin organization. In February, efforts from his collaborative work "Suppression of pervasive noncoding transcription by embryonic stem cells by esBAF" was published in the journal *Genes and Development*. Also this past year, he advised *Amir Hay '15* on his honors thesis studying "The Effects of H3K9 methylation on Transcriptional Regulation in *S. cerevisiae*." Amir was awarded the prestigious MEXT fellowship and will be continuing on to graduate studies at the University of Kyoto in Japan.

Assistant Professor **Dawn Carone** established her lab at Williams this year. Her molecular and cell biology lab focuses on nuclear structure in cancer cells and defining novel regulatory elements of the human genome, particularly within repetitive DNA. She advised honors thesis student *Diana Kang '15*, who established a cell culture model to study a functional role for human satellite sequences in cancer cells. Also joining the Carone lab this past year were *Kiki Landers '16* and *Joyce Lee '17*. Kiki and Joyce compared the nuclear distribution and levels of a master regulatory protein in cancer versus normal cells and will be continuing their research in the summer and over the course of the next year.

In the fall semester, Professor Carone taught the Senior Seminar *RNA Worlds* (BIOL 408), a course focused on reading of primary literature in the field on noncoding and regulatory RNAs. In the spring, she taught *Cellular Regulatory Mechanisms* (BIOL 306). This course covered topics on nuclear structure, pre- and post-transcriptional control, protein dynamics, and cell signaling in the context of aging, cell death and cancer. In the lab portion of this course, students investigated protein levels and designed and carried out independent projects using a wide range of molecular and cell biology techniques including advanced fluorescence imaging and quantitative methods.

During the year, Professor Carone served as a reviewer for the *Journal of Cell Biology* and *Chromosome Research* and gave an invited talk for the Hudson Valley

RNA Club at University at Albany-SUNY.

This year, Assistant Professor **Matt Carter** taught: *Neural Systems and Circuits* (BIOL 311) and *Physiology* (BIOL 205). He published the 2nd Edition of his textbook, "Guide to Research Techniques in Neuroscience" (Academic Press) and co-edited a new book, "Basic Electrophysiological Methods" (Oxford Press). He was also an author on two scientific papers: "Parabrachial calcitonin gene-related peptide neurons mediate conditioned taste aversion" (published in the *Journal of Neuroscience*); and "Antagonistic interplay between hypocretin and leptin in the lateral hypothalamus regulates stress responses" (published in *Nature Communications*).

Matt's lab continues to study the neural basis of food intake and sleep/wake patterns. He advised two summer students, *Anna Ryba '16* and *Zoe Trutner '16*, who collectively developed new ways of targeting hunger-promoting neurons in the brain. He also advised three honors thesis students, *Alison Smith '15, Kelsey Loy '15*, and *Nitsan Goldstein '15*. Alison studied the effects of stimulating hunger-promoting neurons during conditions of appetite suppression, and Kelsey and Nitsan studied the effects of stimulating hunger-promoting neurons on sleep/wake patterns.

Matt gave talks at Albert Einstein College of Medicine, Mt. Sinai School of Medicine, and the Winter Conference on Brain Research. Matt was also honored to be the Fall 2014 Sigma Xi seminar speaker at Williams College.

Lecturer **Derek Dean** continues to teach lab sections for Biology 101, 102, and Genetics. He has also worked on several fronts to bring novel research into the classroom. For example, the BIOL 101 lab course has recently been changed to have students design their own research projects, specifically around the ability of yeast to take up foreign DNA and the regulation of their phosphate metabolism. Dean worked over this past year to collect a host of yeast mutant strains and reagents to give students a host of new options, new tools to ask new questions, and otherwise fuel their creativity in the Biology 101 labs. In Genetics, the famous "Fly Lab" has been revised to allow students to map mutations that have not been mapped to a gene previously. Over the past few years, students have mapped wavy, a mutation in fruit flies causing crinkled wings, to a single gene. This mutant strain was originally identified in the late 1920s, and so the findings here at Williams are of some historical interest within the field of fly genetics. Dean, Luana Maroja, some Williams students in his lab, and off-campus colleagues are currently completing a manuscript to submit on this research. Next year, Genetics students will move on to a new unmapped mutation from dozens of other strains that have been curated by Dean, promising fresh research within the course for many years to come.

During this past year Professor **Dan Lynch** taught two sections of *The Cell (*BIOL 101). In the spring he was on leave. Prof. 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 *Cesar Dominguez '17, Yanira Guerra '17, Seema Amin '18* and *Leila Jean-Mary '18*.

In the summer of 2014, Professor **Joan Edwards** worked with *Alice Stears '15* and *Abby Kelly '16* to study both pollination networks and arctic plants at Isle Royale Wilderness National Park. For our pollination studies, we focused on expanding the species of flowers filmed for insect visitors. We covered four co-blooming species of currant (*Ribes* spp.), filmed *Clintonia borealis* and *Cornus canadensis* at three sites where they co-occurred to test for differences in visitors to the two flowers. We also filmed two species of raspberry--*Rubus parviflorus*, an open flower blow-shaped flower, and *R. ideaus*, a bell-shaped flower as well as twinflower (*Linnaea borealis*) and rosy twisted stalk (*Streptopus lanceolatus*). Our results continue to show marked differences in visitors to bell-shaped vs bowl shaped flowers, defining a major way of partitioning pollinators among the many species of flowers that bloom at the same time. During the academic year, Professor Edwards also worked with *Kayah Walker '15*, *Natalia Miller'18*, *Julia Matacek '16*, and *Elizabeth Jacobs '16* on scoring videos and taking care of the *Oxalis* plants in the greenhouse. Professor Edwards also continues with her long-term studies of both arctic plants on Isle Royale and of garlic mustard plants in Hopkins Memorial Forest.

Professor Edwards taught *Ecology* (BIOL 203) in the fall and and was on leave in the spring. She advised a senior honors theses by *Julie Jung '15, Adrian Mitchell '15* and *Alice Stears '15* who was co-advised by Prof. Maroja. Julie Jung studied the impact of different mowing patterns on flower production and pollinator visitation in field habitats in Hopkins Memorial For-

est. She did a randomized block design with two mowing times (early and late) and two mowing frequencies (annually or every other year). Her results clearly show that late mowing significantly increases both the number of flowering stems and the diversity and number of visiting insects. This has important implications for managing fields to maximize pollinators, which are in decline worldwide. Adie Mitchell studied raindrop dispersal of gemmae (small asexual reproductive propagules) in the liverwort, *Marchantia*. By using 3D printed and machined models of gemmae cups with high speed video, Adie was able to develop a new model for how these splash cups work to effect dispersal. Alice studied the great lakes-arctic disjunct, *Sagina nodosa*. She used microsatellite markers to look at the genetic structure of the sub-populations on the islets of Isle Royale. She also analyzed longitudinal data on populations that we have been following since 1998. Most populations of this species are showing a decline in numbers.

In July, Professor Edwards gave a talk at Isle Royale National Park. This past May 1st, Professor Edwards presented "The Data Behind Pollination Networks" as part of the Mathematics and Statistics Department seminar series.

Professor Edwards published a Dispatch in Current Biology. The article reviewed a paper reporting a new mechanism for bird pollination where the anthers of the flower have a bellows-like system, which when plucked by the bird, spray the bird with a puff of pollen.

Assistant Professor **Alex Engel** continued 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. Honors students *Kairav Sinha '15* and *Gwen Schultz '15* used fluorescence microscopy and biochemical fractionation to investigate the cellular placement of the DNA sensing TLR9, and RNA sensing TLRs TLR7 and TLR13. Joining the honors students in the laboratory was Team Step Gradient: Angela Lui '15, *Minwei Cao '17*, and *Roya Huang '17*. This team implemented a new fractionation protocol to allow improved separation of particular intracellular membrane compartments. Work by the laboratory was presented at the 2014 Gordon Research Conference on Lysosomes and Endocytosis as a poster, "Partitioning of innate immune receptors to endosomal pathogen sensing compartments."

Professor Engel taught Dynamics of internal membrane systems (BIOL 406) in the fall and led a BIOL 101 introductory lab section. Spring teaching responsibilities consisted of the BIMO/BIOL/CHEM 322 lecture section and multiple laboratory sections. With other biology junior faculty and science and psychology colleagues, a Course Design Group led by Dr. Betsy Burris was formed to improve the effectiveness and experience of the classroom and course work. Additionally, Prof. Engel was part of a Teachers Roundtable discussion of laboratory curriculum design and instruction.

Assistant Professor **Luana Maroja** returned to Williams after a one year sabbatical at Cornell University. She taught *Genetics* (BIOL 202) for over 85 students in the Fall and *Evolution* (BIOL 305) in the Spring. This year she advised three honor students: *James Marvel-Coen '16, Alice Stears '16* (co-advised with Prof. Joan Edwards) and *Daniela Zarate '16.* Daniela and James will be starting with their PhD programs in this coming fall (UCSD and U of Chicago respectively). During the coming summer Prof. Maroja will be working with four summer students: *Osama Brosh '17, Kate Bennet '16, Daniel Gainey '17* and *Laura Partida '16*. Kate and Laura will be continuing as honor students in the upcoming academic year.

Professor **Claire Ting** taught *Life at Extremes: Molecular Mechanisms* (BIOL 414) in the fall semester In this capstone course, students explored the molecular survival kits that enable organisms to thrive in diverse environments, including the deep sea. In the spring, she taught *Integrative Plant Biology: Fundamentals and New Frontiers* (BIOL 308), in which students used an integrative approach to understand the mechanisms by which plants grow, develop and respond to their environment. Through laboratories and special projects, students explored the strategies plants have evolved to survive in vastly different habitats on Earth, as well as recent advances in using plants as an energy resource, in biomedicine, and in agriculture.

During the year, Professor Ting continued to pursue her research on photosynthesis in the ecologically important marine cyanobacterium, *Prochlorococcus*. This blue-green bacterium is one of the world's most abundant photosynthetic organisms and is an import-

ant 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. Her group has conducted field work in the Sargasso Sea, which is an open ocean region where *Prochlorococcus* thrives. Professor Ting and six student co-authors (*Katharine Dusenbury '13, Reid Pryzant '16, Kathleen Higgins '14, Catherine Pang '14, Christie Black '15,* and *Ellen Beauchamp '12*) published their research on "The *Prochlorococcus* carbon dioxide-concentrating mechanism: Evidence of carboxysome-associated heterogeneity" in the journal *Photosynthesis Research*. In addition, Professor Ting and her colleagues from the Georgia Institute of Technology published an editor and peer-reviewed book chapter titled "Current perspectives on microbial strategies for survival under extreme nutrient starvation: evolution and ecophysiology." Professor Ting organized and chaired a session on "Next-Gen Approaches for Identification, Interrogation and Engineering of Microbes and their Communities" at the American Society for Microbiology 49th Annual Regional Meeting in Albany, New York. She also presented a talk at this meeting on "(Meta) Genomics as a means to understand marine microbes and their communities."

Undergraduate students who participated in research in her laboratory this past year included *Reid Pryzant '16*, who was named a 2015 Goldwater Scholar by the Barry Goldwater Scholarship and Excellence in Education Foundation. Reid continued as a research assistant and an Independent Study (BIOL 298) student, and used a range of computational methods to study the Ting Lab's genomic, metagenomic and metatranscriptomic data sets. His research goals include extending our understanding of *Prochlorococcus* from the laboratory to the open oceans and examining how environmental selection might shape microbial populations at different depths in the Sargasso Sea. In addition, *Elissa Hult '15* and *Emily (Lily) Gaddis '15* conducted their honors thesis research, and were assisted by *Diana Sanchez '17*. Elissa, Lily and Diana investigated the physiological responses of *Prochlorococcus* to light stress and the ability of this cyanobacterium to acclimate to fluctuations in its light environment. The *Prochlorococcus* strains they studied have evolved distinct differences in their photosynthetic apparatus, including in their light-harvesting complex antenna proteins. Their results support the laboratory's hypothesis that although *Prochlorococcus* isolates exhibit close phylogenetic ties, they have evolved significant differences in their physiological and photosynthetic strategies and thus, in their ability to thrive in specific ecological niches in the open oceans.

Professor **Heather Williams** taught *Neuroscience* (NSCI 201) in the fall, and *Animal Behavior* (BIOL 204)in the spring, subjecting yet another generation of students to 6 AM labs at Eph's Pond. She continued her research on cultural evolution in bird song in Savannah sparrows and on songbird models for syntax with *Gabe Stephens '15*, her honors student.

Steve Zottoli retired as of June 30, 2015 and became the Schow Professor of Biology, Emeritus. He will sponsor two students, *Nicole Perez '18* and *Gabrielle Carmona '18* at the Marine Biological Laboratory in Woods Hole, MA this summer where he is an Adjunct Senior Scientist in the Eugene Bell Center for Regenerative Biology. He will sponsor *Bethany Berry '16* as an Honors student during the upcoming academic year. He published a paper entitled: "The Marine Biological Laboratory (Woods Hole) and the scientific advancement of women in the early 20th century: The example of Mary Jane Hogue (1883-1962)" in the *Journal of the History of Biology*.

Class of 1960 Scholars in Biology

The Biology Department continued to participate in the Class of 1960 Scholars program. The department invited Dr. Dean Li from the University of Utah School of Medicine to be Class of 1960's Scholar speaker Below are the students selected as Class of 1960 Scholars

Victor Arechiga	Intekhab Hossain	Conor Mook
Katherine Bennett	Elissa Hult	Ashley Ngo
Tendai Chisowa	Aubrey Kenefick	Breanna Nguyen
Emily Gaddis	Catherine Landers	Alison Smith
Jacqueline Harris	Angela Liu	Penny Sun
Patricia Ho		

Biology Colloquia

Jose Andres, University of Saskatchewan, Canada
"Social interactions, relatedness and population structure in cervids: implications for pathogen transmission", October 2014

Matt Carter, Williams College
"Strategies for designing and delivering a scientific presentation", September 2014

"The Neuroscience Behind a Good Night's Sleep", Sigma Xi lecture, October 2014

Yves Chabu, Howard Hughes Medical Institute at Yale University
"Mechanisms Governing Tumor Overgrowth: A Fly's Eye View", May 2015

Anne Farewell, STINT Fellow, Sweden
"Global Gene Expression in Stationary Phase E. coli", November 2014

Ethan Graf, Amherst College
"Activating the Active Zone: Control of Synaptic Structure and Function by Rab3, April 2015

Todd Golub, Broad Institute of MIT and Harvard
"Cancer and the Human Genome", February 2015

Dean Li, University of Utah
"Using rare human genetic diseases to uncover new signaling cascades in biology", April 2015

Diane Newman, CalTech
"Why changing color matters to Pseudomonas aeruginosa", September 2014

Steve Swoap, Williams College
"It's not natural to teach natural science." Invited talk in the Williams College teaching lunch, March, 2015

"Sugar, Sugar, Sugar." Invited talk at Bronfman Science Lunch, February 2015

Saul Villeda, University of California, San Francisco
"A Systemic Approach for Rejuvenating the Aging Brain", March 2015

Mariana Wolfner, Cornell University
"Battles and ballets: Reproductive functions and evolution of seminal proteins in Drosophila", November 2014

Off-Campus Biology Colloquia

Lois Banta, Janis Bravo*, Melinda Wang ‘14, Elizabeth Hwang ‘13, Abigail Davies ‘13, Lauren Goldstein-Kral ‘12, Naomi Patterson ‘15, Greg McElroy ‘12, Sam Lewis ‘15, Darcy Mishkind (Carleton College ‘16), Tendai Chisowa ‘16 and Rosalia Deeken.

“Reciprocal Modulation of Basal Defenses in Arabidopsis thaliana and the Agrobacterium tumefaciens Type VI Secretion System (T6SS)” Oral presentation, 35th Annual Crown Gall Conference, West Lafayette, IN. Nov. 2014

Achala Chittor ‘15, Isaiah Clark ‘15, Raza Currimjee ‘16, Zihan Su ‘17, Janis Bravo*, Melinda Wang ‘14 and Lois Banta.

“Characterization of Agrobacterium-Elicited Defense Responses in Arabidopsis thaliana Seedlings.” Poster presentation by two students, 35th Annual Crown Gall Conference, West Lafayette, IN. Nov. 2014

Dawn Carone

“Chromosome-associated RNA from the junk of the genome” Hudson Valley RNA Club, SUNY Albany, May 2015

Luana Maroja

“Barriers to gene exchange and introgression across a cricket hybrid zone” Union College in Schenectady, NY - February 19, 2015

Steve Swoap

Interview on NPR station – WCAI and WGBH News, April 2015

“Some mammals are really cool.” Invited talk at Woods Hole, MA. April 2015

Claire Ting

“(Meta) Genomics as a means to understand marine microbes and their communities.” Invited talk at the American Society for Microbiology 49th Annual Regional Meeting, Albany, New York

“The complexity of marine microbial communities revealed through (meta) genomics”, Invited Colloquium Speaker, Department of Biology, Bard College

Grants Received

National Science Foundation “AREA: Hypothermia vs. Daily torpor: an integrative molecular / biochemical / physiological approach” $409,796 (June 2014-May 2017)

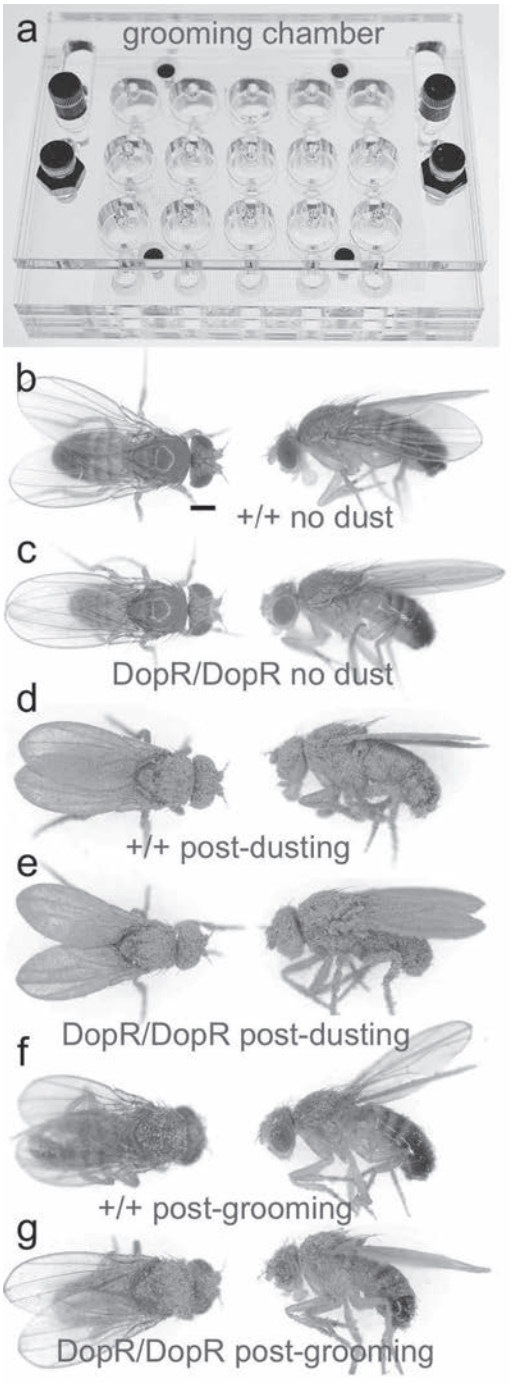
American Physiological Society Undergraduate Fellowship for *Maria Vicente Allende ‘17* - $4,000 (June 2014 - August 2014).

Post-Graduation Plans of Biology Majors

Name	Plans
Alyson Barrett	Undecided
Ryan Barry	Management consulting at McKinsey & Company in Boston, MA.
Rebecca Bell	Working for Jackson labs in Bar Harbor Maine.
Christie Black	Attend the Master of Laboratory Animal Science program at Drexel University College of Medicine. Following my completion of this program I hope to apply to veterinary school.
Brent Bomkamp	Attending Stony Brook University
Ethan Borre	Clinical Research Assistant at Massachusetts General Hospital for two years before graduate school.
Ryan Buchanan	Undecided
Achala Chittor	I will be joining the Molecules, Cells and Organisms doctoral program that is part of the Graduate School of Arts and Sciences at Harvard University starting in the fall.
Isaiah Clark	Undecided
Caitlin Conlon	Undecided
Cody Cotner	Healthcare consulting at ClearView Healthcare Partners in Boston, MA.
Sarah Cottrill	Nashoba Brooks Science teaching fellowship
Rebecca Dryer	Undecided
Simone Frank	Undecided
Emily Gaddis	Project Manager at Epic, a healthcare software company based in Madison, WI.
Jennifer Galaviz	Undecided
Ashley Graves	Undecided
Nitsan Goldstein	Working in a neuroscience lab at Massachusetts General hospital studying the hippocampus and neurodegenerative diseases associated with aging.
Kristin Halvorsen	Premed post-baccalaureate program at NYU.
Amir Hay	Going to Kyoto University in Kyoto, Japan under the MEXT scholarship to obtain a Master's degree in biological studies.
Michelle Higgins	Research Study Technician at the Center for Regenerative Medicine at Boston University Medical Center. I will be working under the Principle Investigator Dr. Andrew Wilson (Williams, '94) in a two year position. Then medical school.
Elissa Hult	Teaching middle school science and music at the Potomac School in McLean, VA
Julie Jung	PhD program at Boston University in Ecology and Evolutionary Biology, studying the red-eyed tree frog in Panama.
Diana Kang	Undecided
Adin Kreiger-Benson	Performing a year of public health work with the Community HealthCorps before attending nursing school to become a family nurse practitioner.
Daniel Kurnick	Healthcare consulting at Clarion Healthcare.
Samuel Lewis	Public Health Organization in Southeast Asia as a Luce Scholar.

En Tzu (Angela) Liu	Working at Triage Consulting Group in San Francisco
Kelsey Loy	Working as a medical scribe in a clinic and emergency room in Seattle for one year while applying to medical school.
James Marvel-Coen	I will be pursuing a Ph.D. in Comparative Human Development at the University of Chicago.
Alexandra McInturf	Travel and gain research experience before applying to a graduate program in Marine Biology.
Michael McPhee	Undecided
Dianna Mejia	Undecided
Tara Miller	Received a Fulbright to study the effects of climate change in several arctic spring ecosystems in the area surrounding Tromsø, Norway.
Adrian Mitchell	Forest ecology research for the summer in Colorado, with a lab out of CSU Fort Collins.
Austin Nguyen	Working as a SEM Analyst at TripAdvisor.
Oladeji Odewade	Undecided
Kwasi Offei-Ado	Undecided
Kimberly Oliva	Applying to Post-baccalaureate research programs (PREP)
Naomi Patterson	Undecided
Elaina Pullano	Attending the Harvard School of Dental Medicine.
Erik Romano	Undecided
Hayden Rooke-Ley	Playing professional basketball in Israel.ho
Phoebe Rosen	Undecided
Amanda Schott	Working at Albert Einstein Medical College, using optogenetics and electrophysiology to do research on cerebellar motor diseases.
Gwendolyn Schultz	Undecided
Christopher Seitz	Healthcare consulting at Health Advances in Boston, MA.
Kairav Sinha	Teach for America in Providence, RI - teaching 10th grade chemistry at Blackstone Valley Prep, a charter school.
Shelby Shote	Undecided
Alison Smith	Post-Bachelor Fellow at the Institute for Health Metrics Evaluation in Seattle, Washington, performing research in the field of health metrics while taking part-time classes at the U. Washington School of Public Health.
Alice Stears	Working as a research assistant at the Rocky Mountain Biological Laboratory in Crested Butte, CO this summer, and I tentatively plan on applying to an ecology Ph.D. program next fall/winter.
Gabriel Stephens	Attending a Ph.D. program at Baylor College of Medicine for Neuroscience.
Adrienne Strait	Clinical research at the UCSF Center for Vulnerable Populations for the next two years.
Ali Tafreshi	Attending medical school at the University of Southern California.
Dylan Thomas	I will be working as a Research Assistant with PI Finn Hawkins at the Center for Regenerative Medicine, which is associated with the Boston University Medical Campus--working with induced pluripotent stem cells and lung disease.

Kiah Walker	Ecological fieldwork,
Daniela Zarate	Attending the University of California San Diego for a Ph.D. program in biological science.
Chelsea Zhu	Attending medical school.



The Lebestky lab designed a new behavioral chamber (a) to study Drosophila grooming behavior. A series of experiments suggest that Dopamine is required for grooming behavior in Drosophila. b, d and f represent Wildtype flies. c, e and g represent Mutant flies lacking the Dopamine Receptor (DopR). Mutant flies retain more colored dust after 30 min of grooming (g) than wild type controls (f).
Photo by Tim Lebestky

Chemistry Department

The 2014–2015 academic year was a busy one for the Chemistry Department and included a record number of chemistry majors. 44 students graduated in 2015 with majors in chemistry of which 16 completed senior theses. The class of 2016 includes 53 chemistry majors and the class of 2017 includes 47 newly-declared majors.

We are very proud of our students accomplishments. A number of students from the class of 2015 were recognized with departmental awards: the John Sabin Adriance prize went to *Claire Lidston* for outstanding work throughout her chemistry career, the James F. Skinner prize was awarded to *Bryn Reinstadler* for her distinguished achievement in chemistry and future promise as a researcher, the Leverett Mears prize went to *Shannon Zikovich* in recognition of both her abilities in chemistry and future in medicine, *Alexander Silver* was awarded the American Chemical Society Connecticut Valley Section Award for his sustained scholastic excellence, *Chelsea Boydstun* was awarded the American Institute of Chemists Student Award for outstanding scholastic achievement, I*van (Jake) Huerfano* received the ACS Undergraduate Award in Inorganic Chemistry, and *Lillian Ma* was presented with the ACS Division of Organic Chemistry Award.

A number of awards were also presented to undergraduate chemistry students for outstanding scholarship. *Dylan Freas '16* was the recipient of the ACS Division of Analytical Chemistry Award, *Ananya Mahalingam-Dhingra '18* and *Xianglong Meng '18* received the CRC Awards as the outstanding students in CHEM 151 and CHEM 155, respectively. Jeffrey *Sload '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, *Matthew Gross '16* received the Polymer Chemistry Award and *Lucy Hoyt '17* was the recipient of the Harold H. Warren Prize.

During the summer of 2015, 33 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, Summer Science Program funds, and the Wege-Markgraf Fund.

Visiting Assistant Professor **Patrick Barber** joined the Department of Chemistry at Williams this year and began by hosting three students in his laboratory: *Miguel Mendez '16, Stella Worters '18*, and *Malcolm Singleton '18*. Together they began two projects on the development of materials for environmental and biological imaging. The project was continued by four students, *Melissa Caplen '17, Alexi McAdams '18, Jahangir Habib '18*, and *Katie Spence '18*, in an *Introduction to Research in Inorganic Chemistry* (CHEM 20) during the winter study term where several luminescent lanthanide ion complexes for imaging applications were prepared. The lab has gained critical knowledge about the synthetic targets and will continue to push the research forward. in addition, Professor Barber taught two upper-level courses during the 2014-2015 academic year: *Instrumental Methods of Analysis* (CHEM 364) in the fall and *Inorganic and Organometallic Chemistry* (CHEM 335) in the spring. Professor Barber received a grant from the NSF-sponsored Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS) program to attend a workshop on materials science and nanotechnology with the goal of developing course materials for *Materials Science* (CHEM 336) planned for fall 2016.

In 2014-2015 Professor **Dieter Bingemann** enjoyed a very productive sabbatical year, which he spent at the University in Göttingen, Germany, a center of research in physical chemistry. There, Bingemann developed and tested new models for the dynamics of supercooled liquids and glasses. He compared those new theories to the results of molecular dynamics simulations of model glass formers on high-speed computers, leading to exciting new insights into the reasons for the dramatic slow-down of the dynamics at the glass transition.

In his third year at Williams, Assistant Professor **Jimmy Blair** kept very active. For the third year in a row, he taught *Organic Chemistry: Intermediate Level* (CHEM 251) in the fall with one section of the lab. During the Winter Study Period, he was joined by Laura Strauch to co-teach 16 students in the *Science for Kids* (CHEM 11) course. And in the spring, Professor Blair taught *Biophysical Chemistry* (CHEM 367) for the first time. CHEM 367 had a record enrollment of 49, and Professor Lovett joined Professor Blair to help teach the laboratory portion of the class. Professor Blair enjoyed developing a new laboratory experiment for CHEM 367 using the differential scanning fluorimetry

technique, and his teaching assistant *Anuj Shah '15* was instrumental in this development.

The year was productive for Blair's research lab. His lab endeavors 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 *C. crescentus* will open the door to potential new antibacterial strategies effective against a broad-spectrum of bacteria. *C. crescentus* contains essential histidine kinase signaling pathways that his lab targets to assess whether pharmacological inhibition of these pathways provides new mechanisms for antibacterial action. Over the summer *Juno Cho '15, John Hammond '16, Tony Huang '16, Lindsey Moran '16* and *Taylor Jackvony '16* joined him to work on the synthesis of potential inhibitors and biochemical testing those small molecules against CckA, an essential histidine kinase to *C. crescentus*. Chemistry thesis students Juno Cho and *Shannon Zikovich '15* spent the school year in the Blair Lab following up on these results. *Becca Dryer '15*, who is the first student Professor Blair has supervised for a Biology Department thesis, joined them. Tony Huang, Taylor Jackvony and *Doug Wassarman '16* joined the effort during the school year as work-study students. Professor Blair presented much of the work these students have accomplished to the Wesleyan University Chemistry Department in March.

Professor Blair served as a member of the Honor and Discipline Committee throughout the academic year. He also served as the faculty liaison for CSAC, the chemistry student group. Outside of the college, he served as a reviewer for *ACS Chemical Biology* and *The Journal of Visualized Experiments*. Along with Professor Tim Lebestky in the Biology Department, Professor Blair organized purchasing a BioTek Synergy HT multimode platereader with generous funds from the Science Center. This instrument has allowed labs in both the Chemistry and Biology Departments to increase assay throughput, and it has seen steady use throughout the year. In June 2014 Professor Blair attended the Bioorganic Chemistry Gordon Conference. Finally, Professor Blair collaborated on two manuscripts, one published in *Microbiology* and the other in *PLoS Biology*, based on work he performed during his postdoctoral studies.

Professor **Amy Gehring** enjoyed teaching in the introductory chemistry sequence during the fall semester, working with nearly 60 students in *Concepts of Chemistry: Advanced Section* (CHEM 153). She looks forward to keeping in touch with many of these students as they continue in the chemistry curriculum. In addition to her appointment as chair of the Chemistry Department starting in the Summer of 2015, Professor Gehring is also a member of the program committees for Biochemistry & Molecular Biology (BIMO) and Public Health. During the spring semester, she taught two required courses in these respective programs – the capstone seminar *Topics in Biochemistry & Molecular Biology* (BIMO 401) and the introductory *Dimensions of Public Health* (PHLH 201). BIMO 401, with its focus on class discussion about recent papers from the primary literature, is always one of her favorite courses to instruct. Public health is a more recent interest of Professor Gehring's, and she enjoyed exploring this highly interdisciplinary field with her co-instructor, Professor Cheryl Shanks, a political scientist.

It was another busy year of research in the Gehring lab, as we continued to define the biochemical and genetic features of antibiotic production and development in the sporulating, antibiotic-producing soil bacterium, *Streptomyces coelicolor*. This species is a representative of a large bacterial genus that is well-known for its production of molecules with antibiotic properties important to medicine. Over the summer, *Megan Steele '16*, an Allison Davis Research Fellow, continued her research to understand the relationship of *whiJ*-like genes to each other and their role in sporulation in *S. coelicolor*. Once the academic year began, three senior honors thesis students joined Megan in the lab: *Salmaan Karim '15, Alex Silver '15* and *Katherine Susa '15*. Katherine made significant progress in defining the relationship of central carbon metabolism to the developmental events that characterize the *Streptomyces* life cycle, confirming a diversion of carbon resources from glycolysis to the pentose phosphate pathway in a mutant strain that fails to initiate aerial mycelium development. Salmaan and Alex focused on two different aspects of a project to understand the role of a phosphodiesterase enzyme in the regulation of antibiotic production by *S. coelicolor*. Salmaan took a genetic approach and explored the effect that the levels of expression of the phosphodiesterase gene had on production of three different antibiotic molecules. Beginning in the spring semester, Salmaan was assisted in this research by Selena Castro '17. Alex took a biochemical approach and explored the substrate specificity of the phosphodiesterase enzyme, which is active on carrier protein substrates that have an integral function in antibiotic biosynthesis. This project required the isolation and purification of a large number of protein substrates. During Winter Study, *John Ahn '18, Abby Dalzell '16, Lia Lee '17* and then in the spring *Jeff Sload '17* made important contributions to these cloning and purification efforts.

Professor Gehring once again served 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. Dianne Newman (Caltech) and Dr. Todd Golub (Broad Institute & Harvard Medical School). She was also able to stay connected with the broader scientific community by presenting a poster at the Microbial Stress Response Gordon Research Conference in July 2014 and by serving as a manuscript or grant reviewer for the *Journal of Bacteriology* and the National Science Foundation. She also gave a presentation about her research to an excited group of community children at the Milne Public Library as part of their summer programming.

Associate Professor **Christopher Goh** taught *Introductory Concepts of Chemistry* (CHEM 151) in the fall semester, and was on leave in the spring. Research in the field of transition-metal mediated homogeneous catalysis continued with four students working during the summer 2014. *Tamuka Chidanguro '15* and *Kimthanh Nguyen '17* 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. *Matt Davies '17* and *Claire Lidston '15* expanded our ACS-PRF funded project on iron-catalyzed epoxidations of alkenes. The designs of these catalysts are based on iron-containing enzymes. In both projects, the students demonstrated that changes in catalyst structure had a significant impact on catalyst performance and discovered active catalyst compositions.

Tamuka and Claire continued their work as senior thesis students, Matt as a research assistant. After spending their summers elsewhere, *Lillian Ma '15* and *Jake Huerfano '15* also re-joined the lab as senior thesis students, Lillian working with Tamuka on the ATRP project, and Jake starting a new project focusing on the synthesis of a class of amine-ether ligands using palladium catalyzed cross-coupling. All considered it was a lively and productive year for the group. Thanks to the support of various funding sources at Williams, the group was fortunate to be able to participate and present some aspects of our work at the national meeting of the ACS in Denver, CO, in March 2015.

Associate Professor **Sarah Goh** spent the summer of 2014 working with incoming thesis students *Denise Park '14* and *Dylan Barber '14*. The lab's research continues to be focused on polymers for drug delivery applications. Denise investigated thermoresponsive polymer-enzyme conjugates while Dylan studied antioxidant-containing micelles. The end of the summer saw Professor Goh attending the Biennial Conference on Chemical Education in Grand Rapids, MI. In addition to participating in the pedagogy symposia and workshops, she also met up with former Visiting Professor Marc Richard (2006-2007, currently at Richard Stockton College) and *Bryn Falahee '12*, who was home visiting in between her Herschel Smith years at Cambridge University. Professor Goh presented at the National American Chemical Society's fall meeting in San Francisco, CA in August. A social occasion as well, she visited with her former graduate labmates and met up with current chemistry graduate students *Matt Zhou '12, Talia Loewen '12*, and *Sara Turner '11*. In the fall, Professor Goh taught the advanced laboratory section (Ford Lab) of *Intermediate Organic Chemistry* (CHEM 251). She and the students had great fun converting their final project reports into published works. With the help of Kate Barber (WCMA), the students each generated a limited-edition publication of their report at WCMA's Publication Studio. In the spring semester, Professor Goh was on sabbatical, remaining on campus to work with her thesis students. Dylan and Denise presented their work at the National American Chemical Society meeting in Denver, CO in April. *Jessica O'Brien '16* also joined the lab, and *David Jaramillo '17* continued working as well. David was able to present his work at the Connecticut Valley ACS Undergraduate Symposium in April. Being on sabbatical, Professor Goh had the opportunity to travel a bit more with her family. With alums being everywhere, she managed to meet up with *Lauren Agoubi '13, Lilli Morris '14* and *Michael Gold '14*. Overall, it was a year of presenting and working with current students and catching up with former ones!

Professor **Lawrence Kaplan** taught two laboratory sections in *Biochemistry I* (CHEM 321) in the fall semester and was on a sabbatical for the spring semester.

He continues to administer the Center for Workshops in the Chemical Sciences with colleagues from Georgia State University, Georgia Institute of Technology and Millersville University. Since its founding fourteen years ago, the CWCS has received major grants from the National Science Foundation totaling approximately $10,000,000 and continues with the current collaborative grants to Williams, Georgia Tech, and Georgia State. As a result of the current NSF grant the CWCS was rebranded the Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS). The cCWCS sponsors workshops

related to the 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 CWCS 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 continues to be expanded and updated with many more members and more educational resources.

Kaplan taught a weeklong CWCS workshop in forensic science during the summer of 2014 at Williams. Sixteen participants from colleges, universities and 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, Chemistry Department Administrative Assistant and Tony Truran, Lecturer/Technical Assistant, assisted Kaplan in the organization and instruction of the workshop.

Kaplan attended the 23rd Biennial Conference on Chemical Education in Grand Valley State University in Allendale, Michigan. He presented the paper "Characterizing the Forces that Stabilize DNA: Biophysical Analysis of Oligonucleotides using Thermal Denaturation and Isothermal Titration Calorimetry" with Williams undergraduate co-authors *Bianca Ulloa '14, Quinn Solfisburg '14*, and *Christopher Corbet '13*. Kaplan also presided at a day and a half symposium "cCWCS: Developing Faculty Communities to Transform Undergraduate Teaching and Learning" in which over 20 cCWCS workshop alumni discussed their innovative educational activities based on their participation in the cCWCS workshops.

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

During the past year Professor **Charles 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 30 years Lovett and Williams' 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 completed the screening of nearly 11,000 compounds and have found 16 compounds that inhibit the SOS response. Summer research students who worked on this project included *Cecilia Castellano '16, Moses Flash '15, Mmaserame Gaefele '15, Miguel Mendez '16, Oladeji Odewade '15, Willis Koomson '14*, and *Edgar Vega '16*. Moses Flash and Mmaserame Gaefele continued as independent research students in the fall of 2013 and Oladeji Odewade continued as a senior thesis students for the academic year. Professor Lovett also supervised work study research students *Jennyfer Galvez '18, Charles Laurore '18, Richard Alex Ruberto '17, Galen Squires '17, Kelly Tellez '17*, and *Miranda Villanueva '18*.

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 14th year of science camp for elementary school students and teachers.

Professor Lovett also 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 as she began her two year commitment as Associate Dean of Faculty. Nevertheless, she tried to stay connected to the department over the year by offering and refining her problem solving sessions for first-year chemistry students during the summer and fall of 2014. She supervised a thesis student, *Chelsea Boydstun '15* who continued working on the synthesis of small conjugated species with electron accepting and donating caps, and began exploring the use of some of those species as fluoride ion sensors. Park also continued her work for the larger chemistry community as a member of the Committee on Professional Training for the American Chemical Society, and as a reviewer for various journals and funding agencies (including ACS-Petroleum Research Fund, Research Corporation) as well as other

academic institutions. She's been enjoying her time in the Dean's office, but is always happy to come home to the Chemistry Department, and is looking forward to getting back to teaching!

During the 2014-2015 academic year Professor **Enrique Peacock-López** taught *Current Topics in Chemistry* (CHEM 155) in the fall to 40 students, and *Physical Chemistry: Thermodynamics* (CHEM 366) and *Computational Chemistry and Molecular Spectroscopy* (CHEM 368T) in the spring. In these courses, Peacock-López extended the use of MATHEMATICA and Python to solve problems in Physical Chemistry and computational chemistry.

Peacock-Lopez extended his work on the Morales model of mutualism. In collaboration with Professor Manuel Morales, of the Biology Department, they submitted a grant proposal "*Dynamics in an Herbivore-protection Mutualism*" to the National Science Foundation. The proposal has been funded for 2015-2018 for an amount of $244,117, including funding for ten summer research students. He taught *Introduction to Research: Physical Chemistry* (CHEM 24) during winter study. In this course *Young Sun Lee '16* considered the diurnal and annual oscillations of neurotransmitter levels and melatonin, which regulate circadian rhythms, in relation to the amount of daytime light. We expect to use this model to predict the clinical implications of the circadian rhythms on conditions such as seasonal affective disorder (SAD). A second student, *Kiran Kumar '18* considered the relevance of a triplex formation in DNA self-replication. In this case, in contrast to other self-replicating mechanism, a duplex is the catalytic active specie. The proposed model will be analyzed during the summer. The spring semester was dedicated to the study of non-fickian diffusion and self-replicating peptide networks. At Ben-Gurion University, Professor Gonen Ashkenazy has been able to synthesize several self-replicating peptide systems, which show interesting networking. Peacock-Lopez analyzed the smallest closed peptide network that shows bi-equilibrium.

While continuing with his research, Peacock-López, Gisela Demant (Thechnical Asst. in the Chemistry Department), and instructor Cheryl Ryan (Hoosac Valley High School: 8 students) organized and taught Advanced Chemistry labs at Williams College. These advanced chemistry students came five times during the year to perform some of the labs from the Williams Advanced Chemistry Lab Program and a newly developed organic synthesis. The latter experiment was implemented and adapted by Demant to include the synthesis of aspirin from salicylic acid and include the characterization of the purity of the product by TLC and melting point determination.

Finally, Peacock-Lopez continued his work in the Editorial Board of *The Scientific World Journal*, and he has served as reviewer for*: Physics Letters A, Chaos, Applied Mathematics and Computation, International Journal of Bifurcation and Chaos, Discrete Dynamics in Science and Society, Israel Journal of Chemistry*, and *Nonlinear Dynamics*.

2014-15 was another busy year for Professor **David Richardson**. In the fall semester, he taught *Toxicology and Cancer* (CHEM 341) along with a laboratory section of *Organic Chemistry: Intermediate Level* (CHEM 251) ; in the spring semester he taught *Organic Chemistry: Introductory Level* (CHEM 156) and a section of its associated lab.

Working together with Jay Racela of the Williams Environmental Studies Lab, he supervised the research efforts of work-study student *Nallely Lopez '18* who continued work on a project focused on determining the phosphorus content of environmental samples, particularly soils. During winter study 2015, together with Professor Steve Zottoli of the Biology Department, he supervised the work of *Nicole Perez '18* who initiated a new project directed at determining the otolith-based age of trout collected as part of an on-going study of PCB contamination in the Hoosic River. He also supervised the senior honors thesis project of *Dylan Griswold '15* involving the isolation of possible anti-cancer compounds from South East Asian plant extracts.

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 several chapters of a new introductory organic chemistry textbook for Oxford University Press.

In July 2014 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 served on the Board of the One World Conservation Center at the New England Tropical Conservatory in Bennington, Vermont. Together with Professors Janneke van de Stadt and James Manigault-Bryant, he served as co-Chair of the College's First3 Program for new faculty at Williams. Throughout the year, he also served on the search committee to hire a new Vice President for Institutional Diversity and Equity.

Dr. **Anne Skinner**, senior lecturer emerita, travelled to South Africa in the summer of 2014 to present her work on early use of fire to the Society of Africanist Archaeologists meeting in Johannesburg. She then travelled to Tanzania to collect material for the study of early human occupation. In December she went to Bordeaux, France, to present a study of climate change in the Southwest Desert of Egypt, which included work by *Nicole Wise '12*. The final semester of the Dreyfus Senior Scientist Mentor grant financed an independent study by *Kevin Eagan, '16*, looking at the 2014 Tanzanian material. In May of 2015 she was invited to give a workshop at the Federal University of Pernambuco, in Recife, Brazil. As well as updating the archaeological dating group on developments in ESR dating, she gave a public lecture to students of geology, physics and archaeology.

Professor **Tom Smith** spent his seventeenth year at Williams pursuing his research in organic synthesis and methods development, *Asymmetric Methods for the Synthesis of Pyran-Based Anticancer Natural Products*, under an NIH Academic Research Enhancement Award (AREA) grant and a Henry Dreyfus Teacher-Scholar Award. Senior honors student *Zaw-htut Naing '15* continued work toward the synthesis of a new cytotoxic marine natural product, enigmazole A. *Ashley Kim '15* also approached the final steps of synthesis of jerangolid D. Professor Smith taught *Medicinal Chemistry* (CHEM 343) and *Synthetic Organic Chemistry* (CHEM 342) and completed his third, and final, year as Department Chair.

In her second year at Williams, Assistant Professor **Becky Taurog** continued to establish her research program. In the summer, she worked with *Katherine Susa '15, Ian Outhwaite '17*, and *Yitong Tseo '17*, who each contributed to the foundation for a separate project. Two of these projects continued through the year, due to the work of Ian and the return of *Linamarie Miller '15*, who completed a senior thesis. During winter study, they were joined by *Helena Barber '16, Graham Buchan '17*, and *Osama Brosh '17*.

Linamarie's senior thesis explored the structure of a complex between the essential protein folding chaperone GroEL and a oxidized variant of the enzyme cobalamin-independent methionine synthase (MetEox). This interaction has been shown to occur in *E. coli* under oxidative stress conditions. MetE is a large enzyme and there are many questions about how such large protein substrates interact with GroEL, which appears to have a limited size capacity. To address these questions, Lina optimized conditions for forming the GroEL•MetEox complex and, in collaboration with researchers at the University of Virginia, obtained over 300 high-magnification images of the complex by cryo-electron microscopy. She began the long process of computationally sorting these images and determined that indeed about 10% of the GroEL molecules are clearly in complex. Next, a three-dimensional structure of the complex will be reconstructed from the 2D images.

Ian, with help from Graham, Osama, and Helena began to explore the movements that MetE might undergo to perform its function, catalyzing the synthesis of the essential amino acid methionine. Ian used computer simulations to determine prime locations to attach pairs of spin labels to MetE. The students then made genetic mutations at the potential labeling sites and expressed the labeled proteins in a special strain of *E. coli* under conditions such that an unnatural amino acid (acetyl-phenylalanine) was incorporated at the mutation sites in the protein. Chemical reactions of a spin label with only the two unnatural amino acids allowed for the very specific labeling of only the desired sites on the enzyme. Electron paramagnetic resonance studies with collaborators at the National Biomedical Center for Advanced Electron Spin Resonance Technology at Cornell University has allowed the distance between the labels to be measured with accuracy on the order of 5 Å. In the future the lab will investigate how these distances are affected by the presence of MetE substrates, as an indication of large-scale movements in the enzyme.

In the fall Prof. Taurog taught *Biochemistry I: Structure and Function of Biological Molecules* (BIMO/BIOL/CHEM 321) and two sections of the associated lab.

Professor **Jay Thoman** taught the lecture and lab for *Physical Chemistry: Structure and Dynamics* (CHEM 361). He assisted Professor Patrick Barber in teaching the laboratory component of *Instrumental Methods of Analysis* (CHEM 364). During winter study 2015 he returned to teaching *Glass and Glassblowing* (CHEM /ARTS 16). In spring 2015, Thoman taught *Chemistry and Physics of Cooking* (CHEM 116) and a lab section of CHEM 256. CHEM 116 included a series of tasty seminars taught by Williams colleagues. Paul Lovegreen, from Tunnel City Coffee, and Joshua Needleman, from Chocolate Springs, gave special seminars.

During summer 2014, Thoman worked with Professor Dave Richardson, *Katie Cavanaugh '16*, and *Chris Stefanik '16* to synthesize some new model compounds to probe the stereochemistry of a deuteration reaction useful in synthesizing deuterofluorobarbon molecules. Richardson, Thoman, *Allie Rowe '16* and *Marissa Shieh '15* continued a long-term project studying PCB pollution in the Hoosic River watershed. In service to the chemistry community, Thoman took on new responsibilities with Educational Testing Services.

Class of 1960 Scholars in Chemistry

This year we continued to participate in the Class of 1960 Scholars Program. Two distinguished scientists were invited to campus to meet with our students and present a seminar. Dr. Martin Burke from the Howard Hughes Medical Institute at the University of Illinois Urbana-Champaign was our Class of 1960 Scholars Program speaker in the fall of 2014. Fourteen students were selected by the faculty to be Class of 1960 Scholars during 2015 and to participate in the seminar program which includes: a preliminary meeting of the Scholars 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. The students selected for 2015 are:

Christopher Bravo	Dylan Freas	Carly Schissel
Cecilia Castellano	Tony Huang	Chloe Snow
Jorge Castro	Irene Lim	Helen Tang
John Chae	Miguel Mendez	Doug Wasserman
Christina Chen	Luxi Qiao	

Chemistry Colloquia

Martin Burke, Howard Hughes Medical Institute, Class of 1960 Scholars
"Making Molecular Prosthetics with a Small Molecule Synthesizer"

Benjamin Gorske, Bowdoin College
"Form and Function: Folding Peptoids for Catalysis and Biochemical Inquiry"

Dan Marquess, Theravance
"Leveraging the Chemistry of Multivalent Design to Create Theravance's Medicines"

Peter Miller '80 and Michael Swartz '90, PerkinElmer
"Big Data, Informatics, Imaging and Life Science Research"

Brian Northrop, Wesleyan University
"The Utility of Selective Thiol-Ene Click Chemistry in Organic Materials Synthesis"

Thomas O'Halloran, Northwestern University, Charles Compton Lectureship
"Transition Metal-Receptor Interactions in Control Cellular Decisions"

Stephen Ragsdale, University of Michigan
"Regulation of Metabolism by Heme, Redox and Carbon Monoxide"

Off-Campus Chemistry Colloquia

Dylan M. Barber ’15, Todd A. Brenner ’14, Luxi Qiao ’16, Sarah L. Goh
“Antioxidant copolymers in biological applications” 249th American Chemical Society’s National Meeting & Exposition, Denver, CO, March 2015

Dieter Bingemann
“Why are Glasses so Slow-Moving?” Universität Göttingen, Göttingen , Germany, January 2015

Jimmy Blair
Developing Histidine Kinase Inhibitors: Antibiotic Drug Discovery at Williams” Department of Chemistry, Wesleyan University, Middletown, CT, March 2015

Tamuka Chidanguro ’15, Lillian Ma ’15, Sarah L. Guillot ’13, Christopher Goh
“Ligand Donor Effects in Copper(I) and Copper(II) Complexes of Polydentate Heteroaromatic-amine Ligands in the ATRP of Styrene” 249th ACS National Meeting, Denver, CO, March 2015

Sarah L. Goh
“Amino Acid-based Amphiphilic Copolymers: Synthesis and Self-assembly” 248th American Chemical Society’s National Meeting & Exposition, San Francisco, CA, August 2014

“Polymers for [oxidative] Stress Relief: Delivery of Polyphenols”Smith College, April 2015

L. David Jaramillo ’17, Alexander J. Lou ’13, Denise Park ’15, Luxi Qiao ’16, Sarah L. Goh
“Amino Acid-based Amphiphilic Micelles” American Chemical Society Connecticut Valley Section’s 2015 Undergraduate Research Symposium University of St. Joseph, West Hartford, CT, April 2015

Claire A.L. Lidston ’15, Matthew R. Davies ’17, Christopher Goh
“Investigating the Oxidation of Olefins Using Derivatives of the Non-heme Iron Catalyst[Fe(BPMEN)$(OTf)_2$]” 249th ACS National Meeting, Denver, CO, March 2015

Denise Park ’15, Matthew N. Zhou ’12, James W. Lowe ’09, Karen Chiu ’10, Sarah L. Goh
“Synthesis of p(NIPAM)-p(DMA) Copolymers for Protein Conjugation” 249th American Chemical Society’s National Meeting & Exposition, Denver, CO, March 2015

Anne R. Skinner
“Exploration of the First Use of Fire” Congress of the PanAfrican Archaeological Association (joint with the Society of Africanist Archaeologists), Johannesburg, South Africa, July 2014

“Scientific Dating in Archaeology: Studying in Our Past” Department of Nuclear Physics, Federal University of Pernambuco, Recife, Brazil, May 2015

Anne R. Skinner and Maxine Kleindienst
“Plumbing the Presence of Paleolithic Hominins in the Western Desert: ESR Dating Molluscs and Herbivore Teeth at Dakhleh Oasis, Egypt”, Symposium on Middle Paleolithic in the Desert, Bordeaux, France, December 2014

Post-Graduation Plans of Chemistry Majors

Dylan Barber	Ph.D. in Polymer Science & Engineering, University of MA, Amherst
Ryan Barry	Business Analyst, McKinsey & Company, Boston, MA
Chelsea Boydstun	Chemist, Magnifica, Inc, Cranbury, NJ, then to medical school
Andrew Bravo	Associate Consultant, Bain & Company, Boston, MA
Marcel Brown	Research Coordinator, MA General Hospital, then to medical school
Alice Chapman	Unknown
Tamuka Chidanguro	Ph.D. in Polymer Science & Engineering, University of Southern MS
Juno Cho	Teach for America, Chicago, IL
Cody Cotner	Unknown
Moses Flash	Biomedical Research, Boston, MA
Mmaserame Gaefele	Unknown
Dylan Griswold	Unknown
Christian Gronbeck	Unknown
Sola Haye	Unknown
Karen (Tiantian) He	Analyst, Broadhaven Capital Partners, Chicago, IL
Joshua Helmkamp	Professional American Football Player, Spain, then to medical school
Ivan (Jake) Huerfano	Research Assistant, Theravance Biopharma, South San Francisco, CA
Veroneque Ignace	Unknown
Gloria Joo	Clinical Research Assistant, Tisch MS Research Center of New York
Aaron Jordan	Unknown
Salmaan Karim	Research Assistant, Boston's Children's Hospital, then to graduate school
Grace Kim	PharmD, UC San Francisco School of Pharmacy
Ashley Kim	Research Assistant, Theravance Biopharma, South San Francisco, CA
Claire Lidston	Ph.D. in Chemistry and Chemical Biology, Harvard University
Lillian Ma	Ph.D. in Chemistry, Cambridge University
Linamarie Miller	Ph.D. in Chemical Biology, Tri-Institutional Program, New York, NY
Felicia-Wrae Morgan	Unknown
Zaw-htut Naing	Research Technician, Boston University Medical, then medical school
Jared Nowell	M.D., Columbia University of Physicians and Surgeons
Denise Park	Unknown
Ashini Patel	Unknown
Bryn Reinstadler	MPhil in Chemistry, University of Cambridge
Anne Rojas	Secondary Chemistry Teacher, Teach for America, Baltimore, MD
Anuj Shah	NIH Intramural Research Program, Psychopharmacology, Bethesda, MD
Marissa Shieh	Unknown
Alexander Silver	Research Assistant, Brigham and Women's Hospital, Boston, MA
Rebecca Staff	Medical School
Katherine Susa	Working at Gilead Sciences, CA, then to graduate school

Melissa Vargas	Planning to attend Law School
Amanda Walker	Unknown
Arran Yip	Unknown
Jimeen Yoo	M.S. in Biosciences, Icahn School of Medicine at Mount. Sinai, NY
Daniela Zarate	Ph.D. in Biological Sciences, UC San Diego
Shannon Zikovich	Tenth Grade Chemistry Teacher, Teach for America, Chicago, IL

(L to R) Denise Park ’15, Jake Huerfano ’15, Tamuka Chidanguro ’15, Dylan Barber ’15, Matt Davies ’17, and Claire Lidston ’15 at the Spring American Chemical Society Conference in Denver, CO, April 2015.

Computer Science Department

Bursting with students, the Computer Science Department saw a record number of majors graduate this past year. Healthy enrollments in all our courses kept the department busy and bustling. We offered the new introductory course *Diving into the Deluge of Data* (CSCI 135), hosted bicentennial award-winner *Ethan Zuckerman '93* during convocation, and sponsored a series of fantastic talks by the machine-learning legend Tom Mitchell. Professors Jeannie Albrecht and Stephen Freund were both awarded National Science Foundation Grants in support of their research.

In October *Sarah Abramson '15, Emma Harrington '15, Jenna Maddock '15, Erica Moszkowski '15, Olivia Pham '15, Abigail Zimmermann-Niefield '15, Nina Kumar '16*, and *Pamela Mishkin '16* attended the Grace Hopper Celebration of Women in Computing in Phoenix, AZ along with Professors Jeannie Albrecht and Andrea Danyluk. Sarah and Emma presented their research as part of the ACM Student Research Competition, and Emma was awarded second place in the undergraduate category.

It was a notable year for national awards with many current and former students earning prestigious prizes, scholarships, and fellowships. Emma Harrington won the celebrated Computing Research Association's Outstanding Undergraduate Female Research Award. This national award honors undergraduate students who show promising research potential. Emma will pursue a PhD at Harvard University next year. *Nathan Miller '15* was named a Watson Fellow, which provides financial support for a year of independent inquiry outside the United States. Nathan will explore artistic processes in folk music culture in Zimbabwe, Serbia, Indonesia, and Japan.

Nick Arnosti '11 (pursuing a PhD at Stanford University) is the recipient of the 2015 Google US/Canada Fellowship in Market Algorithms, which recognizes outstanding graduate students doing exceptional work in computer science. *Reid Pryzant '16* earned a Goldwater Scholarship, *Jennifer Gossels '13* (pursuing a PhD at Princeton University) earned a National Science Foundation Graduate Research Fellowship and *Daniel Seita '14* won a National Physical Science Consortium Fellowship.

The department bids farewell to *Brent Yorgey '04* who had a successful year in our department as a visiting professor. Next year Brent will start a tenure track position at Hendrix College in Conway, AR. We wish him the best.

While on sabbatical leave this year, Professor **Jeannie Albrecht** continued to investigate techniques for using computing to decrease the energy impact of society. She primarily focused on challenges related to the new Environmental Center on campus. The newly renovated and expanded building was originally the Kellogg House, one of the oldest buildings on campus. It is now striving to satisfy the Living Building Challenge (http://living-future.org/lbc), which requires the building to be net zero for both energy and water usage over a 12-month period. If successful, this building will be the first historical building to achieve LBC certification.

The building poses some unique challenges due to its intended use: it consists of classrooms, faculty and staff offices, and a public kitchen. The kitchen is a point of concern regarding energy usage; it contains commercial-grade appliances—including a powerful range hood—that consume significant quantities of electricity when in use. If occupants do not make energy efficient decisions while using the kitchen, the building could go over its energy budget for the year.

To address these challenges, Albrecht worked with *Sarah Abramson '15* on a system for monitoring and visualizing energy usage in the Environmental Center, focusing specifically on the kitchen. For Sarah's senior honors thesis, she developed a prototype visualization that displays both power and energy usage for kitchen appliances in an intuitive and aesthetically pleasing way. She conducted several user studies to measure the effectiveness of her tool, and obtained very promising results. Albrecht plans to fully deploy Sarah's system in the building in the upcoming months. *Devin Gardella '16, Gordon (Mac) Finnie '16*, and *Matt McNaughton '16* will work with Albrecht in the coming year on extensions to Sarah's initial work.

Isaiah Leonard '15 worked with Professor **Duane Bailey** to develop a model for pairing processors with FPGAs to reduce power utilization. Modern processors can make use of only 3% of transistors at any time due to tight power constraints and increasing static power loss. This has led to an era of "Dark Silicon" where programmers will have to develop novel techniques to re-

duce total power costs. Bailey and Leonard have developed techniques to provide programmers a choice of interpreting instructions, traditionally, or transparently targeting runtime reconfigurable hardware. *Gregory Becker '15* and Bailey worked on a system for coordinating CPU and GPU computation that promises to allow better "soft-error" checking in supercomputers. Soft errors come from environmental effects (e.g. cosmic radiation) that are hard to identify and correct efficiently. Their approach makes use of the natural parallelism of GPUs to support redundant computation.

Bailey worked with several teams of students on research projects. *Tong (Tony) Liu '16* and *Diwas Timilsina '16* investigated the structure of curling sequences, a problem in number theory. Their investigations led to long-running and intensely parallel enumerations of "rotten sequences". Managed by a process-coordination language (harmony) designed by Bailey and *Derrick Bonafilia '17*, computations progressed through the spring while Liu and Bailey cut running times by a factor of nearly 10. Bailey and *Riwaz Poudyal '18* will be continuing investigation this summer, with final computations finishing, ideally, in August. The enumeration will take an estimated 95 cpu-years. *Bijan Mazaheri '16* and Bailey worked to leverage proofs of universal computation for Rule 110 1-D cellular automata (by Matthew Cook), to demonstrate universality in Wang tiles and quantum dot cellular automata. While both systems are known to be universal, the use of Rule 110 makes these proofs particularly simple and elegant.

Professor **Andrea Danyluk** continued her research in machine learning, working on a number of different projects in the area of classifier learning. The first involves learning a classifier when the data available for learning are highly imbalanced and where instances for learning are abundant but the class labels are not. An example of this situation involves learning a classifier that can determine first whether a web page belongs to a computer scientist and then whether it belongs to a female computer scientist. In the space of all possible web pages, the percentage of "computer scientist" pages is small, and within that group the percentage of women is small as well. Though web pages are abundant, they do not have labels attached to them that indicate whether they fall into one of these target groups. A second project involves learning to identify individual objects from digital images. A third project is in collaboration with Prof. Jeannie Albrecht in the application area of green computing. The goal of this third project is to apply machine learning techniques to disaggregate household energy usage – that is, given only total energy usage, time of day, and day of week, determine the set of appliances being used at that instant. In summer 2014, three students worked with Prof. Danyluk, one on each of these projects. In summer 2015, she looks forward to continuing this work with *Kai Wang '16, Devin Gardella*, and *Gordon (Mac) Finnie '16.*

During the academic year Prof. Danyluk worked with two independent study students on projects in machine learning and artificial intelligence. *Rahul Nath '15* explored learning high-level knowledge required for planning by observing traces of raw action sequences of problem-solving behavior. Kai Wang explored computational music.

Last year Danyluk had wrapped up her formal service as a member of the steering committee for the ACM/IEEE Computer Science Curriculum 2013. The committee developed international curriculum guidelines for undergraduate programs in computer science. This year she followed up on that work by giving talks on the curriculum and advising faculty on how their departments might implement the recommendations. Danyluk also continues 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 on mentoring programs for graduate students, and early- as well as mid-career researchers.

Professor **Stephen Freund** spent the fall on sabbatical working with colleagues 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. This past year he was awarded a National Science Foundation grant for $198,993 to continue this work. Last July, Freund presented a tutorial on his research related to defect detection at the UPMARC Summer School on Multicore Computing in Uppsala, Sweden.

He also embarked on a new project to study scalability-oriented optimization. Multicore CPUs and mul-

tiprocessors offer the promise of continued software performance improvements as the number of cores they provide increases, but performance improvements are only possible if software can be designed to effectively utilize many cores by running many tasks simultaneously. Designing systems to do that is notoriously difficult for even the most expert programmers. Freund's work will develop automated ways to increase performance of programs through a process called SCORE, or scalability-oriented optimization. SCORE will monitor programs as they run, locate scalability bottlenecks where they fail to make best use of the processing cores available to them, and transform their code or execution environment to eliminate those bottlenecks. Freund received a second National Science Foundation grant for $252,000 for this project, which is in collaboration with University of Massachusetts, Amherst.

Freund advised *Emma Harrington '15* on her senior thesis titled "User Motivation on Stack Overflow." In this work, Emma explored why people contribute to online communities like Stack Overflow, an online question and answer forum for programming questions, and she also examined how changes to the reward structure for participants impact users behavior.

After returning from a successful sabbatical as Research Scientist at the mobile advertising company Fiksu, Professor **Brent Heeringa** took over duties as Chair of the Department of Computer Science. In the fall, he taught *Theory of Computation* (CSCI 361). In the spring he designed, developed, and taught the new introductory course *Diving into the Deluge of Data* (CSCI 135). Using the programming language Python, Heeringa introduced fundamental computing concepts through an exploration of ways to organize and transform information.

Heeringa continued his collaboration with Professor Nate Kornell (Psychology) and *Benno Stein '15* on recognition codes, which transform arbitrary pieces of information into representations that are human-friendly. A working version of their system is available at www.mindburnr.com. Heeringa also started a new research collaboration with Professor Bill Lenhart. Together the two computer science colleagues showed that a natural string packing problem was likely computationally intractable and developed and analyzed an approximation algorithm that finds a provably good solution, one that is never more than one-third smaller than optimal. This work is currently in submission.

As thesis advisor to *Jaclyn Porfilio '15*, Heeringa studied relationships between heapable sequences and permutation graphs. The work is motivated by the classic *secretary problem* where a committee sequentially interviews candidates for a secretarial position. When interviewing a candidate, the committee learns the candidate's rank relative to all the previously interviewed candidates. Immediately following the interview, the committee can either offer the job to the candidate (which he will always accept) or pass on the candidate, in which case the committee considers the next person. Perhaps surprisingly, the optimal hiring strategy samples the first 37% of the candidates and then offers the job to the first candidate in the remaining 63% that exceeds the best candidate seen so far. Heeringa and his colleagues have extended these problems to scenarios where the committee is interesting in hiring *an organization* with the constraint that a candidate will only work under someone who is ranked higher. Porfilio's thesis provides a combinatorial characterization of heapable sequences that provides several promising avenues of attack.

Heeringa reviewed papers for the 2015 European Sympoisum of Algorithms.

Professor **Bill Lenhart** 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 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. Joint work with colleagues at the University of British Columbia, Universität Tübingen, the Karlsruher Institut für Technologie, and Lethbridge University, resulted in the paper "Bar 1-Visibility Graphs and their relation to other Nearly Planar Graphs", which was published in the *Journal of Graph Algorithms and Applications*. 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. Lenhart worked with *Jose Raventos '16* during the summer of 2014 on problems in this area with eye towards completely characterizing those trees that have a given *convex* obstacle number k; that is, those graphs that have an obstacle representation consisting of at most k convex obstacles.

Professor Lenhart was invited to speak at the weekly research colloquium in the Department of Mathematics and Statistics this past fall. He presented joint work with Professor Brent Heeringa on the string packing problem. In this problem, one tries to match as many strings as possible from a given list into a long target string in a way that avoids overlapping.

Finally, he had the pleasure of serving as the College's Interim Chief Technology Officer for the first half of 2015. He enjoyed greatly the opportunity of working with the talented staff at OIT, and will enjoy equally greatly returning to the role of full-time faculty member.

Professor **Morgan McGuire** returned from sabbatical with new interests of virtual reality and film cinematography. He revised the *Computational Graphics* (CSCI 371) course to reflect this and new advances in the field. The 24 local students and four remote mentors in the course produced a series of fantastic CGI short films each week, one of which won the Williams film competition. McGuire worked with faculty in other departments to development new interdisciplinary content for courses about film, including co-lecturing with Professor Shawn Rosenheim in English in both departments this year.

In the graphics lab, he worked closely with undergraduates *Daniel Evangelakos '15, Kelly Wang '16, Samuel Donow '16*, and *Jamie Lesser '17*, and alumnus *Michael Mara '12* (now at Stanford University) on several research projects for virtual reality and cinematic lighting effects.

McGuire's creative scholarly work this year included two new video games, the massive *Skylanders: Superchargers* console game at Activision's Vicarious Visions studio, and the solo *Project Rocket Golfing* for iPhone, iPad, and iPod Touch. He consulted on new special effects for the leading Unity game engine and processor architecture for the next generation of NVIDIA GPUs. He also published several volumes of the Journal of Computer Graphics Techniques as Editor in Chief and a new edition of his *Graphics Codex* textbook.

Professor **Tom Murtagh** spent the past year on a sabbatical leave. He took advantage of this leave to continue his investigation of techniques for optimizing the performance of NAND memory based file systems. Manufacturers have packaged NAND memory with interfaces that imitate disk drives 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 NAND memory. During the year, Tom completed the design of new file system for NAND memory based on generalizing techniques used in log structured file systems. The system takes advantage of the ability to maintain many active logs simultaneously in a NAND memory to minimize the cost of space reclamation. This summer, Tom will be working to complete an experimental implementation of this file system under Linux to evaluate its performance.

Class of 1960 Scholars in Computer Science

Sarah Abramson '15
Gregory Becker '15
Samuel Donow '16
Daniel Evangelakos '15
Gordon Finnie '16
Eli Goldstein '16
Nola Gordon '17
Emma Harrington '15
Matthew LaRose '16
Isaiah Leonard '15
Jamie Lesser '17
Siyao Liu '16
Nile Livingston '15
Blake Mackall '16
Pamela Mishkin '16
Erica Moszkowski '15
Austin Paul '16
Jaclyn Porfilio '15
Reid Pryzant '16
Emily Roach '16
Diwas Timilsina '16
Kai Wang '16
Lauren Yu '16
Abigail Zimmermann-Niefield '15

Computer Science Colloquia

Tom M. Mitchell, Carnegie Mellon University
"Never-Ending Machine Learning"

Brian Scassellati, Yale University
"Socially Assistive Robotics"

Computer Science Faculty, Williams College
"Thinking about Graduate School?"

Franklyn Turbak, Wellesley College
"Not Just for Kids: the Design and Implementation of Blocks Programming in MIT App Inventor"

Anthony Barnes, EnergySavvy
"Utilities, Energy Efficiency, and Possible Applications of Computer Science Principles"

Sophia Malamud, Brandeis University
"Utterance Modifiers, Clause Types, and Speech Acts"

Chris Perry, Hampshire College
"Towards Independent Animation"

Ned Sahin '98, Brain Power, LLC
"Autism and Google Glass: Assessment and Intervention Software Grounded in Brain Sciences"

Computer Science Faculty, Williams College
"Computer Science Research at Williams"

Kristina Striegnitz, Union College
"How to Talk about Objects in Interactive Virtual Environments"

Alexandra Meliou, University of Massachusetts, Amherst
"Reverse Data Management: Deriving Explanations, Diagnoses, and Desirable Outcomes"

Ileana Streinu, University of Massachusetts, Amherst
"Auxetic and Expansive: Mathematical Incursions into Materials Science"

Benjamin Wood '08, Wellesley College
"Implementing Data-Race Exceptions"

Nicholas Hopper, University of Minnesota, Minneapolis
"Special-Purpose Protocols for Internet Censorship Circumvention"

Peter Shirley, Purity, LLC
"Palettes in Painting, Printing, and Computer Graphics: Their History and Use"

Nicholas McPhee, University of Minnesota, Morris
"Graph Databases: From Social Networking to Silico-paleontology"

Computer Science Student Colloquia

Samuel Donow '16, Daniel Evangelakos '15, Isaiah Leonard '15, Benno Stein '15, Diwas Timilsina '16
"What I Did Last Summer – Part I"

Eddie Kelly '15, Rahul Nath '15, Jaclyn Porfilio '15, Kelly Wang '16
"What I Did Last Summer – Part II"

Emma Harrington '15
"The Effects of Rewards on Specialization: The Case of Stack Overflow"

Isaiah Leonard '15
"Using Reconfigurable Hardware to Fight Dark Silicon"

Jaclyn Porfilio '15
"A Combinatorial Characterization of Heapability"

Sarah Abramson '15
"Kellogg House: Instrumentation, Data Collection and Data Visualization"

Greogory Becker '15
"A Tool for Redundant and Parallel General Purpose GPU Computation"

Daniel Evangelakos '15
"A Spatial Data Structure for Efficient GPU Ray Tracing"

Kyle Cheng '16, Devin Gardella '16, Eli Goldstein '16, Matt LaRose '16, Tony Liu '16, Diwas Timilsina '16, Kai Wang '16, Kelly Wang '16
"Ward Prize Nomination Presentation"

Off-Campus Computer Science Colloquia

Jeannie Albrecht

"GENI for Undergraduates" GENI/NSF Workshop, Baltimore, MD, November 2014

"Making Buildings Smarter: Using Technology to Achieve a More Sustainable Future" Environmental Center Opening, Williams College, Williamstown, MA April 2015

Andrea Danyluk

"Computer Science at Williams College: 1987-2014" Symposium on a New Computer Science Department, Whitman College, Walla Walla, WA, June 2014

"Prof or Prez: Choosing your path" Grace Hopper Celebration of Women in Computing Conference, Phoenix, AZ, October 2014

"Small or Liberal Arts Colleges Adapting to CS2013: Making It Work" SIGCSE 2015, Kansas City, MO, March 2015

"Computer Science Curriculum 2013" CUNY Grad Center, New York, NY, April 2015

Stephen Freund

"Analysis Techniques to Detect Concurrency Errors" UPMARC Summer School on Multicore Computing, Uppsala, Sweden, July 2014

Brent Heeringa

"Using Recognition Memory to Encode Information" Radical Words Series: Francine and Sterling Clark Art Institute, Williamstown, MA, October 2014

"Using Recognition Memory to Encode Information" Hampshire College Colloquium, Amherst, MA, December 2014

Morgan McGuire

"Vicarious Visions' Making of Skylanders: SWAP Force" Williams College Summer Science Lecture, Williamstown, MA, July 2014

"Gaze Aware Graphics" NVIDIA Corporation, Santa Clara, CA, April 28, 2015

"Elegance in Video Game Design" Union College, Schenectady, NY, April 29, 2015

"Ex Machina" Images Cinema, Williamstown MA, May 28, 2015

Post-Graduation Plans of Computer Science Majors

Name	Plans
Sarah Abramson	Software Engineer, Google Mountain View CA
Gregory Becker	Computation Division, Lawrence Livermore National Lab Livermore CA
Jeremy Boissevain	Undecided
Mitchell Breitbart	Fiksu, Boston MA
Guedis Cardenas Cabrera	Application development
Kevin Chen	Software Developer, Tesla Government Falls Church VA
Christine Cunningham	MIT Lincoln Laboratory, Lexington MA
Alexandre DeBaere	Undecided
Benjamin Eastburn	Undecided
Daniel Evangelakos	Research Internship, NVIDIA Santa Clara CA
Michael Flynn	Game Developer, Vicarious Visions Menands NY
Emma Harrington	Graduate School for Economics, Harvard University Cambridge MA
Benjamin Jones	Undecided
Edward Kelly	Analyst Credit Suisse New York NY
Isaiah Leonard	Software Engineer, C3 Energy Redwood City CA
Nile Livingston	Undecided
Jenna Maddock	Teacher, Japanese Education and Teaching Programme Japan
Kira Marrero	Undecided
Juan Mena	Ingage Technologies, North Adams MA
Nathan Miller	Watson Fellowship, Studying and recording music globally
Erica Moszkowski	Research Assistant, Federal Reserve Bank of New York NY
Rahul Nath	Undecided
Olivia Pham	Undecided
Jaclyn Porfilio	Management Consultant, McKinsey Boston MA
Michael Shelton	Chief Software Engineer, Rastech Software New York NY
Llewellyn Smith	Software Engineer, Fisku Boston MA
Benno Stein	PhD candidate in Computer Science, University of Colorado Boulder CO
Natalie Weyerhaeuser	Foursquare, New York NY
David Yan	Undecided
Abigail Zimmermann-Niefield	Technology, Goldman Sachs New York NY

Geosciences Department

The Geosciences Department continues to hum with activity. We graduated 11 seniors in 2015 whom we will miss, but we are excited to shepherd our 17 rising seniors into their final year, and very happy to welcome 19 new geoscience majors in the class of 2017. We expect that the department will continue to be productive as this energetic crowd of students makes their way through their Williams careers. We welcomed a new member of the department, Alex Apotsos, who replaces Dave Backus as a Lecturer in Geosciences. Alex brings expertise in shallow marine processes as well as international aid and development experience, and will provide a marvelous geoscience-environmental-policy linkage between our department and CES.

We had a very large student group attend the annual Geological Society of America national meeting in October. *Mary Ignatiadis '16, Laura Stamp '16* (both Clare Booth Luce scholars), *Jorge Castro '16, Emily Gaddis '15, Spencer Irvine '16, Kelly Tellez '17*, and *Oona Watkins '15* all gave poster presentations at the meeting. In March, *Nell Davis '15, Victor Major '15*, and *Will Wicherski '15* attended the NE GSA meeting and gave poster presentations there. They also gave presentations at the annual Keck Geology Consortium held at Union College in April.

This year's recipients of the Lauren Interess Fellowship were *Caroline White-Nockleby '16* and *Abby Kelly '16*. They spent a portion of Winter Study traveling some of the premier areas for research in caves and fossils in Southeast New Mexico and Northwest Texas. During Senior Thesis Day in May *Nell Davis '15* won the American Mineralogist Undergraduate Award from the Mineralogical Society of America, which recognizes that member of the senior class with the most outstanding record of scholarship and research in Mineralogy and Petrology. *Will Wicherski '15* was awarded the annual Freeman Foote Prize for best presentation of a senior honors thesis, and *Nakita VanBiene '15* was awarded the David Major Prize for outstanding Geosciences senior.

We look forward to the summer research session when faculty and students conduct the most focused research of the year. Students will be working in the field and in the lab, internationally and close to home. We have seven students beginning their year-long senior thesis investigations, and a number of underclassmen who are getting an early taste of geoscience research as field and lab assistants.

Assistant Professor **Phoebe Cohen** spent the summer of 2014 doing field and lab work with Williams students. In June, she traveled to the Yukon with *Laura Stamp '16* for two weeks of field work collecting samples that contain evidence of the earliest organisms to use minerals to make hard parts (biomineralization). Later in the summer, she spent a week doing field work in Western New York with *Kelly Tellez '17* and *Mary Ignatiadis '16* examining evidence of the late Devonian mass extinction event. Laura, Mary, and Kelly all spent the remainder of the summer in the Cohen lab working on their research projects. In the fall, Phoebe took all three summer students plus research student *Spencer Irvine '16* to the Geological Society of America meeting in Vancouver, WA, where Laura, Mary, and Spencer presented posters on their research. At this meeting, Phoebe also gave a research talk on a paper now in press at the journal *Paleobiology* on the diversity of fossil life in the Proterozoic Eon. In the fall, Phoebe taught a new upper-level course, *Geobiology* (GEOS 311), which introduced students to the complex interactions that occur between the earth and life over geological timescales.

In the spring, Cohen taught *Paleobiology* (GEOS 212) and brought two new students into her lab – *Gabby Markel '17* and *Maoli Vizcaíno '17*, who both worked on finding fossils from in between two major global glaciation events in the Proterozoic. In addition to teaching and lab work, Cohen submitted a grant proposal to the National Science Foundation and to the Paleontological Society and gave research seminars at Penn State University and Smith College. Cohen had a manuscript published this spring in the journal *Palaios* on enigmatic red algae from between the two major Proterozoic glacial events.

This summer, Professor Cohen will again have a full lab as S*pencer Irvine '16* and *Abby Kelly '16* work on senior thesis research while *Henry Barker '18* learns the ropes as a new research assistant and *Maoli Vizcaíno '17* continues on in the lab as an Allison Davis Fellow.

This year, Phoebe served as a reviewer for the National Science Foundation, *Frontiers in Earth Science*, and the *Proceedings of the National Academy of Sciences*.

She also continued her role as the Social Media Coordinator for the Paleontological Society and finished her two-year term as the Geological Society of America Joint Technical Program Committee representative for the Paleontological Society.

Associate Professor **Mea Cook** attended iPODS-OC3, an international workshop on deep-ocean circulation and ocean biogeochemistry in Bern, Switzerland, and the American Geophysical Union annual meeting in San Francisco, California, where she presented her work on using radiocarbon as a tracer of past ocean circulation. Cook's former honors student *Johanna Eidmann '14* presented her thesis work at the Geological Society of America meeting in Vancouver, Canada, on reconstructing past climate variability using Arctic lake sediments. Five research assistants worked on projects in Cook's lab studying the influence 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 Iowa State University, Massachusetts College of Liberal Arts, and Rensselaer Polytechnic Institute. Cook reviewed manuscripts for *Marine and Petroleum Geology*, *Climate of the Past*, *Earth and Planetary Science Letters*, and the Marine Geology and Geophysics Program of the National Science Foundation. She is a member of the American Geophysical Union, the National Association of Geoscience Teachers, and the Earth Science Women's Network.

Professor **Rónadh Cox** 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. In summer 2014, supported by NSF and by the Williams College Sustainability Fund, Cox took a field team of seven students to the Aran Islands (Ireland) to measure the effects of major storms that had hit the region during the winter. The group documented movements of about 1300 boulders, including 19 very large clasts (with masses 50-430 tonnes), all of which had been transported by storm waves. The work generated some public interest, and the group was filmed for Irish television, as well as being interviewed on NPR. Initial results were presented at the GSA National Meeting in Vancouver last fall (with the entire undergraduate field team as co-authors on the paper), and *Oona Watkins '15* used the data set as the basis for her senior thesis. Work on that project continues, and Rónadh returns to the Aran Islands this summer with thesis student *Josh Harrington '16*, as well as field assistants *Jordan Fields '17* and *Zeke King Phillips '18*. Accompanied by aerial photography expert Peter Cox (who in previous years has taught a winter study course on digital photography), the group will make a detailed 3-D digital map of the boulder deposits, to underpin future monitoring. A new NSF grant, involving collaboration with colleagues at University College Dublin and Queens University Belfast, will support additional investigations into wave interactions with the coast.

Professor **David Dethier** continued his research with students from Williams College and Keck projects, focusing mainly on the measurement of geochemical processes and long-term erosion in the Boulder Creek "critical zone" (CZO), which includes the mantle of soil and weathered material above fresh bedrock. In cooperation with an NSF-RAPID Grant (to *Will Ouimet '01*, University of Connecticut), Dethier worked during July with *Victor Major '15* and *Will Wicherski '15* and a Keck Colorado Project in the Fourmile Creek watershed, an area swept by catastrophic floods in September 2013. Dethier, Ouimet and Jim Kaste (College of William and Mary) continued investigations of Front Range 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 (University 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 30 years of monitoring are available at http://oit.williams.edu/weather/; archived watershed data (streamflow and temperature, stream chemistry and bulk precipitation chemistry) are at: http://web.williams.edu/weather/watershed/index.php.

Dethier was Chair of the Kellogg Building Committee from 2010 to 18 April 2015, when the Class of 1966 Environmental Center was dedicated. The new Center

houses Environmental Studies and the Zilkha Center for Environmental Initiatives, makes all of its energy using PV panels, collects all its water from the roof, and is surrounded by an edible landscape http://ces.williams.edu/.

Mystic Seaport's historic whaleship *Charles W. Morgan*, sailed on its 38th Voyage, the first voyage in nearly a century, during the summer of 2014. As part of the interdisciplinary educational and scholarly program, Associate Professor **Lisa Gilbert** directed onboard oceanography, using both traditional and modern techniques. Following the voyage, she's been working with artists, engineers, teachers, historians, and others to contribute to a new exhibit "Voyaging in the Wake of the Whalers" and supplementary online exhibit. In other interdisciplinary work, Gilbert continues to collaborate on an NSF-funded effort to increase undergraduate preparation in solving complex problems for a sustainable future. Her co-authored module on hurricane hazards and risks was published in July and she has begun work with colleagues from the University of Maine and Carleton College on improving systems thinking across the curriculum, at a national level.

Gilbert continues her work on the origin and evolution of the permeability of oceanic crust with colleagues from Oregon State University and the University of Miami and undergraduates *Caroline Atwood '16* (Williams-Mystic F14), *Caroline White-Nockleby '16* (Williams-Mystic F14), *Luis Urrea '16* (Williams-Mystic S15), Kaitlyn Klema (Williams-Mystic S15; Smith '16), Alana McGillis (Williams-Mystic F13; Smith '15), Molly Weiner (Williams-Mystic S14; University of Rochester '16), and Katherine Enright (Wesleyan '15). In 2014, Gilbert and three of these undergraduate students presented results of collaborative research projects at the American Geophysical Union Fall Meeting in San Francisco.

Emeritus Professor **Markes Johnson** and research scientist **Gudveig Baarli** continue with academic work on a wide range of topics from their office in Morey House. During the fall semester, Johnson followed up with co-operation on research projects regarding Miocene-Pliocene strata on Santa Marina Island in the Azores after summer fieldwork in 2014 during the Eleventh International Workshop on Palaeontology in Atlantic Islands. The group has now published two major reports and the next phase of fieldwork occurs in July 2015. Also during the fall semester, Johnson and Baarli completed a manuscript on Charles Darwin's activities studying interbedded fossil deposits and lava flows in the Cape Verde and Galápagos archipelagos; the manuscript has now passed through review and is ready for publication in the journal *Earth Sciences History*. A version of this paper was delivered at the Thirty-ninth Symposium of the International Commission on the History of Geological Sciences in July 2014, in Pacific Grove, California. In September, they attended the Seventh International Meeting on Taphonomy and Fossilization at the University of Ferrara, Italy. In November 2014, Johnson and Baarli traveled to Baja, Mexico, where lectures were delivered at various venues and discussion was started with the NGO Eco-Alianza de Loreto regarding the possible development of a formal "Geopark" to be coordinated with the Parque Nacional Bahía de Loreto. During the spring semester, Johnson began work on a new book regarding a range of coastal ecosystems in the Gulf of California, aimed at promoting the concept of one or more regional geoparks where reinforcing concepts of ecology and paleoecology may be illustrated. Following a visit to the Palaeontology Museum in Oslo, Norway, in February 2015, Baarli continues with research on Ordovician-Silurian boundary strata and fossils. New fieldwork by Johnson and Baarli will commence in the Oslo region in June 2015.

Professor **Paul Karabinos** continued research on his grant from the National Science Foundation to support an educational initiative *Visualizing Strain in Rocks with Interactive Computer Programs*. This project, in collaboration with Chris Warren from the Office of Information Technology, created a new computer program 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 continued work on another NSF-funded educational project *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 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."

Karabinos attended the National meeting of the Geological Society of America in Vancouver, British Columbia, in October, 2014, where he gave two presentations: "Visualizing Deformation with an Interactive Computer Program: Linking Shape Change with Graphical and Mathematical Representations of Strain" and "An Interactive Program for Visualizing and Estimating Strain in Deformed Conglomerates." He was co-author on "A Short Supercontinent Cycle: Relicts of Early to Middle Ordovician Closure of the Iapetus Ocean in the New England Appalachians."

Karabinos attended the Northeastern Section of the Geological Society meeting in Bretton Woods, New Hampshire, in March 2015 where he gave two presentations: "Was the Early Ordovician Shelburne Falls Arc Built on Gondwanan Crust Close to Laurentia?" and "Detrital Zircon Constraints on the Age of the Poplar Mountain Gneiss in the Pelham Dome: Implications for the Tectonic Setting of the Bronson Hill Arc." He was also co-author on three presentations: "A Structural Investigation of Folded Bascom Fm., US Highway 279 in North Bennington, VT," "The Structural Geology Mapping Challenge: an Evolving Tool for Online Geoscience Education," and "Uniting Taconic Hinterland Deformation with Ordovician Foreland Deposition in New England."

Karabinos published a reply article in *Geology* with colleagues from Harvard University, Middlebury College, and Boise State University, entitled "A Newly Identified Gondwanan Terrane in the Northern Appalachian Mountains: Implications for the Taconic Orogeny and Closure of the Iapetus Ocean, REPLY."

At the annual meeting of the Geological Society of America in Vancouver last fall, Professor **Bud Wobus** was recognized for his 50 years of membership in and service to the Society. Also at GSA he represented Williams for the 28th year on the Board of Representatives of the Keck Geology Consortium (keckgeology.org) and organized a reunion for some 30 Geosciences alumni, faculty, and current students. He hosted a similar gathering for a similar number at the fall meeting of the American Geophysical Union in San Francisco in December. During WSP he led an alumni trip along the volcanic chain of Central America from Costa Rica through Nicaragua to El Salvador.

During spring vacation he was co-author of a poster presented by his honors thesis student, *Nell Davis '15*, at the meeting of the GSA's Northeastern Section which several in the department attended at Bretton Woods, NH. Entitled "Comparison of Icelandic Rootless Cones with Experimental Lava Features," the poster summarized the results of Nell's year-long study as part of a Keck Geology Consortium research project. Her project began with field work in Iceland last summer, leading up to experimental replication of natural basalt lava features at the Syracuse University Lava Project lab.

In April he attended the spring board meeting of the Keck Consortium at the Consortium's annual research symposium, held this year at Union College. Three Williams seniors and two faculty were at the meeting, and they were joined by several alumni from other colleges who were active in Keck research with their students this year.

During Alumni Reunion weekend he will repeat his popular tour of the campus, "Williams Rocks…What the College is Built In, On, and Of" and host a gathering of Geosciences alumni back for reunion.

Class of 1960 Scholars in Geosciences

Charles Chirinos	Maija Lindaas	Rosalia Pembroke
Nell Davis	Akuku Makori	Maoi Vizcaino
Kyrien Edwards	Victor Major	Oona Watkins
Emily Gaddis	Rosalia Pembroke	Will Wicherski
Miaoru Guan	Gemma Porras Nielsen	Jenny Zheng

Mary Ignatiadis '16 and *Kelly Tellez '17* collecting rock samples in Upstate NY, July 2014

Geosciences Colloquia

Paul Bierman '85, University of Vermont
"Erosion in the Ice Box – a Tale Told by Rare Isotopes in Greenland Ice Sheet Sediment"

Matt Jungers '03, Oberlin College
"A Source-to-Sink View of Earth Surface Processes: Cosmic Rays to Castor Canadensis"

Nicole Khan, Rutgers University
"A Tale of Two Proxies: Diatoms and Stable Carbon Isotopes as Indicators of Floods and Past Sea Levels"

Noah Snyder, Boston College
"Dam Removal as an Experiment in River Channel Evolution"

Lisa Gilbert, Geosciences Dept., Williams-Mystic
"Citizen Science Inspired by Moby-Dick"

Tim Schroeder, Bennington College
"Carbonate Precipitation in the Footwall of an Oceanic Core Complex: Mechanisms and Implications"

R. A. Wobus, Williams College Geosciences Dept.
"Williams Rocks…What the College is Built In, On, and Of"

Williams campus geological tour, Alumni Weekend, June 2015

Geosciences Student Colloquia

Nell Davis '15
"Comparison of Icelandic Rootless Spatter Cones with Experimental Lava Features"

Victor Major '15
"Connecting Surficial Deposits and Hydrologic Flux in Leaky, Snowmelt-Dominated Catchments, Niwot Ridge, Colorado

Will Wicherski '15
"Geomorphic Effects of the September 2013 Flood in Fourmile Canyon, Colorado, Using Lidar and Field Studies"

Oona Watkins '15
"Boulder Movements in Western Ireland"

Off-Campus Geosciences Colloquia

Gudveig Baarli
"On the Origin and Demise of Oceanic Islands: Towards a Global Theory Following from the Pioneering Studies of Charles Darwin and James Dwight Dana" 39th Symposium International Commission on the History of Geological Sciences, Pacific Grove, CA, July 2014

Phoebe Cohen
"Digging Deeper into the Proterozoic Record of Eukaryotes" Penn State, March 2015, Smith College, March 2015

"Life Before Snowball: The Tonian Fossil Record of Eukaryotes" Yukon Science Institute, June 2014

Mea Cook
"Productivity and Circulation in the North Pacific During the Last Deglaciation" Iowa State University, November 2014, Rensselaer Polytechnic Institute, April 2015

"The Oceans and Climate, Past and Future" Massachusetts College of Liberal Arts, February 2015

Rónadh Cox
"Gullies, Erosion and Landscape Evolution in Madagascar: Trying to Tease Apart Natural and Anthropogenic Effects" Wesleyan University, June 2014

"Moving Boulders on the Aran Islands" Marine Institute, Galway, Ireland, July 2014

"Regional Erosion Rates in Madagascar Via Cosmogenic Isotopes" Smith College, October 2014

"Megagravel on the Move: the Effects of Last Winter's Storms on Coastal Boulder Deposits in Western Ireland" University College Dublin, Ireland, November 2014, Trinity College Dublin, Ireland, November 2014

Lisa Gilbert
"Sea Change in Marine Technology" NOAA and National Marine Sanctuaries' OCEANSLIVE, July 2014

"Oceanography Aboard the Charles W. Morgan" Mystic Seaport, October 2014

"The Mystic River Estuary and Coastal Resilience" Mystic Seaport, October 2014

"Modern Science on the 38th Voyage of the Charles W. Morgan Inspired by 19th Century Practices" Mystic Seaport, January 2015

Lisa Gilbert (cont.)

"Recent Geologic Activity of Hawaii" Pine Point School, February 2013

"Introduction to InTeGrate Modules: Hands-on, Data-rich, and Socially Relevant Geoscience Activities" Webinar, serc.carleton.edu/integrate/workshops, April 2015

Markes Johnson

"On the Origin and Demise of Oceanic Islands: Towards a Global Theory Following from the Pioneering Studies of Charles Darwin and James Dwight Dana" 39th Symposium International Commission on the History of Geological Sciences, Pacific Grove, CA, July 2014

"Voyages of the Western Flyer and E.W. Scripps to the Gulf of California in 1940: a Marriage of Ecology and Paleoecology" 39th Symposium International Commission on the History of Geological Sciences, Pacific Grove, CA, July 2014

"Taphonomic Range and Sedimentary Dynamics of Modern and Fossil Rhodolith Deposits from North Atlantic Islands" University of Ferrara, Italy, September 2014

"Sedimentary Dynamics of Modern and Fossil Rhodolith Beds from the Gulf of California and North Atlantic Islands" Universidad Autonóma de Baja California Sur, Mexico, November 2014

"Hidden Secrets in the Landscapes of Baja California: Treasures Large and Small from Peninsular Shores and Gulf Islands" Visiting Scientist Series for Eco-Alianza de Loreto, Loreto, Baja California Sur, Mexico, November 2014

"Following John Steinbeck and Ed Ricketts to the Sea of Cortéz: Off-Trail Adventures in Baja California (Mexico)"

Paul Karabinos

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

R. A. Wobus

"From the Peak (Pikes) to the Park (South)…Mid-Tertiary Volcanism and the Shape of the Land" Florissant Fossil Beds National Monument, Colorado, July 2014

Students in Geos 231 the River sorting a trawl sample from Terrebonne Bay on the Mississippi River delta. Photo by Ronadh Cox

Post-Graduation Plans of Geosciences Majors

Alice U. Chapman	Geochemist at e4sciences
Charles B. Chirinos	Undecided
Nell C. Davis	Graduate student at McCall Outdoor Science School (through the Univ. of Idaho)
Amber D. Ellis	Undecided
Emily E. Gaddis	Project Manager at Epic, a healthcare software company, Madison, WI
Victor W. Major	Geocorps Research position for hydrology in Medicine Bow-Routt National Forest
Connor H. McLane	Consultant for Vain & Company, Boston
Rosalia M. Pembroke	Conservation Corps position with American Conservation Experience, an Americorps organization
Nakita G. VanBiene	Teaching Assistant at Blue Engine, a nonprofit company in New York
Oona G. Watkins	Geologic environmental consulting
Will J. Wicherski	Undecided

Prof. Lisa Gilbert (Geosciences & Williams-Mystic) measuring marsh erosion on the Connecticut shore with summer research students.

Mathematics and Statistics Department

This year was the first time that current sophomores could declare a major in Statistics. We had 35 students declaring a major in Statistics, and in addition to 70 students who declared a Mathematics major, making us one of the three largest departments on campus once again.

We would like to thank Stewart Johnson, who is stepping down as chair of our department, for wonderfully leading us over the past three years. And we are excited that Frank Morgan is coming back from leave and will be chair of the department for 2015-2016, his last year at Williams.

Two new assistant professors joined us for their first year: Leo Goldmakher (from a post-doc at the University of Toronto) as a number theorist, and Eyvindur Palsson (from a post-doc at the University of Rochester) as a harmonic analyst. But we are sad to see that Wendy Wang, after three years with us, has decided to move to Bentley University in Waltham.

We have several wonderful new faculty joining us this coming fall: *Ralph Morrison '10*, from UC Berkeley, will join after a post-doctoral year, and Pamela Harris, who was hired a year ago, will also join us after her work at the US Military Academy. We will also have two new visiting faculty: Lauren Childs, who comes from the Harvard School of Public Health, and Alejandro Sarria, who comes from the University of Colorado at Boulder. Finally, *Haydee Lindo '08*, from the University of Nebraska, will join us as a Bolin Fellow.

Professors Bernhard Klingenberg, Frank Morgan, and Allison Pacelli (fall) were on leave for 2014-2015, and Professors Satyan Devadoss, Stewart Johnson, Susan Loepp, and Steve Miller (spring) will be on leave for 2015-2016. Moreover, Allison Pacelli has been promoted to full professor.

We are very proud of the accomplishments of our majors. The Rosenburg Prize for outstanding senior was awarded to *Jesse Freeman '15* and *Isaac Loh '15*. The Goldberg Prize for best colloquium went to *Andrew Best '15* and *Ben Hoyle '15*. The Wyskiel Award in teaching went to *Greg Ferland '16* and *Katie Bennett '16*. The Morgan Prize in applied mathematics went to *Samantha Petti '15*. The Kozelka Award for outstanding student of statistics went to *Nate McCue '15*. The Beaver Prize for department service went to *Mary Gong '16*. The 1st Place Benedict Prize for outstanding sophomore went to *David Burt '17*, *Nina Panda '17*, and *Yuanchu Dang '17*; the 2nd Place prize to *Alex Kastner '17* and *Sarah Fleming '17*. The colloquium attendance prize went to junior *Mary Gong* and senior *Ben DeMeo '15*. The Witte Problem Solving Prize went to *Blake Mackall '16*. Incidentally, *Jesse Freeman* won the prestigious Churchill scholarship, and *Samantha Petti* was runner-up to the AWM Alice T. Schafer prize.

Over a hundred local 10th graders attended our annual MathBlast on December 8. Students and teachers each chose three thirty-minute workshops to attend from among six choices, including Being Bayesian, The Golden Ratio and the Fibonacci Sequence, Patterns and Algorithms, Recommendation Systems and Statistics, Zombies and Calculus, and Gambles, Games and Group Dynamics.

Finally, we would like to thank our student advisory board SMASAB: *David Burt*, *Jesse Freeman, Kristian Lunke '16*, *Ashwin Narayan '16*, Sam Petti, *Allie Jensen '15*, *Carrie Chu '15*, Mary Gong, *Margaret Hughes '15*, *Roger Vargas '16*, *Chris Owyang '16*, *Jaclyn Porfilio '15*, *Alex Guo '15*, *Isaac Loh '15*, *Elizabeth Frank '16*, and *John Bihn '16.*

In 2014-15, Professor **Colin Adams** worked with two thesis students, *Ben DeMeo* and *Wyatt Boyer '15*, both of whom produced interesting results about knots, Ben on hyperbolic knots and Wyatt on the crossing map of stick knots. Adams published two books this year: The first is a revision of the previously existing Calculus, by Jon Rogawski. The second is a novel called "Zombies & Calculus" which recounts the story of a math professor at a small college in western Massachusetts, and how he uses calculus to help his small band survive the zombie apocalypse. Adams did various book signings, including at the Harvard Coop in Cambridge and at Microsoft in Redmond, WA. NOVA produced two videos filmed at Williams and based on the Zombies & Calculus idea.

Adams gave talks at three AMS special sessions, and at a variety of other institutions. He continued to write, perform and produce humorous mathematical theater, with help from his colleagues, at the Joint Mathematics Meetings, based on his math humor column for the expository math magazine the Mathematical Intelligencer. He also published two research papers

with students from SMALL 2012 and SMALL 2013.

Assistant Professor **Julie Blackwood** completed her second year at Williams College. She taught two sections of Calculus I in the fall and a senior seminar on mathematical modeling in the spring.

Over the past year, Blackwood continued her research in math modeling. She advised a Mellon Mays Fellow *(Roger Vargas '16)* on research aimed at understanding the interaction between demographic processes of insects and bacteria (Wolbachia) that interferes with successful mating of these insects. She also continued work on various projects including work on white nose syndrome in little brown bats in addition to the transmission dynamics of pertussis. Over the past year, Blackwood has given several talks on these subjects.

For Professor **Satyan Devadoss**, it has been a wonderful year at Williams. His research is in the areas of topology and geometry, on which he gave several invited talks from coast-to-coast. During the year, he was exhausted by the productivity of the wonderful "Reimagine the Course Catalog" Committee, but thrilled with the output.

Professor **Dick De Veaux** continued his work in data mining and gave a variety of talks, and workshops on teaching and data mining throughout the United States and Europe. He advised *Thomas (Andrew) Beaudoin '15* on his thesis examining technical strategies for investing in the stock market. He continued serving as the representative of the Council of Sections to the Board of Directors of the American Statistical Association and was elected as the next Chair of the section on Statistical Learning and Data Mining. He taught 12 students in his Winter Study course "The History, Geography and Economics of the Wines of France."

Professor **Tom Garrity** has continued his research in number theory. He co-authored three papers: "A Generalized Family of Multidimensional Continued Fractions: TRIP Maps" in the *International Journal of Number Theory*, "Cubic Irrationals and Periodicity via a Family of Multi-dimensional Continued Fraction Algorithms" (with *Neumann-Chun '14*) in *Monatshefte für Mathematik* and his review of "Spherical tube hypersurfaces" by Alexander Isaev in the *Bulletin of the American Mathematical Society*. In January, Cambridge University Press published his book *Electricity and Magnetism for Mathematicians: A Guided Path from Maxwells Equations to Yang-Mills.*

He spent most of July 2014, as he will for July 2015, at the Park City Mathematics Institute (PCMI) in Park City, Utah, as a member of PCMI's steering committee. While there, he gave a number of "pick-up" lectures on beginning real analysis. In January he spoke on work with *Ilya Amburg '14* at the special session on continued fractions in San Antonio at the joint meeting of the American Mathematical Society and the Mathematical Association of America. In April, also in San Antonio, at the Texas meeting of the MAA he spoke to the Texas section of Project Next, gave an invited address on his research and performed with Colin Adams their performance piece: *The Derivative versus the Integral: The Final Smackdown.* He also appeared as a zombie in the NOVA video on Colin Adam's *Zombies and Calculus.*

Assistant Professor **Brianna Heggeseth** continued her research and developed a new course in the area of longitudinal data analysis. Her work studying the effects of DDT on childhood physical development successfully went through a review process and looks to be published in *PLoS ONE* in the near future. In addition, her recent methodological work in clustering longitudinal trajectories is currently in the review process at *Annals of Applied Statistics*. She supervised *Matthew Radford '16* as a summer research student and presented their work on the impact of transformations on correlation structures of longitudinal data. Heggeseth has started a new methodology project studying and developing statistical methods that can detect what factors impact the development patterns over time. She has a summer research student who will be working with her on this project.

Heggeseth has continued to learn and share her ideas with the local community and the larger statistical community through conferences, teaching, and community outreach. She discussed recommendation systems with local high school students in the MathBlast. During Winter Study, she led a course on Data Visualization in which Williams students graphically analyzed institutional data to look into how the time and day of courses have changed over time and to contribute to the Why Liberal Arts? initiative by investigating how students sample the curriculum and whether that behavior has change in recent years.

Professor **Stewart Johnson** remains active in dynamical systems and optimal control. He is continuing his work on optimization in switching systems and the structure of small switching cycles that approximate relaxed fixed points.

Associate Professor **Bernhard Klingenberg** spent a sabbatical at the Institute of Statistics at Technology University Graz in Austria. There, he taught a two-month course on categorical data analysis for masters and PhD students, gave research talks at the Institute of Medical Statistics at the Medical University of Vienna and delivered a half-day, hands-on lecture on statistics to 4th graders at a local elementary school during science days. He presented his newest research on modeling correlated binary data at the annual International Workshop of Statistical Modelling in Linz, Austria and continued to serve as an associate editor for the journal Statistical Modelling. However, most of his time was spent writing the manuscript for the forthcoming 4th edition of the introductory statistics textbook *Statistics. The Art and Science of Learning from Data* and developing interactive online learning tools that are freely accessible on the web.

Professor **Susan Loepp** continues to enjoy teaching and her research in commutative algebra. In 2014, she and *Byron Perpetua '14* wrote a manuscript based on the original results in Byron's senior honors thesis. The paper will appear in the mathematics journal *Involve*. In January 2015, Loepp attended the Joint Mathematics Meetings in San Antonio where she enjoyed attending research presentations and talking to other mathematicians about research in commutative algebra. Loepp is currently serving as an Associate Editor for the American Mathematical Monthly, and she is on committees for the Association for Women in Mathematics and the Mathematical Association of America.

Professor **Steven Miller** continued his research in mathematics and related fields, publishing almost 20 papers and giving over 60 talks with his students. He supervised *Jesse Freeman's '15* thesis in math with Assistant Professor Eyvi Palsson. Jesse will be studying in Cambridge next year on a Churchill fellowship. He also advised *Weng-Him Cheung's '15* thesis with Professor Fred Strauch of the Physics Department. As faculty president of the Williams Phi Beta Kappa chapter he helped run a mini-conference on campus celebrating our 150th anniversary, with talks on the future of education. He has continued working with the Office of Information Technology to place all his classes online through YouTube, and ran a winter study on the Mathematics of Lego bricks, where his students successfully built the 3152 piece SuperStar destroyer in under 10 minutes. He edited a book on Benford's law, which is in press and due out in May. He continued his outreach activities, giving continuing education lectures to teachers in Boston, writing modules for high school students and teachers, and working with local math teachers on enrichment activities.

Professor **Frank Morgan** had a number of sabbatical adventures. He taught developmental algebra at Berkshire Community College, where he appeared on "1350 West Street" TV. He is gearing up as incoming Editor of *Notices of the American Mathematical Society*, with the largest circulation of any publication in higher mathematics. Next year as chair is his last year at Williams. He and his summer research students continue to prove theorems and publish papers on optimal shapes and strategies. He gave 39 talks, including the Science Lecture at the Abel Prize ceremonies in Oslo, Norway.

Professor **Allison Pacelli** was on leave for 2015. She returned to teaching this past spring, with Discrete Math and a new tutorial on Math Education. While on leave, she worked on writing a textbook on *The Beauty of Numbers*. She also worked with elementary and high school math teachers, giving several professional development workshops on mathematics content. She continued her research in algebraic number theory as well.

Williams College Math Camp, a residential math camp for mathematically gifted high school students, was founded by Pacelli in 2013. Now in its third year, WCMC is expanding to a 10-day camp. Pacelli has received funding for the camp through grants from the American Mathematical Society's Epsilon Fund, the Mathematics Association of America's Dolciani Mathematics Enrichment Grant, and Williams College.

Assistant Professor **Eyvindur (Eyvi) Palsson** just finished his first year at Williams College. In the fall, he taught two sections of Calculus II (MATH 140). In the spring, he taught Differential Equations (MATH 209) as well as developed and taught the senior seminar Partial Differential Equations (MATH 453).

Palsson continued his research in Harmonic Analysis, Geometric Measure Theory, and Additive Number Theory. His paper on the size of sum sets in collaboration with Brendan Murphy and Giorgis Petridis appeared in Acta Arithmetica in the Spring 2015. He also submitted a paper on variation norms for the bilinear Hilbert transform with collaborators Yen Do and Richard Oberlin.

Since starting at Williams, Palsson attended a trimester program on Harmonic Analysis and Partial Differ-

ential Equations at the Hausdorff Research Institute for Mathematics where he also gave a lecture. He presented at a Harmonic Analysis conference in Segovia, Spain, gave a colloquium at Trinity College, had seminar talks at SUNY Albany and Brown University, and spoke at the faculty seminar here at Williams College.

With Professor Steven Miller, Palsson ran math puzzle nights, Project Euler lunches, and math contests. For the second consecutive year, we reached over 2% of the campus with the Putnam competition and defended the Green Chicken from Middlebury College.

Palsson looks forward to upcoming talks at an International Harmonic Analysis Conference at the CUNY graduate center and at a joint meeting between the American and European mathematical societies in Porto, Portugal. He is excited to lead a summer research group in SMALL with Professor Steven Miller on Number Theory and Harmonic Analysis.

In summer 2014, Professor **Cesar Silva** supervised five students on research projects during our SMALL summer research program: Julien Clancy (Yale '16), Rina Friedberg (Chicago '15), Indraneel Kasmalkar (Berkeley '15), *Isaac Loh (Williams '15),* and Sahana Vasudevan (Harvard '17). We completed a paper that was posted on the archives and was submitted for publication. The students presented talks at the annual 2015 American Mathematical Society meeting in San Antonio. Silva taught *Real Analysis* (MATH 350) and *Measure Theory and Probability* (MATH 402) in fall 2014, and *Real Analysis* (MATH350) and *Complex Analysis* (MATH 372) in spring 2015. He gave talks at several conferences and published three papers. Silva was invited to be part of a Squares research group and as part of this group met for a week in October at the American Mathematics Institute in Palo Alto, California. He was elected a Fellow of American Mathematical Society, class of 2015.

Associate Professor **Mihai Stoiciu** taught *Discrete Mathematics* (MATH 200) and *Abstract Algebra* (MATH 355) in the Fall Semester and three sections of Linear Algebra (MATH 250) during the Spring Semester 2015. During the year, he continued his research on spectral properties of random and deterministic operators. His paper "Spectral Properties of Random and Deterministic CMV Matrices," was published in the journal "Mathematical Modelling of Natural Phenomena". His paper "Explicit Bounds for the Pseudospectra of Various Classes of Matrices and Operators", written with the undergraduate students *Feixue Gong '16*, *Olivia Meyerson '16*, Jeremy Meza, and Abigail Ward, was submitted for publication.

Stoiciu was invited to present his research at the international conference "The 10th AIMS Conference on Dynamical Systems, Differential Equations and Applications", hosted by Universidad Autonoma de Madrid in Madrid, Spain and at the AMS Special Session on "Spectral Theory, Disorder, and Quantum Many Body Physics", hosted by Michigan State University in East Lansing, MI. At Williams College, Stoiciu gave a talk for high school students at the Williams MathBlast 2014, a talk in the Faculty Lecture Series, and a faculty seminar on his recent research in spectral theory. He also gave a short course titled "Classical Problems and Paradoxes in Probability Theory" for the Osher Lifelong Learning Institute at Berkshire Community College.

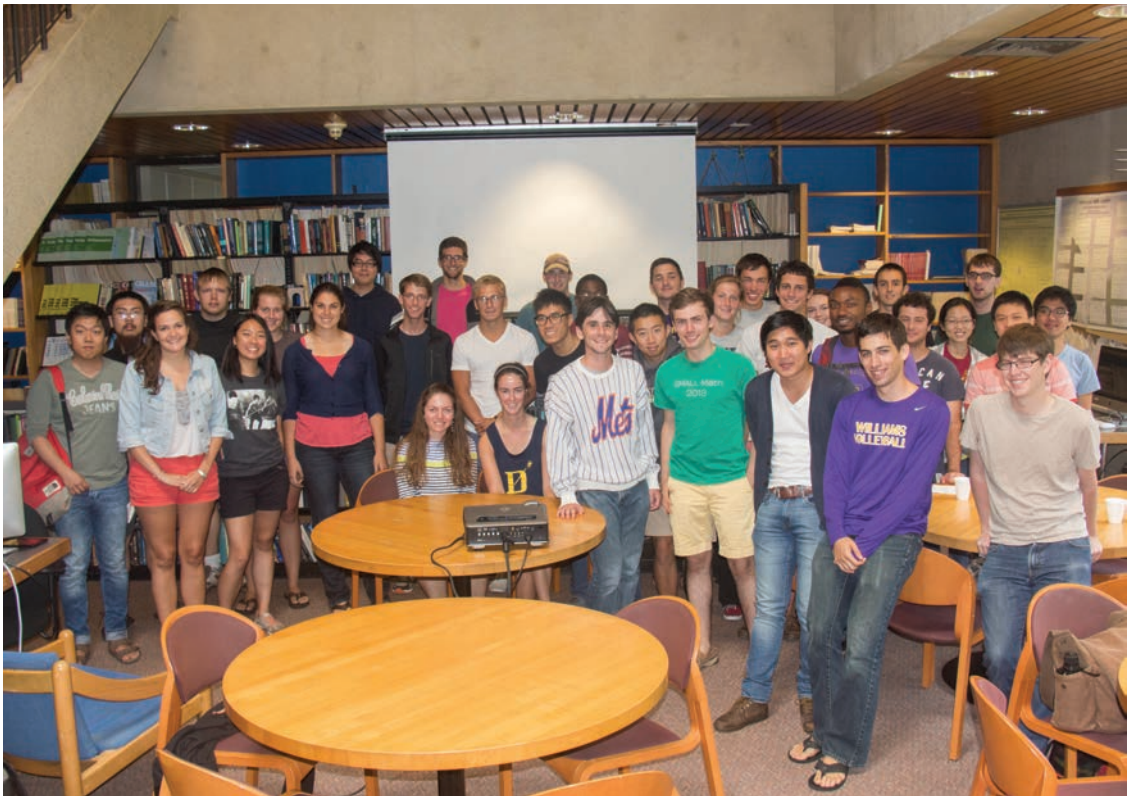
In May 2015, Stoiciu participated, as the Chair of the AMS Menger Prize Committee, in the International Science and Engineering Fair (ISEF), held at the Pittsburgh Convention Center. He was also a member of the Special Judging Team which awarded the 2015 Intel ISEF Grand Awards.

Assistant Professor **Qing (Wendy) Wang** continued her research in the area of Nonparametric Statistics and related fields. She had three papers published over the past year: "Improving Cross-Validated Bandwidth Selection using Subsampling-Extrapolation Techniques" was published in *Computational Statistics and Data Analys*is, and two papers published in collaboration with her thesis students, one at *Economics Letters* (co-author: *Vu Le '14*) and the other at *Statistics & Probability Letters* (co-author: *Shiwen Chen '14*). She also has two articles under review or revision, and a few ongoing projects in progress.

Wang attended several statistical conferences and meetings during the year. She was an invited speaker at the Department of Statistics at Beijing Normal University in China, and was invited to give a talk at Bentley University in Massachusetts. Professor Wang presented her research at the Joint Statistical Meeting in Boston in August, 2014. She participated in the half-day event of MathBlast, talking with local high school students about invalid inversion for conditional probabilities.

Wang accepted a position at Bentley University and will leave Williams College after the spring semester of 2015. She felt very sad to leave a lovely department and

her wonderful students. However, she will be carrying what she has learned from her colleagues beyond Williams campus, and she will consider the Math&Stat department as her family forever.



Mathematics and Statistics students 2015

Mathematics and Statistics Colloquia

Colin Adams and Thomas Garrity, Williams College
"Derivative vs. Integral: The Final Smackdown"

Colin Adams, Williams College
"N-Crossing Number of Knots and the Bracket Polynomial"

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

"Allee Effects and Invasive Insect Management: How to Optimally Allocate Resources"

Edward B. Burger, Southwestern University
"Celebrating 170 Years of Inching Up (On the Cheap)"

Carla Cederbaum, Tubingen University
"A Glimpse of General Relativity Through the Eyes of a Mathematician"

Gregory Chambers, University of Toronto
"The Isoperimetric Problem"

David Cruz-Uribe, Trinity College
"The Rise, Fall and Rebirth of the Muckenhoupt-Wheeden Conjectures"

Satyan Devadoss, Williams College
"Origami Folding and Evolutionary Trees"

"The Shape of Associativity"

Richard De Veaux, Williams College
"The Effect of Age on Human Performance in Sports"

Joan Edwards, Williams College
"The Data Behind Pollination Networks"

Thomas Garrity, Williams College
"A New Family of Multidimensional Continued Fraction Algorithms: Translated Triangle Maps"

"Why Was Alexander Grothendieck So Important"

Leo Goldmakher, Williams College
"A Probabilistic Approach to Prime Factorization"

Matt Harvey, University of Virginia, Wise
"Folding Hyperbolic Polygons"

Brianna Heggeseth, Williams College
"To Transform or Not Transform: What is the Impact?"

Aaron Hill, University of Louisville
"An Analysis of Words Coming From Chacon's Transformation"

Alex Iosevich, University of Rochester
"Combinatorics, Number Theory and Analysis: Connections and Perspectives"

Stewart Johnson
"A Space for Math and Stats"

William Lenhart, Williams College
"An Approximation Algorithm for a String-Packing Problem"

Susan Loepp, Williams College
"Formal Fibers at Height Zero Prime Ideals"

Nathan McNew, Dartmouth College
"Avoiding Geometric Progressions in the Integers" and "Double Bubbles in Hyperbolic Spaces"

Keith McPartland, Williams College
"Probability and Possibility: Two Ways of Thinking About the Principle of Plenitude"

Steven Miller, Williams College
"Some Results on Low-Lying Zeros of L-Functions"

"He's Just Going Through A Phase: Miller's SMALL Students and Phase Transitions"

"Extending Pythagoras"

"Low-Lying Zeros and Random Matrix Theory"

Frank Morgan, Williams College
"The Space of Planar Soap Bubble Clusters"

Ralph Morrison, University of California, Berkeley
"Tropical Curves: Bitangents and Beyond"

Eyvindur Palsson
"Variational Bounds for the Bilinear Hilbert Transform"

Cesar Silva, Williams College
"Examples of Systems in Ergodic Theory"

"Ergodicity of Products With Inverses in Infinite Measure"

"Mixing and Chaos in Kneading Dough"

Mihai Stoiciu, Williams College
"Spectra and Pseudospectra of Non-Hermitian Operators"

"Bounds for the Pseudospectra of Various Classes of Matrices and Operators"

"Classical Problems and Paradoxes in Probability Theory"

"The Golden Ratio and the Fibonacci Sequence"

Ileana Streinu, University of Massachusetts
"Auxetic and Expansive: Mathematical Incursions into Materials Science"

Amanda Tucker, SUNY, Geneseo
"Symmetries of Rational Functions Arising from the Study of Multiple Zeta Values"

Caroline Turnage-Butterbaugh, North Dakota State University
"Moments of the Riemann Zeta-Function and L-Functions"

"Gaps Between Primes and Moments of L-Functions"

Qing "Wendy" Wang
"Pseudo Kernel Method in Cross-Validation Variance Estimation"

"Jackknife and Other Extrapolated Variance Estimators"

Sarah Wolff, Dartmouth College
"Generalized Fourier Transforms"

William Wootters
"Equiangular Vectors in a Complex Vector Space"

Brent Yorgey
"Polynomial Functors Constrained by Regular Expressions"

Mathematics and Statistics Student Colloquia

Paul Adeleke
"Tchoukaillon: An Invitation to Game Theory"

Etienne Aduya
"Winning a Game in Tennis"

Shaan Amin
"Fractions Within Fractions: Continued Fractions"

Lily An
"Ramsey Round 2"

Gregory Becker
"Transcendental e"

Timothy Berry
"God's Number and the Rubik's Cube: Just How Twisty is the Twisty Puzzle?"

Andrew Best
"Surprise, It's Twins! On the Banach-Tarski Paradox"

Emma Bick
"Ancient Rome and the Isoperimetric Inequality"

Rachael Burns
"The Signal and the Noise in College Rankings: Is Williams Really #1?"

Elliot Chester
"Nobody's Perfect, Not Even the Product of Consecutive Integers"

Weng-Him Cheung
"The Finite Field Kakeya Conjecture"

Carrie Chu
"Why You Only Need Four Crayons"

Julia Cline
"How Many Crayons Does a Child Need For Her Colouring Book?"

Benjamin Corwin
"A "Safer" Model for Ebola, and Other Batty Stories With Ben Corwin"

Jean-Luc Etienne
"Obtaining Maximal Information the Normal Way"

Alan Felix
"The Kelly Criterion"

Benjamin Hoyle
"The One Cut Theorem"

Shannon Hsu
"Zero Tolerance Policy: Examining the Riemann Zeta-Function at Special Points"

Christopher Huffaker
"Chebyshev's Inequality: Bounds for the Number of Primes Less Than a Number x"

Aldis Inde
"O'Neill's Theorem and Optimal Strategies for a Dollar Auction"

Alexandra Jensen
"Chaotic Orderings of Number Systems"

Edward Kelly
"Mathematics of a Beatles' Chord"

Simmon Kim
"The Stable Marriage Problem"

Joseph Kinney
"Error Threshold for Language Acquisition"

Donald Kost
"The Mathematics of Borges: Infinity and Fractals"

Timothy Lattimer
"Fishing the Line"

Claire Lidston
"Detecting Chirality With the HOMFLY Versus Kauffman Polynomials"

Brandon Ling
"Representation Theory and Quantum Mechanics"

Aviv Lipman
"Various Proofs in Graph Theory"

Timothy Marchese
"An Infinite Game Exploring Uncountable Sets"

Nathan McCue
"The Smoothing Spline"

Alexander Nanda
"Linear Discriminant Analysis"

Stephanie Neul
"Rigging a Rowing Shell for Minimal 'Wiggle'"

Charles Oddleifson
"Epistemic Logic in Game Theory"

Scott Pelton-Stroud
"Modeling Measles: Wavelet Analysis and Compartmental Models"

Jaclyn Porfilio
"Counting Trees and Forests"

Vanya Rybkin
"Error Propagation"

Daniel Siegel
"The Chinese Remainder Theorem for Integers and Principal Ideal Domains"

Llewellyn Smith
"How to Test a Population for Syphilis"

Anna Spiers
"The Mathematics of Future-Telling: Predicting Critical Transitions in Ecological Systems"

Benno Stein
"Reed-Solomon Error Correction and Visual Encoding"

Phonkrit Tanavisarut
"Stretching the Fishing Net With Penalization"

David Yan
"Finding Convex Hulls in 2 and 3 Dimensions"

Jeewon Yoo
"The Markov Chain in History, Philosophy, and Literature"

Abigail Zimmermann-Niefield
"Finding Paths Between Triangulations is Flippin' Hard"

Off-Campus Mathematics and Statistics Colloquia

Colin Adams
"Blown Away: What Knot to Do When Sailing" AP Calculus Graders Professional Night Speaker, Kansas City, MO, June 15, 2014, Pi Mu Epsilon Conference, St. Norbert's College, Green Bay, WI, November 7 - 8, 2014, Pi Day, Florida Atlantic University, Boca Raton, FL, March 14, 2015

"Zombies & Calculus" Book Signing Harvard Coop, Cambridge, MA, September 24, 2014

"Zombies & Calculus" Pi Mu Epsilon Talk, University of Nebraska Lincoln, NE, October 10, 2014, Nerd Night, DC nine, Washington, DC, October 11, 2014, Middlebury College, Middlebury, VT, October 21, 2014, Berkshire Community College, Pittsfield, MA, October 28, 2014, Pi Mu Epsilon Conference, St. Norbert's College, Green Bay, WI, November 7 - 8, 2014, Microsoft, Redmond, WA, November 20, 2014, Ada's Technical Bookstore, Seattle, WA, November 20, 2014, Texas Section MAA Meeting, San Antonio, TX, April 9 - 11, 2015

"Multi-Crossing Number and the Bracket Polynomial" AMS Sectional Meeting, Greensboro, NC, November 9, 2014

"Mathematically Bent Theater" Mobiusbandaid Players, Joint Mathematics Meetings, San Antonio, TX, January 12, 2015

"Turning Knots into Flowers" Pi Day, Florida Atlantic University, Boca Raton, FL, March 14, 2015

"Generalized Augmented Alternating Links and Hyperbolic Volume" AMS Sectional Meeting, Michigan State University, East Lansing MI, March 15, 2015

"Making Math Fun" Texas Section MAA Meeting, San Antonio, TX, April 9 - 11, 2015

"Derivative vs. Integral: the Final Smackdown" Texas Section MAA Meeting, San Antonio, TX, April 9 - 11, 2015

"Hyperbolic Volume and Generalized Augmented Alternating Links" AMS Sectional Meeting, Las Vegas, NV, April 19, 2015

Julie Blackwood
"Allee Effects & Invasive Insect Management" JMM Special Session on Mathematics in Natural Resource Modeling

"Rabies Persistence in Vampire Bats: Immunity, Pathogenesis, and Immigration" University of Massachusetts, Amherst

Satyan Devadoss
"Convocation Speaker" Gordon College

"Invited Speaker" Renaissance Weekend

"Keynote Lecture" MAA Northeastern Sectional Conference

"Plenary Lecture" Fall Workshop on Discrete and Computational Geometry

"Undergraduate Colloquium" Yale University

"Colloquium" Taipei National University

"Prakesh Labs Minicourse" Stanford University

"Veritas Forum" Columbia University, Rensselaer Polytechnic Institute

Richard De Veaux

"Aging and Sports" Free University, Berlin, October 2014, Imperial College, London, October 2014, University of Kansas, November 2014, University of Manitoba, Winnipeg, Manitoba, January 2015, JMP Discovery Conference Keynote, Brussels, Belgium, March 2015, University of Pittsburgh, April 2015

"Intro Stats in the 21st Century" International Conference on Teaching Statistics (ICOTS9), Flagstaff, AZ, August 2014, United States Conference on Teaching Statistics (USCOTS), State College, PA, May 2015

"Predictive Analytics Workshop" Atlanta, GA, July 2014, Denver, CO, October 2014, Foster City, CA, October 2014, Chicago, IL, April 2015, NTY, New York City, May 2015

"Successful Data Mining and Practice Workshop" Conference on Statistical Practice, New Orleans, LA, February 2015, Grand Valley State University, Grand Rapids, MI, April 2015

"Statistical Engineering and Big Data Workshop" Joint Statistical Meetings, Boston, MA, August 2014

"Presentation Skills Workshop Workshop" Joint Statistical Meetings, Boston, MA, August 2014

"How Much is a Fireplace Worth? Webinar" Business Analytics E Conference, September 2014

Thomas Garrity

"Pick-up Lectures on Real Analysis" Park City Mathematics Institute, July 2014

"A New Family of Multidimensional Continued Fractions: Translated Triangle Maps" Special Session on Continued Fractions, AMS, San Antonio, TX, January 2015

"Using Mathematical Maturity to Shape Our Research, our Teaching and our Careers" Texas Project Next, San Antonio, TX, April 2015

"Derivative Versus the Integral: The Final Smackdown" with Colin Adams, San Antonio, TX, April 2015

"On Writing Numbers" San Antonio, TX, April 2015

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

"A New and Improved Confidence Interval for the Mantel-Haenzsel Risk Difference" Biometrical Colloquium, Center for Medical Statistics, Informatics and Intelligent Systems, University of Vienna, November 2014

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

"Newman's Conjecture for Automorphic and Function Field L-Functions" (presented by Alan Chang), CANT (Combinatorial and Additive Number Theory) Conference, May 28, 2014

"Continued Fraction Digit Averages and Maclaurin's Inequalities" CANT (Combinatorial and Additive Number Theory) Conference, May 28, 2014

"From M&Ms to Mathematics, or, How I Learned to Answer Questions and Help my Kids Love Math" Dr. Philip O. Coakley Middle School, Norwood, MA, June 9, 2014

"Introduction to Zeckendorf Decompositions" AIM, July 7, 2014

"Progress Report on Zeckendorf Decompositions" (with Minnie Catral, Pari Ford, Pamela Harris, Dawn Nelson), American Institute of Mathematics, July 9, 2014

"Zeckendorf Expansions from Kentucky Decompositions to Fibonacci Quilts" (with Minnie Catral, Pari Ford, Pamela Harris, Dawn Nelson), American Institute of Mathematics, July 11, 2014

"Mind the Gap: Distribution of Gaps in Generalized Zeckendorf Decompositions" 16th International Conference on Fibonacci Numbers and their Applications, Rochester, NY, July 25, 2014

"Biases in Elliptic Curve Families" (Blake Mackall '16, Christina Rapti, Karl Winsor), Yale REU Conference, July 25, 2014 (poster)

"A Benford Walk Down Wall Street" (Xixi Edelsbrunner '16, Karen Huan '16, Blake Mackall '16, Jasmine Powell, Madeleine Weinstein, Yale REU Conference, July 25, 2014 (poster)

"Complex Ramsey Theory" (Andrew Best '15, Karen Huan '16, Jasmine Powell, Kimsy Tor, Madeleine Weinstein), Yale REU Conference, July 25, 2014

"Large Gaps Between Zeros of GL(2) L-Functions" (Owen Barrett, Brian McDonald, Patrick Ryan, Karl Winsor), Yale REU Conference, July 25, 2014 (talk), (Owen Barrett, Brian McDonald, Patrick Ryan, Karl Winsor), Yale REU Conference, July 25, 2014 (poster), (given by Karl Winsor & Owen Barrett), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014, (presented by Owen Barrett, Brian McDonald, Patrick Ryan), Conference de Theorie des Nombres Quebec-Maine, Universite Laval, Quebec, 28 Septembre 2014, (joint with Owen Barrett, Brian McDonald, Patrick Ryan, Caroline L. Turnage-Butterbaugh), AMS Session on Number Theory, II, Joint Mathematical Meetings, San Antonio, January 12, 2014, (with Owen Barrett and Karl Winsor), 29th Automorphic Forms Workshop, University of Michigan, March 2, 2015

"Benfordness of Zeckendorf Decompositions" (Andrew Best '15, Patrick Dynes, Xixi Edelsbunner '16, Brian McDonald, Kimsy Tor and Madeleine Weinstein), 16th International Conference on Fibonacci Numbers and Their Applications, July 25, 2014(given by Brian McDonald and Patrick Dynes), Special Session on Difference Equations and Applications, AMS Fall Sectional, Greensboro, NC, November 8, 2014, (joint with Andrew Best '15, Patrick Dynes, Xixi Edelsbrunner '16, Brian McDonald, Kimsy Tor, Caroline Turnage-Butterbaugh and Madeleine Weinstein), MAA General Contributed Paper Session on Research in Number Theory, III, Joint Mathematical Meetings, San Antonio, January 13, 2014, (poster presented by Brian D McDonald & Patrick J Dynes), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Cookie Monster meets the Fibonacci Numbers --- Mmmm, Theorems!" (Andrew Best '15, Patrick Dynes, Xixi Edelsbunner '16, Brian McDonald, Kimsy Tor and Madeleine Weinstein), 16th International Conference on Fibonacci Numbers and Their Applications, July 25, 2014

"Why More is Better: The Power of Multiple Proofs" Hampshire College Summer Studies in Mathematics, July 31, 2014

Steven Miller (cont.)

"Pythagoras at the Bat: An Introduction to Mathematical Modeling" Science Days for Prospective Williams Students, August 14, 2014)

"A Family of Rank 6 Elliptic Curves Over Number Fields" (given by David F. Mehrle & Tomer Reiter), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Universal Lower-Order Biases in Elliptic Curve Fourier Coefficients" (given by Christina Rapti & Karl G. Winsor), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"On a Variant of the Lang-Trotter Conjecture Involving Binomial Elliptic Curve Coefficients" (given by Brian D. McDonald & Patrick J. Dynes), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Complex Ramsey Theory" (given by Madeleine A. Weinstein & Andrew J. Best '15), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Ramsey Theory Problems in Z: Avoiding Generalized Progressions" (given by Jasmine Powell & Kimsy Tor), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014 (combined with previous)

"A Generalized Newman's Conjecture for Function Field L-Functions" (given by Tomer Reiter & Joseph M. Stahl), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Robustness of the Semicircle Law in Patterned and Sparse Matrix Ensembles" (given by Xixi Edelsbrunner '16 & Kimsy Tor), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Gaussian Behavior of Generalized Zeckendorf Decompositions over Small Scales"(poster presented by Madeleine A. Weinstein & Xixi Edelsbrunner '16, Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"One-Level Density for Cusp Forms of Prime Square Level"(poster presented by Owen F. Barrett & Karl G. Winsor), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Finite Conductor Models for Twists of GL(2) L-Functions"(poster presented by Christina Rapti & Owen F. Barrett), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"The Emergence of 4-Cycles Over Extended Integers"(poster presented by Andrew J. Best '15 & Jasmine Powell), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014, (joint with Jasmine Powell, Andrew Best '15, Patrick Dynes and Benjamin Weiss), MAA General Contributed Paper Session on Research in Number Theory, III, Joint Mathematical Meetings, San Antonio, January 13, 2014

"Fredholm Determinants and Vanishing of L-Functions at the Central Point" (poster presented by Jesse B. Freeman '15), Young Mathematicians Conference, August 2014 and poster at Science Days at Williams College, August 2014

"Lower-Order Biases in Elliptic Curve Fourier Coefficients" (presented by Blake Mackall '16 and Karl Winsor), Conference de Theorie des Nombres Quebec-Maine, Universite Laval, Quebec, 27 Septembre 2014, (joint with Blake Mackall '16, Christina Rapti and Karl Winsor), MAA General Contributed Paper Session on Research in Number Theory, II, Joint Mathematical Meetings, San Antonio, January 13, 2014.

"Continued Fraction Digit Averages and Maclaurin's Inequalities" Conference de Theorie des Nombres Quebec-Maine, Universite Laval, Quebec, 28 Septembre 2014

"Newman's Conjecture for Function Field L-Functions"(presented by David Mehrle and Joseph Stahl), Conference de Theorie des Nombres Quebec-Maine, Universite Laval, Quebec, 28 Septembre 2014, (joint with Alan Chang, David Mehrle, Tomer Reiter, Joseph Stahl and Dylan Yott), AMS-MAA-SIAM Special Session on Research in Mathematics by Undergraduates and students in Post-Bac Programs, Joint Mathematical Meetings, San Antonio, January 10, 2014

"Using Modern Technologies to Enrich the Classroom Experience"

All-Faculty NFD Lunch, October 3, 2014

"Generalizing Zeckendorf's Theorem: The Kentucky Sequence" (given by Pamela Harris), Special Session on Difference Equations and Applications, AMS Fall Sectional, Greensboro, NC, November 8, 2014

"From Fibonacci Quilts to Benford's Law through Zeckendorf Decompositions" Williams College, Science Talk, November 11, 2014, AMS Special Session on Difference Equations & Applications, Joint Meetings of the AMS/MAA, San Antonio, January 10, 2015

"Results On GL(2) L-Functions: Biases in Coefficients and Gaps Between Zeros" Workshop on Families of Automorphic Forms and the Trace Formula, Banff International Research Station, Calgary, Canada, December 1, 2014

"A Family of Rank 6 Elliptic Curves over Number Fields" (joint with David Mehrle, Tomer Reiter, Joseph Stahl and Dylan Yott), AMS-MAA-SIAM Special Session on Research in Mathematics by Undergraduates and students in Post-Bac Programs, Joint Mathematical Meetings, San Antonio, January 10, 2014

"Continued Fraction Digit Averages and Maclaurin's Inequalities" AMS Special Session on Continued Fractions, San Antonio, January 12, 2015

"On a Variant of the Lang-Trotter Conjecture Involving Binomial Elliptic Curve Coefficients" (joint with Patrick J Dynes, Brian McDonald and Christina Rapti), MAA General Contributed Paper Session on Research in Number Theory, II, Joint Mathematical Meetings, San Antonio, January 13, 2014

"Toward Combinatorial Proofs of the Sato-Tate Law and The Weil Bound For Kloosterman Sums" (joint with Xixi Edelsbrunner '16, Stephan Garcia, Kimsy Tor and Karl Winsor), MAA General Contributed Paper Session on Research in Number Theory, III, Joint Mathematical Meetings, San Antonio, January 13, 2014

"Ramsey Theory Over Imaginary Quadratic Number Fields" (joint with Andrew Best '15, Karen Huan '16, Nathan McNew, Jasmine Powell, Kimsy Tor and Madeleine Weinstein), MAA General Contributed Paper Session on Research in Number Theory, III, Joint Mathematical Meetings, San Antonio, January 13, 2014

"On the Vanishing of L-Functions at the Central Point Through the Method of Fredholm Determinants" (given by Jesse Freeman '15), MAA General Contributed Paper Session on Research in Analysis, Joint Mathematical Meetings, San Antonio, January 13, 2014

"Generalizing Repulsion of Elliptic Curve Zeros Near the Central Point to Other GL(2) Forms" (with Owen Barrett), 29th Automorphic Forms Workshop, University of Michigan, March 2, 2015

"Biases in the Second Moments of Fourier Coefficients in One-Parameter Families of Elliptic Curves" (with Blake Mackall '16 and Karl Winsor), 29th Automorphic Forms Workshop, University of Michigan, March 3, 2015

"From the Kentucky Sequence to Benford's Law through Zeckendorf Decompositions" AMS Special Session on Difference Equations, March 7, 2015

"The Fibonacci Quilt Sequence" (presented by Pari Ford), AMS Special Session on Difference Equations, March 7, 2015

Steven Miller (cont.)

"YouTube University: The Benefits of Recording Lectures" Conference for the 150th Anniversary of the Williams College Phi Beta Kappa Chapter, March 18, 2015

"Why the IRS Cares About the Riemann Zeta Function and Number Theory (And Why You Should Too!)" Carnegie Mellon, March 25, 2015, Winona State University, March 30, 2015, Williams College 2015 Faculty Lecture Series, February 12, 2015

"Finite Conductor Models for Zeros Near the Central Point of Elliptic Curve L-Functions and Biases in the Second Moments" Number Theory and Algebraic Geometry Seminar, Boston College, May 1, 2015

"Benford's Law: Why the IRS cares about Algebra and Number Theory (and Why You Should Too!)" SACNAS, Washington, DC, October 2015

Frank Morgan

"Geometric Measure Theory, Isoperimetric Problems, and Manifolds With Density" CIME Course, Cetraro, Italy

"Chambers Proves LCD Conjecture" Univ. Napoli

"Soap Bubbles and Mathematics" Williams College MathCamp, Summer Program for Mathematical Problem Solving, Siena College, Jean Taylor Symposium, Courant Institute, MoSAIC, NYC, For 3rd Graders, Berkshire Community College, Teachers College, NYC, Ensworth High School, Nashville, TN, Koh Lecture, North Carolina State University, X-Stem, Washington DC, MAA Carriage House Lecture, Abel Prize Science Lecture, Oslo, Norway , Western MA Science and Engineering Fair, Massachusetts College of Liberal Arts, For High School Teachers, Radford University

"The Convex Body Isoperimetric Conjecture" MathFest, Portland, OR

"New Isoperimetric Theorems and Open Questions" KIAS, Seoul, Korea

"Bubbles and Tilings: Art and Mathematics" Bridges, Seoul Korea

"The Isoperimetric Problem in Manifolds With Density" ICM, Coex, Seoul, Korea

"Math Chat TV"

"The Recent Proof of Two Isoperimetric Conjectures" Vassar College

"Optimal Tilings" Friends of Math Luncheon, Berkshire Community College, Univ. Puerto Rico Mayagüez
North Carolina State University

"Teaching Developmental Algebra at Berkshire Community College" Joint Mathematics Meetings, San Antonio, Texas

"Soap Bubbles in R^n Density" SIDIM UPRM

"Soap Bubbles in Euclidean Space With Density"

Tilings From Williams College to Berkshire Community College" Two-Year Math Conference, Campbell's Resort, Lake Chelan, Washington

"Isoperimetric Problems in R^n With Density" Budapest, László Fejes Tóth Centennial

"Isoperimetric Problems" Grenoble, Geometric Measure Theory

Allison Pacelli

"So Many Primes!" Keynote Speaker, Connecticut State MathCounts Competition, March 2015

"Albany Math Content Workshops for K-2 Elementary School Teachers" Albany, NY, September 2014, October 2014, January 2015, March 2015, April 2015

"STEM and Common Core Math" A Workshop for Principals, Albany Central School District, March 2015

"STEM and Project Based Learning" A Workshop for Principals, Albany Central School District, May 2015

Eyvindur Palsson

"Restricted Convolution Inequalities, Multilinear Operators and Applications" Harmonic Analysis to Celebrate Michael Cowling's 65th Birthday Segovia, Spain, July 2014

"Finite Point Configurations and Multilinear Radon Transforms" Hausdorff Research Institute for Mathematics, Bonn, Germany, July 2014, Trinity College, Hartford, CT, October 2014

"Variational Bounds for a Dyadic Model of the Bilinear Hilbert Transform" SUNY, Albany, November 2014, Brown University, March 2015

Cesar Silva

"Notions of Weak Mixing and Examples in Infinite Measure, Logic, Dynamics and Their Interactions" University of North Texas, Denton, June 2014

"Rank-One Transformations of Ergodic Index k in Infinite Measure" AMS Annual Meeting, San Antonio, TX, January 2015

"Notions of Weak Mixing and Rank-One Examples for Infinite Measure-Preserving Transformations" Dynamics and Analysis Seminar, Wesleyan University, February 2015

"Weak Rational Ergodicity Does Not Imply Rational Ergodicity" AMS Special Session on Fractal Geometry and Ergodic Theory, Huntsville, AL, March 2015

Mihai Stoiciu

"Dynamical Systems and Spectral Theory" 10th AIMS Conference on Dynamical Systems, Differential Equations and Applications, Madrid, Spain

"Spectral Theory, Disorder, and Quantum Many Body Physics" Invited Talk, AMS Central Spring Sectional Meeting, Michigan State University

Qing Wang

"An Improved Method in Bagging Cross-Validation With Second-Order Extrapolation" Beijing Normal University, Beijing, China

"An Improved Method in Bagging Cross-Validation With Second-Order Extrapolation in Bandwidth Selection" Joint Statistical Meeting, Boston, MA

"Finding the Best Model With a U Model Selection Tool" Bentley University

Post-Graduation Plans of Mathematics and Statistics Majors

Shaan Amin	Business Management Analyst at Booz Allen Hamilton
Lily An	Working as an Equity Research Analyst for J.P. Morgan
Thomas Beaudoin	Working for Landmark Partners, a private equity firm in West Hartford, CT.
Gregory Becker	Working at Lawrence Livermore National Laboratory doing computer science research
Michael Berry	Study Chinese in Taipei
Andrew Best	Pursuing a Ph.D. in pure math at Ohio State University
Emma Bick	Attending medical school at the University of North Carolina

Elliot Chester	Working in Technical Services at Epic Systems in Madison, Wisconsin
Carrie Chu	Teaching 10th grade math and coaching swimming at King's Academy in Jordan
Julia Cline	Attending physics graduate school at the University of Colorado
Benjamin Corwin	Working at Analysis Group in Denver, CO.
Benjamin Demeo	Attending Cambridge University on a Hershel Smith Fellowship obtaining a Master's Degree in Mathematics
Jean-Luc Etienne	Working as a Data Science and Advanced Statistical Analyst
Alan Felix	Working as an Investment Analyst in Santa Monica, California
Jesse Freeman	Take Part III of the Mathematical Tripos at Cambridge University under a Churchill Scholarship. Then plan to pursue a Ph.D. in Math
Nicholas Gardner	Working for the consulting firm, Oliver-Wyman in Boston
Christopher Huffaker	Attending Columbia Journalism School to pursue an MSc in Journalism
Edward Kelly	Working at Credit Suisse
Donald Kost	Teaching Math for Teach for America in Rhode Island
Benjamin Hoyle	Working at the architecture firm, William Rawn Associates in Boston
Joseph Kinney	Working at Centerview Partners, an independent investment banking advisory firm
Claire Lidston	Attending Harvard University's Chemistry and Chemical Biology Ph.D. program
Aviv Lipman	Attending Yale Law School
Isaac Loh	Pursuing a Ph.D. in Economics at Northwestern University
Samantha Petti	Entering the Ph.D. program in Algorithms, Combinatorics, and Optimization at Georgia Tech Pursing a BPhil in philosophy at Oxford University
Jaclyn Porfilio	Business Analyst for McKinsey in Boston
Ivan Rybkin	Working for the economic consulting firm, Analysis Group in Boston
Eric Schneider	Working as a Media Analyst at Ampush in New York City
Daniel Siegel	Working in consulting at Oliver Wyman
Llewellyn Smith	Working as a Software Engineer for Fiksu in Boston
Anna Spiers	Working in Quality Assurance in a healthcare software company called Epic in Madison, Wisconsin
Benno Stein	Entering the Ph.D. program in Computer Science at the University of Colorado, Boulder, in the Programming Languages and Verification Group
Phonkrit Tanavisarut	Working as a Data Analyst for an economic consulting firm in Boston

Neuroscience

This year we temporarily lost Professor Noah Sandstrom to the Williams at Oxford Programme, but gained Visiting Assistant Professor Lauren Williamson ’07 in his stead. She brought us a new upper-level course, Brain, Behavior, and the Immune System (PSYC 312). Williamson also taught the capstone senior seminar for the program, and co-taught the core Neuroscience course with the new Chair, Professor Heather Williams. We had a full slate of electives that allowed students to engage in sophisticated investigation, including *Neural Systems and Circuits* (NSCI 311) with Professor Matt Carter and *Nature via Nurture* (NSCI 317) with Professor Betty Zimmerberg, in which students carry out research projects they design themselves.

Many students conducted research with neuroscience faculty, exploring topics such as neurochemical influences on arousal in Drosophila with Professor Tim Lebestky and neuroendocrine and cardiac responses to stress in human infants with Professor Amie Hane. Sixteen graduating seniors completed the neuroscience concentration in 2015; seven of these completed honors theses.

Anuj Shah ‘15 was awarded the Patricia Goldman-Rakic Prize in Neuroscience for 2015.

The Neuroscience Class of 1960 Scholars program co-sponsored several speakers during the year. we had students attend the fall symposium on zebra fish research and the Connecticut Valley Zebra Fish meeting, which was hosted in the fall by Lecurer Martha Marvin. We enjoyed visits and seminars by neuroscience program alumni *Erika Williams ’08* and Dr. *Michael Scott ’62* during winter study, and Lauren Williamson organized a number of events centered around National Brain Awareness Week, including outreach to the elementary school, activities for Williams students, and a talk for the general community. Martha Marvin’s work with local schools on the BioEyes project expanded to include more schools, and met with great enthusiasm from all participants.

Professors Hane and Williamson maintain a facebook page for the Neuroscience Program; it can be viewed at https://www.facebook.com/Williamsneuro. it provides information about activities such as brain awareness week, thesis presentations, and the painting of the Neuroscience Cow.

Martha Marvin continued investigating the development of the cardiovascular system and the stress response in zebrafish. Her work centers on the role of the heat shock protein *hspb7* in guiding normal heart development. Previous work in the lab demonstrated that reduction of *hspb7* causes overgrowth of heart valves and multiple heart malformations, including left-right asymmetry defects. Honors student *Christie Black ’15* undertook an ambitious project to create a mutation in *hspb7* using genomic editing via the CRISPR/Cas9 technique. *Sarah Weimann ’16* carried out confocal microscopy studies demonstrating that the overgrowth of heart valves was due to enlargement rather than proliferation of the valve precursor cells. *Ashley Ngo ’16* and *Jacob Kim ’16* studied how *hspb7* affects heart valve development by studying a similar effect caused by altered prostaglandin signaling. The lab also observed that estrogen receptor 1 is expressed in heart valves, and future work will pursue the question of whether estradiol receptor signaling is important for normal heart valve development.

The Neuroscience side of the lab began a new study on early life stress and its effect on gene expression and behavior. Embryos that experience a single 24-hour stress caused by exposure to dexamethasone, have lifelong behavioral changes. These changes may be mediated by a few target genes whose expression is transiently up-regulated by dexamethasone. The responsive genes include *fkbp5*, which has previously been implicated in human mood disorders. This work was primarily carried out by honors student *Anuj Shah ’15*, with the assistance of *Jacob Verter ’16, Jackie Harris ’16*, and *Madelynn Taylor ’16*. Using transgenic fish that glow green in the presence of heat shock or the stress hormone cortisol, they 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.

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

Post-Graduation Plans of Neuroscience Concentrators

Lillian Audette	M.Psyc. counseling program Loyola University
Ellen Cook	M.Sc. biomedical program Tufts University
Sarah Cottrill	science teaching at Nashoba Brook.
Nitsan Goldstein	R.A. hippocampal neurodegeneration and aging Mass. General.
Ashley Graves	undecided
Michelle Higgins	R.A. stem cell research Boston.
Kelsey Loy	medical scribing in Seattle applying to medical school.
Michael McPhee	undecided.
Claire Miller	ESPN - marketing
Rani Mukherjee	Goucher post-bac program preparing for medical school.
Erik Romano	undecided.
Amanda Schott	research assistant at the Albert Einstein College of Medicine.
Anuj Shah	post-bac program working on alcohol research the N.I.H.
Gabe Stephens	Ph.D. program in Neuroscience at Baylor University.
Ali Tafreshi	M.D. program at UCLA.
Daniela Zarate	Ph.D. program in evolutionary biology at UCSD.

Students attempting to complete the 3152 piece Lego SuperStar destroyer in under 10 minutes.

Physics Department

With the close of the 14-15 academic year we say goodbye to Assistant Professor **Ward Lopes**, who will be moving to California to start a research position developing the computer display technology of the future. We wish him the best in his new position. We also say goodbye to Ilya Amburg ’14 who has spent a post-baccalaureate year with us as an Assistant Lab Instructor. He is headed to a PhD program in Math at the University of Wisconsin.

Student interest in physics remains strong. This June we graduated 15 students majoring in Physics or Astrophysics. The next class classes - ’15 & ’16 – have 18 and 21 majors respectively. During the summer of 2015 we have 17 students working with Physics department faculty doing research. Student interest in research is high and available positions are keenly sought after. These students are supported by a combination of outside research grants, overhead on outside grants that the college voluntarily puts toward the support of research students, and endowed funds given by generous alumni and foundation support. This includes funds from the Claire Boothe Luce Foundation specifically to support women in science.

Professor **Sarah Bolton** continues to serve as Dean of the College. We look forward to her return to research and teaching in the department in the near future. Professor Tiku Majumder continues to serve part time as Director of the Science Center. This year has been a busy one as planning for the new science buildings is ramping up to full speed. The department is looking forward to having consolidated offices and labs in a new building, while continuing to use the nice teaching spaces in the venerable Thompson Physical Laboratory.

Professor **Daniel Aalberts** taught *Computational Biology (*PHYS/CSCI 315T), *The Making of the Atomic Bomb (*PHYS 011), and *Thermal and Statistical Physics (*PHYS 302). In the Aalberts Lab, *Michael Flynn ’15* completed an honors thesis "RNA Macrostates and Computation Tools". *Ashwin Narayan ’16* conducted summer research on microRNA binding sites, *Samantha Petti ’15* did an independent study on RNA pseudoknots, and *Daniel Wong ’17* worked on modeling RNA features for protein expression. Aalberts did science outreach presentations at the Williamstown Public Library and the Williams College Children’s Center.

After departing from the APS DAMOP conference in Madison, WI in late May, new Assistant Professor **Charlie Doret** arrived on campus in June 2014 and promptly got things started in the research laboratory, beginning work on an apparatus for cooling and trapping atomic ions. In this work he was joined by incoming thesis student *Cole Meisenhelder ’15* and *Will Kirby ’17*, who built diode lasers and wrote software for stabilizing them. During the fall semester Doret taught an upper level tutorial in *Classical Mechanics* (PHYS 411T), followed by *Electromagnetism and the Physics of Matter* (PHYS 132) in the spring. He continued his work in the research laboratory with Meisenhelder during Winter Study, when the two were joined by *John Russell ’16*.

Professor Doret’s work aims to trap atomic calcium ions for use in experiments on quantum simulation, wherein one quantum mechanical system is used to emulate the behavior of a second system which is challenging to study in the laboratory. As the laboratory is just getting started, present efforts are aimed primarily towards the construction of the experimental apparatus. Cole Meisenhelder’s thesis focused on the assembly and characterization of several diode lasers which will be used for laser cooling and fluorescence detection of the ions. Cole is headed to Harvard to begin graduate school in physics, but the lab will be in good hands during the coming summer. *Ariel Silbert ’16, Sierra Jubin ’17, Owen May ’17*, and *Elena Polozova ’17* will share work on two new lasers, a vacuum chamber, and an imaging system for monitoring trapped ion fluorescence, supported in part by a new Cottrell College Science Award from the Research Corporation (beginning July 2015); Ariel will continue this work in her senior thesis.

Professor and Department Chair **Kevin Jones** taught *Mechanics and Waves* (PHYS 141)in the fall and *Applications of Quantum Mechanics* (PHYS 402T)in the spring. The latter is one of the three junior/senior physics tutorials offered regularly on an alternate year basis. Although not required of majors, many students select two or three of these tutorial courses and they are thus a major feature of the junior/senior experience for most Physics and Astrophysics majors. Physics 402T is unusual in having a laboratory experiment as the

culminating experience in the course. The final three weeks of the semester explore the quantum nature of light. Students work out the theory for, and carry out, an experiment on the interference of non-classical light beams.

Jones continues a long-standing research collaboration with the Laser Cooling and Trapping group at the National Institute of Standards and Technology. In the summer of 2015, the experimental work moves from Gaithersburg to the new Joint Quantum Institute laboratory building at the University of Maryland. *Anneliese Rilinger '17*, one of our Clare Boothe Luce scholars, is working with Jones this summer on a project to investigate the spatial distribution of photons in an entangled state of light produced by a "twin beam" source. Jones also is working on other experiments in quantum optics. This work is supported by a grant from the National Science Foundation.

During the 2014-15 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 extensively this year on the planning for an exciting new science center construction project. He taught *Sound, Light, and Perception (*PHYS 109), as well as laboratories for *Foundations of Modern Physics (*PHYS 142). He continued to pursue diode laser and atomic physics experiments in his research lab, teaming up with senior thesis students *Ben Augenbraun '15*. With funds from a new ($350K) NSF grant, the Majumder group hired a new postdoctoral fellow, Dr. Milinda Rupasinghe, whom we welcomed to Williams in January of this year.

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). In the summer of 2014, *Sauman Cheng '16* and *Talia Calnek-Sugin '15* worked on building and testing a new laser system for the thallium vapor cell experiment.

Ben Augenbraun worked through the summer of 2014 and continued his senior thesis work during the 2014-15 academic year, nearly completing a very challenging follow up to the 2013 project in the indium atomic beam apparatus in which a second, infrared laser was added to perform a more complicated two-step spectroscopy experiment. The group expects to complete analysis of data for this experiment in summer 2015, with the help of incoming thesis student *Allison Carter '16*. Meanwhile *Sauman Cheng '16* will return from her Spring semester at CERN to begin her senior thesis work on the thallium vapor cell project. Both students will be working with postdoc Rupasinghe and Majumder this summer.

Ben and Melinda accompanied Majumder to the annual American Physical Society DAMOP conference in Columbus, OH, in early June, where they presented a poster on this most recent project. Ben will begin a Ph.D. program at Harvard this fall where he expects to continue in the field of atomic and laser physics. We wish him all the best!

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.

Recently Strait and students built a new fiber laser pumped with laser diodes. The new laser produces stable pulses that can be as short as 0.4 picosecond. It uses optical fibers designed for transoceanic communication that have both positive and negative dispersion, allowing control over the overall dispersion in the laser.

Strait serves as pre-engineering advisor, as department webmaster, and as a member of the Campus Environmental Advisory Committee.

Associate Professor **Frederick Strauch** taught *Seminar in Modern Physics* (PHYS 151)in the Fall, and in the Spring he taught *Foundations of Modern Physics* (PHYS 142) and *Mathematical Methods for Scientists (*PHYS 210).

Strauch continued his theoretical work in superconducting quantum circuits, quantum algorithms, and other applications to quantum information processing. His senior thesis student *Teddy Amdur '15,* explored numerical methods for designing quantum algorithms and their application to the quantum Fourier transform. This work was supported by an NSF grant with Kurt Jacobs at the University of Massachusetts, Boston. Teddy developed several optimizations of a well-known numerical search algorithm, and implemented a parallelized version in MPI for future use on high-performance computing clusters.

Strauch also continued his work with Professor Steven Miller in Mathematics on statistical-physics-based models for Benford's Law, a curious empirical observation regarding for the first digits encountered in a variety of data sets. They are exploring the statistical properties when a conserved quantity such as energy, mass, or other physical quantity is subject to a fragmentation process. They have recently proven a conjecture that these processes lead to Benford's Law. A paper based on this and the senior thesis work of Joe Iafrate '14 was recently accepted for publication. This work was continued by *Weng-Him Cheung '15* for his senior thesis, who refined the criteria and convergence properties of the analysis of these processes. Finally, during Winter Study, Strauch worked with *Matt Radford '16, Andy Yao '17* on quantum computing and *Maria Prado '17* on scientific computing.

During his sabbatical, associate professor **David Tucker-Smith** pursued research in theoretical particle physics. In the summer of 2014 Tucker-Smith participated in a particle physics workshop at the Aspen Center for Physics. There he began a new project on signatures of new physics at the Large Hadron Collider. After the workshop he completed a paper on work carried out with Williams students *Isaac Hoenig '14* and *Gabriel Samach '15*, which was published with Isaac and Gabriel as coauthors. In the Spring of 2015 Tucker-Smith visited Fermilab to work with a collaborator and participated in workshops on baryon and lepton number violation and on the CP nature of the Higgs boson, both at the University of Massachusetts.

In the summer of 2014 and throughout the academic year, Professor **Bill Wootters** worked with two thesis students, *Brandon Ling '15* and *Gabe Samach '15*, who investigated different aspects of the "ubit model," a theoretical construction that generates a one-parameter modification of standard quantum mechanics. Gabe studied the evolution of wavepackets in the model and found that the simplest version of the theory entails the existence of a preferred reference frame. Meanwhile Brandon studied in detail several distinct ways of modeling environmental decoherence, an effect that plays a central role in the theory.

In January of 2015, Professor Wootters worked with *Will Kirby '17* on a quantitative study of entanglement, which is a peculiarly quantum mechanical kind of correlation that can exist between two or more particles. The specific focus of the work was the change in the amount of entanglement when the individual particles are subjected to measurements. Will plans to continue this research over the summer. Professor Wootters will also be starting a new research project this summer with *Jay Choi '17* and *Sam Steakley '17*.

In the classroom, Professor Wootters collaborated with Professor Keith McPartland of the philosophy department to offer, for the first time, a junior-level interdisciplinary course *Philosophical Implications of Modern Physics* (PHYS 312). The readings included some of the original papers on the interpretation of quantum theory as well as philosophical writings on space, time, and probability. The course featured a guest lecture by the philosopher of science Arthur Fine.

Class of 1960 Scholars in Physics

Samuel T. Amdur
Benjamin L. Augenbraun
Weng-Him Cheung
Julia R.K. Cline
Michael J. Flynn
Brandon V. Ling
Cole M. Meisenhelder
Gabriel O. Samach

Physics and Astronomy Colloquia

Kristin Beck, MIT
"Single Photon Switching in an Optical Transistor"

Guy Blalock, UMass Amherst
"Wringing John Bell"

Charles Doret
"Atoms at Work: Applying atomic physics tools to research and technology" Summer Science Lunch, August 2014

Brian Gerke '99, Lawrence Berkeley National Lab
"A Physicist's Approach to Energy Efficiency Policy"

Anne Goodsell, Middlebury College
"Exciting Physics with Excited Atoms: Push and Pull on Rydberg States"

Anne Jaskot '08, Smith College
"Green Peas: High-Redshift Galaxies in a Low-Redshift Universe"

Masha Kamenetska, Yale University
"Measuring mechanical properties of single molecules"

Steven Kearnes, Stanford University
"Computational Approaches to Drug Discovery and Development"

Andrew Kerman '93, MIT Lincoln Laboratory
"Flux-charge duality and quantum phase fluctuations in one-dimensional superconductors"

Dan Lewis, Huntington Library
"The Feathery Tribe: Robert Ridgway and the Modern Study of Birds"

Jeffrey Linsky, University of Colorado Laboratory for Astrophysics and Space Physics
"Solar and stellar ultraviolet and extreme-ultraviolet radiation and effects in exoplanet atmospheres"

Nathan Lundblad, Bates College
"Quantum-gas physics in orbit: prospects for microgravity Bose-Einstein condensates aboard NASA's Cold Atom Laboratory"

Katherine Mesick, JLAB
"The Proton Radius Puzzle"

Ana Maria Rey, JILA
"Building with Crystals of light and Quantum Matter: From clocks to computers"

Crystal Senko, Harvard
"Simulating Quantum Many-Body Spin Systems with Trapped Ions"

Clark Semon, RSMHS

"Rocket Stove"

Jared Strait '07, Cornell University
"Shining Light on Future Electronic Materials"

Nick Wilding, Georgia State University
"The History of Forging Early Modern Books"

William Wootters
"Equiangular vectors in a complex vector space" Faculty seminar, Department of Mathematics and Statistics, October 2014

Off-Campus Physics Colloquia

Daniel Aalberts
"RNA features controlling protein expression" Poster at Cold Spring Harbor Labs Translation meeting, September 2014

"Somewhere over the RNAbow, a new way to describe free energy landscapes" Mount Holyoke College Physics Colloquium, February 2015

"RNA features controlling protein expression" Invited talk at The RNA Symposium, U. Albany, March 2015

Charles Doret
"What's a Qubit? Quantum mechanics and quantum systems for information processing and sensing applications" Technical Seminar, Georgia Tech Research Institute, Atlanta, GA September 2014

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

Tiku Majumder
"Measurement of the Indium 6p1/2 state scalar polarizability using an atomic beam" Contributed poster with B.L. Augenbraun '15, Nathan Bricault '14 and P.M. Rupasinghe APS Division of Atomic, Molecular, and Optical Physics Meeting, Madison, WI, June 2014

"Heavy Metal, Cheap Lasers, and Tests of Fundamental Physics" Invited departmental colloquium, Hamilton College, November 2014

"Heavy Metal, Cheap Lasers, and Tests of Fundamental Physics" Invited departmental colloquium, Smith College, February 2015

"Indium atomic beam spectroscopy: polarizability and tests of atomic theory in Group IIIA atoms" Atomic Physics seminar, Yale Univ. Dept. of Physics, March 2015

"Are we there yet: Clocks, Navigation, and Cold Atoms" Williams College Alumni event, New York City, March 2015

Fred Strauch
"Quantum control toolbox for superconducting resonators"" Syracuse University Condensed Matter Seminar, November 2014

William Wootters
"The ubit model in real-amplitude quantum theory" University of New Mexico, January 2015 The University at Albany, April 2015

"Why does nature like the square root of negative one?" Bard College, April 2015

"Cycling through mutually unbiased bases" Quantum information seminar, MIT, May 2015

Post-Graduation Plans of Physics Majors

Name	Plans
Burhan Aldroubi	Seeking employment
Samuel Amdur	Teach for America, Milwaukee, WI
Benjamin Augenbraun	PhD program in physics, Harvard University
Talia Calnek-Sugin	Teaching physics for a year in Costa Rica, Fall 2015
Weng-Him Cheung	PhD program in physics, University of Wisconsin
Julia Cline	PhD program in physics, University of Colorado Boulder
Daniel Evangelakos	Seeking employment
Michael Flynn	Working with Prof. Aalberts Summer 2015, then game development at Vicarious Visions
Alexander Foucault	Seeking employment within the year
Jacob Goldenring	Greylock McKinnon Associates, consulting firm in Boston
Brandon Ling	PhD program in physics, Boston University
Cole Meisenhelder	PhD program in physics, Harvard University
Gabriel Samach	Quantum Information and Integrated Nanosystems group at Lincoln Lab, MIT
Herbert Smith	Sustainability coordinator for Zilkha Center at Williams
John Sutton	Management consulting for Oliver Wyman in Boston

Psychology Department

The psychology major at Williams College attracts a very large number of students with diverse interests, goals, and backgrounds. Our students follow a curriculum that teaches them not only about *what* we know about mind and behavior, but also about *how* we know it, using experiential teaching as our core pedagogy. Students learn how to use the methods of scientific inquiry to critically evaluate information, generate new knowledge and imagine its implications and applications in the world. Students take a range of courses spanning the sub-disciplines of neuroscience, cognitive, clinical, developmental, and social psychology, as well as the psychology of education. Psychology faculty work closely with the Neuroscience and Cognitive Science Programs, and the new Public Health Program.

Psychology students have multiple opportunities to conduct research collaboratively with professors. Some of these are empirical projects conducted within required 300-level lab courses, and others are in work-study or research assistant positions, or as more formal independent studies. Also, in 2014-15, six students completed year-long senior honors thesis research under the direction of Psychology faculty. Their projects are listed in the Student Thesis Abstracts section of this report. 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. Our student liaison committee met to discuss departmental policies and host "snacks" in our lounge. To encourage students to explore careers in psychology, the Class of 1960 Scholars Program brought accomplished researchers from universities to campus to give colloquia. The junior and senior 1960 Scholars read the speaker's work and then joined the speaker and faculty for a reception and dinner afterward. This year marked the sixth year of the G. Stanley Hall Prize in Psychology, funded by a generous gift from the family 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 *Erin Curley '15* for her outstanding thesis and contributions to teaching and departmental life.

The faculty of the Psychology Department continued their varied and productive teaching and research programs. We were thrilled to have Nate Kornell receive tenure this year. Nate is an exceptionally productive scholar, with an international level of scholarly recognition. He has an earnest passion for our students' process of learning, uniquely informed by his research on cognition and education. Nate is a creative and knowledgeable colleague who has made valuable contributions to the Psychology Department and the Program in Teaching. We also were happy to have three of our visiting faculty stay on this year, Laura Sockol and Nicole Harrington, teaching in clinical psychology, and Alison Sachet, teaching in developmental psychology. We have two Visiting Assistant professors in the department this year: *Lauren Williamson '07* Joined us in behavioral neuroscience, and Jeff Moher in cognitive psychology. Next fall, we will welcome two new faculty in social psychology, Jeremy Cone and Laura Smalarz, and a visiting faculty professor in clinical psychology, Kristen Haut. We all gathered this spring to warmly congratulate Robert Kavanaugh, Hales Professor of Psychology, on his retirement after 39 years of innumerable contributions to the field of developmental psychology and the life of the department and college. He has been a valued mentor to us all.

Through all of these activities, we could not function without the invaluable help of Christine Russell, Department Administrative Assistant, C.J. Gillig, Psychology Department Technical Assistant, and Beth Stachelek, Department Financial Coordinator. Their wisdom and cheerfulness, as well as ability to step in, often at the last minute, to support our work is well-known to students from Introductory Psychology through senior honors theses students, and they help keep our large department feeling friendly and accessible. They are deeply appreciated by faculty as well.

Professor Emeritus **Phebe Cramer** continued her research on the longitudinal study of personality development. Based on this research, she published three new papers this year.

At the annual meeting of the Society for Personality Assessment, held in Brooklyn, New York, she was the Chair of a Symposium, "Defense Mechanisms: Assessment with the TAT and Structured Interviews," and she presented a paper, "The Interaction of Defense Mechanisms and Gender Identity." She was also invit-

ed to become an Honorary member of the editorial board of the Ukrainian journal *Visnyk* (*Bulletin*).

Cramer continues as a Consulting Editor for the *Journal of Personality Assessment*, and as an ad hoc reviewer for research papers submitted to multiple professional journals. She completed her five-year term as Associate Editor for the *Journal of Research in Personality*.

This past year, Professor **Susan Engel** published two books, *The Hungry Mind: The Development of Curiosity in Childhood* (Harvard University Press 2015) and *The End of the Rainbow: How Educating for Happiness (Not Money) Would Transform Our Schools* (The New Press 2015).

She published a series of articles related to these two books in: *The Bloomberg View*, *The Atlantic Monthly*, *The Boston Globe*, *Salon*, *Aeon Magazine*, and *Huffington Post*, and was interviewed for NPR as well as a range of other public radio shows around the country.

Engel gave the keynote address to the Florida Council of Kindergarten Teachers, and a series of talks to the Common Ground Educational Consortium in Palo Alto, CA. She also began serving as an advisor to a large-scale study examining the impact of non-academic factors on high school students, supported by the Templeton Foundation and directed by Angela Duckworth and William Damon. She began serving on the board of advisors for Planet Word, a museum of the language arts, to be built in Washington DC.

With the help of *Hana Tomozawa '15* and *Chase Davenport '13*, she conducted the first phase of a two-year study on the impact of college on the way students think.

The Program in Teaching events included presentations by Ferentz Lafargue, Director of the Davis Center, Steven Swoap and Matt Carter from the Biology Department, Allison Pacelli, Math Department, Harry Brighouse, Department of Philosophy at the University of Wisconsin, Madison, and Sarah Koenig, Producer of Serial.

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 cognitive factors in individual and relationship difficulties, outcomes of residential treatment for major mental illness, and global mental health.

At the June 2014 International Society for Psychotherapy Research Conference in Copenhagen, Denmark, she presented a semi-plenary address, "Fools Rush In…: Family Therapy Research Advances and Future Opportunities;" a paper with *Jesse Fitts '13* and *Pacifique Irankunda '13* (based partly on Pacifique's thesis research and subsequent work by Jesse), "Adapting and Implementing Psychotherapy Interventions in a Village Clinic in Burundi;" and a Structured Discussion, "The Alliance in Couple and Family Therapy." In July 2014, she attended the First SOFTA/SOATIF Conference on Therapeutic Alliance in Couple and Family Therapy, Santiago de Compostela, Spain, where she presented on publication strategies for family therapy researchers.

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

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, Kassin continued working on his National Science Foundation grant to study "The Videotaping of Interrogations: Testing Proposed Effects on Police, Suspects, and Jurors." He also continued to serve as a Network Member for NSF Research Coordination Network: Understanding Plea Bargains, 2014-present. In April of 2015, Kassin represented the APA Science Directorate in a Capitol Hill Briefing to Congress in Washington, DC. He appeared in a televised World Science Festival Panel on Science and Justice in New York. Over the past year, Kassin gave a number of invited talks throuhout the Unites States and abroad.

In 2015, Kassin presented a number of papers at the Annual Meeting of the American Psychology-Law Society (AP-LS) in San Diego. He also presented two papers, including a plenary session paper, at the Annual

Meeting of the American Academy of Forensic Sciences (AAFS), in Orlando. These lectures were titled: "Confessions in Context: Why Confessions Corrupt Forensic Perceptions and Judgments" and "The Forensic Confirmation Bias: Problems in Human Nature and Solutions." In May of 2015, he gave two invited talks at the Annual Meeting of the Association of Psychological Science (APS), entitled: "From Kitty Genovese to the Central Park Five: Lessons for Psychology from the History of New York" and "Why Confessions Trump Innocence." This second lecture was followed by a viewing of the film *The Central Park Five* and a panel discussion.

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,* 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 a number of criminal and civil cases. His work was recently cited by the Supreme Court of Canada in *R. v. Hart (2014).*

This past year Professor **Kris Kirby** published an article in which he reviewed Mohandas Gandhi's views on vows and self control, and evaluated them in the context of the Ainslie-Rachlin delay-discounting theory of self control. Professor Kirby also served on the editorial boards of the *Journal of Behavioral Decision Making* and *Judgment and Decision Making*, and served as an *ad hoc* reviewer for *Behavioural Processes, Behavior Research Methods,* the *Journal of Experimental Psychology: Learning, Memory & Cognition, Psychology of Addictive Behaviors,* and *Psychological Science*.

Associate Professor **Nate Kornell** continues his research on cognition, education, and self-regulated learning. He received a $600,000 grant from the James S. McDonnell Foundation to study self-regulated learning.

Kornell 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 six journal articles this year that examined the efficacy of a variety of ways to improve learning (e.g., retrieving knowledge from long-term memory, mixing study of various materials, highlighting expecting to teach), as well as the ability of students and children to make accurate judgments and decisions about their own learning.

This year, Visiting Professor **Jeff Moher** began conducting research in his lab at Williams on human cognition, attention, and action. Several new projects are underway that examine the role of distraction. Specifically, he is interested in determining whether intermittent breaks during task performance reduce distractibility, as well as whether the activities engaged in during those breaks (including whether a person has access to their smartphone) affects subsequent distractibility. Additional experiments are underway examining the role of context in learning to ignore distractions. That is, can people learn to ignore the kinds of objects that typically capture attention if they frequently occur in the same environment? Two undergraduate students joined his lab for the year: *Irene Lim '16* and *Penny Sun '16*. They were both heavily involved in both the design and execution of these projects.

In addition, Professor Moher began to set up the college's new electroencephalography setup. This technology allows for the recording of electrical activity from a human's brain by placing a series of electrodes on their scalp. He was able to demonstrate the use of this machine in his 300-level class, Understanding Attention and Distraction, and looks forward to integrating it into his research and teaching more fully in the coming year. He also has ongoing collaborations with colleagues at Johns Hopkins University, Brown University, and Michigan State University.

Professor Moher's other research activities over the past year have included the publication of several previous research projects in peer-reviewed journals, co-organizing a conference workshop on object perception, attention, and memory in Long Beach, CA, and presenting posters on his research at the annual meetings of the Psychonomic Society (November 2014, Long Beach, CA), and Vision Sciences Society (May 2015, St. Pete Beach, FL).

Assistant Professor **Mariko Moher's** research focuses on the development of infants' and young children's memory. This year, she worked with 3- to 5-year-olds at local preschools with the help of *Lauren Glenn '15* and *Jacqueline Lee '15*, and collected data on children's understanding of categories. In her *Experimentation & Statistics* (PSYC 201) class, her students collected data on social media use and sleep, on how people's perception of

chocolates change depending on what they are told about its quality or brand, and on how emotional arousal can affect memory, all the while learning about experimental design and data analysis techniques. In addition, Professor Moher presented her research at the biennial meeting of the Society for Research in Child Development.

This summer, she will be hosting a workshop at Williams College for developmental psychologists from other liberal arts institutions such as Amherst, Barnard, Smith, and Wesleyan, with a grant obtained through the Faculty Workshop Program at the Alliance to Advance Liberal Arts Colleges.

Professor **Marlene Sandstrom** focuses on children's social relationships. She is particularly interested in victimization, bullying, bystander behavior, peer rejection, popularity, and social influence. Professor Sandstrom spent the 2014-15 academic year in the United Kingdom, directing the Williams-Exeter Programme at Oxford University. While overseas, she has been analyzing a longitudinal data set in which children who participated in her peer relations project as 4th graders were asked to report on their well-being in early adulthood. Professor Sandstrom is interested in exploring the extent to which rejection sensitivity might moderate the association between peer status in childhood and subsequent adjustment.

In the fall, Professor Sandstrom served as a consultant for a grant application to the Netherlands Organization for Scientific Research: Innovative Research Incentives Scheme (*Implicit Attitudes: A new approach to peer victimization).* In the spring, she was invited to present a research talk at Raboud University (Nijmegen, Netherlands) entitled *Chasing the Ghost in the Machine: Inherent Challenges in Implicit Attitude Research.* Professor Sandstrom was also invited to review submissions to the Social Relations Panel for the 2015 Biennial meeting of the Society of Research in Child Development. In addition, she was invited to join the editorial board of a new peer-reviewed journal, *Adolescent Research Review.* Professor Sandstrom was also invited to serve as an external dissertation committee member for a DPhil defense at Raboud University entitled *Peers in Proximity: New perspectives on interpersonal processes in the classroom*. Over the past year, Professor Sandstrom has served as an ad hoc reviewer for *Journal of Early Adolescence, Journal of Educational Psychology,* and *Journal of Youth and Adolescence.*

Professor **Noah Sandstrom** spent the 2014-2015 academic year on sabbatical in Oxford, UK where he joined the Behavioural Neuroscience Unit at Oxford University. While in the UK, he has continued to collaborate with a team of researchers in the United States, exploring the relationship between participation in college athletics and long-term health and well being. Professor Sandstrom completed his term as Past-President of the international organization *Faculty for Undergraduate Neuroscience*. In this capacity, he was the organizer of their annual meeting in November in Washington, D.C.

Professor Sandstrom has continued serving as a reviewer for several journals including *Hormones & Behavior* and *Brain Research*. He has also participated in the external review of faculty at other institutions. Professor Sandstrom will remain in Oxford as Director of the Williams-Exeter Programme at Oxford for the 2015-2016 academic year and will return to Williamstown in the summer of 2016.

Visiting Assistant Professor **Laura Sockol** focuses on mental health during pregnancy and the early postpartum period. She published several articles this year. One article, published in the *Archives of Women's Mental Health,* compared the experiences of first-time mothers to pregnant and postpartum women who already had older children. This study found that mothers with older children report lower levels of social support and marital satisfaction, but that these groups have similar attitudes about motherhood and that the risk factors for depression and anxiety are comparable in both groups. She also published a meta-analysis of cognitive-behavioral interventions for treating and preventing perinatal depression in the *Journal of Affective Disorders,* which found that these interventions are effective in a wide range of populations and administered in a variety of contexts.

At the annual meeting of the Association for Behavioral & Cognitive Therapies (ABCT) in Philadelphia, PA in November of 2014, Professor Sockol received the Women's Special Interest Group Early Career Investigator Award for a paper investigating *The relationship between maternal attitudes and symptoms of depression and anxiety among pregnant and postpartum first-time mothers* (*Archives of Women's Mental Health,* 2014). She moderated a panel at the conference, *Plugging the leaky pipeline: Mentoring women in clinical psychology,* at which experienced mentors discussed their success-

es and challenges helping women successfully navigate academic careers as clinical psychologists.

Students from Professor Sockol's lab presented several posters at ABCT. *Caroline Kaufman '15* presented two posters. The first, which was co-authored with Professor Sockol, was a comparison of risk factors and psychological symptoms between first-time mothers and pregnant and postpartum women who already had older children. This poster received the Student Poster Award from the Women's Special Interest Group. Caroline also presented a poster on the effects of symptoms of depression on empathy, which was co-authored with Professor Sockol and former Visiting Assistant Professor of Psychology Alicia Hofelich Mohr. *Rachel Caffey '14*, *Julia Juster '14*, and *Natalie Szykowny '14* presented findings from a study initially conducted for an empirical laboratory course *Gender & Psychopathology* (PSYC 353) at the conference. This study found that tasks related to the job search, such as writing a cover letter, lead to comparable increases in anxiety for male and female seniors. *Lillian Audette '15* presented results of a study that found that maladaptive coping strategies were more strongly associated with symptoms of depression among female undergraduate students than social support. Finally, Mariah Girouard (Smith College '15), who was a research assistant at Williams College in the summer of 2014, presented a poster on women's participation in professional organizations within clinical psychology. She co-authored an article on this topic with Professor Sockol for the newsletter of the ABCT Women's Special Interest Group.

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. *Erin Curley '15* completed a senior honor thesis examining sexual experiences, stress generation, serotonergic vulnerability and depressive symptoms among early adolescent girls. Catherine and *Effua Sosoo '13* presented their work on rumination and stress generation at the Annual Meeting of the Association for Behavioral and Cognitive Therapies (ABCT). Stroud and her colleagues also presented their work examining the stress-depression association at ABCT. *Elizabeth Albert '14* and Stroud presented their work on chronic stress, diurnal cortisol rhythms and pubertal timing at the Annual Meeting of the Association for Psychological Science (APS). Also at APS, *Emily Norkett '14* and Stroud presented their work examining adolescents' perceptions of stress, diurnal cortisol rhythms and depressive symptoms. Stroud and her colleagues also presented their research on anxiety, depression and negative anxiety response styles at APS. She gave an invited talk on the causes and consequences of girls' responses to negative emotions and stress at Colby College. Stroud and her colleagues published a manuscript examining personality, rumination and stress generation in the *Journal of Research on Personality.* She co-authored a chapter on family therapy for the *APA Handbook of Clinical Psychology.* In addition, Catherine and her colleagues published a manuscript in *The Behavior Therapist* describing the ABCT special interest group she created promoting research in clinical psychology at liberal arts colleges. Stroud became an Associate Editor of *Family Process*.

Professor **Betty Zimmerberg** continued her service as chair of the Psychology Department this year. In November, she attended the annual meeting of International Society for Developmental Psychobiology in Washington, DC. There she met up with former thesis student, *Sierra Germeyan '13*, who is working in a neuroimaging lab at NIH. Sierra presented her thesis research, entitled "Effects of neonatal fluoxetine exposure on affective and social behavior in high and low vocalizing rats". Zimmerberg also attended the Society for Neuroscience annual meeting in Washington, DC, in November.

Thesis student *Amanda Schott '15* continued her research on the role of NK1 receptors in mediating anxiety behaviors in an epigenetic model. *Daniela Zarate '15*, *Rose Miles '17*, *Emma Cannon '15*, *Lauren Steele '18*, and *Anika Mitchell '18* all worked in the Zimmerberg lab this year. Zimmerberg redesigned her tutorial this year to include a laboratory component. The tutorial, *Nature via Nurture: Topics in Developmental Psychobiology* (PSYC 317), examines the relative contributions of genetics and the environment that lead to individual differences in behavior. In connection with that course, she hosted a visit by Dr. Regina Sullivan from the Emotional Brain Institute at New York University. Other professional activities included serving on the Editorial Board of *Developmental Psychobiology*, and reviewing manuscripts for that journal as well as for *Hormones and Behavior*, *Plos One*, *Neuroscience & Biobehavioral Reviews*, and *Behavioural Brain Research*.

Class of 1960 Scholars in Psychology

Erin Curley ‘15
Fiona Dang ‘15
Ellen Finch ‘16
Michaela Kearney ‘15
Jospeh Ryan Kilcullen ‘15
Jacqueline Lee ‘15
Jessamyn Lockard ‘15
Minica Long ‘15
Marilisande Montes De Oca ‘15
Abra Owens '15
Abigail Pugh ‘16
Silvio Resuli '16
Amanda Schott ‘15
Penny Sun ‘16

Psychology Colloquia

K. Anders Ericsson, Florida State University
“Anyone Can Become and Expert with 10,000 Hours of Practice”

Harry Brighouse, University of Wisconsin (Madison)
"Justice, Privilege and Elite Higher Education"

Chuck Sanislow, Wesleyan University
"Diagnosing Psychopathology: What's in a Name"

Ned Sahin ‘98, Brain Power, LLC
"At the Intersection of Wearable Computers and Brain Sciences: Transforming Google Glass into a Neuro-assistive Device for Autism"

Regina Sullivan, The Emotional Brain Institute, NYU
“The Neurobiology of Infant Attachment and the Development of Fear”

Marilyn R. Sanders, MD, FAAP University of Connecticut School of Medicine
“The Preterm Infant: Vulnerabilities and Outcomes”

Nate Kornell
“Student Evaluations of Teaching” Talk delivered at Networks for Faculty Development, March 2015

“The Science of Learning” Talk delivered to Mt. Greylock students during Williams College Science Blast, May 2015

“How to Teach an Old Dog New Tricks” Talk delivered to Williams alumni, July 2014; Talk delivered to Williams College summer science students, July 2014; Talk delivered to a consortium of liberal arts college librarians, October 2014

Off-Campus Psychology Colloquia

Saul Kassin

"From Kitty Genovese to the Central Park Five: Lessons for Psychology from the history of New York" Invited Address at the Teaching Institute of the Association for Psychological Science, New York City, 2015

"Why Confessions Trump Innocence" Invited paper at the Annual Meeting of the Association for Psychological Science, New York City, 2015

"Using Evidence Lineups to Reduce the Forensic Confirmation Bias in Handwriting Judgments" Paper presented at the Meeting of the American Psychology-Law Society, San Diego, 2015

"When do Confessions Taint Judgments of Handwriting Evidence? Testing Three Moderators of Forensic Confirmation Bias" Paper presented at the Meeting of the American Psychology-Law Society, San Diego, 2015

"Confessions as Hollywood Productions: A Content Analysis Comparison of Corroborated and False Confesions" Paper presented at the Meeting of the American Psychology-Law Society, San Diego, 2015

"Confessions in Context: Why Confessions Corrupt Forensic Perceptions and Judgments" Plenary Session Paper presented at the Meeting of the American Academy of Forensic Sciences, Orlando, 2015

"The Forensic Confirmation Bias: Problems in Human Nature and Solutions Paper presented at the Meeting of the American Academy of Forensic Sciences, Orlando, 2015

Additional presentations over the past twelve months at: Oregon Innocence Project, Portland, OR; Reed College, Portland, OR; Raritan Valley Community College, Raritan, NJ; Statewide Meeting of Pennsylvania Judges, Pittsburgh, PA; Administrative Judicial Institute, New York, NY; Northeast Chapter of Certified Forensic Interviewers, New York, NY; University of Maastricht, The Netherlands; World Science Festival Panel on Science and Justice, New York, NY; New York State Association of Criminal Defense Lawyers, New York, NY

Nate Kornell

"Teaching Workshop: Productive Struggle" Talk delivered at Reed College, February 2015

"Productive Struggle" Keynote delivered at Richard K. Reznick Wilson Centre Research Day at the University of Toronto, October 2014

"How to Teach an Old Dog New Tricks: Productive Struggle" Talk delivered at Trinity University, October 2014

"Performance Bias: Judgments of Learning are Insensitive to Observable Improvement" Talk delivered with *Hannah Hausman '12* at the meeting of the International Association for Metacognition, November 2014

"Which Benefits More From Retrieval, Word Pairs With Mediators Or Word Pairs Without?" Paper presented with *Hannah Hausman '12* at the 55th Annual Meeting of the Psychonomic Society, November 2014

Mariko Moher

"Broad Category Membership Guides Visual Attention in Young Children" Poster presented with B. Long, T. Konkle, G.A. Alvarez & S. Carey at the biennial meeting of the Society for Research in Child Development, Philadelphia, PA, March 2015

"Chunking Promotes the Selective Encoding and Maintenance of Information in Infant Working Memory" Poster presented with M.M. Kibbe, & L. Feigenson at the biennial meeting of the Society for Research in Child Development, Philadelphia, PA, March 2015

"Infants' Abilities to Update Quantity Representations Across Multiple Locations" Poster presented with R. Feiman, & S. Carey at the biennial meeting of the Society for Research in Child Development, Philadelphia, PA, March 2015

"Broad Category Membership Guides Visual Attention in Young Children" Poster presented with B. Long, T. Konkle, G.A. Alvarez & S. Carey, S. at the annual meeting of the Budapest CEU Conference on Cognitive Development, Budapest, Hungary, January 2015

Noah Sandstrom

"Faculty for Undergraduate Neuroscience (FUN): Multiple Mechanisms for Supporting the Development of Undergraduate Students and Faculty in the Neurosciences" Presented with J.S. Smith & L.A. Gabel at the Society for Neuroscience, Washington, D.C., November 2014

Catherine Stroud

"Predictors of Pubertal Timing Among Adolescent Girls: The Roles of Interpersonal Stress and Diurnal Cortisol Rhythms" Poster presented with *E. Albert '14* & L. D. Doane at the annual conference of the Association for Psychological Science, New York, NY, May 2015

"Vulnerability to Depression in Adolescent Girls: A Longitudinal Study of Diurnal Cortisol Rhythms and Subjective Appraisals of Stress" Poster presented with *E. M. Norkett '14* & L. D. Doane at the annual conference of the Association for Psychological Science, New York, NY, May 2015

"Anxiety Response Style as a Moderator of the Prospective Association between Anxiety and Depression among Adolescent Girls" Poster presented with L.R. Starr, & I. Li at the annual conference of the Association for Psychological Science, New York, NY, May 2015

"Understanding Girls' Responses to Negative Emotions and Stress: Causes and Consequences" Invited talk at Colby College, Department of Psychology, February 2015

"Chronic and Episodic Interpersonal Stress as Statistically Unique Predictors of Depression in Two Samples of Emerging Adults" Oral symposium presented with S. Vrshek-Schallhorn, C. Hammen, S. Mineka, R. Zinbarg & M.G. Craske at the Annual Meeting of the Association for Behavioral and Cognitive Therapies, Philadelphia, PA, November 2014

"Coping and Rumination as Predictors of Stress Generation Among Early Adolescent Girls" Poster presented with *E.E. Sosoo '13* at the Annual Meeting of the Association for Behavioral and Cognitive Therapies, Philadelphia, PA, November 2014

Betty Zimmerberg

"Effects of neonatal fluoxetine exposure on affective and social behavior in high and low vocalizng rats"International Society for Developmental Psychobiology Annual Meeting, Washington D.C., November 13, 2014

Post-Graduation Plans of Psychology Majors

Lillian Audette	Attending Loyola University Maryland's Masters of Counseling Psychology Program - Thesis Track
Tatum Barnes	Unknown
Emma Benjamin	Working a summer internship with a real estate developer in San Diego
Kathleen Brantley	Working in urban agriculture in Chicago and after that hoping to be in California doing a teacher-in-residence program for environmental education
Jonathan Brenner	Hoping to work at a social/cognitive psych lab in a research position
Sarah Brink	Attending Boston University's Masters in Speech Language Pathology program
Gabriela Bronfman	Working at Estée Lauder
Emma Cannon	Working at the Walworth Barbour American International School in Israel as a research and writing tutor for high school students
Joowon Choi	Working for a cultural exchange program at Princeton University over the summer; applying to clinical research positions for my gap year before applying to medical school
Eduard Ciobanu	Working in the Williams College Office of Admission
Ellen Cook	Attending Tufts's Masters in Biomedical Science Program
Louisa Costa	Unknown
Erin Curley	Working as a Clinical Research Coordinator for the Trichotillomania Clinic in the OCD & Related Disorders Program at Massachusetts General Hospital
Fiona Dang	Unknown
Adam Datema	Hoping to work in scouting in the NFL
Cathleen Donohue	Unknown
Elizabeth Eades	Working in Debt Capital Markets in the investment bank at UBS
Adrienne Favis	Unknown
Qadir Forbes	Working in Finance at J.P. Morgan in the Investor Services Sales Division
Kyle Gaffney	Working in South Norwalk, CT, for the Seurat Group, a firm that provides consulting primarily for the consumer packaged goods industry
Jennifer Galaviz	Unknown
Andrea Garduno	Hoping to go into teaching elementary school
Lauren Glenn	Working at a clinic for children with autism as an ABA Therapist
Nitsan Goldstein	Working at a neuroscience lab at Massachusetts General Hospital studying the hippocampus and neurodegenerative diseases associated with aging
Jonathan Gonzalez	Unknown
Clarissa Granados	Hoping to either work in psychology research, teach the Russian language at the high school level, or teach in a middle-school setting
Adlyne Harris	Applying to graduate school for Occupational Therapy
Katherine Jolin	Attending Georgetown's Post-Baccalaureate Pre-Med Program

Aaron Jordan	Attending dental school at NYU
Caroline C. Kaufman	Attending the University of Memphis for my Ph.D. in Clinical Psychology
Michaela Kearney	Continuing my studies to become a psychiatric APRN
Joseph Kilcullen	Working as a Clinical Research Coordinator in the Psychiatry Department at Massachusetts General Hospital, assisting Dr. Gagan Joshi with several of his Autism Spectrum Disorder research studies
Haley Ladd-Luthringshauser	Interviewing with various non-profits organizations in Boston and considering pursuing a career in nutrition in the future
Hanna Lee	Unknown
Jacqueline E. Lee	Unknown
Victoria Lippman	Hoping to attend law school the year after next
Jessamyn Lockard	Hoping to do social psychology research
Minica Long	Looking into Research Assistant jobs in clinical and developmental psychology, biology, or chemical research labs
Daniel Loughran	Working as an Associate Consultant at Oracle in Reston, Virginia
Alison Magruder	Working for Morgan Stanley's Global Capital Markets division in New York
Tyler Mallery	Unknown
Joseph Mallock	Working as a product manager at MBI Inc., a marketing company in Norwalk, CT
Melissa Martinez	Unknown
Tanzim Milkey	Working as a Marketing Manager in Stamford, CT, for MBI Inc.
Claire Miller	Working at ESPN's offices in New York City in their marketing department as a NFL Marketing Coordinator
Marilisande Montes De Oca	For the summer, I will be a bunk leader at Camp Ramapo (a camp for children with cognitive and behavioral challenges). Afterwards, I hope to do research for a couple of years before applying to graduate school.
Matthew Muralles	Unknown
Emily O'Day	Working as a research assistant at Mass General Hospital's Center for Anxiety and Traumatic Stress Disorders (CATSD)
Abra Owens	Pursuing a job at an Ecommerce startup company
Ashini Patel	Joining the Parthenon Group, a business strategy consulting firm based in Boston, and working out of their New York office
Alina Penny	Unknown
Amber Penny	Unknown
Maria Pylypiv	Unknown
Raea Rasmussen	Working with Professor Nate Kornell doing cognitive educational research
David Rodriguez Lenge	Attending Montclair State University’s Speech-Language Pathology Program
Erik Romano	Looking into teaching positions as well as volunteering with Food Corps
Emalie Rott	Attending the University of Tulsa College of Law to receive my J.D. as well as a joint masters degree in Clinical Psychology

Amanda Schott	Working on cerebellar movement disorders as a research assistant at Albert Einstein College of Medicine in NYC
Ali Tafreshi	Attending Medical School at the University of Southern California
Sara Thompson	Unknown
Sarah Thompson	Working as a Project Lead for MetLife in Denver, CO
Hana Tomozawa	Working in finance in New York and hoping to get my Masters in Education in a few years
Samantha Troia	Unknown
Kelly Wall	Hoping to work at a non-profit organization while volunteering at a research lab in New York City
Lilly Wellenbach	Unknown

Miller House, which houses the Social Psycology Research Center, is being prepared for a move to another loaction to make room for the new science center. Construction is expected to begin in summer 2016. Siskind House was demolished for the project during the summer of 2015.

Abstracts from Student Theses

Biology

A High-Fat Alternate Day Fasting Diet in Mice Imparts Fluctuating Glucose Tolerance due to Changes in Insulin Production and Gene Expression

Rebecca Bell

A high-fat alternate day fasting diet (ADF) is capable of inducing significant weight loss and beneficial metabolic changes in diet-induced obese mice. The present study demonstrates the decreased body weight, improved glucose tolerance, insulin signaling, and expression of glucokinase (GK), angiopoietin-like 4 (Angptl4), and insulin-like growth factor binding-protein 1 (IGFBP1) in high-fat male C57BL/6J mice placed on an ADF diet for ten weeks. After maintaining 31 male C57BL/6J mice on a 60% high-fat diet for five weeks, the mice were randomized to either an ad libitum high-fat (5.3kcal/g) diet group (HF-Fed), or a high-fat ADF diet group. These diet regimens were compared to a group of 12 C57BL/6J mice fed a normal lab chow diet consisting of 3.7kcal/g (Chow-Fed). This study further investigated the relative impaired glucose tolerance of the mice on an ad libitum feeding day as compared to a fasted day on the ADF diet. When injected simultaneously with insulin (0.75U insulin per kg body weight), glucose tolerance in fasted mice was improved relative to the ADF mice on a fed day**.** ADF mice on a fasted day also trended towards demonstrating reduced circulating plasma insulin levels. Collectively, these results suggest that the impaired glucose tolerance in ADF mice on a fasted day is due to decreased insulin production.

This study also followed the effects of an ad libitum high-fat feeding period following the ten-week ADF diet regimen. After a nine-week "refeeding" period, the body weights, glucose tolerance, insulin production, and hepatic gene expression of the ADF mice were almost completely deteriorated to a state similar to mice fed an ad libitum high-fat diet for the entirety of the study. This result suggests that the benefits of the ADF diet are temporary and specific to the time period spent on the diet.

CRISPR/cas9 Mediated Knock Down of *hspb7* in Zebrafish (*Danio rerio)*

Christie Black

In previous studies, morpholino knockdown of *hspb7* expression in zebrafish resulted in heart laterality defects and randomized heart jogging. However, it has been shown that morpholinos can generate off target effects, especially in the cardiovascular system. Consequently, there has been an increasing need to explore alternative methods of *hspb7* knockdown in zebrafish, such as the CRISPR/cas9 system. CRISPR is a microbial adaptive immune response that uses single guide RNA (sgRNA) to direct the Cas9 nuclease to specific locations in the genome for cleavage. sgRNA can target any 20 base pair sequence that is adjacent to a protospacer adjacent motif (PAM) sequence. Here, we used the web tool CHOPCHOP to generate optimal target sites for sgRNA design. The target sites used for this study were in sequences 250 and 286 in exon 1, sequence 1331 in intron 1, and sequences 1706 and 1854 in the 5' untranslated regions (UTR) regions. We initially followed the Gagnon et al. (2014) method of sgRNA generation, whereas a gene-specific oligonucleotide containing the target sequence is annealed to a constant oligonucleotide and then transcribed into the sgRNA. However, their method of sgRNA generation proved to be problematic, specifically in the oligonucleotide-annealing step. The oligonucleotides only annealed successfully through conventional PCR methods with taq polymerase. Following the generation of sgRNA, it was co-injected along with Cas9 into 1-4 cell staged zebrafish embryos for the *in vivo* assay. DNA extracted from these embryos and analyzed through restriction enzyme digestion revealed that no mutagenesis occurred. There was also no evidence of mutagenesis in DNA from the *in vitro* Cas9/sgRNA cleavage assay. Subsequent experiments with cas9 mRNA is required to determine if the lack of DNA editing is due to poorly designed sgRNA or a nonfunctional Cas9 protein.

Central Adenosine A1 Receptor Activation Does Not Induce Torpor in Mice

Ethan Borre

Mice enter bouts of daily torpor, drastically reducing metabolic rate, core body temperature, heart rate, and locomotor activity in response to reduced caloric intake and cool ambient temperatures. It is believed that a central signaling molecule initiates the torpor pathway and many researchers have recently pointed to adenosine as a candidate. We hypothesized that activation of the A_1 adenosine receptors would induce torpor in mice. To test this hypothesis, C57BL/6 mice were implanted with T_b/ECG telemeters as well as cannulas to the lateral ventricle. While measuring physiological parameters, the animals underwent either a vehicle injection, an injection of the selective A_1 receptor agonist N^6cyclohexyl adenosine (CHA), or caloric restriction (CR) to instigate spontaneous entry into torpor. Body temperature (T_b) and heart rate (HR) fell in response to both CR and injection of CHA, with no difference in minimum T_b. T_b fell more rapidly in the CHA condition (M=-0.13°C/min ± 0.06) than CR (M= -0.09°C/min ± 0.02, $p<0.05$). During descent, HR is lower in the CR condition at 30°C (M=210bpm ± 40) than CHA (M=465bpm ± 32, $p<0.05$). Quantification of the area between the descent and recovery curves on a graph of HRvT_b revealed blunted hysteresis in the CHA condition (M=441bpm•°C ± 386) as compared to CR (M=2394bpm•°C ± 154, $p<0.05$). There was no significant difference between the frequency of asystoles observed between the CHA and CR condition. Analysis of the normalized standard deviation of the interbeat interval (sdIBI) showed less variance in descent during the CHA condition (M=0.016=± 0.0093) than CR (M=0.11 ± 0.03, $p<0.05$), indicating increased sympathetic nervous system (SNS) activity during the CHA condition. Lastly, a comparison of lactate levels during the hypothermic bout revealed no significant difference between the CHA and CR condition. We conclude that the CHA-induced hypothermia and natural torpor are different physiological states.

Agrobacterium tumefaciens T6SS Upregulates the *Arabidopsis thaliana* Negative Regulator WRKY62 to Dampen Host Defenses in the Seedling Apoplast

Achala Chittor

The plant pathogen *Agrobacterium tumefaciens* causes Crown Gall Disease. In other bacterial species, the recently discovered type VI secretion system (T6SS) releases effectors that act as toxins in inter- and intra-bacterial competition and subvert host defenses. To explore the contribution of the T6SS to *A. tumefaciens* pathogenesis, we examined the effect of the T6SS on plant defense gene expression in *Arabidopsis thaliana* seedlings. We found that, in *efr-* plants, which lack the primary receptor for *Agrobacterium* detection, the T6SS triggers the expression of early defense-related genes such as FRK1 and GST1, and this was most effective in 11 to 13 day old seedlings. In contrast, the T6SS dampens defenses in wild-type Col-0 seedlings, possibly by activating an inhibitor of plant defenses in *A. thaliana* known as WRKY62. The T6SS triggering and dampening of defenses were greater with the force of suction infiltration, suggesting that T6SS effects occur in the apoplast once the bacterium has breached the host cell physical barriers. These data validate and optimize the seedling infection model, which we hope to employ in a mutant screen to identify the host receptor responsible for detecting the bacterial T6SS.

Evaluation of 3-4 Diaryl Pyazoles as Inhibitors of Cell Growth in *Caulobacter crescentus*

Rebecca Dryer

With the rise of antibiotic resistance in combination with a decrease in research and resources dedicated to the field of antibiotic study, it is pertinent now more than ever to develop novel antibiotics. A promising target of new antibiotics is the histidine kinase, a molecule essential for functioning two-component systems in bacteria. Specifically, we are interested in inhibiting CckA, a histidine kinase in freshwater bacteria *Caulobacter crescentus* that mediates cell division via the CckA/CtrA two-component pathway. *Caulobacter* and CckA provide a model system on which to study pharmacological inhibition.

BlairLab has successfully identified a small molecule inhibitor of CckA through testing known inhibitors of Hsp90, a molecular chaperone that has similar catalytic and ATP-binding domains to CckA. This small molecule, CCT 018159, was formed into a scaffold from which to derivatize new compounds. As new compounds are synthesized, we have continually assessed their relative potency to elucidate chemical and structural features that are most important in inhibition. I have taken the 3-4 diaryl pyrazole compounds synthesized in BlairLab and put them in a biological context to confirm they do have an effect on *Caulobacter* cell growth rate and cell

size. My work has prepared the lab to go forward with continued biological analyses of developed compounds to reach our end goal of verifying the histidine kinase as a new target for pharmacological inhibition in antibiotic development.

Physiologic Responses To Stable And Dynamic Light Environments In Prochlorococcus

Emily Gaddis

Prochlorococcus is a photosynthetic prokaryote that numerically dominates the open oceans in subtropical and tropical regions, and is a key contributor to global biogeochemical cycles (Johnson et al., 2006, Ting 2014). We hypothesized that *Prochlorococcus* has evolved distinct, genome-based photosynthetic strategies and responses to environmental stress that allow ecotypes to acclimate to specific environmental niches. In particular, we hypothesize that *Prochlorococcus* strains have evolved dissimilar strategies for acclimating to stable and fluctuating irradiance levels.

Two strains of *Prochlorococcus*, MED4 and MIT9313, were grown at 20 μmol photons $m^{-2}s^{-1}$ and 2 μmol photons $m^{-2}s^{-1}$. Growth rates, photosynthetic pigment concentrations, and cell densities were characterized at these irradiance levels. Light shift experiments were also performed by shifting cultures that were acclimated to these irradiance levels (2 and 20 μmol photons $m^{-2}s^{-1}$) to higher irradiance levels (20 and 100 μmol photons $m^{-2}s^{-1}$, respectively).

We found that *Prochlorococcus* strains differ in their ability to acclimate to changes in irradiance levels, both in the short and long term. MIT9313 thrives at very low and moderate irradiance levels, but can also survive at least 10 fold changes in irradiance levels on short (24 hour) time scales. MED4, however, cannot sustain growth at very low irradiance levels (2 μmol photons m^{-2} s^{-1}), but can sustain growth at higher (100 μmol photons $m^{-2}s^{-1}$) irradiances. These differences in physiological responses to irradiance levels are likely due to dissimilarities in the molecular mechanisms of key processes, including photosynthetic and stress responses.

The Effects of H3K9 methylation on Transcriptional Regulation in *S. cerevisiae*

Amir Hay

Histone tail modifications are epigenetic marks correlated with specific transcriptional regulatory outcomes. However, it is unclear whether they are sufficient to induce the changes with which they are associated, and furthermore, whether they are transgenerationally epigenetically inherited. Here we use H3K9 methylation, a histone modification associated with transcriptional repression, as a model to suggest that histone modifications are capable of inducing transcriptional regulatory changes. To evaluate whether H3K9 methylation is sufficient to induce transcriptional repression, we created and induced an artificial (CRISPR)-Cas9 H3K9 methylation system to target Green Fluorescent Protein (GFP) in various GFP-tagged strains of *Saccharomyces Cerevisiae*. Through flow cytometry fluorescence analysis we obtained results that are indicative of H3K9 methylation induced transcriptional repression. This indication more generally implies the possibility of histone modification regulated transcription, as well as potential for transgenerational epigenetic inheritance.

AgRP Neuron Stimulation During Wakefulness Decreases REM Sleep During Subsequent Sleep

Nitsan Goldstein

The hypothalamus is a region in the brain that controls many homeostatic functions such as body temperature, thirst, and hunger. A specific region in the hypothalamus called the arcuate nucleus is responsible for controlling food intake. Neurons in the arcuate nucleus that express the neuropeptide agouti-related peptide (AgRP neurons) cause an increase in food intake. Previous research indicates that the nutritional state of an animal can have an impact on parameters of sleep and wakefulness, however, the degree to which activity in AgRP neurons affects sleep is unknown. We asked whether AgRP neuron stimulation during wakefulness affects sleep architecture during subsequent sleep. Using optogenetic stimulation and electroencephalography (EEG), we stimulated AgRP neurons during the last hour of the active period and then recorded sleep patterns during the onset of the inactive period. We hypothesized that AgRP neuron stimulation would cause maladaptive changes in sleep architecture regardless of actual food intake. Our results support this hypothesis: AgRP neuron stimulation decreased REM sleep, increased NREM sleep, and decreased transitions between sleep states, indepen-

dent of food consumption. These results suggest that activation of the hunger pathway disrupts transitions into REM sleep and elongates bouts of NREM sleep. Because REM sleep is primarily involved in the consolidation of declarative and emotional memories, these findings may have clinical implications for learning and memory.

Characterization of the Retinoic Acid Receptor in Central Nervous System Development of *Helobdella robusta*

Michelle Higgins

The molecular and cellular bases of developmental mechanisms operating in annelids are poorly understood currently. Prior studies in vertebrates implicate a developmental regulatory molecule, the Retinoic Acid Receptor (RAR), in central nervous system patterning. RAR specifically acts in cell fate specification of neuronal precursors and establishment of cell fates along the Anterior-Posterior axis in vertebrates. However, very little is known about the role of RAR in invertebrates. This thesis completed sequence comparative analysis and a detailed characterization of the expression patterns of RAR and its gene products in the developing central nervous system of the annelid *Helobdella robusta*. In the sequence comparison studies, the high amino acid sequence identity shared between diverse phyla suggests that RAR has retained its biochemical function in annelids. However, the data gathered here suggests that the ligand binding to RAR in mollusks and annelids is not retinoic acid, as it is in vertebrates. In the whole mount *in situ* studies in leech embryos, I discovered two transient, anterior-to-posterior waves of RAR expression in the CNS. The first wave coincides with when neuronal precursors migrate to the midline, and the second wave occurs with gangliogenesis. Overall, this data suggest that RAR function may play a similar role in CNS specification in both protostomes and deuterostomes, as they share a similar anterior-posterior progression of expression. These results provide the opportunity to infer the role of RAR and its gene products in the developing nervous system of invertebrates.

A Capacity for Change: A Genomic and Physiological Study of the Effects of Light on the Marine Cyanobacterium *Prochlorococcus*"

Elissa Hult

The marine cyanobacterium, *Prochlorococcus,* is thought to be the most abundant photosynthetic organism in the ocean and presumably on Earth (Partensky et al., 1999). As a prokaryotic organism found ubiquitously throughout the epipelagic zone of the tropical and subtropical oceans, Prochlorococcus ecotypes display different structural, physiological, and genetic characteristics, allowing for survival in varied light habitats within the dynamic ocean environment.

In this study, we test the abilities of *Prochlorococcus* strains MIT9312 and SS120 (representing eMIT9312 and eSS120, respectively) to grow under a range of irradiance levels between 2 μmol photons m^{-2} sec^{-1} and 40 μmol photons m^{-2} sec^{-1}. Fluorescence measurements and cell counts were used to unearth patterns in cell growth and maximum cell densities, and concentrations of the photosynthetic pigment, Chlorophyll *a*, were also measured in order to determine the effects of light irradiance on the photosynthetic apparatus of these Prochlorococcus strains. In general, the data show that doubling rates and average concentrations of Chlorophyll *a* decrease with increasing light intensity in MIT9312 and in SS120. Because the ocean is characterized in part by the strong physical mixing of the water column that occurs as a result of currents, tides, and particularly seasonal weather patterns, we also spent significant time investigating the ability of MIT9312 and SS120 to acclimate to rapid shifts in light irradiance. Cultures of both MIT9312 and SS120 were subjected to changes in light shifts from 2 to 25 μmol photons m^{-2} sec^{-1}, 40 to 2 μmol photons m^{-2} sec^{-1}, and 2 to 25 to 2 μmol photons m^{-2} sec^{-1}. Notably, only MIT9312 was able to adequately acclimate and continue growth at the new light condition when moved from a low to high light condition, however, both MIT9312 and SS120 were able to acclimate when moved from a high to low light irradiance.

In addition to physiological studies of *Prochlorococcus*, part of this thesis was devoted to understanding the underlying genetic components of the cyanobacterial stress response. The presence, orientation, and overall sequence similarity of the multi-stress associated regulatory sequence (MARS) element was investigated across seven strains of Prochlorococcus (Sato et al., 2007). Interestingly, the element was highly conserved across strains upstream of Hsps dnaK2, groEL2, and groES, but was not present in any of the strains upstream of

dnaK1, dnaK3, or groEL1.

Overall, different isolates of *Prochlorococcus* have evolved unique mechanisms for dealing with stable and fluctuating light environments. Results from our light shift experiments clearly suggest that isolates of *Prochlorococcus* have varying abilities to acclimate to changes in their light environments. Future work will address the molecular mechanisms underlying these physiological responses in the world's most ubiquitous cyanobacterium, *Prochlorococcus*.

The Influence of Land Management Practices on the Abundance and Diversity of Fall-Blooming Asteraceae and Their Pollinators

Julie Jung

Fall blooming Asteraceae provide an important resource for overwintering pollinators, yet field species are increasingly rare because of reforestation and changes in land-use practices (Foster and Aber 2004). Here we test the impact of mowing schedules on the abundance and diversity of flowers and their pollinators. Four mowing treatments- early annual (EA), early biennial (EB), late annual (LA), and late biennial (LB)- were randomly assigned to blocks of four plots, grouped by similarity in location and vegetation. Conducted plant surveys of the inner quadrats of each plot show that early mowing results in significantly fewer flowering stems, smaller patches, and shorter plants. Simultaneously filmed stems of *Solidago rugosa* show that early mowing yields significantly fewer insect visitors (N), fewer species attracted (S), and lower diversity (H') of insect visitors. These data indicate that delaying mowing until October is an effective and feasible land management strategy that would yield significantly more floral resources, more pollinator abundance, and higher diversity of insect visitors.

Development of a System to Investigate the Functional Role of Satellite 2 RNA

Diana Daeun Kang

Satellite DNA is short high tandem repeated DNA located in centric and pericentric regions of multiple human chromosomes. Satellite heterochromatin constitutes around 10% of the human genome, whereas protein-coding regions only constitute roughly 2% of the entire genome. Although it is thought that Satellite RNA has little function, previous findings indicate that Satellite RNA levels are markedly increased when cells are induced to stress, suggesting they may have a potential functional role. More relevant to my thesis, human Satellite 2 RNA is expressed exclusively in cancer and accumulates as distinct bodies. RNA bodies usually consist of aberrantly high copy number of RNA bound to specific proteins. Preliminary results suggest that MeCP2 (Methyl-CpG-binding Proteins 2) is recruited to and co-localizes with Sat2 RNA bodies. These findings indicate a possible functional role of Satellite RNA in cancer. To investigate whether Satellite RNA has a specific function, I will transfect non-Sat2 expressing HeLa and Tig-1 primary fibroblasts with a Sat2 expression construct. The transfected cells will be analyzed by RNA FISH to detect whether Sat2 RNA bodies form, and MeCP2 antibody staining to assess differences in distribution. My findings suggest that HeLa cells are more permissive to transfection than Tig-1 primary fibroblasts. Transiently transfected HeLa cells even displayed distinct Sat2 RNA bodies that resembled Sat2 RNA bodies found in U2OS cell line, which endogenously expresses Sat2 RNA bodies. Along with Sat2 RNA bodies, the chromatin of transfected cells exhibited abnormal distributions that were markedly different than HeLa cells that were not transfected with Sat2. However, upon creation of a stable Sat2 expressing HeLa cells, there were no detectable Sat2 RNA bodies. This indicates that long-term Satellite 2 RNA expression and accumulation might be unstable for the viability of the cell, leading to silencing of Sat2.

AgRP Neuron Stimulation During Sleep Increases Sleep Fragmentation and Decreases REM Sleep

Kelsey Loy

Sleep quality is important for many physiological processes, including learning and memory. Therefore, it is important to know about factors that can improve or impair sleep quality. One factor that may impact sleep quality is the degree to which an animal is hungry or motivated to seek food. There are several known physiological relationships between food intake circuitry and sleep circuitry, including common hormones and neuropeptides. Despite these connections, the effects of food intake and hunger on sleep quality have yet to be elucidated.

Agouti-related peptide (AgRP) neurons, found in the arcuate nucleus of the hypothalamus, are known to induce feeding behavior. Therefore, AgRP stimulation, combined with recordings of cortical activity during sleep, provides us the opportunity to learn about how hunger affects sleep quality. The aim of this research project was to examine the effects of activating food intake circuitry during sleep on sleep architecture. We hypothesized that stimulating AgRP neurons would cause an increase in sleep fragmentation.

We found that optogenetic stimulation of AgRP neurons is sufficient to cause a reduction in sleep-to-wake latency, as well as an increase in the total number of transitions between sleep and wake states during the stimulation. Increased AgRP neuronal activity also suppresses transitions from non-rapid eye movement (NREM) sleep to REM sleep, and consequently increases episodes of wake at the expense of REM sleep. Because AgRP stimulation causes a deficit in REM sleep, an interesting future direction would be to assess the effects of AgRP stimulation during sleep on learning and memory function.

Sequence Data from *Gryllus* System Provides No Evidence for Genomic Islands or Role of Genomic Architecture in Speciation with Gene Flow

James Marvel-Coen

The genomic islands hypothesis provides a model for how speciation with gene flow could occur (*1*). Further theory and evidence in rabbits suggests that genomic architecture, and particularly location on the X chromosome, may contribute to heterogeneous levels of differentiation between sites (*2*). However, the genomic islands hypothesis has recently come under attack: Cruickshank and Hahn (2014) suggest that islands are unlikely to occur in nature and that relative measures of divergence should not be used to identify them, suggesting that absolute measures should be used instead (*3*). In this study, we selected 83 loci with known introgression levels in hybrid zones of *Gryllus firmus* and *Gryllus pennsylvanicus* (*4*, *5*). We sequenced these loci in 98 individuals from six pure populations of *G. firmus* and *G. pennsylvanicus* and then calculated d_{xy} between species for each locus. We did not find any evidence that introgression in hybrid zones or chromosomal location were related to differentiation between non-hybridizing populations. While this may provide evidence against the genomic islands hypothesis, there are several possible alternative explanations. Given that we used only sites that had fixed or nearly fixed differences between allopatric populations, it is possible that all of the sites we studied were on genomic islands. It is also possible that we only sampled sites linked to barrier genes, rather than the barrier genes themselves, and that if we used actual barrier genes we might find evidence for increased differentiation at those sites.

Spatio-Temporal Variation in the Benefits of Ant Tending in an Ant-Homopteran System

Alexandra McInturf

Mutualisms are highly context-dependent interactions. In the ant-treehopper mutualism that we studied, ants provide both a direct and indirect benefit to treehoppers in exchange for honeydew. Because these benefits are density-dependent, they can shape the population dynamics of the system. In this study, we used a Bayesian state-space approach to determine the factors that drive spatial and temporal variation in treehopper survivorship. We conclude that predation intensity and density-dependent predator protection by ants exert the most influence on shaping the functional form of the mutualism.

Retrograded Starches (RS3) Lower Body Weight and Improve Insulin Resistance in Diet Induced Obese C57BL/6J Mice

Dianna Mejia

The effects of three types of resistant starches, RS2, RS3, and RS4, on body weight, caloric absorption, and insulin resistance were studied. Thirty-two weight- and age- matched C57BL/6J male mice were fed a high fat diet (60% energy in fat) until they showed impaired glucose clearance when injected with insulin, indicating insulin resistance, when compared to a control group of mice fed standard chow. After 19 weeks of the preparatory diets, the mice were split into three experimental diets supplemented with RS (HF + RS2, HF + RS3, and HF + RS4) and a second control group which continued the high fat diet. After 6 weeks of the experimental diets the

HF + RS3 mice showed improvement in blood glucose clearance, and after 11 weeks matched the blood glucose clearance to that of the chow fed mice. At the end of the 12 week experimental feeding, the HF + RS3 group had a net body weight loss compared to the other experimental diet and high fat fed groups. Bomb calorimetry of food and fecal samples from all groups showed no significant difference in caloric consumption but mice fed the RS supplements had significant difference in calories eliminated through fecal waste compared to the high fat fed group. The HF + RS3 group closely matched the amount of calories eliminated by the chow fed mice. ELISA analysis of plasma samples harvested at sacrifice, showed that the HF + RS3 group helped correct the hyperinsulinemia present in the other experimental and high fat fed groups. Leptin concentration was significantly elevated for all experimental and high fat fed groups. RS3 addition to a high fat diet lowers body weight, likely through decreased caloric absorption, which is associated with increased insulin sensitivity.

A New Model for the Splash-Cup Dispersal Mechanism in the Liverwort *Marchantia*

Adrian Mitchell

Liverworts were the first plants to colonize land, 400 MYA. They are non-vascular plants which can reproduce both sexually and asexually. In *Marchantia polymorpha*, asexual reproduction occurs by the raindrop-powered dispersal of gemmae. Gemmae develop in gemmae cups from which they are splashed to distances of greater than 1m. Here, we examine the morphology of gemmae and gemmae cups. We also use high-speed video of splashes on machined model gemmae cups to elucidate the mechanism of splash cup dispersal and to investigate the adaptation of gemmae cups to splash dispersal. We propose a new model in which the first raindrop impact 'primes' the cup, freeing gemmae for dispersal, and subsequent impacts splash the gemmae out of the cup.

Analysis of SOS System Inhibitors: A Search for Molecules that Could Block the Development of Antibiotic Resistance

Oladeji Odewade

Using a high throughput *in vitro* assay we screened a library of bioactive compounds for inhibitors of the bacterial SOS system, which has been implicated in the development of antibiotic resistance. The SOS system is an inducible DNA repair network that includes an error- prone DNA repair mechanism in which DNA polymerases with relaxed fidelity contribute to a high level of mutagenesis. Recent evidence showing that many antibiotics, including those that do not damage DNA, activate the SOS response suggests that using inhibitors of SOS induction during antibiotic treatment of bacterial infections could be an effective means of combatting the development of resistance. Because the regulation of the SOS system has been highly conserved among the bacterial kingdom, our assays focus on inhibitors of the RecA-mediated cleavage of the LexA repressor that causes the derepression of SOS genes during the onset of the SOS response. In this study, we screened about 5000 compounds and found three inhibitors in addition to eleven inhibitors previously identified in the Lovett laboratory. To ensure that the inhibitors would be effective against a wide range of bacterial species, we performed *in vitro* assays using RecA and LexA protein from *Escherichia coli* and *in vivo* assays in the distantly related *Bacillus subtilis*. We found that all compounds that were identified in the *in vitro* screen also inhibited SOS induction in *Bacillus subtilis* cells. I report here the IC50 values from the *in vivo* assays of the three newly identified inhibitors as well as two of the previously identified inhibitors.

Endosomal Immune Sensing: Toll-like Receptor 13

Gwendolyn Schultz

Toll-like receptors (TLRs) are important sensors of the innate immune system, which is the first line of defense against microbial infection in animals. The location of a given TLR within a cell can have particular consequences for both activation of the receptor as well as downstream signaling events. TLR11, TLR12, and TLR13 are closely related endosomal TLRs that recognize inner components of pathogenic microbes. For instance, TLR13 has been shown to recognize bacterial rRNA, and TLR11 and TLR12 have been shown to act as a homodimer to recognize the cytoplasmic protein profilin. Although these three TLRs are not found in humans, understanding their trafficking pathways can give us valuable information pertinent to human TLRs. In this study, we found that TLR13 is localized to lysosomes, a finding that is logical given the nucleic acid ligand of TLR13. We also did preliminary experiments into the localization of TLR11 and TLR12, which do not appear to strongly localize to

the lysosome. The differences in localization and receptor function are an intriguing look into the tight control of TLR localization and the overall complexity of the innate immune system.

Early Life Stress and the Development of the HPA Axis

Anuj Shah

Chronic early life stress (ELS) can cause dysfunctional development of the hypothalamic-pituitary-adrenal (HPA) axis, predisposing individuals to pathological responses to subsequent stressors. Indeed, exposure to ELS has repeatedly been linked to the onset of various stress-related disorders, such as depression, anxiety, and post-traumatic stress disorder. Many studies have elucidated interactions between environmental stressors and genetic polymorphisms implicated in these disorders. However, there is little evidence describing specific genes that reprogram stress reactivity in response to chronic or intensified stress in early life. Therefore, the aim of the current study was to seek a viable experimental model for studying HPA axis reprogramming, and to determine the differential expression of HPA axis-related genes underlying the early development of healthy and pathological responses to stress. We used a previously proposed drug treatment paradigm, which demonstrated that a single dose of dexamethasone (DEX) at embryonic day 4 induced lifelong changes in anxiety-like behavior in zebrafish. Surprisingly, we found that DEX-treated fish exhibited less anxiety than control fish, suggesting that this model may not be suitable for studying the effects of ELS. At the genetic level, we found that *fkbp5*, *11βhsd2*, and *nr1I2* are up-regulated at 5 days post-fertilization (dpf) in response to DEX treatment at 4 dpf. The previous study also demonstrated that caffeine pretreatment prevented the behavioral changes induced by DEX. In our hands, caffeine pretreatment attenuates the increase in *fkbp5* expression, and fluoxetine, a selective serotonin reuptake inhibitor (SSRI), mitigates the DEX-induced up-regulation of all three genes. The findings presented here may contribute to the creation of a viable model to study early HPA axis reprogramming.

The Effects of AgRP Neuron Stimulation on Food Intake During Appetite Suppression

Alison Smith

Proper regulation of food intake is critical to survival and depends on a balance between activity in orexigenic and anorexigenic brain regions. The arcuate nucleus of the hypothalamus is a central hub for this regulation. In particular, a population of arcuate neurons expressing agouti-related protein (AgRP neurons), are a known to be a key orexigenic center. Optogenetic stimulation of arcuate AgRP neurons causes an increase in food intake. However, it is not known whether AgRP neuron stimulation is sufficient to evoke voracious eating behavior under conditions of appetite suppression.

In this research project, we tested the hypothesis that stimulation of AgRP neurons would be sufficient to increase food intake during pharmacologically-induced appetite suppression. We injected mice intraperitoneally with amylin, cholecystokinin, and lithium chloride to generate appetite-suppressing conditions, then optogenetically stimulated arcuate AgRP neurons and recorded the food intake before, during, and after the photostimulation period. As expected, AgRP neuron stimulation evoked a significant increase in food intake following the intraperitoneal injection of PBS, our negative control compound. The administration of amylin and cholecystokinin each eliminated the AgRP neuron-evoked increase in food intake, while lithium chloride attenuated but did not entirely eliminate the food intake response. These results indicate that AgRP neurons' ability to evoke voracious eating behavior is limited by exposure to appetite-suppressing conditions.

Future research should include a wider range of anorexigenic compounds and vary the concentrations of the compounds to determine the threshold dose at which each compounds' effects are overridden by AgRP neuron stimulation. We also hope to better characterize the projections from AgRP neurons to downstream brain regions involved in appetite suppression.

Toll-like receptors 7 and 9 localize to late endosomes"

Kairav Sinha

In mammals, the innate immune system is the first line of defense against foreign pathogens, and a crucial first step in that defense is the activation of pattern recognition receptors (PRRs) that recognize highly conserved molecular motifs known as pathogen-associated molecular patterns. One important class of PRR is the Toll-like

receptor (TLR); two key endosomal TLRs are TLR7, which senses viral single-stranded RNA, and TLR9, which senses DNA with CpG motifs. Because TLR7 and TLR9 recognition of nucleic acids is largely sequence-independent, these receptors can be activated by self-RNA and -DNA, which can result in autoimmunity. Consequently, a network of mechanisms exists to regulate TLR7 and TLR9 sensing, including the fact that the sensing domain of the TLR is localized to and activated within endosomes, so the TLR senses exogenous nucleic acids from degraded pathogens rather than extracellular self nucleic acid. Using biochemical fractionation and immunofluorescence, my thesis establishes that in steady-state mouse macrophages, TLR7 and TLR9 both localize primarily to late endosomes; co-localizing and co-fractionating with the late endosomal marker Lamp1. Additionally, both TLR7 and TLR9 co-localize with each other in the same endosomes and exhibit very similar fractionation patterns. Finally, both TLR7 and TLR9 do not exhibit co-localization with early endosomal markers EEA1, Rab5, Appl, or Vamp3. These results have implications for the designs of drugs and vaccines that seek to exploit TLR signaling, since those therapeutics can be more precisely targeted to their subcellular compartments, having a greater impact on the immune response.

Sagina nodosa on Isle Royale,MI: Shifting Genetic Structure and Demography in a Changing Cimate

Alice Stears

In the context of accelerating anthropogenic climate change, it is becoming increasingly important to understand the effects of these changes on biological populations. This information will contribute to more effective conservation and mitigation efforts now and in the future. In this study, we examine the effect of climate change on a sub-structured population of the arctic perennial herb *Sagina nodosa* var. *borealis* in Northeastern Isle Royale National Park, MI, USA. Because this population exists at the southern-most extreme of the species range, it is already subject to significant climate-induced stress. As a result, we hypothesized that these populations will be highly sensitive to further climate change. To determine the response of *S. nodosa* to both long-term and inter-annual changes in climate, we used population size and fitness data collected at seven sub-populations as part of a long-term monitoring project (1999-2014), in conjunction with microsatellite genotypic data collected from 324 individual plants at 14 sites. We found that population size decreased in a majority of sub-populations over the course of the study, and all sub-populations have been declining consistently in size since 2011. This decline is consistent with long-term trends of local climate change. However, there has been no corresponding overall shift if population reproductive output. Changes in these population demographic data do not track annual changes in measured climate parameters, indicating that *S. nodosa* population decline is driven by minor fitness costs accumulated over a plant's lifespan. Our genetic analysis supports the hypothesis that this population is highly structured by island, with very low gene flow between sub-populations. Further analysis is required to fully characterize the changes in genetic landscape over time. Overall, our analyses indicate that *S. nodosa* populations on Isle Royale are adversely affected by changing climate.

Chaos from Order: Dopamine Receptors Modulate Syntax Variability in Zebra Finch Song

Gabriel Stephens

The striatum, as part of the basal ganglia, is essential for the production of ordered motor sequences, and disorders of the basal ganglia and its inputs result in movement disorders such as Parkinson's and Huntington's disease in humans. Dopamine (DA) inputs to the striatum activate two DA receptor subtypes (D1 and D2). Lower DA concentrations preferentially activate D1 receptors, and higher concentrations activate D2 receptors. D1 receptor activation increases the firing rate of striatal neurons and D2 receptor activation decreases their firing rate. I propose that the ratio of D1:D2 receptor activation determines the firing rate of striatal neurons and thereby mediates striatal motor sequencing. To test this hypothesis, I measured changes in the order of zebra finch song syllables (syntax variability) by infusing dopamine receptor antagonists into Area X, the portion of the striatum associated with the neural circuit for song. Treatment with a D2 receptor antagonist, which shifted the D1:D2 activation ratio towards D1 receptor activity, reduced song "linearity" (the extent to which a syllable sequences follow the same path through the song), and increased syntax variability by introducing new syllables and syllable-to-syllable transitions. Treatment with a D1 receptor antagonist reversed these effects. Thus, as predicted, changes in the D1/D2 receptor activation ratio modulate zebra finch song syntax, suggesting that

relative activity of these two dopamine receptors may also act in the striatum to regulate motor sequencing in other contexts and organisms.

The Modulation of Salicylic-Acid Accumulation in *Arabidopsis* thaliana By *Agrobacterium tumefaciens*

Adrienne Strait

Salicylic acid (SA) is a key signal molecule that regulates plant defenses in response to pathogen attack. Despite its fundamental role in conferring long-term resistance to pathogens, little is known about the way in which SA influences *A. tumefaciens* infection. By monitoring SA levels at different time points during *A. tumefaciens* infection, we hoped to elucidate how this pathogen subverts defenses in host *Arabidopsis thaliana*, and in particular, to investigate the potential role of the *A. tumefaciens* Type VI Secretion System (T6SS) in modulating SA accumulation. We determined that that the ability of *A. tumefaciens* to alter SA content was most apparent in 6 week-old plants at 24 hours after a morning inoculation. This ability seemed to be T6SS-dependent. However, the differences in the SA responses between mock-infected and the *A. tumefaciens*-infected host tissue were never statistically significant, suggesting that this pathogen has evolved to avoid triggering this line of defense within the examined infection window of 2hpi to 48hpi.

A second component of this study attempts to elucidate how the function of the T6SS intersects with the pathways regulating pathogen attachment to host tissues and biofilm formation. Since the unipolar polysaccharide UPP mediates the initial bacterial surface attachment that leads to biofilm formation, we hypothesized that over-expressing *avmA*, proposed to be a negative regulator of UPP, might alter the aberrantly high biofilm that forms in the T6SS mutant. Our results show that overproducing the diguanylate cyclase AvmA does not affect the amount of biofilm formed by the WT or T6SS mutant *A. tumefaciens*, but does alter the morphology of the biofilm.

Developing Molecular Markers for endangered arctic plant *Tofieldia pusilla*

Daniela Zarate

Tofieldia pusilla is a small, herbaceous perennial dicot, an arctic-alpine flowering plant in the family *Liliacae.* It is commonly known as the Scottish False Asphodel and its geographic range extends over much of Canada and parts of northern Eurasia. Disjunct populations, interpreted to be remnants of southern refugia throughout the last great glaciation of the Quaternary period, exist in the northern United States. In the states of Michigan and Minnesota, *T. pusilla* is listed as a threatened or endangered species, respectively. The need of *T. pusilla* for a cool, moist habitat is concerning in the light of current anthropogenic-driven climate change and global warming which could negatively affect the fragile disjunct populations in the United States. In general, climate change is predicted to have a major impact on biodiversity and biogeography, with many species being forced to either adapt or migrate to the changing environment as they are unable to cope with changes in temperature or moisture. Understanding the evolutionary history and landscape genetics of *T. pusilla* will help inform efforts aimed at conservation for both itself and several other similar arctic-alpine species that are also being threatened by current climate changes. Here we aim to develop molecular markers in the form of polymorphic microsatellite loci that can be used to explore the genetic diversity and phylogeographic history of *T. pusilla* across its geographic distribution as well the landscape genetics of disjunct populations located in Isle Royale, Michigan.

Chemistry

Synthesis and Characterization of Gallic Acid-Functionalized Diblock Copolymer Aggregates

Dylan Barber

The state of the art of chemical treatment in cancer chemotherapy has seen vast improvement in the last seventy years since sulfur mustard used in the First World War was adopted as one of the first anti-cancer agents. However, cytotoxic cancer treatment still has poor selectivity towards the target tissue, resulting in systemic toxicity that can severely impair a patient's quality of life, as well as limiting the dose to low levels that are not always capable of fulfilling their objective. The use of nanoscale drug delivery tools with features like selective delivery and protection

of the drug payload from breakdown and excretion pathways in vivo as a potential treatment method has come to the forefront of next-generation oncological research. In this work, we design and implement a synthetic pathway for gallic acid-functionalized and non-functionalized amphiphilic diblock copolymers by RAFT polymerization. Polymers are composed of dimethyl acrylamide (DMA), comprising the hydrophilic block, and n-butyl, n-hexyl, 2-ethylhexyl, or n-dodecyl acrylate (nBA, nHA, 2EtHA, nDA, respectively) comprising the hydrophobic block. In the case of the GA-functionalized diblocks, the hydrophilic block is comprised of p(DMA) interspersed with GlyHEMA units partially-functionalized with gallic acid (GA) to give p(DMA0.83-*b*-(GA0.25)GlyHEMA0.17). In aqueous solution, these polymers self-assemble to form spherical micellar or vesicular aggregates, as observed by TEM. Critical aggregate concentrations (CAC) were measured by analysis of a fluorescent dye, and some polymers were found to have bimodal CAC plots, indicating both a critical point of initial self-assembly and a secondary critical point of structural reconfiguration. These particles are 40-210 nm in diameter in water at concentrations above their critical aggregation concentrations, as observed by DLS. Gallic acid-functionalized particles successfully demonstrate radical scavenging ability. We hope that our efforts in synthesis and characterization of gallic acid-functionalized amphiphilic diblock copolymers will lead to the eventual employment of such structures in clinical oncology.

Synthesis and Characterization of Highly Conjugated Molecules for Use in Organic Photovoltaics and Fluoride Ion Sensors

Chelsea Boydstun

Work in Park Lab has previously focused on the functionalization of highly conjugated molecules for use in organic photovoltaics and organic light-emitting devices (OLEDs). Functionalization of polycyclic aromatic hydrocarbons, including anthracene, pyrene, and perylene, as well as phenylenevinylene-based oligomers has previously been explored through the incorporation of diphenylamine as an electron donor along with bromine, formyl, nitrile, and boryldimesityl groups as electron acceptors. Synthetic work this year has focused on developing the synthesis of compounds functionalized with the benzodiazaborole electron donating group. Functionalization of monosubstituted benzene, anthracene, and perylene with benzodiazaborole variants was successful, and spectroscopic analysis by UV-Vis and fluorescence indicated a bathochromic shift of these compounds compared to their unsubstituted counterparts. Additionally, the ability of compounds functionalized with the boryldimesityl group to act as Lewis acids for several anions, with a focus on fluoride ions, was also explored. The ability of boryldimesityl-containing compounds to complex with anions was probed by UV-Vis and fluorescence spectroscopy. Upon addition of fluoride ions, most of the boryldimesityl-containing compounds showed wavelength shifts in UV-Vis absorbance and/or wavelength shifts in fluorescence, along with quenching of fluorescence intensity. In contrast, the benzodiazaborole-containing compounds showed no such effects upon addition of fluoride ions. The final areas of exploration included initial, but largely unsuccessful, development of a synthetic route to several perylene tetracarboxylic diimides as well as development and reproduction of monomers for future synthesis of perylene-containing trimers.

Polymeric Carriers for Small Molecule Antioxidant Delivery

Tamuka Chidanguro

Atom Transfer Radical Polymerization is a living radical polymerization process that produces polymers with controlled architectures, compositions and molecular weights. Central to this process is a dynamic equilibrium between dormant polymer chains and active radicals that is mediated by a transition metal complex. The ligand coordinated to the metal has been shown to affect the metal's reduction potential, complex's solubility and ability to mediate ATRP. Using two previously successful ligands for ATRP complexes as a starting point, we integrated their structural features and designed a series of four tripodal tridentate and tetradentate ligands with a pyridine-amine backbone and a fourth moiety including benzyl as control, thiophene, thiazole, and methyl-imidazole. These ligands were synthesized in good yield, complexed with copper(I) bromide and copper(II) bromide and the resulting complexes used to mediate the ATRP of styrene. All four complexes efficiently controlled the polymerization of styrene, with rate constants ranging from k_{obs} = 1.29 x 10^{-4} s^{-1} to 3.76 x10^{-4} s^{-1}. We investigated the effect of ligand structure on the complexes' structures, redox potentials and efficiencies in mediating ATRP. The complexes of the tetradentate ligands in the series mediated ATRP faster than the tridentate ligands but with less molecular weight control.

Optimization of CckA Expression and Purification for the Mechanistic Study of CckA Inhibition

Juno Cho

With the rise of antibiotic resistant bacteria strains and the decline of effective antibiotic agents, the need for new antibiotics is more urgent than ever. The two-component system, and especially the histidine kinase, provides an attractive target for novel antibiotics. In order to test the potential of histidine kinase as an antibacterial target, we have employed CckA, a histidine kinase found in Caulobacter, as our model histidine kinase system.

However, the lab has experienced some difficulty in past in successfully expressing and purifying this model system. Reported in this thesis are the steps taken in order to optimize the production of the protein and its activity. Furthermore, a mechanistic study of the CckA inhibition by CDV009 was conducted. The results of the study indicated a non-competitive inhibition of CckA by CDV009, and the implications of this finding are discussed.

In Pursuit of a Novel Anticancer Compound in Crude *Xylocarpus sp.* Extract: Bioassay-guided Fractionation and Isolation of Bioactive Components in an Indonesian Plant Extract

Dylan Griswold

An Indonesian plant extract, *Xylocarpus sp.*, supplied to us by Dr. Andria Agusta of the Indonesian Institute of Sciences (LIPI), was analyzed for its anticancer activity against the colorectal cancer cell line, Colo-205, supplied to us by Dr. Matthew Meyerson of the Dana-Farber Cancer Institute. *Xylocarpus* plant extract has already been noted for its anticancer activity against a number of colorectal cancer cell lines in previous ethnobotanical research. Isolation and purification of one component from the EtOAc fraction of *Xylocarpus* shows promise as a potential anticancer compound. While this component has not yet been fully purified or characterized, cell viability levels remain below 20% at concentrations of 100-80 μg/mL for the EtOAc fraction when compared to a 0.1% MeOH treated control.

The attempt at the isolation of this compound was made using a bioassay-guided fractionation procedure that we had adapted from existing literature methods and then developed for use in the Richardson Lab. The foundation of this procedure was a bioassay developed in the Meyerson Lab during the summer of 2014 and adapted for use in the tissue culture room, TBL 108, of Williams College. It enabled us to examine the anticancer components of a particular fraction of a plant extract against any given cell line. TLC analysis and flash column chromatography were used to isolate suspected bioactive components of interest. Structural characterization was begun using ^{1}H-NMR spectroscopic methods.

The Syntheses of a Series of Bidentate Amine-Ether Ligands and of Their Complexes to Aluminum

Ivan (Jake) Huerfano

The recent green chemistry movement has placed a greater emphasis on the use of environmentally-friendly materials. The polymer polylactide (PLA), a biodegradable polyester derived from the renewable resource lactic acid, is one material of particular interest. Its properties are similar to those of polystyrene making it an attractive alternative material to manufacture many commonly used plastics. One synthetic route to PLAs involves a condensation reaction of two lactic acids to give the cyclic ester, lactide, followed by a subsequent ring-opening polymerization (ROP) through a coordination-insertion mechanism facilitated by a metal catalyst. In this thesis I lay the foundation for a new project in our research group to explore single-site catalysts containing bidentate amine-ether ligands for the ROP of lactide. I was able to synthesize five ligands by coupling the aryl bromide, 2-bromoanisole, to anilines with pK_a values ranging from 1.7 to 6.6 to give a series of ligands with a range of donor abilities. Ligands L100, L106, L108, and L109 were synthesized in 73% or greater yield while L104 was isolated in 28% yield through Buchwald-Hartwig amination using a palladium-diphenylphosphino-ferrocene (DPPF) catalyst. Model reactions of L100 and L106 with aluminum isopropoxide gave intractable solid products with IR data showing no evidence of metal-ligand binding. To date, we have been unable to synthesize complexes of aluminum with the ligands. Further exploration of a general procedure for the synthesis of amine-ether aluminum complexes is warranted.

Calcium Dependent Antibiotic Production in *Streptomyces coelicolor* A3(2): An *in vivo* Study of the SCO6672 Phosphodiesterase

Salmaan Karim

The biosynthesis of calcium-dependent antibiotic (CDA) by *Streptomyces coelicolor* A3(2) is carried out by a multimodular enzymatic complex called a nonribosomal peptide synthetase (NRPS). One of the three repeating domains of the NRPS, the peptidyl carrier protein domain (PCP), is where amino acid residues are attached prior

to condensation and elongation of a growing CDA peptide chain. For amino acid attachment to occur, a PCP domain must undergo a posttranslational modification: the addition of a 4'-phosphopantetheine (Ppant) cofactor from coenzyme A. This phosphopantetheinylation of CDA NRPS PCPs is catalyzed by a phosphopantetheinyl transferase (PPTase), SCO6673. Previous studies have also identified a phosphodiesterase, SCO6672, which can cleave the Ppant cofactor from CDA peptide synthetase PCPs. SCO6672's *in vitro* phosphodiesterase activity against CDA peptide synthetase holo-PCPs has not yet been translated into an understanding of its *in vivo* function.

This study focused on the *in vivo* function of SCO6672 by studying the antibiotic production of *SCO6672* deletion and overexpression strains compared to wild type. The primary interest of this study was the effect of *SCO6672* deletion or overexpression on CDA production. However, due to the *SCO6672* gene's proximity to the *SCO6673* PPTase gene, which can influence undecylprodigiosin (RED) production in addition to CDA, the *SCO6672* overexpression strains were also assessed for RED and actinorhodin (ACT) production. CDA bioassays as well as RED and ACT assays demonstrated that SCO6672 is a putative posttranslational antibiotic biosynthesis regulator as overproduction of SCO6672 led to decreased antibiotic production for all antibiotics assayed, and the deletion mutant overproduced CDA. The effect of *SCO6672* on ACT production was the most enigmatic and surprising given *in vitro* studies showing no direct effect of SCO6672 on the ACT acyl carrier protein domain.

Further studies need to be done to better understand the effect of *SCO6672* deletion and overexpression on antibiotic production in *S. coelicolor.* Such studies would benefit from a more quantitative CDA production assay as compared to the CDA bioassay currently implemented which relies on antibiosis of CDA against *B. mycoides*. Some efforts were made to begin developing a potential liquid assay that would allow for time-dependent assays and would not be dependent on antibiosis to visualize CDA. Bioassay guided fractionation to isolate CDA was a promising step that needs much further exploration.

Approaching the Total Synthesis of Jerangolid D

Ashley Kim

Jerangolid D is a secondary metabolite produced by the So ce 307 strain of the myxobacterium Sorangium cellulosum. Its key structural features include a western α,β-unsaturated δ-lactone, a central, doubly allylic methyl-bearing stereocenter, and an eastern cis-dihydropyran. Jerangolid D bears a strong structural resemblance to another secondary metabolite of S. cellulosum, ambruticin, which is a well-known antifungal agent. Jerangolid D also shares its antimicrobial spectrum and conserved genetic sequences with ambruticin, which suggests that jerangolid D could also possess antifungal properties. This document highlights the progress made toward the total synthesis of jerangolid D. The synthesis of the central, doubly allylic fragment and preparation for the final steps of the synthesis via asymmetric hydroformylation, Wittig, and DIBAL-H reduction reactions were successfully conducted. The Weinreb amide and α,β-unsaturated aldehyde synthesized via the Wittig and DIBAL-H reduction reactions, respectively, were characterized by 1H NMR, 13C NMR, COSY, HMQC, DEPT, ATRIR, and HRMS. Only three steps remain until the completion of Jerangolid D.

Investigating the Oxidation of Olefins Using Derivatives of the Non-heme Iron Catalyst [Fe(BPMEN)](OTf)$_2$

Claire Lidston

Non-heme iron complexes are effective olefin epoxidation catalysts. Systems employing complexes containing BPMEN ligand framework have been demonstrated to preferentially form the desired epoxide product over the *cis*-diol in high yields. This thesis aimed to identify trends in the reactivity of [Fe(BPMEN)(OTf)$_2$]-derived catalysts influenced by to the steric and electronic properties of substituents at the amine nitrogens in the BPMEN framework. The synthesis and characterization of six derivatives of this iron complex with varying substituents on the amine nitrogen are reported. These [Fe(L)(OTf)$_2$] complexes are employed as catalysts for the oxidation of *cis*-cyclooctene and 10-undecenoic acid and compared to the activity of the [Fe(BPMEN)(OTf)$_2$] standard. While [Fe(BPMEN)(OTf)$_2$] exhibited the highest conversion, greater chemoselectivity for the epoxide was achieved with catalysts incorporating more sterically bulky substituents at the amine nitrogens than methyl. While the [Fe(L)(OTf)$_2$] catalysts varied significantly in their abilities to epoxidize *cis*-cyclooctene, they demonstrated similar reactivity with respect to 10-undecenoic acid. Further work is necessary to fully characterize the structural properties of the [Fe(L)(OTf)$_2$] complexes by X-ray crystallography.

The Investigation of Copper (I) and Copper (II) Complexes With Pyridine Based Ligands as Atom

Transfer Radical Polymerization Catalysts

Lillian Ma

Atom transfer radical polymerization (ATRP) is a polymerization technique that uses a control agent, often a metal complex, to produce polymers with good control over molecular weight, composition and microstructure. ATRP achieves control over polymer growth by reversibly attaching a halogen "cap" to the active radical species. This capping leads to a decrease in concentration of active species, results in fewer termination events and allows for uniform chain growth. One of the main factors that influence the catalytic capabilities of a complex is the structure of its respective ligand. This study examines a closely-related series of tridentate and tetradentate ligands which have a common pyridine-amine-amine backbone with a propyl linkage chain between the amine donor atoms. As expected, the tetradentate ligand was the fastest, although it exhibited less control than its slower counterparts as evidenced a greater deviation from the theoretical molecular weight growth curve. In these systems, the copper (II) oxidation state is more favored than in it is for the complexes with tridentate ligands. This change is consistent with an increase in active chain ends resulting in more termination events. Differences in NMR, UV-Vis and ESI-MS spectra indicated that the complexes contained structural differences that may have resulted in their varying behavior as ATRP catalysts.

Characterization of the GroEL • $MetE_{ox}$ Domplex Using Cryo-electron Microscopy

Linamarie Miller

GroEL is a protein chaperone in *E. coli*. It aids protein folding by allowing proteins to enter its central cavity and enclosing them in coordination with its co-chaperone GroES. The cavity has an estimated capacity of about 60 kDa, but many proteins over 60 kDa interact with GroEL *in vivo.* The interaction between GroEL and a protein substrate over 60 kDa is not yet understood structurally. Here, work towards understanding the structure of GroEL in complex with oxidized MetE ($MetE_{ox}$), an 84.5 kDa protein from *E. coli*, was accomplished using cryo-electron microscopy (cryo-EM). The purification of GroEL • $MetE_{ox}$ complex was optimized and the presence of the complex was confirmed using immunoblotting. Cryo-EM of the sample was performed and 27,065 particles were processed and sorted into 2,400 class averages using the EMAN2 program. Currently there is evidence for particles containing substrate density in the GroEL cavity. Future work will further process these particles and eventually produce a 3D model of GroEL • $MetE_{ox}$.

Towards the Total Synthesis of Enigmazole A: Continued Efforts Towards the Synthesis of the C_1–C_{12} Fragment

Zaw Htut Naing

Enigmazole A is a phosphorylated 18-membered macrolide natural product isolated from the marine sponge *Cinachyrella enigmatica*. The molecule is known to exhibit potent cytotoxic activity although its cellular mechanism of action remains unclear. Enigmazole's biological activity and its unique chemical structure have drawn significant interest as a synthetic target. Enigmazole's unique architecture includes a disubstituted pyran ring, a 2,4-substituted oxazole moiety and eight stereocenters. The Smith lab plans to synthesize enigmazole A via a convergent approach in which the two substructures (a C_1–C_{12} western fragment and a C_{13}–C_{24} eastern fragment) of enigmazole are synthesized independently and eventually united via esterification and olefin metathesis. This thesis mainly focuses on the synthesis of the C_1–C_{12} western fragment. The original plan for the synthesis of the western fragment envisioned the use of Evans β-ketoimide aldol to construct the C_1–C_4 dispropionate unit while also installing three of the eight stereogenic centers. However, due to the subsequent inability to remove the superfluous C_3-hydroxyl group, we were forced to redesign our synthetic plan by establishing the configuration at the C_2-position through a Myers alkylation. Herein we report on continued efforts to synthesize the C_1–C_{12} western fragment of enigmazole A with this redesigned synthetic approach. In particular, we focus on the generation of the C_7–C_{11} pyran system.

Synthesis and Characterization of Acrylamide-based Polymers for Protein Conjugation

Denise Park

Proteins and enzymes have great potential as therapeutics drugs due to their high affinity and specificity. However, their use is limited by a number of its inherent properties such as variable solubility, short in vivo half-life, and limited stability. Conjugation of polymers to the protein can afford it improved stability, solubility while maintaining native structure and activity. Herein, hydrophilic polymer poly(*N*,*N*-dimetyhlacrylamide) (p(DMA)) and thermoresponsive polymer poly(*N*-isopropylacryalmide) (p(NIPAM)) of 10 kDa size were synthesized by reverse addition-fragmentation chain transfer (RAFT) polymerization

using 2-(dodecylthiocarbonothioylthio)-2-methylpropanoic acid (CTA-12) as the chain transfer agent. 10 kDa p(DMA)-b-p(NIPAM) block copolymer was also synthesized by chain extension of p(NIPAM) with DMA. Post-polymerization modification to remove the hydrophobic trithiocarbonate moiety yielded in thiol and hydroxyl terminated polymers. Polymer size and lower critical solution temperature (LCST) behavior were observed by dynamic light scattering (DLS) and turbidity measurements. Conjugation to the model protein trypsin was attempted using 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDAC) coupling agent in situ. Effect of pH on conjugation was investigated. Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) of crude conjugate solution suggested the optimal conjugation pH to be 7.5. Purification of conjugates was attempted by filtration. LCST behaviors of conjugates observed by visual analysis suggested successful integration of polymer characteristics to protein by conjugation.

Enzymatic Selectivity of Phosphopantetheinyl Transferases and SCO6672 in Production of Antibiotics by *Steptomyces coelicolor* A3(2)

Alex Silver

The *Streptomyces* genus is an important source of bioactive antibiotic compounds, making this family of filamentous, Gram-positive, soil-dwelling bacteria a particularly appealing draw for scientific inquiry. The subject of this investigation, the species *Streptomyces coelicolor* A3(2), is a well-studied model organism for the genus and the lessons learned about its regulation of synthesis of bioactive secondary metabolites often find broader application. There are four compounds with antibiotic activity produced by the *S. coelicolor* genome: calcium dependent antibiotic (CDA), undecylprodigiosin (RED), actinorhodin (ACT), and the cryptic polyketide (CPK). The production of these compounds is accomplished by two types of multimodular biosynthetic enzymes, non-ribosomal polypeptide synthases (NRPSs) or polyketide synthases (PKSs), both of which require a covalently-attached 4'-phosphopantetheinyl cofactor to function. The genome of *S. coelicolor* encodes three phosphopantetheinyl transferases (PPTases) with the potential to catalyze the addition of this cofactor to carrier protein domains of NRPSs and PKSs. It also encodes the SCO6672 enzyme which exhibits *in vitro* the carrier protein phosphodiesterase activity required to cleave off this cofactor.

The motivation of this study was to examine the *in vitro* substrate selectivity of these PPTases and SCO6672 for the purpose of documenting the potential *in vivo* network of regulatory influences acting on antibiotic production. The potential *in vivo* regulatory role of SCO6672 in particular is unclear, as it is the only phosphodiesterase known to exhibit activity against carrier proteins from antibiotic-producing biosynthetic enzymes. This investigation sought to provide *in vitro* evidence for either one of two hypotheses regarding this enzyme's *in vivo* function. It has been proposed elsewhere that enzymes like SCO6672 may act as editing enzymes for biosynthetic enzymes, a role which would be consistent with a broad substrate acceptance. Conversely, SCO6672 has also been proposed to act as a post-translational negative regulator of antibiotic synthesis by decreasing the pool of available active carrier proteins, a function that could be consistent with a more restricted substrate specificity.

In previous work, it has been found that SCO6672 and one of the PPTases, SCO6673, have significant activity against the carrier proteins domains of the CDA synthetase. Here, both SCO6672 and SCO6673 were found to have only modest activity on all carrier proteins tested outside of the CDA biosynthetic cluster. It was also demonstrated that the PPTase AcpS has broad and strong activity against acyl carrier proteins (ACPs) from multiple antibiotic clusters while the PPTase RedU has very restricted activity against the tested carrier proteins, including those involved in RED production. For SCO6672, these results suggest a specific post-translational regulatory role for CDA production. Comparison across the actinomycetes revealed a high level of conservation of SCO6672-type proteins, suggesting that any antibiotic-specific regulatory capacity exhibited by SCO6672 may be a co-option of a more general physiological role.

Characterizing the SigU System of *Streptomyces coelicolor*:Activation and Metabolic Consequences

Katherine Susa

The *Streptomyces* comprise a genus of gram-positive bacteria with an unusually complex life cycle involving mycelium formation, multicellular differentiation, sporulation, and antibiotic production. *Streptomyces coelicolor* is the model species for the genus due to its sequenced genome and colored antibiotic production, offering visible cues of life cycle progression. This study focuses on a mutant strain of *S. coelicolor*, called the NY415 bald strain. This strain has a mutation in *rsuA,* encoding an anti-sigma factor that regulates the activity of a stress response sigma factor, σ^U. This mutation is hypothesized to deregulate σ^U, allowing it to be constitutively active and available to bind to RNA polymerase, turning on transcription of the *sigU* regulon. The transcription

of these genes leads, directly or indirectly, to a bald phenotype, in which the aerial mycelium is not formed. The NY415 mutant also has striking differences in its cytoplasmic protein profile as compared to the wild type, with many differentially expressed proteins involved in primary metabolic pathways.

To clarify this connection between constitutive σ^U activity and altered metabolism, the activities of eight enzymes in the glycolysis pathway and four enzymes in the pentose phosphate were assayed. In the glycolysis pathway, all but one enzyme, glucose kinase, showed significantly lower activity in the NY415 cell extracts as compared to the wild type extracts, indicating that the NY415 strain has decreased flux through this pathway. Conversely, three out of four enzymes in the pentose phosphate pathway showed significantly higher activity in the NY415 cell extracts as compared to the wild type extracts, suggesting increased flux through this pathway in NY415. Additionally, the concentration of pyruvate, the end product of the glycolysis pathway, was assayed in the cell extracts of both NY415 and the wild type, although no significant difference was found between the two. Lastly, to determine conditions that may naturally activate σ^U in the wild type, transcriptional reporter experiments were conducted in the presence of various chemical stressors. Of all the stressors tested, including acids, bases, antibiotics, cell membrane damaging reagents, and oxidative stressors, only acidic conditions (1.0 N HCl and 5% acetic acid) were found to lead to transcription from the *sigU* promoter in the wild type reporter strain. Because only acidic conditions seem to activate σ^U, it is hypothesized that σ^U activity may decrease flux through the glycolytic pathway, leading to the production of fewer acidic metabolites and allowing ATP to be diverted to power the F_1F_0-ATPase to pump protons out of the cell. Thus, the altered metabolism seen in the NY415 strain may be a survival strategy that allows for de-acidification of the cytosol during acidic stress conditions.

Synthesis of Monophenolic 3,4-Diarylpyrazoles for Discovery of Novel Antibiotics

Shannon Zikovich

The overuse and misuse of antibiotics has ushered us into an era where diseases and infections once easily treated are at times incurable. Bacteria have developed resistance mechanisms to all modes of antibacterial action used by antibiotics on the market today. In light of this urgent need for antibiotics that target new mechanisms controlling bacterial growth and survival, we aim to prove that histidine kinases, the often essential and widely conserved mediators of two-component signaling pathways in bacteria, are viable antibiotic targets for drug discovery.

Employing CckA—a histidine kinase in *Caulobacter crescentus* that is essential for cell cycle progression—as our model histidine kinase, we are developing a small molecule CckA inhibitor that might act as a broad-spectrum antibiotic, targeting many histidine kinases. The lab has found that the commercially available Hsp90 inhibitor CCT018159, a 3,4-diarylpyrazole, inhibits CckA ATPase activity. By derivatizing this chemical scaffold, and screening these CCT018159 analogs against CckA, we are able to garner a better understanding of which substituents on this chemical scaffold might be important for pharmacological inhibition of CckA. I have continued to expand our small library of 3,4-diarylpyrazoles by synthesizing monophenolic 3,4-diarylpyrazoles. Upon testing these compounds against CckA using an ATP-coupled assay, we hope to better understand the structure activity relationship of the CCT018159 resorcinol ring. Discovering which hydroxyl group of the resorcinol ring is crucial for CckA inhibition will give us a better picture of how these inhibitors bind to CckA, thereby informing our continued refinement of these small molecules to ultimately develop as potent a histidine kinase inhibitor as possible.

Computer Science

Measuring and Visualizing Energy Consumption in a Living Building

Sarah Abramson

Energy use is an important concern today. However, to be able to reduce their energy consumption, people must first be able to understand it. We examine the collection and visualization of consumption data in a new sustainable building on campus, the Kellogg House. In order for the Kellogg House to meet it's net-zero energy goals it will need to be a smart building with smart occupants. We look at what infrastructure is needed within the building to help the occupants recognize how their behavior effects energy use and thereby reduce the energy consumption.

We present a plan for the instrumentation of the house including hardware to collect the consumption data and a format for data storage. We also discuss the potential uses for such a dataset. Next, we reproduce a study using an animation for a kitchen activity to test college affiliates understanding and use of energy. We update that animation and again evaluate its possible benefits to understanding consumption. Finally, we discuss how this animation will be utilized in the new Kellogg House building.

HYDRA: A CUDA Based Tool Supporting Error-resilient GPU Computation and General Purpose Heterogeneous Programming

Gregory Becker

The large-scale supercomputers popular in high performance computing require support for error-resiliency to protect against soft errors. We present Hydra, a scalable, CUDA-based tool supporting resilience in heterogeneous GPU/CPU applications. Hydra provides a framework to support redundancy for resilience, as well as programming tools that leverage that framework for other heterogeneous programming tasks. Hydra executes CUDA kernels redundantly on both CPU and GPU to leverage the parallelism of the heterogeneous architecture. To support redundancy with minimal additional programmer effort, Hydra provides wrappers for the CUDA functions involving memory manipulation. Our results indicate that Hydra redundancy can be an efficient model for error-resilience in heterogeneous architectures, as well as a useful tool in heterogeneous programming.

A Light Field Representation for Real Time Global Illumination

Daniel Evangelakos

Modern rendering algorithms perform image synthesis by stochastically sampling millions of light paths through the scene. This process involves finding the intersection points of rays with the geometry of the scene. This geometry is commonly represented by millions of individual triangles. To increase the efficiency of these ray intersections, data structures have been created to efficiently perform these ray intersections. The data structures used often times do not map well to modern high performance hardware such as graphics processor units(gpus). I present a novel spatial data structure that can be used for all ray or path based rendering algorithms, and that will map well to high performance hardware. My solution will be based on a field of individual probes placed throughout the scene. At each probe we will build the analog of a quad tree of min distances upon the inside of the probes sphere. We then use an adaption of Musgrave's heightfield tracing to solve for parallax corrected ray casts.

User Motivation on Stack Overflow

Emma Harrington

On Stack Overflow, millions of programmers donate their time to answering one another's questions online. None of these programmers are paid for their contributions, raising the question of what they get for their efforts. Programmers may want the ``warm glow" of doing good, prestige of doing well, connections with other programmers, or credible credentials. These motivations may interact with one another as the desire to prove one's programming chops distorts the signal sent by answering questions on the site. Stack Overflow launched the Careers recruiting service in October 2009 and Careers 2.0 in February 2011. Careers 1.0 and 2.0 made it easier for users to signal their programming ability and land new jobs through their Stack Overflow participation. Our goal is to model and empirically evaluate the effect of credentialing on the behavior and composition of users generating content online.

We find that users who join Stack Overflow after Careers tend to have shorter tenures on the site and contribute fewer edits and votes on one another's posts. These users also tend to specialize more in specific topics. Existing users, on the other hand, appear to respond to Careers 1.0 and 2.0 by editing others' posts more often: they may want to signal their generosity now that posts may be selfishly motivated. Avid users appear to diversify more after the launch of Careers 2.0 perhaps because employers want programmers with a broad range of skills or the recruiting service allows programmers to more easily capitalize on their self-discoveries and options to switch specialties.

Using Reconfigurable Hardware to Fight Dark Silicon

Isaiah Leonard

After four decades of exponential improvement, computing performance has hit a wall. Power constraints and physical limitations have led to the rise of *dark silicon*: most modern processors can run only 3% of their transistors at their maximum frequency without overheating. Pairing reconfigurable hardware with a general purpose processor (GPP) to build a partnered computation processor can yield performance and efficiency improvements that are not possible with GPPs alone. Because GPPs waste roughly 90% of their energy on computational overhead, hardware circuits can significantly decrease the energy of targeted computations. In this work, we explore the possibility of using the recent Xilinx Zynq processor—which tightly couples GPPs with an FPGA—to implement a system that combines GPP with a dynamically reconfigurable co-processor to provide efficient, general purpose, partnered computation.

A Combinatorial Characterization of Heapability

Jaclyn Porfilio

We say a sequence is heapable if you can sequentially insert its terms into a binary heap. You can determine whether or not a sequence is heapable in polynomial time, but many questions about heapable subsequences remain open. To better tackle these problems, we create a notion of the space of heaps for a given sequence, fully characterize its properties, and give the tools necessary to move between that space and the original sequence. This work includes a connection between heapability and a class of graphs called permutation graphs, providing the first opportunity to apply the power of graph theory to heapability problems.

Geosciences

Comparison of Icelandic Rootless Spatter Cones and Experimental Lava Features

Nell C. Davis

Northeastern Iceland is an area of active rifting and volcanism along the emergent Mid-Atlantic Ridge. About 2,000 years before present, the Threngslaborgir-Lúdentsborgir eruption created a basaltic lava flow called the Younger Laxárhraun. This flow contains many clusters of rootless cones, volcanic cones formed through the interaction of lava with water and without an underlying conduit to magma. Studying the dynamics at play during rootless cone formation can lead to a better understanding of phreatic eruption processes. Knowledge of phreatic processes is important to the welfare of humans living near volcanoes and water.

Two clusters of Younger Laxárhraun rootless cones were mapped in the field, and one cluster of cones was mapped remotely. From these maps, the centroid of each cone was calculated, and cluster-wide spatial distributions were statistically analyzed by Geological Image Analysis Software (GIAS). The results indicated a correlation between water abundance and rootless cone spatial distributions, implying that during formation rootless cones may actively compete for scarce water resources.

The Syracuse University Lava Project melts hundreds of pounds of basalt in order to create experimental lava flows under controlled conditions, thus allowing careful study of analogues to natural processes. At Syracuse, two flows were produced in order to study the interaction of lava with wet substrates. The positions of lava bubbles in these flows were analyzed in GIAS, and the results mirrored those of the Icelandic sites, suggesting that cones or bubbles are less likely to cluster spatially in water-limited environments. Both rootless cones and Syracuse lava bubbles are more likely to have a uniform spatial distribution (landforms as equidistant from each other as possible) in water-limited environments, suggesting competition for water resources during formation.

Connecting Surficial Geology and Hydrologic Flux in Leaky, Snowmelt Dominated Catchments, Niwot Ridge, CO

Victor M. Major

Alpine and subalpine snowmelt-dominated catchments are an important fresh water source in the western and northeastern United States, but understanding the hydrology of these catchments is challenging. Highly porous

and permeable surficial deposits in some alpine areas provide subsurface pathways for snowmelt, resulting in "leaky" basins. This study investigated the surficial geology and hydrology of four alpine and subalpine catchments (total area 2 km^2) on Niwot Ridge, Colorado Front Range to help characterize how surface and subsurface flow interact above the glacial limit. Martinelli, Saddle, Como, and Upper Fourmile basins support tundra communities and patchy forest that grows from thin soils developed on 2 to >5 m of mainly coarse, unconsolidated periglacial deposits (Leopold et al., 2008). Fractured igneous and high-grade metamorphic rocks underlie the layered surficial deposits. I have characterized local surficial geology with field mapping, inversion of electrical resistivity measurements, and well-log data. In areas above spring outcrops, I measured a saturated/capillary fringe zone with low resistivity values of ~200-800 Ωm beneath a shallow vadose zone (1500-2500 Ωm) and above bedrock surfaces (>2500 Ωm) at depths of <1 to 5.5 m. I investigated basin hydrologic flux by measuring surface flow at selected sites by: (1) modeling snowmelt, (2) estimating and compiling K-values, and (3) compiling groundwater and mass-budget measurements. Estimates of the hydraulic conductivity of unconsolidated deposits on the Niwot Ridge ranged from $3.16x10^{-3}$ ms^{-1} to $8.63x10^{-5}$ ms^{-1}. Total potential storage on Niwot Ridge is high, ranging from 1.4x104 to 3.1x104 m^3 in shallow fractured bedrock and from 7.9x106 to 3.69x107 m^3 in surficial deposits. Initial calculations indicate that flow through the subsurface is delayed yet significant, and the expression of surface water is dependent upon subsurface geometry, thickness, and hydraulic conductivity of the subsurface as well as the lateral and vertical extent of the saturated zone. This research has implications for understanding alpine geomorphological and hydrogeological narratives, on water quality, and on future water balance studies.

Coastal Boulder Movements in Western Ireland

Oona G. Watkins

Boulder ridges form above the high tide on rocky coasts exposed to the Northeastern Atlantic. Ridges are activated and modified by storm waves, and they provide a record of high-energy wave events. Some ridges accumulate at elevations up to 50 m above high water (AHW) and others are found up to 250 m inland. We performed a before and after analysis of deposits in Western Ireland using re-take photography to document impressive boulder movements in the field. We demonstrated the role of record-breaking 2013-2014 winter storms in this ridge reorganization. These storms contributed to the progressive inland migration of boulders in ridges: boulders moved from the platform into the accumulation and those within the ridge moved up the face and sometimes over the crest to the backside. Last winter's storm waves also excavated fresh bedrock slabs; some were between 40 t - 80 t and some traveled 10s of meters before deposition in the ridge. We recorded moved boulders as large as 430 t, and we measured transport distances of almost 100 meters. Steep or stepped coasts mark our sites, and the fluid dynamics that occur here are not well understood. Hydrodynamic equations exist to describe block transport, but they oversimplify the scenario by disregarding elevation and the complexities of bore flow. We know this because the results of these equations differ from the offshore sea states that actually moved boulders last winter. The difference in values is a direct result of simplifying the high-energy interactions responsible for boulder movement, and we additionally point out that the equations are not appropriate for our use because they describe simple wave progression, which does not occur at our sites. Our work provides insight to the way boulder ridges are migrating and growing, and our research gives direction to further work in hydrodynamics.

Geomorphic Effects of the September 2013 Flood in Fourmile Canyon, Colorado, Using Lidar and Field Studies

Will J. Wicherski

This research uses the results of field measurements and remote sensing to reconstruct flood discharge, sediment transport, channel changes, and sediment budgets for a catastrophic flood along a 15 km reach of Fourmile Canyon, Colorado. From September 9 to 15, 2013, rainfall totals of up to 43.6 cm caused extensive flooding and local debris flows in the Front Range foothills west of Boulder, Colorado. Locally intense rainfall and continued effects of recent wildfires probably contributed to the scale of the geomorphic response, especially in catchments such as Fourmile Canyon, which flows from the alpine zone to Middle Boulder Creek in the semiarid foothills. Field surveys focused on flood height and width indicators, point counts of overbank deposits, and sieve analysis

of gravel-rich deposits thicker than 0.5m. The availability of 1-meter resolution LiDAR from before (Aug. 2010) and after the flooding (Oct. 2013) provided an unusual opportunity to measure the geomorphic effects of the flood in the surveyed field areas. Cross-sectional profiles allowed us to estimate peak discharge using the slope-area and critical-depth methods, as well as the competence and power of the event. Combining these approaches at 12 sites shows 44,000-65,500 m^3 of local deposition and 44,500-96,000 m^3 of net erosion from the valley floor, entrainment of boulders weighing over 3 metric tons, and estimated peak discharges of 58.5-97.9 m^3/s. The mass balance of sediment in the canyon, the profile differences, and field observations all indicate that the flood event produced net erosion, mainly by channel widening, despite significant (>100m long, >1m thick) depositional zones throughout the canyon. Similar effects have been reported in other headwater catchments due to extreme floods such as Hurricane Irene in Vermont.

Mathematics & Statistics

Analysis of Technical Stock Trading Strategies

Thomas Andrew Beaudoin, Jr.

Technical analysis has been used by traders for decades, but it has been difficult to examine with the same level of rigor as fundamental analysis due to its highly subjective nature where two traders could see the same data and perform two different actions. In this paper, I evaluate the effectiveness of a few technical strategies that are less subjective and thus could be used algorithmically. I apply these strategies to the 1500 largest US stocks over the period of January 1, 1998 to December 31, 2007. By comparing the gains when testing the strategy over the time period versus the gains when holding the stock from the beginning of the time period, and by comparing the success rate on a stock to stock basis, I find that over the 10 year period one strategy is successful, many unsuccessful yielding potential shorting opportunities, and others yield no difference.

The Crossing Map of Knots

Wyatt Bradley Boyer

The crossing map is a sphere around a knot where each point on the sphere is labeled with the number of crossings one sees in the knot when projected in that direction. Regions of constant value on the crossing map are divided by three types of curves that correspond to the three Reidemeister moves. We explore what each curve determines about the embedding of the knot in space.

Cusp Thicknesses of Checkerboard Surfaces for a Family of Links

Benjamin Demeo

The *cusp thickness* of a surface bounded by a hyperbolic knot K is a natural measure of its geodesicity, and depends crucially on the structure of the surface's limit points in the universal cover H^3. We introduce a method for analyzing limit sets of checkerboard surfaces using polyhedral decompositions and apply it to a family of links, obtaining the limit sets and cusp thicknesses. We then apply our results to relevant areas and consider further applications.

Fredholm Theory and Optimal Test Functions for Detecting Central Point Vanishing Over Families of L-functions

Jesse Benjamin Freeman

The Riemann Zeta-Function is the most studied L-function – its zeros give information about the prime numbers. We can associate L-functions to a wide array of objects. In general, the zeros of these L-functions give information about those objects. For arbitrary L-functions, the order of vanishing at the central point is of particular importance. For example, the Birch and Swinnerton-Dyer conjecture states that the order vanishing at the central point of an elliptic curve L-function is the rank of the Mordell-Weil group of that elliptic curve.

The Katz-Sarnak Density Conjecture states that this order vanishing (and other behavior) are well-modeled by random matrices drawn from the classical compact groups. In particular, the conjecture states that an average order vanishing (over a "family" of L-functions) can bounded using only a given weight function and a chosen

test function φ. The conjecture is known for many families when the test functions are suitably restricted.

It is natural to ask which test function is best for each family and for each set of natural restrictions on φ. Our main result is a reduction of an otherwise infinite-dimensional optimization to a finite-dimensional optimization problem for all families and all sets of restrictions. We explicitly solve many of these optimization problems and compute the improved bound we obtain on average rank. While we do not verify the density conjecture for these new, looser restrictions, with this project, we are able to precisely quantify the benefits of such efforts with respect to average rank. Finally, we are able to show that this bound strictly improves as we increase support.

History Dependent Stochastic Processes and Applications to Finance

Nicholas Gardner

In this paper we focus on properties of discretized random walk, the stochastic processes achieved in their limit, and applications of these processes to finance. We go through a brief foray into probability spaces and sigma-fields, discrete and continuous random walks, stochastic process and Ito calculus, and Brownian motion. We study the properties that make Brownian motion unique and how it is constructed as a limit of a discrete independent random walk. Using this understanding we propose a different kind of random walk that remembers the past. We investigate this new random walk and find properties similar to those of the symmetric random walk.

We look at a well-studied stochastic process called fractional Brownian motion, which uses the Hurst parameter to remember past performance. Using Brownian motion and fractional Brownian motion to model stock behavior, we then detail the famous Black-Scholes options formula and a fractional Black-Scholes model. We compare their performance and accuracy through the observation of twenty different stocks in the market. Finally we discuss under what circumstances is the fractional model more accurate at predicting stock price compared to the standard model and explanations for why this might occur.

On Partially Rigid, Strictly Doubly Ergodic Rank One Transformations and Related Examples

Isaac Loh

Rank one cutting and stacking transformations are a useful source of examples in infinite measure spaces. Interestingly, the structure of these cutting and stacking transformations can be reduced to integer sequences, and characterized by combinatorial methods. Our main work is to use these characterizations to develop new classes of transformations meeting certain properties. We develop a transformation which is strictly partially rigid and strictly doubly ergodic (i.e. with non-ergodic Cartesian square), and also give some general conditions for the conservativity of products of cutting and stacking transformations. We also have examples of fully rigid, strictly doubly ergodic transformations. We further the study of power weakly mixing transformations in infinite measure spaces by showing that all (t,q)-type Chacon maps are power weakly mixing, and demonstrating that there are such maps which also have strict partial rigidity but closely bounded recurrence--a result which could not be previously obtained from arguments on genericity. Finally, we come close to answering an open question by Bergelson by showing that there is an infinite measure preserving transformation T with extreme asymmetry: all rectangles sweep out under T, and T has infinite conservative index, but TxT^(-1) is not ergodic.

Imagining a Space of Circular Split Networks

Samantha Petti

Phylogenetic trees are structures used to represent evolutionary histories. A circular split network is a generalization of a tree in which multiple parallel edges signify divergence. We introduce a space of circular split networks and explore its properties. This space, which we call CSN_n, is the natural extension of Billera, Holmes, and Vogtman's tree space to circular split networks. We introduce this space and a topologically rich subspace C_n. We describe the interesting gluing properties of the space. Further, in computing the homotopy of the space, we find a connection between C_n and the real moduli space $M_{0,n}$.

Partial Rigidity Values on the Levels of Chacón-type Transformations

Eric George Schneider

We describe a variety of Chacón-Type Transformations based on the Canonical Chacón Transformation that

appeared in Friedman in 1970, including finite point extensions. In our search for an alternative proof to Del Junco in 1978 that the Canonical Chacón Transformation is Mildly Mixing we discovered many partial rigidity values over the levels. We provide a method for determining if a partial rigidity value on the levels of the Chacón Transformation is possible as well as establishing an upper bound. This method is then generalized to a class of Chacón-Type Transformations.

Neuroscience

Early Life Stress and the Development of the HPA Axis

Anuj Shah

Chronic early life stress (ELS) can cause dysfunctional development of the hypothalamic-pituitary-adrenal (HPA) axis, predisposing individuals to pathological responses to subsequent stressors. Indeed, exposure to ELS has repeatedly been linked to the onset of various stress-related disorders, such as depression, anxiety, and post-traumatic stress disorder. Many studies have elucidated interactions between environmental stressors and genetic polymorphisms implicated in these disorders. However, there is little evidence describing specific genes that reprogram stress reactivity in response to chronic or intensified stress in early life. Therefore, the aim of the current study was to seek a viable experimental model for studying HPA axis reprogramming, and to determine the differential expression of HPA axis-related genes underlying the early development of healthy and pathological responses to stress. We used a previously proposed drug treatment paradigm, which demonstrated that a single dose of dexamethasone (DEX) at embryonic day 4 induced lifelong changes in anxiety-like behavior in zebrafish, and that caffeine pretreatment neuroprotects against such effects. Surprisingly, we found that fish treated with either DEX or caffeine exhibited less anxiety than control fish, in contrast to the previous report on a different line of fish. At the genetic level, we found that *fkbp5*, *11βhsd2*, and *nr1I2* are up-regulated at 5 days post-fertilization (dpf) in response to DEX treatment at 4 dpf. Additionally, caffeine pretreatment attenuates the increase in *fkbp5* expression, and fluoxetine, a selective serotonin reuptake inhibitor (SSRI), mitigates the DEX-induced up-regulation of all three genes. The findings presented here may contribute to the creation of a viable model to study early HPA axis reprogramming.

Anxiolytic effects of neurokinin-1 receptor antagonism in rats bred for an infantile affective trait.

Amanda Schott

Interest in understanding the etiology and developing new treatments for anxiety disorders in children and adolescents has led to recent studies of neurotransmitters not traditionally associated with neural pathways for fear and anxiety. Animal models have proved useful in developing new anxiolytics, but the majority of these studies use rodents with normal baseline levels of anxiety like behavior. This experiment used a genetic rodent model to examine the role of one neurotransmitter system that has been recently implicated in anxiety behavior, the substance P/neurokinin1 (SPNK1) pathway. Two lines of rats that had been selectively bred for high and low levels of baseline anxiety were administered a pharmacological NK1 receptor antagonist, CP99,994 dihydrochloride, and the behavioral effects on the elevated zero maze (EZM) were examined. High line rats displayed significantly more anxiety like behavior than low line rats. Inhibition of the SPNK1 system had an anxiolytic effect on both lines. Moreover, CP99,994 had line specific effects on several measures of anxiety like behavior, suggesting a physiological difference in the SPNK1 pathway dependent on affective temperament. These data indicate that the SP-NK1 pathway could be an important therapeutic target for the treatment of various stress disorders, but drug response might be influenced by the individual's state anxiety or history of chronic stress.

Physics

Quantum Optimal Control of Large Dimensional Systems

Samuel T. Amdur

The quantum Fourier transform (QFT) has been shown to offer an exponential speedup over classical Fourier

Transform algorithms. We attempt to use optimal control to determine whether QFT implementations using qudits, rather than qubits, offer improved time performance. Numerical modeling of the QFT using gradient search methods suggests that qudit-based systems may be more time-efficient than qubit-based systems for small systems. We also study the scaling of computational time for single-qudit systems implementing the QFT, finding preliminary evidence that the timesteps needed for a single-qudit system to implement the QFT is linear in the dimension of the system. We implement improvements to existing gradient search methods to allow for the scaling of numerical simulation to larger quantum systems.

Scalar Polarizability of the Indium $6P_{1/2}$ State: Atomic Beam Stark Shift Measurements using Two-Step Laser Spectroscopy

Benjamin L. Augenbraun

We have nearly completed a high-precision measurement of the scalar polarizability of the indium $6P_{1/2}$ state using two-step laser spectroscopy in an atomic beam. Preliminary data reveals the polarizability to be 7938(60 stat)(200 sys) in atomic units. This is in excellent agreement with recent theoretical calculations. We make use of a newly implemented two-tone FM spectroscopy scheme to observe the two-step transition in an atomic beam. The methods outlined in this thesis represent the first time our group has observed a multi-step transition in an atomic beam. We lock one laser, at 410 nm, to the lower transition in an atomic vapor cell while simultaneously scanning a second laser, at 1343 nm, across the upper transition. Furthermore, we have introduced a new, robust method of laser stabilization, making use of an EOM and frequency modulation to routinely lock to several hundred kHz noise. As part of this polarizability measurement, we have also obtained a measurement of the hyperfine structure in the $6P_{1/2}$ state. This result is in rough agreement with existing measurements, but an order of magnitude more precise. Determination of systematic errors remains to be done, requiring more data collection. In parallel to experimental advances that led to this preliminary measurement, we have undertaken a theoretical study of three-level systems to understand how the observed Stark shift arises in these simultaneously coupled states. With more data collection, we aim to measure the polarizability to <1% precision, providing a stringent test of ab initio atomic theory calculation methods.

Converging Towards Benford's Law

Weng-Him Cheung

We build upon previous work on a model for the fragmentation of a conserved quantity. Using new bounds on partition numbers, we re ne a previous result on the magnitude of the conserved quantity required for Benford's law to appear. We also study a model for breaking up a conserved quantity via a random bisection process, in which each quantity is randomly split into two pieces at each step. We show that this also leads to a Benford distribution, and we derive an expression for the deviation from the Benford distribution based on which step of the bisection process we are on.

The Evolution of Order in Thin Film Diblock Copolymer Systems

Julia R. Cline

It is a common assumption that all striped systems with the same fundamental symmetry evolve in the same manner. Experimental studies on diblock copolymers systems have established ordering behavior that is assumed common to all thin film striped systems with a constant period of stripes (away from defect cores). Previous research has investigated cylindrical phase diblock copolymers that are strongly segregated ($\chi N \approx 28$) [1]. To test if this behavior extends to weakly segregated systems, we are studying a diblock closely related to one used previously, but with a lower segregation strength ($\chi N \approx 14$).

We investigated thin films of cylinder-forming weakly-segregated polystyrene-block-poly(methyl methacrylate). The orientational correlation length of the microdomains was measured by atomic force microscopy and found to grow following a power law $\xi(t)$ t^(0.32), in contrast to the previously found t^(0.25) and t^(0.26) [1, 2]. This suggests that the ordering mechanisms do not depend solely on fundamental symmetry and may be influenced by segregation strength.

RNA Macrostates and Computational Tools

Michael J. Flynn

In my thesis I developed computational tools increasing the efficiency of RNA partition function algorithm and the stochastic traceback algorithm. These were in service of exploring the idea of RNA Macrostates, which are defined as sets of structures clustered around local energy minima. I then develop an algorithm to compute the partition function of Macrostates and the transition states between them, based on computing restricted versions of the original partition function.

The Environment and Decoherence in the Ubit Model

Brandon V. Ling

Previous thesis students have explored a real-vector-space model of quantum theory, the main feature of which is the existence of an universal auxiliary binary object, the ubit, that interacts with everything in the universe. The ubit can only rotate; this together with the ubit's omnipresent interactions leads to standard complex quantum theory in a certain limit. Stopping short of this limit yields a theory similar to, but not quite the standard theory. In this thesis we further examine the original model, specifically focusing on a spin-1/2 particle in a magnetic field but changing the model of the environment, that is, the rest of the universe. We find that our results depend on the model of the environment and in particular its interactions with the ubit.

Design and Construction of Laser Systems for Trapping and Cooling $^{40}Ca^{+}$

Cole M. Meisenhelder

We have worked towards trapping $^{40}Ca^{+}$ ions in a Paul trap, so that they can be used as an analog quantum simulator. We have constructed a system of external cavity diode lasers which will be used to ionize neutral calcium and Doppler cool ions in our trap. Using a scanning Fabry-Perot cavity and a reference laser we can provide feedback to the frequencies of these lasers to stabilize them to within an error of 2MHz RMS. We have also designed a system of magnetic field coils which will sit inside the vacuum chamber and provide three-axis control of the magnetic field at the trap center. These tools represent the majority of the tools necessary for controlling the electronic states of the ions, but multiple other systems must still be developed.

The Ubit Model: Decoherence in Real-Amplitude Quantum Theory

Gabriel O. Samach

In this thesis, I consider the implications of the spontaneous decoherence effects exhibited by the Ubit Model: a particular model of real-amplitude quantum theory where the complex phase factors of traditional quantum mechanics are reinterpreted as interactions with a universal binary system called the Ubit. Building from prior work, I explore the challenges which arise in using the Ubit Model to model discrete quantum systems larger than two states as well as traveling wavepackets. Studying the discrete system, we find that the spontaneous decoherence effect depends directly on the seemingly artificial choice of which basis we choose to express our Hamiltonian in. Studying the evolution of a wavepacket, we find that the decoherence effect increases depending on the observer's velocity relative to the wavepacket, a result which is in clear violation of classical Galilean relativity. Drawing on the particular formalism of the Dirac Equation, we then attempt to solve these two interesting issues by using the first to solve the second, defining our basis such that relativistic invariance is preserved.

Psychology

Adolescent Sexual Experiences and Depressive Symptoms: A Moderated Mediation Model of Serotonergic Vulnerability and Stress Generation

Erin Curley

There is extensive literature supporting a bi-directional association between adolescent romantic experiences and depressive symptoms. However, very few studies have explored the unique effects of sexual experiences or the moderators and underlying mechanisms of these reciprocal effects. To fill this gap, the present study examined the bi-directional associations between adolescent sexual experiences and depressive symptoms

among a sample of early adolescent girls. In addition, serotonergic vulnerability was explored as a moderator of these associations. Furthermore, chronic and acute forms of interpersonal stress generation were examined as pathways through which sexual experiences confer risk for depressive symptoms, and visa-versa. These questions were explored in a one-year longitudinal study of 90 early adolescent girls (*M* age = 12.35 years) and their primary female caregivers using diagnostic and objective stress interviews, as well as genetic samples. Findings indicated that non-coital sexual experiences predicted increases in subsequent depressive symptoms, particularly among girls with high levels of serotonergic vulnerability. Moreover, both chronic and acute stress interpersonal generation emerged as pathways through which non-coital sexual experiences conferred risk for depressive symptoms among the high vulnerability adolescents. In contrast, depressive symptoms did not predict subsequent engagement in non-coital sexual experiences, regardless of serotonergic vulnerability, and neither form of interpersonal stress generation served as a mechanism of the prospective association. Clinical implications and future directions of research were discussed.

"If I Don't Seek Information About This Environmental Threat, I Must Not Be Worried About It": Information Avoidance as Information

Aaron Jordan

Information avoidance refers to any behavior designed to prevent or delay the acquisition of unwanted information. Previous research has documented information avoidance in a number of domains, including personal health (e.g., not wanting to know one's own HIV status) and the environment (e.g., not wanted to know one's own carbon footprint or the particulars of an environmental threat), and has shown that people avoid information for a number of distinct reasons, including the worry that information will induce unpleasant emotions, that it will require one to change or abandon cherished beliefs, and that it will compel undesired actions. The present research turns the tables on this past research and demonstrates that people use their own (Studies 2, 3, and 4) and others' (Study 1) information seeking and avoidance as information, using them to infer their own and others' level of concern about issues such as environmental threats (e.g., "If I am not seeking information about deforestation of tropical rainforests, I must not be concerned about it"). I argue that this inference, consistent with research on self-perception theory, is an important piece in a sequence of self-deceptive reasoning. Specifically, I argue that people may engage in information avoidance strategically, in order to determine that they are not concerned about an issue, so that they may conclude, in turn, that there is nothing to be concerned about. This reasoning amounts to self-deception, I argue, inasmuch as individuals use their own behavior (information avoidance) as the basis for concluding the very thing (lack of concern) that motivated their behavior in the first place. The present studies provide preliminary evidence for a portion of this sequence.

A Meta-Analytic and Qualitative Examination of Predictors of Mother-Infant Bonding

Caroline Kaufman

Mother-infant bonding is a mother-based perspective of the complex relationship between mother and infant. Research has examined predictors of mother-infant bonding utilizing a variety of experiment types across several populations. In this study, we systematically and narratively examine research assessing predictors of mother-infant bonding including psychiatric, demographic, interpersonal, and other predictors. We found that maternal anxiety, maternal depression, and female infant sex predicted impaired mother-infant bonding. We also found that interventions and fetal attachment predicted healthy mother-infant bonding. Our results have important implications for both health care providers and clinicians.

Time for Disney to Let It Go: Real and Fictional Thin-Ideal Media Exposure on Women's Body Satisfaction

Minica Long

In today's media, women are often portrayed through the thin-ideal standard, where models and actresses in magazines and television are attractive, with small waists and slender bodies. Children's media also portray fictional female characters in this way. Effects of exposure to thin-ideal models has shown to decrease body satisfaction in women and girls (Groesz, Levine, & Murnen, 2002); however, there is limited information

about the role of thin-ideal fictional cartoon characters. The current study investigated how exposure to thin-ideal real women and fictional cartoon characters affects women's body satisfaction. A sample of 104 college-aged women were exposed to either real thin-ideal, fictional thin-ideal, real normal-sized, or fictional normal-sized images while playing an interactive ball-tossing game. Participants' body satisfaction was measured both before and after being exposed to the images in the game. Results indicated that media type (real vs. fiction) and body type (thin-ideal vs. normal-sized) did not significantly impact women's body satisfaction from before to after exposure to the images. However, before being exposed to the images, women who were told they would play the ball tossing game with real people reported higher body satisfaction than women who were told they would play with fictional characters. This significant finding suggests that simply believing they will be engaging in an interaction with real peers increases women's body satisfaction. The potential underlying reasons for this finding as well as its implications are discussed.

In and Out of the College "Estro-Gym:" Investigating Social Norms, Individual Differences, and the "Perfect Storm" for Disordered Eating and Exercise

Abra Owens

This study examined relationships between social norms and individual difference factors and disordered eating behaviors in college men and women. Specifically, we examined the role of descriptive (frequency) and injunctive (social acceptability) norms surrounding disordered eating behavior on the college campus in conjunction with measures of body dissatisfaction, perfectionism, compulsive exercise, and varsity athletic participation to study whether these factors jointly predicted a change in disordered eating from the beginning of the semester to the end of the semester. It was hypothesized that social norms would mediate change over time in disordered eating, with body dissatisfaction and compulsive exercise moderating this relationship, specifically for first-year women. Participants were 78 female and 46 male Williams College students who completed measures in September and in November on their own eating behaviors, body dissatisfaction, perfectionism, compulsive exercise, and their perceptions of the norms surrounding disordered eating on campus for both genders separately. Forty-five staff/faculty members also completed measures on their perceptions of disordered eating among students on campus, for comparison purposes. Results showed that disordered eating behaviors did not change over time, and that the only predictor of disordered eating behavior at the end of the semester was disordered eating behavior at the beginning. Correlations were found between many of the key variables: disordered eating, body dissatisfaction, compulsive exercise, and the social norms surrounding disordered eating behavior. Social and clinical implications of these associations and future research directions are explored.

Effects of Self-Affirmation on Willingness to Discuss Race

Raea Rasmussen

The current study investigated whether self-affirmation would lead to stronger multiculturalist racial attitudes and greater desire to talk about race-related issues. Studies 1 (N=75) and 2 (N=69) found that self-affirmation increased non-Black participants' propensity to recognize race and their desire to talk about a race-related topic with a Black partner. Study 3 (N=43) examined whether self-affirmation predicted a decrease in colorblindness and an increase in multicultural racial attitudes as demonstrated on the Color-Blind Racial Attitudes Scale, and results indicated a significant relationship among women. These studies extend upon previous findings to demonstrate for the first time that self-affirmation can lead to increased desire among non-Black participants to engage in interracial discussions about race-related topics, as well as encourage a multiculturalist racial attitude within interactions. Limitations of the current study as well as potential future applications of self-affirmation to a broader population and to other issues of social inequality are discussed.

Abstracts from Presentations and Publications

Astronomy

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, ***125-126****, April 2015, 59–77*

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)].

Observations of the same-day 2011 stellar occultation by Charon and graze by Pluto

Gulbis, A. A. S., J. P. Emery, M. J. Person, A. S. Bosh, C. A. Zuluaga, J. M. Pasachoff, and B. A. Babcock

Icarus, ***246****, 226-236. DOI: 10.1016/j.icarus.2014.05.014*

Pluto's lower atmosphere has been observed to evolve since the first definitive occultation detection in 1988. Possibilities for explaining the lower atmospheric structure include a steep thermal gradient and/or extinction, the latter of which can be characterized as a dependence between occultation flux and wavelength. On 2011 June 23, a 14.43 UCAC2 magnitude star (R=13.64) was occulted by Pluto as observed from multiple sites. Observations made at NASA's 3-m Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii, showed a full occultation of the star by Charon followed by an atmospheric graze by Pluto. Data were taken simultaneously in visible-wavelength images and low-resolution, near-infrared spectra. This dataset is unique in that (i) the double occultation allows astrometric measurements for Pluto and Charon as well as accurate calibration of the Pluto light curve, and (ii) the wavelength-resolved data serve as a test for atmospheric extinction. The graze reached a minimum normalized flux level of roughly 0.35, serving primarily as a probe of Pluto's upper atmosphere (which is typically defined to be above half-light level in occultation light curves). However, the light curve is well fit by atmospheric models with a clear upper atmosphere and a thermal gradient plus haze in the lower atmosphere. We find a negative dependence between flux and wavelength in the deepest part

of Pluto's atmosphere probed by the graze and in a spike during emersion. A simple extinction model for spherical, μm-sized tholins matches the observed spectral trends. While other particle compositions and size distributions are possible, the feasibility of this fit suggests that Pluto's lower atmosphere contained haze in 2011. These results provide an important link in monitoring Pluto's dynamic atmosphere.een published up to date on TOS occurred over Africa [Mauritania (1973), Zimbabwe (2001) and Nigeria (2006)].

The State of Pluto's Atmosphere in 2013

Bosh, A. S., M. J. Person, S. E. Levine, C. A. Zuluaga, A. M. Zangari, A. A. S. Gulbis, G. Schaefer, E. W. Dunham, B. A. Babcock, A. B. Davis, J. M. Pasachoff, P. Rojo, E. Servajean, F. Förster, T. Oswalt, D. Batcheldor, D. Bell, P. Bird, D. Fey, T. Fulwider, E. Geisert, D. Hastings, C. Keuhler, T. Mizusawa, P. Solenski, B. Watson

Icarus, ***246****, 237-246. http://dx.doi.org/10.1016/j.icarus.2014.03.048*

We observed two stellar occultations on UT 4 May 2013 and UT 9 September 2012, with the aim of measuring Pluto's atmospheric parameters. Both of these events were observed by world-wide collaborations of many observers, and both occurred within one month of Pluto's stationary points. The PC20120909 event was observed at the McDonald Observatory (MONET 1.2-m), and Olin Observatory (the Ortega 0.8-m); the P20130504 event was observed at the Las Campanas Observatory (du Pont 2.5-m), the Cerro Tololo Inter-American Observatory (SMARTS 1-m), and the Cerro Calán National Astronomical Observatory (Goto 0.45-m). Analysis of the data indicates an atmospheric state similar to that in June 2011. The shadow radius for the event is unchanged from recent events, indicating an atmosphere that is holding stable and not in the midst of global collapse. We discuss the advantages and disadvantages of comparing various atmospheric parameters across events (the shadow radius vs. the pressure at a particular radius). These analyses suggest that Pluto will still have an atmosphere when the New Horizons spacecraft arrives in July 2015.

Structure and Dynamics of the 13/14 November 2012 White-Light Corona

Pasachoff, J. M., V. Rušin, M. Saniga, B. A. Babcock, M. Lu, A. B. Davis, R. Dantowitz, P. Gaintatzis, J. H. Seiradakis, A. Voulgaris, D. B. Seaton, and K. Shiota

Astrophysical Journal 800, 90

Continuing our series of observations of the motion and dynamics of the solar corona over the solar-activity cycle, we observed the corona from sites in Queensland, Australia, during the 13 (UT)/14 (local time) November 2012 total solar eclipse. The corona took the low-ellipticity shape typical of solar maximum, unlike the similar composite coronal images that we had observed and analyzed in this journal and elsewhere for the 2006, 2008, 2009, and 2010 eclipses. After crossing the northeast Australian coast, the rest of the path of totality was over the ocean, so further totality was seen only by shipborne observers. During the 36 minutes of passage from the Queensland coast to a ship north of New Zealand, a coronal mass ejection erupted (estimated speed of 413 km s−1), and we analyze its dynamics. Our higher-resolution composite Queensland images of the solar corona show a plethora of different features, including, many helmet streamers, very faint bright and dark loops at the base of helmet streamers, voids and radially oriented thin streamers. The eclipse observations are further compared with a hairy-ball model of the magnetic field and near-simultaneous images from the Atmospheric Imaging Assembly on the NASA's Solar Dynamics Observatory (SDO/AIA), the Extreme Ultraviolet Imager on NASA's Solar Terrestrial Relations Observatory (STEREO/EUVI), the Sun Watcher using Active Pixel System Detector and Image Processing on ESA's PRoject for OnBoard Autonomy 2 (PROBA2/SWAP), and NRL's Large Angle and Spectrometric Coronagraph on ESA's Solar and Heliospheric Observatory (SOHO/LASCO). The Ludendorff flattening coefficient is 0.01 matching the expected ellipticity of coronal isophotes at 2 R , for this maximum phase of the solar-activity cycle.

Simon Marius's Mundus Iovialis: 400th Anniversary in Galileo's Shadow

Pasachoff J. M

Journal for the History of Astronomy, May 2015

Simon Marius, Court Astronomer in Ansbach in Germany, independently discovered the moons of Jupiter one day after Galileo's widely accepted discovery on 7 January 1610. Because Marius was using the Julian calendar

(so-called O.S., Old Style), his discovery was made in 1609, though adding the 10 days of difference to transform, to the Gregorian calendar (so-called N.S., New Style) that Galileo was using, his notes of his discovery give 8 January 1610 (N.S.). Further, though Galileo famously published his Sidereus Nuncius in March 1610, Marius did not publish his discovery of four moons circling Jupiter until 1611, in a locally circulated almanac. He then published this work in a major book, Mundus Iovalis, though not until 1614. Galileo, who was forceful in asserting his priority, accused Marius of plagiarism in Il Saggiatore (1623), and Marius's reputation was ruined for hundreds of years. Only in the early 1900s did a jury in the Netherlands assess the discovery claims and vindicate Marius, though Marius deserves more credit and recognition with the general public than he currently has. Still, the current names we use for the four major moons of Jupiter—Io, Europa, Ganymede, and Callisto—come from Marius's book, of which approximately 30 copies from 1610 survive. Marius's 1614 frontispiece, and his earlier almanac, show the four satellites in orbits, in contrast to Galileo's use of asterisks and the letter O, so arguably Marius provided the first images of the orbits of what we call the Galilean satellites and what Galileo himself called first the Cosmean stars (Cosmica Sidera) and finally, in print, the Medicean stars (Medicea Sidera).

Coordinated Occultation Observations for Pluto, Nix, and Quaoar in July 2014

Pasachoff, Jay M., Adam R. Schiff, Christina H. Seeger, Bryce A. Babcock, Michael J. Person, Amanda A. S. Gulbis, Amanda S. Bosh, Carlos A. Zuluaga, Stephen E. Levine, David J. Osip, Patricio Rojo, Molly Kosiarek

Tucson DPS, 419.01 2014

We observed Pluto, its moon Nix, and Quaoar during a predicted series of occultations in July 2014 with the 1-m telescope of the Mt. John University Observatory in New Zealand. The observations were based on new USNO photometry. We successfully detected occultations by Pluto of an R=18 mag star on 23 July (14:23:30 ± 00:00:10 UTC to 14:25:30 ± 00:00:10 UTC), with a drop of 5%, and of an R=17 star on 24 July (11:41:30 ± 00:00:10 UTC to 11:43:30 ± 00:00:10 UTC), with a drop of 3%, both with 20 s exposures with our frame-transfer POETS. Since Pluto had a geocentric velocity of 22.51 km/s on 23 July and 22.35 km/s on 24 July, these intervals yield limits on the chord lengths (surface + lower atmosphere) of 2700 ± 130 km and 2640 ± 250 km respectively, indicating that the events were near central, and provide astrometric data. Our coordinated observations with the 4-m AAT in Australia on 23 July and the 6.5-m Magellan/Clay, the 4.1-m SOAR, the 2.5-m DuPont, the 0.6-m SARA South, and the 0.45-m Cerro Calán telescopes in Chile on July 27 and 31, which would have provided higher-cadence observations for studies of Pluto's atmosphere, were largely foiled by clouds. This work was supported in part by NASA Planetary Astronomy grants to Williams College (NNX12AJ29G) and to MIT (NNX10AB27G), as well as grants from USRA (#8500-98-003) and Ames Research (#NAS2-97-01) to Lowell Observatory. A.R.S. was supported by NSF grant AST-1005024 for the Keck Northeast Astronomy Consortium REU, with partial support from U.S. DoD's ASSURE program. P.R. acknowledges support from FONDECYT through grant 1120299.

Evidence of haze in Pluto's lower atmosphere in 2011

Gulbis, A. A. S., Josh P. Emery, Michael J. Person, Amanda S. Bosh, Carlos A. Zuluaga, Jay M. Pasachoff, and Bryce A. Babcock

Tucson DPS, 401.01 2014

Based on stellar occultation observations since 1988, Pluto's lower atmosphere has been evolving (e.g., Elliot et al. 2007, AJ, 134, 1; Young et al. 2008, AJ, 136, 1757; Bosh et al. 2014, Icarus, in press). The structure of the lower atmosphere is likely due to a steep thermal gradient and/or extinction, the latter of which can be characterized as a dependence between observed occultation flux and wavelength. On 2011 June 23, a 13.64 R-magnitude star was occulted by Pluto as observed from multiple sites (Person et al. 2013, AJ, 146, 83). Observations made at NASA's 3-m Infrared Telescope Facility (IRTF) on Mauna Kea, Hawai'i, showed a full occultation of the star by Charon followed by an atmospheric graze by Pluto. Data were taken simultaneously in visible-wavelength images and low-resolution, near-infrared spectra. This unique, wavelength-resolved dataset serves as a test for atmospheric extinction.

The graze primarily probed Pluto's upper atmosphere. Th e upper atmosphere is typically defined to be above

half-light level in occultation light curves (approximately three pressure scale heights above the surface), and the graze reached a minimum of roughly 0.35 flux. However, the light curve is well matched by an atmospheric model with a power-law thermal gradient, a clear upper atmosphere, and haze in the lower atmosphere. Furthermore, there is a negative dependence between flux and wavelength in the deepest part of the atmosphere probed by the graze, as well as in an emersion spike. We find that a simple extinction model for spherical, micron-sized tholins matches the observed spectral trends (Gulbis et al. 2014, Icarus, in press). While the atmospheric fits cannot rule out a clear atmosphere having a steep thermal gradient at the bottom, the flux-wavelength dependence and the feasibility of our particle-scattering fits suggest that Pluto's lower atmosphere contained haze in 2011. These results provide an important link in monito ring Pluto's dynamic atmosphere, especially placed in context of the imminent arrival of the New Horizons spacecraft.

Recreating Galileo's 1609 Discovery of Lunar Mountains

Pasachoff, Jay M., Paul Needham, Ernest T. Wright, and Owen Gingerich

Tucson DPS, 106.06 2014

The question of exactly which lunar features persuaded Galileo that there were mountains on the moon has not yet been definitively answered; Galileo was famously more interested in the concepts rather than the topographic mapping in his drawings and the eventual engravings. Since the pioneering work of Ewen Whitaker on trying to identify which specific lunar-terminator features were those that Galileo identified as mountains on the moon in his 1609 observations reported in his Sidereus Nuncius (Venice, 1610), and since the important work on the sequence of Galileo's observations by Owen Gingerich (see "The Mystery of the Missing 2" in Galilaeana IX, 2010, in which he concludes that "the Florentine bifolium sheet [with Galileo's watercolor images] is Galileo's source for the reworked lunar diagrams in Sidereus Nuncius"), there have been advances in lunar topographical measurements that should advance the analysis. In particular, one of us (E.W.) at the Scientific Visualization Studio of NASA's Goddard Space Flight Center has used laser-topography from NASA's Lunar Reconnaissance Orbiter to recreate what Galileo would have seen over a sequence of dates in late November and early December 1609, and provided animations both at native resolution and at the degraded resolution that Galileo would have observed with his telescope. The Japanese Kaguya spacecraft also provides modern laser-mapped topographical maps.

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

Widemann, Thomas, Sarah Jaeggli, Kevin Reardon, Paolo Tanga, Christophe Père, Jay M. Pasachoff, Ann Carine Vandaele, Valerie Wilquet, Arnaud Mahieux, Colin Wilson

Tucson DPS, 302.06 2014

The transit of Venus in June 2012 provided a unique case study of the Venus' atmosphere transiting in front of the Sun, while at the same time ESA's Venus Express orbiter observed the evening terminator at solar ingress and solar egress.

We report on mesospheric temperature at Venus' morning terminator using SDO/HMI aureole photometry and comparison with Venus Express. Close to ingress and egress phases, we have shown that the aureole photometry reflects the local density scale height and the altitude of the refracting layer (Tanga et al. 2012). The lightcurve of each spatially resolved aureole element is fit to a two-parameter model to constrain the meridional temperature gradient at terminator. Our measurements are in agreement with the VEx/SOIR temperatures obtained during orbit 2238 at evening terminator during solar ingress (46.75N – LST = 6.075 PM) and solar egress (31.30N – LST = 6.047 PM) captured from the Venus Express orbiter at the time Venus transited the Sun.

We also performed spectroscopy and polarimetry during the transit of Venus focusing on extracting signatures of CO2 absorption. Observations were taken during the first half of the transit using the Facility InfraRed Spectropolarimeter (FIRS) on the Dunn Solar Telescope (DST). Although the predicted CO2 transmission spectrum of Venus was not particularly strong at 1565 nm, this region of the H–band often

used in magnetic field studies of the Sun's photosphere provides a particularly flat solar continuum with few atmospheric lines. Sun-subtracted Venus limb observations show intensity distribution of vibrational CO2 bands 221 2v+2v2+v3 at 1.571 μm and 141 v1+4v2+v3 at 1.606 μm.

400th Anniversary of Marius's Book with the First Image of an Astronomical Telescope and of Orbits of Jovian Moons

Pasachoff, Jay M., and Pierre Leich

Presented at 225th meeting of the American Astronomical Society in Seattle, WA, January 2015

Simon Mayr's (Marius's) Mundus Iovialis Anno M·DC·IX Detectus Ope Perspicilli Belgici was published in Nuremberg in 1614; Marius was the Ansbach court mathematician. The frontispiece includes not only a portrait of Marius (1573-1624) himself but also, in the foreground, a long tube labelled "perspicillum," the first known image of a telescopic device; the name "telescope" came later. A schematic diagram of Jupiter with four moons appears at upper left; Marius, following a suggestion from Kepler, gave these Galilean satellites the names now still in us: Io, Europa. Ganymede, and Callisto. The title continues Hoc est, Quatuor Joviali cum Planetarum, cum Theoria, tum Tabulae, Propriis Observationibus Maxime Fundate.... A variety of conferences and other special events were held in Germany in 2014 to commemorate the 400th anniversary of Marius's book and to discuss Marius's work and its relation to Copernicus's work (http://www.simon-marius.net; http://www.simon-marius.net/index.php?lang=en&menu=1). Marius (Mayr) had independently discovered the four satellites of Jupiter, apparently one day after Galileo, on December 29 O.S., 1609; by the time he published his work four years later (a local-circulation publication had appeared in Nuremberg in 1611 in Prognosticon Astrologicum auf das Jahr 1612), Galileo had gained fame and priority, and Galileo accused Marius of plagiarism in Il Saggiatore (1623). With his Belgian telescope, Marius also noted the tilt of the orbital plane of Jupiter's moons, sunspots (1611), and the Andromeda Nebula (1612). A crater, the Marius Hills, and the Rima Marius on the Moon are named for him by the I.A.U.

Trio of stellar occultations by Pluto One Year Prior to New Horizons' Arrival,

Pasachoff, Jay M., Michael J. Person, Amanda S. Bosh, Amanda A. S. Gulbis, Carlos Zuluaga, Stephen E. Levine, David J. Osip, Adam R. Schiff, Christina H. Seeger, Bryce A. Babcock, Patricio Rojo, Molly R. Kosiarek, and Elise Servajean

Presented at 225th meeting of the American Astronomical Society in Seattle, WA, January 2015

Our campaign in July 2014 yielded three successful stellar occultations (~m=15, 17, and 18) of Pluto (~m=14), observed from telescopes in New Zealand, Australia, and Chile. Telescopes involved including Chile: Magellan's Clay (6.5 m), SOAR (4.1 m), Carnegie's DuPont (2.4 m); Australia: AAT (4 m); and Canterbury's Mt. John McLellan (1-m); as well as various smaller telescopes in Australia and Chile. Though our observations were coordinated across continents, each successfully observed event was seen from only one site because of bad weather at the other sites. Two of the events were uniquely observed from Mt. John (Pasachoff et al., DPS 2014) and one, with only Chile sites in the predicted path, from the Clay (Person et al., DPS 2014). This last event was expected to be of the brightest star with the largest telescope we have ever observed for a Pluto occultation, but clouds arrived at the 6.5-m Clay 90 s before the predicted time; a 1% occultation was nonetheless seen and eventually, confirmed by Keck AO observations, to be of a 15th magnitude star previously hidden in the brightness of the 12th mag star. Our scientific conclusion is that as of these observations, one year before New Horizons' passage of Pluto, the atmosphere of Pluto remained robust and of the same size.

Acknowledgments: This work was supported in part by NASA Planetary Astronomy grants to Williams College (NNX12AJ29G) and to MIT (NNX10AB27G), as well as grants from USRA (#8500-98-003) and Ames Research (#NAS2-97-01) to Lowell Observatory. A.R.S. was supported by NSF grant AST-1005024 for the Keck Northeast Astronomy Consortium REU, with partial support from U.S. DoD's ASSURE program. P.R. acknowledges support from FONDECYT through grant 1120299. J.M.P. thanks Andrew Ingersoll and Caltech Planetary Astronomy for hospitality.

Co-spatial Long-slit UV/Optical Spectra of 10 Galactic Planetary Nebulae with HST/STIS. I. Description of the Observations, Global Emission-line Measurements, and CNO Abundances

Reginald J. Dufour, Karen B. Kwitter, Richard A. Shaw, Richard B. C. Henry, Bruce Balick, and Romano L. M. Corradi

The Astrophysical Journal, 803:23 (24pp), 2015 April 10

We present observations and initial analysis from a Hubble Space Telescope (HST) Cycle 19 program using STIS to obtain the first co-spatial, UV–optical spectra of 10 Galactic planetary nebulae (PNs). Our primary objective was to measure the critical emission lines of carbon and nitrogen with unprecedented signal-to-noise ratio (S/N) and spatial resolution over the wavelength range 1150–10270 Å, with the ultimate goal of quantifying the production of these elements in low- and intermediate-mass stars. Our sample was selected from PNs with a near-solar metallicity, but spanning a broad range in N/O based on published ground-based and IUE spectra. This study, the first of a series, concentrates on the observations and emission-line measurements obtained by integrating along the entire spatial extent of the slit. We derived ionic and total elemental abundances for the seven PNs with the strongest UV line detections (IC 2165, IC 3568, NGC 2440, NGC 3242, NGC 5315, NGC 5882, and NGC 7662). We compare these new results with other recent studies of the nebulae and discuss the relative merits of deriving the total elemental abundances of C, N, and O using ionization correction factors (ICFs) versus summed abundances. For the seven PNs with the best UV line detections, we conclude that summed abundances from direct diagnostics of ions with measurable UV lines give the most accurate values for the total elemental abundances of C and N (although ICF abundances often produced good results for C). In some cases where significant discrepancies exist between our abundances and those from other studies, we show that the differences can often be attributed to their use of fluxes that are not co-spatial. Finally, we examined C/O and N/O versus O/H and He/H in well observed Galactic, LMC, and SMC PNs and found that highly accurate abundances are essential for properly inferring elemental yields from their progenitor stars. Future papers will discuss photoionization modeling of our observations, of both the integrated spectra and spatial variations of the UV versus optical lines along the STIS slit lengths, which are unique to our observations.

Cospatial Longslit UV-Optical Spectra of Ten Galactic Planetary Nebulae with HST STIS: Description of Observations, Global Emission-Line Measurements, and Empirical CNO Abundances

Dufour, R.J., Kwitter, K.B., Shaw, R.A., Balick, B., Henry, R.B.C., Miller, T.R., & Corradi, R.L.M.,

Presented at 225th meeting of the American Astronomical Society in Seattle, WA, January 2015

This poster describes details of HST Cycle 19 (program GO 12600), which was awarded 32 orbits of observing me with STIS to obtain the first cospatial UV-optical spectra of 10 Galactic planetary nebulae (PNe). The observational goal was to measure the UV emission lines of carbon and nitrogen with unprecedented S/N and wavelength and spatial resolution along the disk of each object over a wavelength range 1150-10270 Å. The PNe were chosen such that each possessed a near-solar metallicity but the group together spanned a broad range in N/O. This poster concentrates on describing the observations, emission-line measurements integrated along the entire slit lengths, ionic abundances, and estimated total elemental abundances using empirical ionization correction factors and the ELSA code. Related posters by co-authors in this session concentrate on analyzing CNO abundances, progenitor masses and nebular properties of the best-observed targets using photoionization modeling of the global emission-line measurements [Henry et al.] or detailed analyses of spatial variations in electron temperatures, densities, and abundances along the sub-arcsecond resolution slits [Miller et al. & Shaw et al.]. We gratefully acknowledge AURA/STScI for the GO 12600 program support, both observational and financial.

Central Star Properties and C-N-O Abundances in Eight Galactic Planetary Nebulae from New HST/STIS Observations

Henry, R.B.C., Balick, B., Dufour, R.J., Kwitter, K.B., Shaw, R.A., & Corradi, R.L.M.

Presented at 225th meeting of the American Astronomical Society in Seattle, WA, January 2015

We present detailed photoionization models of eight Galactic planetary nebulae (IC2165, IC3568, NGC2440, NGC3242, NGC5315, NGC5882, NGC7662, & PB6) based on recently obtained HST STIS spectra. Our interim goal is to infer Teff, luminosity, and current and progenitor masses for each central star, while the ultimate goal is to constrain published stellar evolution models which predict nebular CNO abundances. The models were produced by using the code CLOUDY to match closely the measured line strengths derived from high-quality HST STIS spectra (see poster by Dufour et al., this session) extending in wavelength from 1150-10270 Å. The models assumed a blackbody SED. Variable input parameters included Teff, a radially constant nebular density, a filling factor, and elemental abundances. For the eight PNs we found a birth mass range of 1.5-2.9 Msun, a range in log(L/Lsun) of 3.10-3.88, and a Teff range of 51-150 kK. Finally, we compare CNO abundances of the eight successful models with PN abundances of these same elements that are predicted by published stellar evolution models. We gratefully acknowledge generous support from NASA through grants related to the Cycle 19 program GO12600.

Analysis of Co-spatial UV-Optical STIS Spectra of Planetary Nebulae From HST Cycle 19 GO 12600

Miller, T.R., Henry, R.B.C., Dufour, R.J., Kwitter, K.B., Shaw, R.A., Balick, B., & Corradi, R.L.M

Presented at 225th meeting of the American Astronomical Society in Seattle, WA, January 2015

We present an analysis of five spatially resolved planetary nebulae (PNe), NGC 5315, NGC 5882, NGC 7662, IC 2165, and IC 3568, from observations in the Cycle 19 program GO 12600 using HST STIS. Details of the observa ons and data are presented in the poster by Dufour et al. in this session. These five observations cover the wavelength range 1150-10,270 Å with 0.2 and 0.5 arcsec wide slits, and are co-spatial to 0.1 arcsec along a 25 arcsec length across each nebula. This unprecedented resolution in both wavelength and spatial coverage enabled detailed studies of physical conditions and abundances from UV line ion emissions (compared to optical lines). We first analyzed the low- and moderate-resolution UV emission lines of carbon using the resolved lines of C III] 1906.68 and 1908.73, which yielded a direct measurement of the density within the volume occupied by doubly-ionized carbon and other similar co-spatial ions. Next, each PN spectrum was divided into spatial sub-regions in order to assess inferred density variations among the sub-regions along the entire slit. Variations in electron temperature and chemical abundances were also probed. Lastly, these nebulae were modeled in detail with the photoionization code CLOUDY. This modeling tested different density profiles in order to reproduce the observed density variations and temperature fluctuations, and constrain central star parameters. We gratefully acknowledge generous support from NASA through grants related to the Cycle 19 program GO 12600, as well as from the University of Oklahoma.

New CNO Elemental Abundances in Planetary Nebulae from Spatially Resolved UV/Optical Emission Lines

Shaw, R.A., Kwitter, K.B., Henry, R.B.C., Dufour, R.J., Balick, B., & Corradi, R.L.M.

Presented at 225th meeting of the American Astronomical Society in Seattle, WA, January 2015

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.

Biology

Unmasking host and microbial strategies in the Agrobacterium-plant defense tango.

Hwang, E.E. ('13), Wang, M.B. ('14), Bravo, J.E., and ***Banta LM****.*

Front Plant Sci. 2015 Mar 31;6:200. doi: 10.3389/fpls.2015.00200

Coevolutionary forces drive adaptation of both plant-associated microbes and their hosts. Eloquently captured in the Red Queen Hypothesis, the complexity of each plant-pathogen relationship reflects escalating adversarial strategies, but also external biotic and abiotic pressures on both partners. Innate immune responses are triggered by highly conserved pathogen-associated molecular patterns, or PAMPs, that are harbingers of microbial presence. Upon cell surface receptor-mediated recognition of these pathogen-derived molecules, host plants mount a variety of physiological responses to limit pathogen survival and/or invasion. Successful pathogens often rely on secretion systems to translocate host-modulating effectors that subvert plant defenses, thereby increasing virulence. Host plants, in turn, have evolved to recognize these effectors, activating what has typically been characterized as a pathogen-specific form of immunity. Recent data support the notion that PAMP-triggered and effector-triggered defenses are complementary facets of a convergent, albeit differentially regulated, set of immune responses. This review highlights the key players in the plant's recognition and signal transduction pathways, with a focus on the aspects that may limit Agrobacterium tumefaciens infection and the ways it might overcome those defenses. Recent advances in the field include a growing appreciation for the contributions of cytoskeletal dynamics and membrane trafficking to the regulation of these exquisitely tuned defenses. Pathogen counter-defenses frequently manipulate the interwoven hormonal pathways that mediate host responses. Emerging systems-level analyses include host physiological factors such as circadian cycling. The existing literature indicates that varying or even conflicting results from different labs may well be attributable to environmental factors including time of day of infection, temperature, and/or developmental stage of the host plant.

16S rRNA survey of microbial communities in Winogradsky columns

Rundell, E., L. M. Banta, D. V. Ward, C. D. Watts ('10), B. Birren, and D. J. Esteban

PLoS One 9(8):e104134.

A Winogradsky column is a clear glass or plastic column filled with enriched sediment. Over time, microbial communities in the sediment grow in a stratified ecosystem with an oxic top layer and anoxic sub-surface layers. Winogradsky columns have been used extensively to demonstrate microbial nutrient cycling and metabolic diversity in undergraduate microbiology labs. In this study, we used high-throughput 16s rRNA gene sequencing to investigate the microbial diversity of Winogradsky columns. Specifically, we tested the impact of sediment source, supplemental cellulose source, and depth within the column, on microbial community structure. We found that the Winogradsky columns were highly diverse communities but are dominated by three phyla: Proteobacteria, Bacteroidetes, and Firmicutes. The community is structured by a founding population dependent on the source of sediment used to prepare the columns and is differentiated by depth within the column. Numerous biomarkers were identified distinguishing sample depth, including Cyanobacteria, Alphaproteobacteria, and Betaproteobacteria as biomarkers of the soil-water interface, and Clostridia as a biomarker of the deepest depth. Supplemental cellulose source impacted community structure but less strongly than depth and sediment source. In columns dominated by Firmicutes, the family Peptococcaceae was the most abundant sulfate reducer, while in columns abundant in Proteobacteria, several Deltaproteobacteria families, including Desulfobacteraceae, were found, showing that different taxonomic groups carry out sulfur cycling in different columns. This study brings this historical method for enrichment culture of chemolithotrophs and other soil bacteria into the modern era of microbiology and demonstrates the potential of the Winogradsky column as a model system for investigating the effect of environmental variables on soil microbial communities.

Coevolution: Puff Pollination in Tropical Flowers

Joan Edwards

Current Biology (Impact Factor: 9.57). 07/2014; 24(14):R649–R651. DOI: 10.1016/j.cub.2014.06.020

ABSTRACT A new study shows that birds plucking anthers of the Melastome, Axinaea, demonstrate a novel bird pollination mechanism. Each stamen of Axinaea offers a nutrient-rich, berry-like food body that, when bitten, releases a puff of pollen allowing transfer to stigmas by wind or the pollen-dusted bird.

Group housing and nest building only slightly ameliorate the cold stress of typical housing in female C57Bl/6J mice

Maher, R. L., S.M. Barbash, D.V. Lynch and S.J. Swoap

American Journal of Physiology – Regulatory, Integrative and Comparative Physiology (308: in press). 2015.

Huddling and nest building are two methods of behavioral thermoregulation utilized by mice under cold stress. In the laboratory, mice are typically housed at an ambient temperature (T_a) of 20°C, well below the lower end of their thermoneutral zone. We tested the hypothesis that the thermoregulatory benefits of huddling and nest building at a T_a of 20°C would ameliorate this cold stress as compared to being singly housed at 20°C as assessed by heart rate (HR), blood pressure (BP), triiodothyronine (T3), brown adipose (BAT) expression of Elovl3 mRNA, and BAT lipid content. A series of experiments using C57BL/6J female mice exposed to 20°C in the presence or absence of nesting material and/or cage mates was used to test this hypothesis. Mice showed large differences in HR, BP, shivering, and core body temperature (T_b) when comparing singly housed mice at 20°C and 30°C, but only a modest reduction in just HR with the inclusion of cage mates or bedding. However, group housing and/or nesting at 20°C decreased T3 levels as compared to singly housed mice at 20°C. Singly housed mice at 20°C had a 22-fold higher level of BAT Elovl3 mRNA expression and a significantly lower triacylglycerol (TAG) content of BAT when compared to singly housed mice at 30°C. Group housing at 20°C led to blunted changes in both Elovl3 mRNA and TAG levels. These findings suggest that huddling and nest building have a limited effect to ameliorate the cold stress associated with housing at 20°C.

Chronic rapamycin treatment causes diabetes in male mice

Schindler, C.E., U. Partap, B. Patchen, and ***Steven J. Swoap***

Am J Physiol Regul Integr Comp Physiol. 307:4 R434-R443, 2014

Current evidence indicates that the mammalian target of rapamycin inhibitor rapamycin both increases longevity and, seemingly contradictorily, impairs glucose homeostasis. Most studies exploring the dimensions of this paradox have been based on rapamycin treatment in mice for up to 20 wk. We sought to better understand the metabolic effects of oral rapamycin over a substantially longer period of time in HET3 mice. We observed that treatment with rapamycin for 52 wk induced diabetes in male mice, characterized by hyperglycemia, significant urine glucose levels, and severe glucose and pyruvate intolerance. Glucose intolerance occurred in male mice by 4 wk on rapamycin and could be only partially reversed with cessation of rapamycin treatment. Female mice developed moderate glucose intolerance over 1 yr of rapamycin treatment, but not diabetes. The role of sex hormones in the differential development of diabetic symptoms in male and female mice was further explored. HET3 mice treated with rapamycin for 52 wk were gonadectomized and monitored over 10 wk. Castrated male mice remained glucose intolerant, while ovariectomized females developed significant glucose intolerance over the same time period. Subsequent replacement of 17β-estradiol (E2) in ovariectomized females promoted a recovery of glucose tolerance over a 4-wk period, suggesting the protective role of E2 against rapamycin-induced diabetes. These results indicate that 1) oral rapamycin treatment causes diabetes in male mice, 2) the diabetes is partially reversible with cessation of treatment, and 3) E2 plays a protective role against the development of rapamycin-induced diabetes.

High-fructose feeding fails to induce excessive weight gain or leptin resistance in mice

Tillman, E.J., D.A. Morgan, K. Rahmouni, and ***Steven J. Swoap***

High-fructose diets have been implicated in obesity via impairment of leptin signaling in humans and rodents. We investigated whether fructose-induced leptin resistance in mice could be used to study the metabolic consequences of fructose consumption in humans, particularly in children and adolescents. Male C57Bl/6 mice were weaned to a randomly assigned diet: high fructose, high sucrose, high fat, or control (sugar-free, low-fat). Mice were maintained on their diets for at least 14 weeks. While fructose-fed mice regularly consumed more kcal and expended more energy, there was no difference in body weight compared to control by the end of the study. Additionally, after 14 weeks, both fructose-fed and control mice displayed similar leptin sensitivity. Fructose-feeding also did not change circulating glucose, triglycerides, or free fatty acids. Though fructose has been linked to obesity in several animal models, our data fail to support a role for fructose intake through food lasting 3 months in altering of body weight and leptin signaling in mice. The lack of impact of fructose in the food of growing mice on either body weight or leptin sensitivity over this time frame was surprising, and important information for researchers interested in fructose and body weight regulation.

Group Housing and Nest Building Do Not Completely Ameliorate the Cold Stress of Typical Housing in Mice.

Maher, R., S. Barbash, D. Lynch, and ***Steven J. Swoap***

Am J Physiol Regul Integr Comp Physiol, In press, 2015. .

Huddling and nest building are two methods of behavioral thermoregulation utilized by mice under cold stress. In the laboratory, mice are typically housed at an ambient temperature (Ta) of 20°C, well below the lower end of their thermoneutral zone. We tested the hypothesis that the thermoregulatory benefits of huddling and nest building at a Ta of 20°C would ameliorate this cold stress as compared to being singly housed at 20°C as assessed by heart rate (HR), blood pressure (BP), triiodothyronine (T3), brown adipose (BAT) expression of Elovl3 mRNA, and BAT lipid content. A series of experiments using C57BL/6J female mice exposed to 20°C in the presence or absence of nesting material and/or cage mates was used to test this hypothesis. Mice showed large differences in HR, BP, shivering, and core body temperature (Tb) when comparing singly housed mice at 20°C and 30°C, but only a modest reduction in just HR with the inclusion of cage mates or bedding. However, group housing and/or nesting at 20°C decreased T3 levels as compared to singly housed mice at 20°C. Singly housed mice at 20°C had a 22-fold higher level of BAT Elovl3 mRNA expression and a significantly lower triacylglycerol (TAG) content of BAT when compared to singly housed mice at 30°C. Group housing at 20°C led to blunted changes in both Elovl3 mRNA and TAG levels. These findings suggest that huddling and nest building have a limited effect to ameliorate the cold stress associated with housing at 20°C.

The Prochlorococcus carbon dioxide-concentrating mechanism: Evidence of carboxysome-associated heterogeneity

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Photosynthesis Research 123:45-60. (Electronic version published on September 6, 2014)

*Williams College student

The ability of *Prochlorococcus* to numerically dominate open ocean regions and contribute significantly to global carbon cycles, is dependent in large part on its effectiveness in transforming light energy into compounds used in cell growth, maintenance and division. Integral to these processes is the carbon dioxide-concentrating mechanism (CCM), which enhances photosynthetic CO_2 fixation. The CCM involves both active uptake systems that permit intracellular accumulation of inorganic carbon as the pool of bicarbonate, and the system of HCO_3^- conversion into CO_2. The latter is located in the carboxysome, a microcompartment designed to promote the carboxylase activity of Rubisco. This study presents a comparative analysis of several facets of the *Prochlorococcus* CCM. Our analyses indicate that a core set of CCM components is shared and their genomic organization is relatively well-conserved. Moreover, certain elements, including carboxysome

shell polypeptides CsoS1 and CsoS4A, exhibit striking conservation. Unexpectedly, our analyses reveal that the carbonic anhydrase (CsoSCA) and CsoS2 shell polypeptide have diversified within the lineage. Differences in *csoSCA* and *csoS2* are consistent with a model of unequal rates of evolution rather than relaxed selection. The *csoS2* and *csoSCA* genes form a cluster in *Prochlorococcus* genomes, and we identified two conserved motifs directly upstream of this cluster that differ from the motif in marine *Synechococcus* and could be involved in regulation of gene expression. Although several elements of the CCM remain well-conserved in the *Prochlorococcus* lineage, the evolution of differences in specific carboxysome features could in part reflect optimization of carboxysome-associated processes in dissimilar cellular environments.

The Marine Biological Laboratory (Woods Hole) and the scientific advancement of women in the early 20th century: The example of Mary Jane Hogue (1883-1962)

Steven Zottoli

Journal of the History of Biology, February 2015, Volume 48, Issue 1, pp 137-167
First online: 08 August 2014

The Marine Biological Laboratory (MBL) in Woods Hole, MA provided opportunities for women to conduct research in the late 19th and early 20th century at a time when many barriers existed to their pursuit of a scientific career. One woman who benefited from the welcoming environment at the MBL was Mary Jane Hogue. Her remarkable career as an experimental biologist spanned over 55 years. Hogue was born into a Quaker family in 1883 and received her undergraduate degree from Goucher College. She went to Germany to obtain an advanced degree, and her research at the University of Würzburg with Theodor Boveri resulted in her Ph.D. (1909). Although her research interests included experimental embryology, and the use of tissue culture to study a variety of cell types, she is considered foremost a protozoologist. Her extraordinary demonstration of chromidia (multiple fission) in the life history of a new species of Flabellula associated with diseased oyster beds is as important as it is ignored. We discuss Hogue's career path and her science to highlight the importance of an informal network of teachers, research advisors, and other women scientists at the MBL all of whom contributed to her success as a woman scientist.

Chemistry

Cell Fate Regulation Governed by a Repurposed Bacterial Histidine Kinase

W. Seth Childers, Qingping Xu, Thomas H. Mann, Irimpan I. Mathews, *Jimmy A. Blair*, Ashley M. Deacon, Lucy Shapiro

PLoS Biology, 12, e1001979, 2014.

One of the simplest organisms to divide asymmetrically is the bacterium *Caulobacter crescentus*. The DivL pseudo-histidine kinase, positioned at one cell pole, regulates cell-fate by controlling the activation of the global transcription factor CtrA via an interaction with the response regulator (RR) DivK. DivL uniquely contains a tyrosine at the histidine phosphorylation site, and can achieve these regulatory functions *in vivo* without kinase activity. Determination of the DivL crystal structure and biochemical analysis of wild-type and site-specific DivL mutants revealed that the DivL PAS domains regulate binding specificity for DivK~P over DivK, which is modulated by an allosteric intramolecular interaction between adjacent domains. We discovered that DivL's catalytic domains have been repurposed as a phosphospecific RR input sensor, thereby reversing the flow of information observed in conventional histidine kinase (HK)-RR systems and coupling a complex network of signaling proteins for cell-fate regulation.

(p)ppGpp Modulates Cell Aize and the Initiation of DNA Replication in Caulobacter crescentus in Response to a Block in Lipid Biosynthesis

Kristina V. Stott, Shannon M. Wood, *Jimmy A. Blair*, Bao T. Nguyen, Anabel Herrera, Yannet G. Perez Mora, Math P. Cuajungco, Sean R. Murray

Microbiology, 161, 553-564, 2015.

Stress conditions, such as a block in fatty acid synthesis, signal bacterial cells to exit the cell cycle. *Caulobacter*

crescentus FabH is a cell-cycle-regulated β-ketoacyl-acyl carrier protein synthase that initiates lipid biosynthesis and is essential for growth in rich media. To explore how *C. crescentus* responds to a block in lipid biosynthesis, we created a FabH-depletion strain. We found that FabH depletion blocks lipid biosynthesis in rich media and causes a cell cycle arrest that requires the alarmone (p)ppGpp for adaptation. Notably, basal levels of (p)ppGpp coordinate both a reduction in cell volume and a block in the over-initiation of DNA replication in response to FabH depletion. The gene *ctrA* encodes a master transcription factor that directly regulates 95 cell-cycle-controlled genes while also functioning to inhibit the initiation of DNA replication. Here, we demonstrate that *ctrA* transcription is (p)ppGpp-dependent during fatty acid starvation. CtrA fails to accumulate when FabH is depleted in the absence of (p)ppGpp due to a substantial reduction in *ctrA* transcription. The (p)ppGpp-dependent maintenance of *ctrA* transcription during fatty acid starvation initiated from only one of the two *ctrA* promoters. In the absence of (p)ppGpp, the majority of FabH-depleted cells enter a viable but non-culturable state, with multiple chromosomes, and are unable to recover from the miscoordination of cell cycle events. Thus, basal levels of (p)ppGpp facilitate *C. crescentus*' re-entry into the cell cycle after termination of fatty acid starvation.

Monitoring Tectonic Uplift and Paleoenvironmental Reconstruction for Marine Terraces Near Magaracik and Samandag, Hatay Province, Turkey

Jonathan A. Florentin, Bonnie A.B.Blackwell, Okan Tüysüa, Ufuk Tari, S. Can Genç, Caner Imren, Shirley Mo, Yiwen E. W. Huang, Joel I. B. Blickstein, *Anne R. Skinner*, Maria Kim

Radiation Protection Dosimetry, 159 (1-4), 220-232, 2014.

Near Hatay, the Antakya-Samandağ-Cyprus Fault (ASCF), East Anatolian (EAFZ), and Dead Sea Fault Zones (DFSZ), the large faults that form the edges of the African, Anatolian, Cyprus, and Arabian Plates, all produce large earthquakes, which have decimated Hatay repeatedly. Near Samandağ, Hatay, differential vertical displacement on the ASCF has uplifted the southeastern side relative to northwestern side, producing large fault scarps that parallel the Asi (Orontes) River. Tectonic uplift coupled with Quaternary sealevel fluctuations has produced several stacked marine terraces stranded above current sealevel. This study dated 24 mollusc samples from 10 outcrops on six marine terraces near Samandağ electron spin resonance (ESR). Ages were calculated using time-averaged and volumetrically averaged external dose rates, modelled by assuming typical water depths for the individual species and sediment thicknesses estimated from geological criteria. Uplift rates were then calculated for each fault block.

At all the Mağaracık terraces, the dates suggest that many shells were likely reworked. On the 30 m terrace at Mağaracık IV (UTM 766588-3999880), Lithophagus burrows with in situ shells cross the unconformity. One such shell dated to 68 ± 6 ka, setting the minimum possible age for the terrace. For all the Mağaracık terraces at ~ 30 m amsl, the youngest age for the reworked shells, 66 ± 8 ka, sets the maximum possible age for this unit. Thus, the terrace must date to 67 ± 7 ka. Older units dating to MIS 7 and 5 likely were being eroded to supply some fossils found in this terrace. At Mağaracık Dump (UTM 765391-4001048), ~ 105 m amsl, Ostrea and other shells were found cemented in growth position to the limestone boulders outcropping there less than 2.0 m above a wave-eroded notch. If the oysters grew at the same time as the wave-cut notch and the related terrace, the date, 113 ± 12 ka, for the oysters, this fault block has been uplifted at 0.96 ± 0.12 m/ky, since the MIS 5e/5d boundary. At Samandağ Kurtstream at 39 m amsl, molluscs were deposited fine sandy gravel, which was likely formed in a large tidal channel. Three molluscs averaged 132 ± 8 ka. If these molluscs have not been reworked, this fault block has uplifted at 0.30 ± 0.04 m/ky since the MIS 6/5e boundary. The differences in these uplift rates suggests that at least one, and possibly two, hitherto undiscovered faults may separate the Mağaracık Dump site from the other Mağaracık sites and from the Samandağ Kurtstream site.

Electron Spin Resonance (ESR) Dating. General Principles

Anne R. Skinner

Encyclopedia of Scientific Dating Methods, DOI 10.1007/978-94-6326-5_6-1, 2014.

Dating Human Occupation at Toca do Serrote das Moendas, São Raimundo Nonato, Piauí-Brasil by Electron Spin Resonance and Optically Stimulated Luminescence

Angela Kinoshita, *Anne R. Skinner*, Niede Guidon, Elaine Ignacio, Gisele Daltrini Felice, Cristiane de A. Buco, Sonia Tatumi, Marcio Yee, Ana Maria Graciano Figueiredo, Oswaldo Baffa

Journal of Human Evolution, 77, 187-195, 2014.

The excavation of Toca do Serrote das Moendas, in Piauí state, Brazil revealed a great quantity of fossil wild fauna associated with human remains. In particular, fossils of cervidae (Blastocerus dichotomus) were found, an animal frequently pictured in ancient rock wall paintings. In a well-defined stratum, two loose teeth of this species were found in close proximity to human bones. They were independently dated by electron spin resonance (ESR) in two laboratories. The archaeological doses (D_e) found by additive dose method were: (37±4) Gy and (32±2) Gy, respectively. The main radioisotope concentrations present in the samples and in the soil were determined by Neutron Activation Analysis (NAA) for the dose rate determination and conversion of D_e to age. The ages found for the teeth were (24±3) ka and (20±2) ka, in good agreement. The concretion layer above the stratum where teeth and human remains were found was dated by optically stimulated luminescence (OSL) of the quartz grains giving an age of (20±2)ka, stratigraphically consistent with the dates found for teeth. As these values were found independently in three different laboratories, using different methods and equipment, these results are compelling evidence of early habitation in this area.

Geosciences

The Proterozoic Record of Eukaryotes

Phoebe Cohen and Francis Macdonald

Paleobiology, in press

Proterozoic strata host evidence of global "Snowball Earth" glaciations, large perturbations to the carbon cycle, proposed changes in the redox state of oceans, the diversification of microscopic eukaryotes, and the rise of metazoans. 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 Proterozoic Earth system and the geological context of fossil occurrences, including improved age constraints. However, the evaluation of relationships between Proterozoic environmental change and fossil diversity has been hampered by several factors, particularly lithological and taphonomic biases. Here we compile and analyze the current record of eukaryotic fossils in Proterozoic strata to assess the effect of biases and better constrain diversity through time. Our results show that mean within-assemblage diversity increases through the Proterozoic Eon due to an increase in high diversity assemblages, and that this trend is robust to various external factors including lithology and paleogeographic location. In addition, assemblage composition changes dramatically through time. Most notably, robust recalcitrant taxa appear in the early Neoproterozoic Era, only to disappear by the beginning of the Ediacaran Period. Within-assemblage diversity is significantly lower in the Cryogenian Period than in the preceding and following intervals, but the short duration of the nonglacial interlude and unusual depositional conditions may present additional biases. In general, large-scale patterns of diversity are robust while smaller-scale patterns are difficult to discern through the lens of lithological, taphonomic, and geographic variability.

Fossils of Putative Marine Algae from the Cryogenian Glacial Interlude of Mongolia

Phoebe Cohen, Francis Macdonald, Sara Pruss, Emily Matys, and Tanja Bosak

Palaios 30, 238-247, 2015

Neoproterozoic carbonate successions provide a new taphonomic window into the diversification of eukaryotes. We report recently discovered macroscopic organic warty sheets (MOWS) in macerates of limestone from the ca. 662–635 Ma Taishir Formation (Tsagaan Olom Group, Mongolia). Sheets are applanate. One surface contains raised ridges and conspicuous, 100-mm-tall warty protuberances with depressed tops that enclose internal cavities containing cellular structures. The Taishir MOWS may be the remains of unusual bacterial, protistan, or fungal biofilms, or a previously undocumented, extinct taxon. However, multiple lines of evidence including the morphology of warty protuberances and the presence of cellular architecture within protuberances support the interpretation of MOWS as marine algae, perhaps a member of the Rhodophyta. Regardless of their specific taxonomic affiliation, MOWS increase the diversity of biota reported from the Cryogenian glacial interlude and indicate the presence of macroscopic and morphologically complex multicellular organisms in the Cryogenian.

Taphonomy of Vase Shaped Microfossils from the Late Tonian Callison Lake Dolostone, Yukon

Spencer Irvine '16, Phoebe Cohen, and Justin Strauss

Geological Society of America Abstracts with Programs 46 (6), 542, 2014

Vase-shaped microfossils (VSMs) are interpreted as the remains of testate amoebae, and are found in Late Tonian sedimentary rocks around the world. A new assemblage of VSMs has recently been described from the Callison Lake dolostone in Yukon, Canada. Dated with a Re-Os isochron age of 739.9 +/- 6.1 Ma, these microfossils are indicative of the early diversification of eukaryotic life before the Sturtian-age Snowball Earth event, and are roughly coeval with diverse VSM assemblages from the Chuar Group of Grand Canyon, Arizona. Here we investigate the taphonomy of the Callison Lake VSMs. We analyzed fossils in petrographic thin section, on etched rock surfaces, and from HF macerations. EDS maps were used to analyze the spatial distribution of elements in all three preparation techniques to interpret the taphonomic pathways. We found that silica is pervasive in all samples from thin sections and etched surfaces. In most samples, there are accumulations of carbon at the edges of fossils, and in some, a high concentration of carbon throughout. In other cases, however, we do not see heightened concentrations of these elements. Rather, aluminum and other clay minerals were found to be associated with fossil rims. Fossils from macerated samples are comprised entirely of organic carbon, as all silica would have been removed during maceration. We hypothesize that these macerate fossils represent the internal molds of VSMs. This suggests there are multiple modes of preservation for VSMs in this assemblage. We suggest that at least three taphonomic processes are involved: authigenic mineralization, original preservation, and internal molds. By selecting fossils in thin section and using EDS techniques on these same specimens we are able to more easily and quickly associate certain taphonomic pathways with VSM specimens. This will allow us to determine which mode is dominant in the preservation of VSMs and better understand their relationship to other VSM assemblages, which are preserved via different taphonomic pathways. Understanding the preservation of VSMs will help us to better determine why these fossils are absent from younger rocks, and give us insight into their potential use as index fossils for the Late Tonian.

Paleobiology, Sedimentology, and Distribution of Chert in the Tonian Fifteenmile Group of Yukon-Alaska Mount Slipper Assemblage

Laura Stamp '16, Phoebe Cohen, and Jason Strauss

Geological Society of America Abstracts with Programs 46 (6), 542, 2014

Carbonate and chert deposits from the Tonian (ca. ~800 Ma) Fifteenmile Group, Yukon, Canada contain both unique 'scale' microfossils and a diverse microbial and eukaryotic population of organic-walled microfossils. While the organic-walled components of this fossil assemblage bear similarity to biota described from coeval strata worldwide, the scale microfossils have not been found in deposits of similar age from other sections within the Proterozoic inliers of northern Canada or elsewhere. The fossiliferous strata of the Fifteenmile Group located near Mount Slipper on the Yukon-Alaska border consist of approximately 40 meters of interbedded organic-rich parallel-laminated limestone, tabular clast or edgewise conglomerate, and calcareous black and grey shale. The absence of wave-generated bedforms, abundance of hemipelagic deposits, and presence of matrix-supported conglomerates interpreted as debrites suggests these strata were deposited well below storm-wave base in a slope environment. Interestingly, all of the autochthonous deep-water and allochthonous redeposited facies contain chert, but it is highly variable in abundance, distribution, and form. Chert deposits include nodules ranging from 1 mm to greater than 4 cm in diameter, many of which exhibit evidence of extremely early formation within sediments. Other chert deposits appear in the form of discontinuous beds and silicified debrites. Here we present a detailed stratigraphic section of the fossiliferous strata and document the distribution of chert and microfossils they contain. Detailed sub-sampling reveals patterns of fossil abundance and distribution relative to the variety of chert types present, as well as relative to organic carbon content and inorganic carbon isotope values of the host limestone. These factors shed light on why these unique fossil assemblages have not yet been found elsewhere despite extensive examination; furthermore, this deposit presents a key window into deep-water chert preservation, a taphonomic window

that is quite unique among fossiliferous Proterozoic chert deposits that are generally constrained to peritidal settings.

A Diverse Fossil Assemblage from the Early Neoproterozoic Reefal Assemblage of the Fifteenmile Group, Coal Creek Inlier, Yukon

Mary Ignatiadis '16, Phoebe Cohen, and Francis Macdonald

Geological Society of America Abstracts with Programs 46 (6), 542, 2014

Organic-walled fossils from well-constrained strata of the early Neoproterozoic are rare, especially in comparison with the abundance of younger Tonian, Cryogenian, and Ediacaran assemblages. We report organic-walled eukaryotic and bacterial fossils from macerated carbonates of the early Neoproterozoic (pre-811 Ma) Reefal Assemblage of the Fifteenmile Group in the Coal Creek Inlier, Yukon. The Reefal Assemblage consists of ~500 meters of mixed siliciclastic and carbonate rocks deposited in stromatolitic fore-reef, reef core and back-reef environments. Fossils were extracted from fore-reef organic-rich molar tooth micritic limestones more than 400 meters below the 811 Ma ash bed in the upper Reefal Assemblage. This assemblage thus predates the 'scale' microfossils found in the uppermost Reefal Assemblage.

Fossils include organic filaments, which may represent both bacterial and eukaryotic organisms, and acritarch taxa inferred to be eukaryotic. Non-branching septate filaments are similar to fossils from the Mesoproterozoic Lower Belt Supergroup (Montana), which have been interpreted as oscillatorian cyanobacterial sheaths. A variety of non-branching, non-septate filaments are similar to specimens found in early Neoproterozoic strata including the Little Dal Formation (Northwest Territory, Canada). The acritarch assemblage contains both smooth-walled specimens and those with asymmetrical processes, thus making it similar to assemblages from late Mesoproterozoic to early Neoproterozoic strata. Both groups of acritarchs display medial splitting and well-defined, uniform holes that represent possible excystment structures.

While fossils reported here are syngenetic, we also discovered significant fungal contamination in some samples. To determine the extent of contamination, we stained macerated samples with Calcifluor White, which binds to the chitin in fungal mycelia, and fluoresces under UV light. Using this technique, we were able to differentiate between contaminants and syngenetic material. The use of stains such as Calcifluor White can thus be a helpful aid in the process of determining potential contamination in macerated samples.

Reassessing the Role of Prasinophyte Algae in Modern and Ancient Oceans

Robin Kodner, *Phoebe Cohen,* Thereasa Keates, and *Kelly Tellez '17*

Geological Society of America Abstracts with Programs 46 (6), 76, 2014

Acritarchs are organic-walled microfossils of uncertain taxonomic affinity. Many smooth-walled acritarchs from the Paleozoic are inferred to be reproductive structures, called phycoma, made by a single genus within the green algal group Prasinophycea. The inferred green algal affinity of these acritarch forms is often used as the basis for various proxies, including diversity and primary production. However, these inferences are often made without detailed morphological comparisons between fossils and modern Prasinophycean analogs. As a result, implied diversity of photosynthetic taxa in the fossil record as well as any proxies derived from this diversity are not robust without a deeper understanding of modern Prasinophycean groups. Here, we present a comparison of the morphology and ecology of modern Prasinophytes and fossil taxa inferred or known to belong to the Prasinophycea, and demonstrate how knowledge of the biology of modern taxa is required for realistic interpretation of the fossil record of acritarchs. Examples include significant size differences between fossil and modern taxa, and differences between modern and paleo-environmental distribution. In addition, we will discuss the biology and function of modern Prasinophyte phycoma, which are a reproductive structure and not cysts, as often described in the literature. A more comprehensive understanding of the fossil record of Prasinophytes will not only help us to better understand the evolutionary history of the green algae, but also better understand ancient marine ecosystems.

Radiocarbon Profiles of the NW Pacific from the LGM and Deglaciation: Evaluating Ventilation Metrics and the Effect of Uncertain Surface Reservoir Ages

Mea Cook and Lloyd Keigwin

Paleoceanography 30, 174-195, 2015

During the last deglaciation, the ventilation of the subarctic Pacific is hypothesized to have changed dramatically, including the rejuvenation of a poorly ventilated abyssal water mass that filled the deep ocean, and fluctuations in the strength of North Pacific intermediate and deep water formation at millennial timescales. Foraminiferal radiocarbon reconstructions of past ventilation changes in the Pacific are valuable but are hampered by poor carbonate preservation, low sediment accumulation rates, bias from bioturbation, and poorly constrained past surface reservoir age. In this study, we present paired benthic-planktonic radiocarbon measurements from the Okhotsk Sea and Emperor Seamounts. We take advantage of large contemporaneous peaks in benthic abundances from the last glacial maximum, Bolling-Allerod (BA), and early Holocene to produce time slices of radiocarbon from 1 to 4 km water depth. We explore the impact of uncertain surface reservoir age and evaluate several approaches to quantifying past ocean radiocarbon distribution using our NW Pacific data and a compilation of published data from the North Pacific. Both the calendar age and the absolute value of an ocean radiocarbon estimate depend on the assumed surface reservoir age. But for a time slice from a small geographical area with radiocarbon-independent stratigraphic correlation between cores, the shape of a water column profile is independent of surface reservoir age. The NW Pacific profiles are similar in shape to the compilation profiles for the entire North Pacific, which suggests that deglacial surface reservoir age changes across the N Pacific did not diverge dramatically across the areas sampled. The Last Glacial Maximum (LGM) profile >2 km spans a wide range of values, ranging from values similar to today to lower than today. However, by the BA the profile has a similar shape to today. Ultimately, local surface reservoir ages, end-member water mass composition, and mixing ratios must each be constrained before a radiocarbon activity reconstruction can be used to confidently infer ventilation changes.

Sedimentologic Analysis of Coastal Boulder Deposits in the Northeast Atlantic Region

Kalle Jahn '14 and *Rónadh Cox*

Geological Society of America Abstracts with Programs 46 (6), 452, 2014

Coastal boulder ridges are widespread in the NE Atlantic region. As we unravel the roles of storms vs. tsunami in assembly of high-energy deposits world-wide, it is helpful to have data from areas subject to big storms, but without recent tsunami. We therefore report the morphology and sedimentology of active boulder ridges from the Aran Islands and Mullet Peninsula (western Ireland) and Mainland Shetland (Scotland). Topographic analysis is based on 165 ridge transects, and grain-size data come from 54 ribbon counts at a subset of those sites.

The deposits—asymmetric coast-parallel ridges, each with a steeply dipping seaward face and a longer, gently-sloping landward side—occur up to 50 m above high water (AHW), with 13 m AHW the median elevation. They are found up to 260 m horizontal distance inland from high water, the median being 43 m inland. Typically the area seaward of the ridge is scoured clean of both clasts and vegetation. Massive clasts occur in the ridges—blocks up to 75 t were measured—but the median is in the coarse pebble to fine boulder range (4-39 cm equivalent spherical diameter). Grain-size analysis (from ribbon counts of all clasts >1 cm along 54 ridge-normal transects) reveals that the deposits are poorly to moderately-well sorted, with median standard deviation in the poorly-sorted range. Most ridges have unimodal clast-size distributions.

Ridge height, width, and largest clast size tend to decrease with elevation, but—surprisingly—those farther inland tend to be bigger, with larger clasts. Trends are noisy, but all are significant at the 0.0001 level. Slope is a strong control on ridge morphology and clast size, with the largest boulders and the biggest deposits accumulating in locations with low elevation:inland-distance ratios. When coastal slope is sufficiently low, large deposits can accumulate far inland: for example, at locations with slopes less than 0.1, ridges were found up to 260 m inland. Ridges 250-260 m inland were 3-4 m high and 30-35 m wide, with clasts up to 6 t.

This is, as far as we know, the first such dataset to have been collected. Interest in these kinds of deposit is growing, as we try to understand the ways in which high-energy waves interact with coasts and coastal

materials; and this study provides baseline data with which coastal boulder deposits from other locations can be compared.

Measuring the Effects of Winter Storms (2013-2014) on Boulder and Megagravel Accumulations in Western Ireland

Rónadh Cox, Oona Watkins '15, Kelly Tellez '17, Laura Stamp '16, Spencer Irvine '16, Jorge Castro '16, Caroline Atwood '16, and *Kelsey Adamson '16*

Geological Society of America Abstracts with Programs 46 (6), 453, 2014

Coastal boulder ridges accumulate above high tide, and are active only during extreme wave conditions. Some are found on cliff tops as much as 45 m above high water (AHW); others occur up to 250 m inland at the back of gently sloping platforms. They can include megagravel of order 100 t. These deposits record maximum wave intensities for their locations and hold the key to understanding inland transmission of fluid forces, but little is known about their dynamics. The winter of 2013-14 brought record-breaking storms and high seas (with wave heights up to 25 m measured in Irish waters), causing dramatic geomorphologic change at many coastal locations. Using a database of boulder-ridge photographs collected in recent field seasons, we were able to document changes in the accumulations, and measure movements of specific clasts at locations in western Ireland, including coastal Clare, the Belmullet peninsula, and the Aran Islands.

Cobbles and boulders were moved in abundance, but some of the megagravel was impressively large. Examples of masses include an isolated block of ~430 t transported ~5 m laterally on a supratidal platform; slabs >20 t ripped from bedrock and incorporated into a ridge at 11 m AHW and 90 m inland; and an 18.5 t block moved from ridge base to crest (translated 12 m inland and 4.5 m vertically) in a ridge located 130 x m inland and 17 m AHW.

Our data document reorganisation of existing boulder accumulations as well as creation of new clasts from ripped-up bedrock. Within the boulder ridges, clasts shifted upward and inland. Boulders that had been low down on the seaward face of a ridge in last year's photos were found further up the face, or in some cases at the ridge crest. Other clasts moved from the ridge face over the crest and into the back-ridge area. Within the back ridge, clasts travelled further landward. These observations indicate that the ridges migrate progressively landward. Mass was also added to the deposits. Uplift and dismemberment of bedrock slabs subjacent to the ridge base was the most common source of new material, but in some cases bedrock blocks were quarried and transported several 10s of m to their final resting places

The changes documented in this study prove the role of storms in growth and migration of supratidal boulder ridges, and provide insight into the sediment dynamics of these enigmatic deposits.

Madagascar Erosion Rates and Insight into Anthropogenic Effects from in-situ ^{10}Be Analysis of River Sediments

Rónadh Cox, Paul Bierman '85, and A.F.M. Rakotonddrazafy

Geological Society of America Abstracts with Programs 46 (6), 799, 2014

Cosmogenic isotope data provide a time-averaged look at landscape erosion rates in Madagascar, and comparison of samples from contemporary rivers with dated terrace deposits gives insight into the effects of recent human activities. Eighty analyses, from 64 watersheds representing 30% of Madagascar's total area, provide new perspective on the landscape evolution of this culturally and ecologically significant country.

Madagascar's relief is substantial (comparable to New Zealand) despite deeply weathered bedrock (saprolites commonly 10s of m thick). The preservation of such thick saprolite, in the face of regional elevation gradients and very steep (>50°) local slopes, implies that low erosion rates have characterised the region for some time. This is borne out by ^{10}Be data, which indicate rates ranging from 1.5-78 m My^{-1}, with median of only 16 m My^{-1} (much less than the global drainage-basin median of 54 m my^{-1}:tinyurl.com/lnh9fxt). Highest rates (40-78 m My^{-1}; n = 20) come from the arid lowlands of the west and southwest, and from the steep forested eastern escarpment. Lowest rates (<10 m My^{-1}; n = 23) come from the rolling highlands of the central plateau.

We were able at 4 locations to sample both the modern river sand and ^{14}C datable older terrace deposits, to try and see through the time-averaged ^{10}Be window (approx. 104 yrs for slowly eroding terranes) and evaluate the extent to which anthropogenic effects have affected erosion rate in the more recent past. Terrace ages range from 0.76-13.6 ky. The younger part of the age range overlaps with human presence in Madagascar, but the upper end long pre-dates it. In two cases, the modern rates exceed the rates recorded in the terrace sands: a >0.76 ky terrace implies paleo-erosion of 11.4 m My^{-1} compared with 15.9 m My^{-1} in modern river sand, and a >1.9 ky terrace yields 24.8 m My^{-1} compared with 41.3 m My^{-1} in its modern equivalent. In one case (terrace ≈1 ky) the rates are identical within error (11.8 m My^{-1} and 13.0 m My^{-1} respectively). In the final case, the modern river rate of 6.7 m My^{-1} is exceeded by a 13.6 ky terrace rate of 9.6 m My^{-1}. The fact that rates measured from the terrace deposits exceed the modern values in some cases argues against a dramatic post-human-arrival increase in erosion rates.

Hillslope Lowering Rates and Mobile-Regolith Residence Times from In Situ and Meteoric ^{10}Be Analysis, Boulder Creek Critical Zone Observatory

Melissa Foster, Robert Anderson, Cianna Wysnytzky, *William Ouimet '01*, and *David Dethier*

Geological Society of America Bulletin 127 (5/6), 862-878, 2015

Cosmogenic radionuclides (CRNs) are commonly employed to quantify both the production rates and residence times of mobile regolith. Meteoric and in situ CRNs have different accumulation mechanisms and can independently constrain landscape evolution rates. Here we use both in situ and meteoric ^{10}Be to investigate where in the regolith ^{10}Be is stored, and to quantify production rates and residence times of mobile regolith on active hillslopes in Gordon Gulch, within the Boulder Creek Critical Zone Observatory (CZO), Colorado, USA. Our data reveal that two-thirds of in situ ^{10}Be in regolith is produced within saprolite, and at least one-tenth of the meteoric ^{10}Be inventories is stored in saprolite, highlighting the importance of consistent terminology and identification of the mobile regolith–saprolite boundary. We find that mobile-regolith production rates are on average 3.1 cm/k.y. and residence times are between 10 and 20 k.y. A notable exception exists at the depositional north-facing footslope, where residence times likely exceed 40 k.y. Close agreement between the meteoric and in situ results indicates that upper- and mid-slope positions are consistent with steady, uniform lowering of the landscape. In addition to comparing the two methods, we develop a one-dimensional analytical model for the ^{10}Be concentration fields on an active, steady-state catena with uniform erosion. We then compare model predictions with measurements to evaluate how well our sites adhere to the steady-state assumption underlying the calculations for mobile-regolith residence time and production rates. Such comparisons suggest that calculated residence times and lowering rates are likely no closer than ±25% of the geomorphic reality.

Cryosphere: Ice on Niwot Ridge and in the Green Lakes Valley, Colorado Front Range: Plant Ecology and Diversity

Matthias Leopold, *Gabriel Lewis '13, David Dethier*, Nel Caine and Mark Williams

Plant Ecology and Diversity DOI:10/1080/17550874.2014.992489

Background: Subsurface ice preserved as ice lenses and within rock glaciers as well as glacial and lake ice provides sensitive indicators of climate change and serve as a late-season source of meltwater.

Aims: We synthesize the results of geomorphological, geophysical and geochemical studies during the past two decades, building on a long history of earlier work focused on ice and permafrost studies on Niwot Ridge and the adjacent Green Lakes Valley (GLV), which is part of the Niwot Ridge Long-term Ecological Research (LTER) Site.

Methods: These studies are discussed in the context of how bodies of ice and rock glaciers reflect changing local climate and how the hydrogeochemistry of ice melt regulates the chemistry of alpine surface water after seasonal snowfields melt. We review recent results from geophysical investigations (resistivity, seismic refraction and ground-penetrating radar) of the shallow subsurface, ongoing monitoring of Arikaree Glacier, three rock glaciers and lake ice in the GLV, and measurement and modeling of the geochemistry of surface

waters.

Results and conclusions: Permafrost conditions reported from Niwot Ridge in the 1970s are generally not present today, but ice lenses form and melt seasonally. Ice is present permanently within the Green Lakes 5 rock glacier and at nearby favorable sites. Arikaree Glacier shows a marked decline in cumulative mass balance during the past 12 years after a 30-year period when net mass balance was ~0. Surface temperature measurements from rock glaciers do not show strong trends during the past 15 years. Lake ice duration increases with elevation in GLV but has decreased on all 7 lakes that have been monitored during the last three decades. This decrease has been most marked at the lowest elevation where it amounts to a reduction of about 1 d/yr and least at Green Lake 5 where the loss has been at a rate of 0.5 d/yr.

Caine (2010) suggests that almost all of the 2.5 mm/yr increase in September-October stream discharge from the upper GLV has been derived from melting of subsurface ice.

Meteoric ^{10}Be, Clay and Extractable Iron Depth Profiles in the Colorado Front Range: Implications for Understanding Soil Mixing and Erosion

Cianna Wyshnytzky, *William Ouimet '01, James McCarthy '11, David Dethier*, Ralph Shroba, *Paul Bierman '85*, Dylan Rood

Catena 127, 32-45, 2015

Analyzing meteoric ^{10}Be in soil profiles along with soil measurements such as pedogenic Fe and clay content permits better understanding of meteoric ^{10}Be transport in soils, soil formation, and hillslope geomorphology. This study presents meteoric ^{10}Be depth profiles from saprolite-derived soil catenas sampled in the Gordon Gulch catchment, Colorado Front Range and from nearby c. 130 and 15 ka glacial moraines. We compare meteoric ^{10}Be data with more classically used soil analyses of clay and extractable iron (Fed) content. Meteoric ^{10}Be and Fed do not show consistent trends in the hillslope profiles. Meteoric ^{10}Be and clay concentrations, however, generally decrease with depth and highest concentrations of ^{10}Be in horizons coincide with highest clay concentrations. Soils at moraine sites are better developed than those on hillslopes, and correlations of ^{10}Be, Fed, and clay are stronger. In Gordon Gulch, south-facing hillslopes display meteoric ^{10}Be bulges at depth and lower near-surface concentrations compared to the declining profiles and higher near-surface concentrations of north-facing hillslopes. The aspect differences imply that south-facing hillslopes experience greater vertical mixing than north-facing hillslopes, and that greater lateral transport and erosion has occurred over the last 15–20 ka on south-facing hillslopes relative to north-facing hillslopes. Meteoric ^{10}Be depth profiles at moraine sites display bulge profiles with highest meteoric ^{10}Be concentrations in B-horizons, reflecting landform stability and pedogenic processes. Overall, our data demonstrate that signatures of chemical weathering in soils (Fed and clay) may or may not correlate to the meteoric ^{10}Be added through atmospheric deposition, and that profile shape of meteoric ^{10}Be can provide insight into the relative contribution of vertical mixing and surface erosion in relation to catena location and aspect during hillslope evolution.

Geomorphic Effects of the September 2013 Flood in Fourmile Canyon, Colorado, Using Lidar and Field Studies

Will Wicherski '15, David Dethier, and William Ouimet '01

Geological Society of America Abstracts with Programs 47 (3), 65, 2015

This research uses the results of field measurements and remote sensing to reconstruct flood discharge, sediment transport, channel changes, and sediment budgets for a catastrophic flood along a 15 km reach of Fourmile Canyon, Colorado. Persistent rainfall from September 9 to 15, 2013 caused extensive flooding and local debris flows in the Front Range foothills west of Boulder, Colorado. Locally intense rainfall and persistent effects of recent wildfires probably contributed to the scale of the event, especially in catchments such as Fourmile Canyon, which heads in the alpine zone and flows into Middle Boulder Creek in the semiarid foothills. Field surveys focused on flood height and width indicators, point counts, and sieve analysis of gravel-rich deposits thicker than 0.5m. The availability of 1-meter resolution LiDAR from before (Aug.

2010) and after the flooding (Oct. 2013) provided an unusual opportunity to measure the geomorphic effects of the flood in the same areas as our detailed field surveys. Cross-sectional profiles allowed us to estimate peak discharge using the slope-area and critical-depth methods, as well as the competence and power of the event. Combining these approaches at 12 sites shows ~31,000 m^3 of local deposition despite ~80,000m^3 of net erosion from the valley floor, entrainment of boulders weighing over 3 metric tons, and estimated peak discharges of 58.5-97.9 m^3/s. Comparison with other discharge estimates yields similar values (Jarrett, in press), but our combination of techniques characterizes the flood in greater detail. The mass balance of sediment in the canyon, the profile differences, and field observations all indicate that the flood event produced net erosion, mainly by channel widening, despite significant (>100m long, >1m thick) depositional zones throughout the canyon. Similar effects have been reported in other headwater catchments due to extreme floods such as Hurricane Irene in Vermont.

Connecting Surficial Geology and Hydrologic Flux in Leaky, Snowmelt-Dominated Catchments; Niwot Ridge, CO

Victor Major '15, David Dethier, and Matthias Leopold

Geological Society of America Abstracts with Programs 47 (3), 125, 2015

This study investigated the surficial geology and hydrology of four alpine and subalpine catchments (total area 2 km^2) on Niwot Ridge, Colorado Front Range to help characterize how surface and subsurface flow interact above the glacial limit. Martinelli, Saddle, Como, and Upper Fourmile basins support tundra communities and patchy forest that grows from thin soils developed on 2 to >5m of coarse, unconsolidated periglacial deposits (Leopold, 2008). Fractured igneous and high-grade metamorphic rocks underlie the layered surficial deposits. We have characterized local surficial geology with field mapping, inversion of electrical resistivity measurements, and well-log data. In areas without surface water expression, we measured a saturated/capillary fringe zone with low resistivity values of ~200-800 Ω m beneath a shallow vadose zone (1500-2500 Ω m) and above bedrock surfaces (>2500 Ω m) at depths of <1 to 5.5 m. We investigated basin hydrologic flux by measuring surface flow at selected sites by: (1) modeling snowmelt and (2) compiling groundwater and mass-budget measurements. Recent estimates of the hydraulic conductivity of unconsolidated deposits on the Niwot Ridge ranged as low as $9.82x10^{-5}$ to $2.85x10^{-4}$ m/s in the Martinelli basin (King, 2012), to as high as $1.1x10^{-3}$ to 2.6 m/s in the nearby Loch Vale (Clow et al., 2003). Our initial calculations indicate that flow through the subsurface is delayed yet significant, and the expression of surface water is dependent upon subsurface geometry and hydraulic properties as well as the lateral and vertical extent of the saturated zone. This research has implications on catchment morphology, water quality, and future water balance studies.

Thirty-Year Trends in Acid Deposition and Mass Balance in Two Headwater Catchments, NW Massachusetts

Scott Wieman, *Jay Racela, and David Dethier*

Geological Society of America Abstracts with Programs 47 (3), 126, 2015

This study reports thirty-year trends in the concentration and flux of acid deposition anions (SO_4^{2-}, NO_3^-) and base cations (Ca^{2+}, Mg^{2+}, Na^+) in two adjacent headwater catchments in the forested Taconic Range of western Massachusetts. Birch Brook, for which we have thirty years of data, is underlain by till and phyllite with local lenses of carbonate; Ford Glen (five years of data) is developed in till overlying dolomitic marble. Since the industrial revolution, acid rain has significantly impacted New England, but recent legislative controls have been aimed at curbing its influence. Composite precipitation data show that rainfall pH is fairly constant throughout the year, but nitrate and sulfate show strong seasonal trends. Since 1990, sulfate in precipitation has declined, decreasing more rapidly since the turn of the millennium and implementation of much stricter pollution legislation. Sulfate deposition from rainfall has decreased from an average of ~30 kg/ha.yr in 1983 to less than 20 kg/ha.yr in 2011. Concurrently, precipitation pH has increased from 4.4 to 4.8. Streamflow from the catchments shows a corresponding decrease in sulfate and a rise in pH over the years and a sulfate flux decrease from 53 kg/ha.yr to 38 kg/ha.yr and a pH increase from 7.2 to 7.4 between 1985 and 2012. There has also been a decrease of Ca and HCO_3^- flux from the catchments over three decades. Annual Ca loss fell

from 42 kg/ha.yr to just over 30 kg/ha.yr from Birch Brook and HCO_3^- flux decreased from ~120 kg/ha.yr to 80 kg/ha.yr. Cation export from Birch Brook is lower than export from Ford Glen. In Ford Glen, for instance, Ca flux ranged from ~400 kg/ha.yr in 2008 to 150 kg/ha.yr in 2012. Overall, we observe acid deposition in northwestern Massachusetts has decreased over the past thirty years and stream chemistry is better buffered, implying that continued management of acid rain compounds can effectively combat acid deposition and its effects.

Application of Meteoric ^{10}Be, ^{137}Cs and Elemental Profiles to Studies of Soil Mixing and Erosion—a Front Range Perspective

David Dethier, William Ouimet '01, James Kaste, Neil Shea, Cianna Wyshnytzky, *Paul Bierman '85*, and Hannah Mondrach

Geological Society of America Abstracts With Programs 46 (6), 241, 2014

Accumulation profiles and inventories of cosmogenic nuclides such as meteoric^{10}Be, weapons-derived radionuclides such as ^{137}Cs, and weathering-derived metals (Zr and pedogenic Fe (Fed)) allow estimates of soil residence time and erosion rates, and provide insight into geomorphic processes at short, millennial and longer time scales. Met ^{10}Be and ^{137}Cs profiles integrate surface erosion and vertical mixing whereas Fed and Zr reflect mainly bottom up accumulation and rates of vertical mixing. Manganese and Zn profiles reflect vegetative cycling and the control of mobility by organic matter. We report data from stable soils, mobile regolith on slopes, and alluvium from the Colorado Front Range where parent material is granitic, climate is cool, dry, and vegetation is coniferous. Profiles on stable surfaces generally reflect depositional and pedogenic processes, but on 24° slopes, vertical mixing of met^{10}Be is incomplete in mobile regolith that has residence times of 10 to 20 ky. Zr values are irregular, likely reflecting local parent material variability, and accumulation profiles at many sites may derive from enrichment in fine, eolian-derived material, rather than strain. Catena studies using met^{10}Be and ^{137}Cs show that inventories are highest in toeslopes and in adjacent alluvial fans, demonstrating recent erosion and downslope transport of near-surface materials. Steady-state assumptions do not provide a complete description of slope evolution in the changing climates of latest Pleistocene and Holocene time. Reconnaissance sampling of toeslope and flood deposits suggests that near-surface processes following fires may profoundly alter the inventory of cosmogenic isotopes and organically mediated elements in hillslope soils. On the slow-weathering slopes of the Front Range, in-situ cosmogenic techniques may provide better descriptions of long-term slope evolution.

Meteoric ^{10}Be, Hillslope Erosion and Landscape Evolution Along the Colorado Front Range

William Ouimet '01, David Dethier, Neil Shea, Cianna Wyshnytzky, and *Paul Bierman '85*

Geological Society of America Abstracts With Programs 46 (6), 241, 2014

Fallout radionuclides, such meteoric ^{10}Be, are valuable as geochronometers and as tracers of hillslope sediment transport, vertical mixing, and residence time. Meteoric ^{10}Be is particularly useful for long-term geomorphic assessments because it readily adsorbs to mineral matter in the near surface and its half-life is long (~1.36 Ma). Here, we discuss the application of meteoric ^{10}Be to study hillslope erosion and landscape evolution along the Colorado Front Range. Local calibration of meteoric ^{10}Be deposition is essential for geomorphic studies. Meteoric ^{10}Be inventories for 6 dated landforms indicate: (1) long-term deposition varies spatially and temporally across this mountain landscape; (2) soil erosion and site-specific deposition from snowdrifts account for differences; (3) the region has 30-50% higher deposition over past 20ka than predicted by current models. Meteoric ^{10}Be depth profiles for 10 hillslope pits indicate that concentrations consistently decrease with depth over ~40 cm. Shallow bulges and lower overall concentrations on south-facing hillslopes compared to exponential/declining profiles and higher overall concentrations on north-facing hillslopes imply that more rapid vertical mixing and lateral transport and significantly greater erosion have stripped fines and meteoric 10Be over the last 15-20 ka. Meteoric ^{10}Be inventories for 40 hillslope locations within Gordon Gulch watershed indicate that average soil residence time for mobile regolith is ~19 ka, but that significant spatial variation exists. Meteoric ^{10}Be inventories consistently increase downslope on north-facing hillslopes, but not on south-facing slopes. Regolith thickness patterns and meteoric ^{10}Be age constraints indicate transport of

hillslope material to toeslope areas prior to and during the colder climates associated with the end of the last glacial maximum, with latest Pleistocene and Holocene regolith currently stored at the bottom of hillslopes. Meteoric ^{10}Be inventories can be compared with inventories of fallout radionulcides ^{137}Cs and ^{210}Pb, which measure sediment movement over the past century, to analyze behavior at short vs. long timescales. Recent fire activity in the region allows us to use meteoric ^{10}Be to evaluate the role of wildfires in longer-term hillslope evolution.

Characterizing Sediment Mobilization and Landscape Response to Wildfire and Extreme Flooding Using Short-Lived Fallout Radionuclides ^{137}Cs and ^{210}Pb, Colorado Front Range

William Ouimet '01, David Dethier, James Kaste, Sheila Murphy, Benjamin Purinton, Hannah Mondrach, and Edward Abrahams

Geological Society of America Abstracts With Programs 46 (6), 800, 2014

The fallout radionuclides ^{137}Cs and ^{210}Pb adhere strongly to mineral and organic matter and are useful for studying sediment mobilization through a landscape. Rapid decay of ^{137}Cs and ^{210}Pb (half-lives of 30 and 22 years, respectively) make them useful tools to measure sediment movement over the past century. Here, we present radionuclide analyses from Fourmile Canyon, Colorado Front Range, which experienced a 25 km^2 wildfire in September 2010, post-fire hillslope erosion and flooding in summer 2011 and 2012, and severe flooding and erosion in September 2013. We have sampled burned and unburned hillslopes, gully and tributary deposits, alluvial fans at the toes of tributaries, overbank deposits along Fourmile Creek of layered post-fire and 2013 flood stratigraphy, active channel deposits such as sediment (sands/fines) directly adjacent to the current Fourmile Creek main channel, and suspended sediment. Depth profiles of ^{137}Cs and ^{210}Pb on hillslopes consistently show highest concentrations of both fallout radionuclides in the upper 3 cm, a sharp decline with depth, and total inventories contained within 7-9 cm. A comparison of select unburned and burned/eroded hillslopes sites reveals differences consistent with ~3-5 cm of post-fire erosion and removal of ash-rich surface material enriched in ^{137}Cs and ^{210}Pb in the three years following the 2010 wildfire. Prior to the 2013 flooding, layered alluvial fan and overbank deposits, sand samples within and adjacent to the channel, and suspended sediment displayed concentrations of radionuclides consistent with surface erosion, mobilization and deposition of near surface hillslope material. Layered overbank sand and gravel deposits, tributary sands, and near-channel sand collected after the September 2013 floods, however, had near-zero concentrations consistent with erosion, mobilization and deposition of deep (>10 cm depth) material containing no ^{137}Cs or ^{210}Pb. Overall, deposits sampled and analyzed to date highlight the utility of fallout radionuclides for source-to-sink tracking of sediment derived from shallow processes, particularly overland flow, compared with deeper processes such as the landslides, debris flows and channel erosion that occurs in association with intense rain and flooding.

Geochemical Impacts of Legacy Mine Waste Contributions to Fourmile Canyon, Colorado

R. Samuels, *William Ouimet '01, and David Dethier*

Geological Society of America Abstracts With Programs 46 (6), 303, 2014

The history of 19th to mid-20th century mining and milling in Fourmile Canyon, Colorado has left the hillslopes and valley bottoms scarred with potentially dangerous legacy sediment. Fourmile Creek is the primary source of drinking water for several communities; mine and mill waste sediment represent potential threats to these populations. The 2010 Fourmile fire, followed by floods in 2011, 2012, and catastrophic flooding in Sept. 2013, severely eroded some areas of legacy sediment, exposed them to future erosion, and transported significant volumes downstream. We present data on the chemical composition, potential mobility of heavy metals, eroded volumes and spatial distribution of waste rock and mill waste sediment from Fourmile Creek and four side tributaries.

To assess the potential danger of the mining legacy in relation to the above physical processes, we took bulk samples from over forty waste rock piles and over fifty layer-specific samples from sites containing mill waste sediment cut by Fourmile Creek. We determined the mobility of the chemicals within the waste rock piles and the mill tailings using leach tests, such as the Meteoric Water Mobility Procedure and the

Toxicity Characteristic Leaching Procedure. For samples that had high toxicity, we determined the chemical composition (ICP-OES). Preliminary bulk sediment geochemical analysis indicates that select mill tailings exhibit consistently high levels of arsenic, lead, and other trace metals.

Pre- and post-flood LiDAR images were analyzed to find the mill waste sediment volume lost during the 2013 flood. Loss from the largest site, Salina, was at least 20% (3200m^3) of the total volume. We used bulk and layer-specific sampling of the mill sediments to estimate chemical mass transport downstream. We tracked some of the mill waste deposition through sampling sediments downstream of the deposits.

The tailings do not appear to contribute enough to the stream chemistry during low flow to cause the water to exceed state and federal safe limits. However, the composition of the mining legacy sediment poses a separate danger to the soil, and the increased erosion of trace metals such as arsenic and lead is cause for concern for the local communities. If erosive events are increasing, the harmful influence of the legacy sediments in the watershed will only increase.

A Comparison of Oceanic Crustal Permeability at the Outcrop, Hand Sample and Thin Section Scales

Lisa A. Gilbert, Susan Schnur, Katherine Enright, Alana McGillis, and S. Adam Soule

American Geophysical Union Fall Meeting, *V21A-4723, 2014*

Hydrothermal flow through the oceanic crust controls heat and mass fluxes between the crust and the ocean, with implications for element cycling and Earth's heat budget. Permeability in oceanic crust is generated by a combination of high-porosity faults and volcanic deposits. Whereas faults generally increase permeability in the vertical direction, volcanic deposits impart an isotropic permeability. This study is focused on evaluating the permeability in volcanic rocks from the outcrop to thin-section scales including: large inter-pillow voids and hyaloclastite zones (m-cm), vesicles (cm-mm), and micro-scale pore networks (mm-μm). Quantifying hydrothermal fluxes requires measurements of crustal permeability. However, most physical measurements of oceanic crustal permeability are made on core pieces and rock fragments. The importance of large pore space for controlling formation-scale permeability is not known in detail but has been interpreted from in situ measurements of bulk permeability at boreholes. To better quantify formation-scale permeability of oceanic crust we integrate 2D and 3D permeability measurements at the outcrop, hand sample and thin section scales. We estimate outcrop-scale permeability using LiDAR scans and photographs of a pillow lava outcrop in the Talcott basalt of southeastern Connecticut. Permeability is quantified from a 2D classified image of dense pillow cores and permeable inter-pillow hyaloclastite zones using equations based on the equivalent channel model of Walsh and Brace (1984). We apply the same method to 2D images of porous rock hand samples and thin sections that have likewise been segmented into pore and matrix space. Our results will help evaluate how porosity and permeability measurements made at the sample and thin section scale can be adapted to understand magnitudes of fluid flow through oceanic crust at the regional and global scales.

A Salt Marsh Erosion Model: Interplay Between Biotic and Physical Factors at the Seaward Edge

Molly E. Weiner, *Lisa A. Gilbert*, Catherine Alves, Phoebe Poole, and Sophie Schleicher

American Geophysical Union Fall Meeting, B13H-0294, 2014

We present a new model to monitor the cycle of erosion occurring on the seaward edge of salt marshes as sea level rises. In our model, a southern New England salt marsh edge is stable when the bank edge exhibits a normal slope, is fringed by the low-marsh grass *Spartina alterniflora,* and the ribbed mussel *Guekensia demissa* is abundant. As erosion proceeds, the seaward bank becomes vertical (Stage 1), then undercut (Stage 2), then slumped (Stage 3), and finally a detached island (Stage 4) to expose a new vertical bank. If erosion progresses relatively slowly, *S. alterniflora* will dominate and *G. demissa* will be abundant.

We applied this model to four sites at the Barn Island Salt Marsh in southeastern Connecticut. The central headland of the heavily mosquito-ditched Headquarters Marsh appears to be the most rapidly retreating: from 2006 to 2014, the seaward bank advanced two erosional stages and lost 3 m horizontally. This headland is dominated by low-marsh *S. alterniflora*, with mid-marsh grasses *Distichlis spicata* and *Spartina patens* also present on the seaward edge. By comparison, the nearby seaward edge of Wequetequock Point has only *S.*

alterniflora and bare patches with no mid-marsh species. Wequetequock Point also appears more stable, with about one quarter of the seaward bank on a normal slope and abundant mussels (mean 4,500 m^{-2}; max 20,000 m^{-2}).

Repeat surveys since 2006 show mussel vacancy rate is related to the rate of erosion. Open holes appear in normal slope banks due to wave erosion of rocks and other material embedded in the exposed peat. Banks that remain in the same erosion stage for multiple years show increased mussel occupation of these holes. In contrast, rapidly eroding banks at Barn Island Marsh have very few mussels (<100 m^{-2}) and are typically fringed by grasses other than *S. alterniflora*. Much of the Barn Island Marsh bank is eroding too rapidly for mussel settlement and growth and normal marsh grass succession. In addition to documenting the recent rates and mechanisms of marsh loss, using a model that combines multiple indicators of marsh edge stability can help us assess the vulnerability of salt marshes to sea level rise and storms.

Sustainable Agriculture as a Recruitment Tool for Geoscience Majors

Katherine P. Enright, *Lisa A. Gilbert*, and Alana McGillis

American Geophysical Union Fall Meeting, ED34C-11, 2014

Small-scale agriculture has exploded with popularity in recent years, as college-age students and teenagers gain interest in sourcing their food. An interest in and connection to the natural world, including gardening and farming, are among the reasons students take their first geoscience course in college. The actions and theories of small agriculture translate well into geologic research questions, especially in the unique setting of college campus farms and gardens. We propose an activity to engage student-farmers in thinking about geosciences, and connect them with geoscience departments as a gateway to the major and career field. Furthermore, the activity will encourage a new generation of passionate young farmers to integrate the principles of earth science to design and implement more sustainable food systems. The activity includes mapping interviewing agriculture professionals, and problem-solving and results in a the students writing a series of recommendations for their campus or other farm. The activity includes assessment tools for instructors and can be used to give credit for a summer farming internship or as part of a regular course. We believe reaching out to students interested in farming could be an important recruitment tool for geosciences and help build interdisciplinary and community partnerships.

Laurentide: The Crime Fighting Geologist, a Comic-Book Curriculum Tool

Alana McGillis. *Lisa A. Gilbert***,** and Katherine P. Enright

American Geophysical Union Fall Meeting, ED34C-03, 2014

When the police are just too ill informed on matters of earth science to solve the case it is up to Laurentide and her crew of geologists to bring justice to evildoers. Using every tool available, from a rock hammer to LiDAR, Laurentide fights crime while teaching her apprentice Esker about how geologists uncover mysteries everyday. This is the first of what will be a series of free teaching materials targeted at grades 5-8 based around the National Science Education Standards. Students will get the chance to practice problem solving and data analysis in order to solve mysteries with a combination of comic book style story telling and hands-on worksheets. The pilot story, "The Caper of the Ridiculously Cheap Condominiums" will cover 4 of the 9 Earth Science Literacy Principles 'Big Ideas'. Material will explore earthquakes, the hazards and risks they present, and the tools geologists use to map faults and estimate reoccurrence intervals.

Natural Hazards and Risks: Hurricanes

Lisa A. Gilbert, Joan Ramage, and Joshua Galster

InTeGrate module hosted by the Science Education Resource Center, 2014
http://serc.carleton.edu/integrate/teaching_materials/hazards/index.html

Making the difficult decision to evacuate before a hurricane makes landfall can save lives and property. This two week module explores how hurricanes connect the ocean-atmosphere-terrestrial systems and society. Students evaluate how hurricane hazards and risks have changed with coastal development. Students use data

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 hurricane evacuation in their town.

History and Modern Science Collide for the 38th Voyage of the *Charles W. Morgan*
Lisa Gilbert

Ocean Portal, Smithsonian National Museum of Natural History, 2014

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.

This summer's voyage is an unusual one. Along with the scientific research done onboard, I'm also coordinating a cohort of artists and scholars selected as 38th Voyagers, who will sail for a day out of Provincetown, Massachusetts into Stellwagen Bank National Marine Sanctuary in mid-July. The 38th Voyagers are researchers from a variety of disciplines including artists, musicians, scientists, journalists, teachers, scholars, and whaler descendants. They will take part in a public-history project, each producing a work of research reflecting their time aboard the *Morgan*.

Uncharted Waters
Lisa Gilbert

Williams College Magazine, 2014
http://magazine.williams.edu/2014/fall/muse/uncharted-waters/

This past May, the *Charles W. Morgan*—the last remaining wooden whaling ship in the world—set sail for the first time in nearly a century. Its 38th voyage was unlike any that came before it.

The ship once roamed every corner of the ocean in pursuit of whales. But it spent last summer sailing the New England coast, hosting artists, scholars and scientists—85 in all. Selected by Mystic Seaport, with funding from the National Endowment for the Humanities, these "38th Voyagers" were engaged in a public history project to raise awareness of America's maritime heritage and to call attention to issues of ocean sustainability and conservation.

Palaeoecology, Taphonomy, and Preservation of a Lower Pliocene Shell Bed (Coquina) from a Volcanic Oceanic Island (Santa Maria Island, Azores, NE Atlantic Ocean)
S. Ávila, R. Ramalho, J. Habermann, R. Quartau,, A. Kroh, B. Berning, *M. Johnson*, M. Kirby, V. Zanon, J. Titschack, A. Goss, A. Rebelo, C. Melo, P. Madeira, R. Cordeiro, R. Meireles, L. Bagaço, A. Hipólito, A. Uchman, C. Silva, M. Cachão, and J. Madeira

Palaeogeography, Palaeoclimatology, Palaeoecology, 430, 57-73, 2015

Massive fossil shell accumulations require particular conditions to be formed and may provide valuable insights into the sedimentary environments favouring such concentrations. Shallow-water shell beds appear to be particularly rare on reefless volcanic oceanic islands on account of narrow, steep and highly-energetic insular shelves where the potential for preservation is limited. The occurrence of an exceptional coquina at Pedra-que-pica within the Miocene–Pliocene deposits of Santa Maria Island (Azores), therefore provides a rare opportunity to understand the conditions that led to the formation and preservation of a massive shell bed at mid-ocean insular setting. In this paper we provide a detailed analysis regarding a 10-11 m-thick bivalve-dominated fossil assemblage exposed at Pedra-que-pica on Santa Maria Island in the Azores. Integration of taphonomical, palaeoecological and sedimentological observations are used to reconstruct the genesis of the coquina bed and related events, and to discuss why such exceptional sedimentary bodies are so rare on shelves around reefless volcanic oceanic islands. The sequence at Pedra-que-pica demonstrates a complex succession of sedimentary environments in response to the drowning of an existing coastline during a period of rapid sea-level rise. The Pedra-que-pica shell bed incorporates storm-related materials and possible debris falls that originated nearby in a shallow and highly productive carbonate factory. Deposition took

place below fair-weather wave base, at around 50 m depth, as inferred from the overlying volcanic succession. The preservation of this coquina is explained by deposition on a platform laterally protected by a rocky spur, combined with rapid burial by water-settled volcanic tuffs and subsequent volcanic effusive sequences. The recent exhumation of the deposit is the result of island uplift and subsequent erosion.

Stromatolitic Mats from an Uplifted Pleistocene Lagoon at Punta Chivato on the Gulf of California (Mexico)

David Backus and *Markes Johnson*

Palaios 29, 460-466, 2014

Crusts identified as a stromatolitic mat are described for the first time from a small, tectonically uplifted basin associated with a marine terrace along the central Gulf coast of the Baja California peninsula at Punta Chivato. Microscopic analyses of crustal laminae exhibit calcified features directly comparable to microbial processes that precipitate carbonates in modern stromatolites. Floating calcified mats recently described from extremely hypersaline, closed lagoon systems in the northern Gulf of California (Isla Angel de la Guarda) provide the best analog to the Punta Chivato locality. Preservation of the Punta Chivato stromatolites is likely due to the persistence of arid conditions through multiple glacial-interglacial cycles. Comparison with the marine terrace sequence at Punta Chivato implies an age range of 334 ka to 712 ka years for the deposit. This study lends support for a dedicated survey of closed lagoons and terraces where microbialites and their fossil stromatolite representatives may be found along the roughly 3,000-km length of peninsular gulf shores and related islands.

Role of Environmental Change in Rock-Boring Echinoid Trace Fossils

A.Santos, E. Mayoral, C. Dumont, C. Silva, S. Ávila, *G. Baarli*, M. Cachão, *M. Johnson*, and R. Ramalho

Palaeogeography, Palaeoclimatology, Palaeoecology 432, 1-14, 2015

Well preserved groove-borings related to the boring activity of regular sea urchins are preserved on Neogene rocks associated with rocky palaeoshores in a volcanic oceanic island (Santa Maria, Azores archipelago) and a continental margin (Foz de Fonte, Central West Portugal). The new trace fossil consists of a series of relatively deep grooves, with sinuous pathway and with a fairly uniform width along its trajectory. A series of forward oriented concave markings occur frequently inside the grooves, reflecting the movement direction of the producer. The trace fossil is designated as *Ericichnus* igen.n. with two new ichnospecies, *Ericichuns bromleyi* isp.n. and *Ericichnus asgaardi* isp. n. *Ericichnus* ign. n. could have been produced by regular echinoids, similar to the extant echinometrid echinoid *Echinometra lucunter* (Linaeus, 1758) for *E. bromleyi* sip. n., and similar to the echinid *Paracentrotus lividus* Lamark, 1816 for *E. asgaardi* isp. n. Ethologially, the compound trace fossil *Ericichnus* igen.n-*Cicrolites* may correspond to an agrichnion-pascichnion and/or domichnion. Our study suggests that the new ichnospecies *E. bromleyi* may be used as a palaeoenvironmetal tool, indicating the boring activity of termophile rock-boring echinoids in the fossil record.

A Short Supercontinent Cycle: Relicts of Early to Middle Ordovician Closure of the Iapetus Ocean in the New England Appalachians

Francis Macdonald, James Crowley and *Paul Karabinos*

Geological Society of America Abstracts with Programs 46 (6), 371, 2014

The tenure of the Iapetus Ocean is bracketed by the break-up of the supercontinent Rodinia and the Ordovician docking of Gondwanan terranes on the Laurentian margin. New U-Pb zircon geochronology demonstrates that the Shelburne Falls arc was built on a Gondwanan-derived microcontinent that is preserved in part in the Moretown Fm. of Vermont and Massachusetts. The Moretown Fm. was intruded by rocks as old as 502 Ma, and by the 475 Ma Hallockville Pond Gneiss, which is coeval with peak activity in the Shelburne Falls arc. Importantly, the structurally higher Hawley Fm. contains distinctly Grenvillian detrital zircon and was intruded by the 475 Ma Dell Trondhjemite. We suggest that metasediments in the Hawley Fm. captured detritus, shed from Laurentia onto the Gondwanan Moretown terrane during the closure of the Iapetus at or just prior to 475 Ma.

The closure of the Iapetus in New England has traditionally been dated by the appearance of foreland detritus

in the ca. 457-453 Ma Mount Merino-Pawlet succession of the Taconic Allochthon. We suggest that the Taconic Allochthon restores between the Berkshire massif para-authochthon and the more distal Laurentian-derived Rowe belt, and that Early to Middle Ordovician peripheral foreland deposits are present in the Poultney Formation of the Taconic Allochthon and the Chazy Group of the Berkshire massif. The onset of Early to Middle Ordovician accretion is recorded at the base of the Chazy Group as a sandstone-capped unconformity. Late Ordovician foreland deposits preserved in rocks of the Taconic Allochthon formed after closure of the Iapetus Ocean, slab reversal, and subduction under North America during shortening above a west-dipping slab in a Cordilleran-style orogeny. These data indicate that the 70 Myr duration of continental rifting from ca. 610-540 Ma was followed by a brief 65 Myr history for the Laurentian passive margin and an even shorter 40 Myr interval of sea-floor spreading before the initiation of subduction in Iapetus. The Laurentian margin was active for the next 200 m.y. during amalgamation of Gondwanan terranes that culminated with the formation of Pangea.

Visualizing Deformation with an Interactive Computer Program: Linking Shape Change with Graphical and Mathematical Representations of Strain

Paul Karabinos

Geological Society of America Abstracts with Programs 46 (6), 385, 2014

Deformed pebbles conglomerates are commonly used to introduce students to the concept of strain. It is relatively easy to visualize how strain will transform initially circular objects, but it is more challenging to grasp how deformation will affect a population of elliptical objects, and how a preferred-shape fabric corresponds to the intensity and orientation of the strain. Strain can be quantified as a linear transformation, and graphs of pebble axial ratios (Rf) vs. long axis orientations (Phi) can be used to estimate the orientation and magnitude of the strain ellipse. It is difficult for most students, however, to connect the 2x2 strain matrix to shape change, and to visualize how the deformation of pebbles will manifest in Cartesian and polar Rf-Phi plots. We developed a platform independent Java program that allows users to visually link a deforming set of pebbles with the corresponding strain matrix and Rf-Phi plots. The user creates or loads a set of ellipses and then deforms them by simple shear, pure shear, or rotation. As the shape and long axis orientation of ellipses change in one window, the Rf-Phi plot simultaneously tracks those changes in another, and the corresponding deformation matrix is displayed. Deformation can be specified precisely, altered in small increments using arrow keys, or controlled by click-and-drag with a mouse. The program shows both Cartesian and polar Rf-Phi plots. Elliptical objects can be loaded from a text file or quickly digitized from an imported photograph. When a population of naturally deformed ellipses is digitized, the ratio of the strain ellipse and the maximum initial ellipticity can be determined with the equations provided by Ramsay and Huber (1987). It is also possible to graphically un-strain the population to determine the inverse strain ellipse. This allows students to inspect the original shapes and orientations of pebbles, to evaluate the plausibility of the estimated strain values, and to assess the key assumption of no initial preferred orientation of pebble long axes. The source code and program are freely available for academic purposes.

The instantaneous visual feedback provides a critical link between deformation of a population of pebbles and changes in the graphical representation of the population via the linear algebraic description of strain.

An Interactive Program for Visualizing and Estimating Strain in Deformed Conglomerates

Paul Karabinos

Geological Society of America Abstracts with Programs 46 (6), 289 , 2014

Deformed pebbles and oolites are commonly used by researchers to estimate strain in rocks, and by instructors to teach fundamental principles of strain. The Rf-Phi method is useful for determining strain from a population of deformed pebbles, although it relies on the assumption that pebbles were deposited with no initial preferred orientation of long axes. We developed a simple yet robust interactive program that allows users to explore visually how deformation of a set of elliptical objects appears on Cartesian and polar Rf-Phi plots. The user creates or loads the ellipses and then deforms them by simple shear, pure shear, or rotation. As the shapes (Rf) and long-axis orientations (Phi) of the pebbles change, the Cartesian and polar Rf-Phi plots

are instantaneously updated. Deformation can be specified precisely, incrementally changed using the arrow keys, or simulated by click-and-drag with a mouse. The program provides both the Cartesian Rf-Phi graph (Ramsay and Huber, 1987), and the polar plot of ln(Rf) vs. 2(Phi), as suggested by Elliott (1970). Elliptical objects can be loaded from a text file or quickly traced from an imported photograph. When a population of naturally deformed ellipses is digitized, the ratio of the strain ellipse and the maximum initial ellipticity can be determined with the equations provided by Ramsay and Huber (1987). In addition, graphical experiments to un-strain the population using a range of inverse strain ellipses can be done quickly and easily, making it possible to inspect the shapes and orientations of the retro-deformed objects. Thus, it is possible to assess the assumption of no initial preferred orientation of the pebble long-axes over a range of strain values. Users can export information about the pebble shapes and orientations to spreadsheets for rigorous statistical analysis. The platform independent program is written in Java, and the source code and application are freely available for academic purposes.

A Structural Investigation of Folded Bascom Fm., US Highway 279 in North Bennington, VT

Amanda Van Lankvelt, Michael Williams, Phillip Geer, Claire Pless, Sean Regan, Jeffrey Webber and *Paul Karabinos*

Geological Society of America Abstracts with Programs 47 (3), 94, 2015

A new road cut exposed north of Bennington, VT provides an excellent opportunity for collaborative teaching and research. During the fall of 2014, the metamorphic structural geology class from the University of Massachusetts, Amherst spent several days investigating the new cut, which exposes the Ordovician Bascom Fm. along the southbound side of US Highway 7. The Bascom Fm. here consists of well-bedded dolostone and limestone with finer-grained, phyllitic beds. Carbonate-dominated layers host stylolites, whereas phyllites preserve bedding surfaces, some with ripples and rip-up clasts. The structure consists of a mesoscopic (>100 m), upright fold train with a central zone of vertical bedding. We subdivided the outcrop into 6 structural domains, with domain 1 beginning on the westernmost edge of the outcrop and domain 6 ending before a chaotic section at the east end of the outcrop. Domains 1, 2, & 6 contain open synforms and antiforms, whereas domain 4 contains steeply dipping to vertical beds. Domains 3 & 5 contain a transition from the open folds to the vertical beds, and these domains contain parasitic and tight, asymmetric folds. Phyllite layers host subtle S-C fabrics, with bedding defining the C-surfaces. S-C fabrics in domains 1, 2 & 6 consistently suggest west-directed, bedding-parallel thrusting. Some S-C fabrics in "transitional" domains 3 & 5 show top-east vergence, suggesting flexural shearing during folding. Sub-horizontal tensions gashes are present in domain 4, suggesting vertical extension. Bedding orientations were obtained in all six domains (D). From west to east, fold axis orientations are: D1 & D2: 24/143; D3: 28/167; D4: 29/166; D5: 20/163; and D6: 09/165. The shallower plunge of the eastern domains may reflect some rotation across the vertical bedding in domains 4 & 5. We interpret the structure to indicate early west-directed thrusting and folding followed by nearly pure-shear shorting with strain accumulating on the steep central fold limb. We propose this outcrop could be an excellent collaborative research and teaching location, where classes from New England colleges and universities might study aspects of the structural geology and contribute to a common database and discussion website. In this spirit, our measurements will be made available to serve as a starting point for future research.

The Structural Geology Mapping Challenge: an Evolving Tool for Online Geoscience Education

Declan De Paor, Steven Whitmeyer, Mladen Dordevic, *Paul Karabinos*, Barbara Tewksbury, and G. Richard Whittecar

Geological Society of America Abstracts with Programs 47 (3), 48, 2015

The Structural Geology Mapping Challenge is a highly interactive game-like activity that leverages the Google Earth application program interface (API) to present students with opportunities to develop skills in recognizing and mapping geological structures in the field. Students fly to an instructor-generated location in Google Earth where they can translate, rotate, and scale a semi-transparent plane in order to fit it to the map traces of planar structures. The fit of the plane to a flat-iron is particularly striking. It makes the three-

dimensionality of the structure 'pop-out.' The planes orientation is linked to an interactive great circle on a stereographic projection that floats over the Google Earth window. Students can drag the pole to the great circle in order to see the effects o the ground.

The challenge for students in our current version is to estimate bedding at several points around a fold in Big Horn Basin, WY. Student estimates of strike and dip are auto-scored by the computer, which calculates the cross-product of the poles to student and instructor bedding planes. Students are awarded medallions based on closeness of these estimates. After fitting bedding planes, students fit a great circle through the poles to bedding in order to determine the fold axis and they fit a plane to hinge points of successive beds to pin down the axial plane. Finally, students can fit bézier curves to periclinal fold cross sections and long sections. This is important to teach the lesson that inclined folds do not plunge uniformly forever. Guerrilla testing is scheduled for Spring 2015 and initial results will be reported.

Uniting Taconic Hinterland Deformation with Ordovician Foreland Deposition in New England

Paul Karabinos, Francis Macdonald, and James Crowley

Geological Society of America Abstracts with Programs 47 (3), 80, 2015

Following the Ediacaran breakup of Rodinia, Grenville-derived sediment dominated the rift to drift sediments of the Laurentian margin of western New England. A dramatic change in detrital zircon age distribution coincides with the Rowe Schist-Moretown Fm contact, and provides evidence that this is the Laurentian-Gondwanan suture. Ultramafic lenses are concentrated along this suture in VT and western MA, suggesting that it is a paleo-subduction zone. Structurally above and east of the Moretown Fm are forearc mafic volcanic rocks and sediments of the Hawley Fm. Both the Moretown and Hawley Fm were intruded by 475 Ma arc-related plutons, the Hallockville Pond Gneiss and Dell Metatrondhjemite, respectively. These intrusive rocks are coeval with the plutonic core rocks of the Shelburne Falls dome; we include the Hallockville Pond Gneiss and the Hawley Fm in the Shelburne Falls arc, which we suggest was built on the Moretown terrane. However, detrital zircon from Hawley Fm metasediments are dramatically different from those in the underlying Moretown Fm, and constrain the timing of collision between Laurentia and the Shelburne Falls arc. Two samples contain Laurentian-derived detrital zircons and suggest that the Shelburne Falls arc was proximal to Laurentia at ca. 475 Ma. One contains Ordovician arc zircons and indicates that deposition was active during or after arc magmatism. The Shelburne Falls arc is dominated by felsic plutonic and volcanic rocks that formed between 475 to 470 Ma, when the Shelburne Falls arc was close to Laurentia. This burst of magmatic activity may have been triggered by the onset of subduction of water-rich Laurentian sediments of the Rowe Schist or slab breakoff. Collision between 480 and 470 Ma is consistent with the oldest Ar cooling ages from Laurentian margin rocks. A newly dated 466 Ma rhyolite from the Barnard Volcanic Member was erupted after collision of Laurentia and the Shelburne Falls arc; it may be coeval with slab breakoff of the older east-dipping subducting plate or initiation of younger west-dipping subduction beneath the newly accreted Moretown terrane. This subduction polarity reversal produced a younger Laramide-style phase of the Taconic orogeny responsible for the youngest Ordovician thrusts in the Taconic Range and the Late Ordovician Black River and Trenton Groups basin.

Was the Early Ordovician Shelburne Falls Arc Built on Gondwanan Crust Close to Laurentia?

Paul Karabinos, James Crowley, and Francis Macdonald

Geological Society of America Abstracts with Programs 47 (3), 81, 2015

Following the Ediacaran breakup of Rodinia, Grenville-derived sediment dominated the rift to drift sediments of the Laurentian margin of western New England. A dramatic change in detrital zircon age distribution coincides with the Rowe Schist-Moretown Fm contact, and provides evidence that this is the Laurentian-Gondwanan suture. Ultramafic lenses are concentrated along this suture in VT and western MA, suggesting that it is a paleo-subduction zone. Structurally above and east of the Moretown Fm are forearc mafic volcanic rocks and sediments of the Hawley Fm.. Both the Moretown and Hawley Fm were intruded by 475 Ma arc-related plutons, the Hallockville Pond Gneiss and Dell Metatrondhjemite, respectively. These intrusive rocks are coeval with the plutonic core rocks of the Shelburne Falls dome; we include the Hallockville Pond Gneiss

and the Hawley Fm in the Shelburne Falls arc, which we suggest was built on the Moretown terrane. However, detrital zircon from Hawley Fm metasediments are dramatically different from those in the underlying Moretown Fm, and constrain the timing of collision between Laurentia and the Shelburne Falls arc. Two samples contain Laurentian-derived detrital zircons and suggest that the Shelburne Falls arc was proximal to Laurentia at ca. 475 Ma. One contains Ordovician arc zircons and indicates that deposition was active during or after arc magmatism. The Shelburne Falls arc is dominated by felsic plutonic and volcanic rocks that formed between 475 to 470 Ma, when the Shelburne Falls arc was close to Laurentia. This burst of magmatic activity may have been triggered by the onset of subduction of water-rich Laurentian sediments of the Rowe Schist or slab breakoff. Collision between 480 and 470 Ma is consistent with the oldest Ar cooling ages from Laurentian margin rocks. A newly dated 466 Ma rhyolite from the Barnard Volcanic Member was erupted after collision of Laurentia and the Shelburne Falls arc; it may be coeval with slab breakoff of the older east-dipping subducting plate or initiation of younger west-dipping subduction beneath the newly accreted Moretown terrane. This subduction polarity reversal produced a younger Laramide-style phase of the Taconic orogeny responsible for the youngest Ordovician thrusts in the Taconic Range and the Late Ordovician Black River and Trenton Groups basin.

Detrital Zircon Constraints on the Age of the Poplar Mountain Gneiss in the Pelham Ddome: Implications for the Tectonic Setting of the Bronson Hill Arc

Paul Karabinos, James Crowley, and Francis Macdonald

Geological Society of America Abstracts with Programs 47 (3), 41, 2015

Several controversies surround the tectonic significance of the Bronson Hill arc (BHA) and the Pelham Dome (PD) in the New England Appalachians including 1) whether the BHA is a peri-Laurentian or peri-Gondwanan arc, 2) the nature of the contact between the Ordovician arc rocks and the Neoproterozoic core rocks of the PD, and 3) whether the PD is a fragment of Ganderia or Avalon. We confirmed and refined the Neoproterozoic age of the Dry Hill Gneiss in the PD with an upper intercept U/Pb CA-ID-TIMS zircon age of ca. 607 Ma. Diatexite of the Poplar Mtn. Gneiss, which was also assigned a Neoproterozoic age, was sampled from a structural window in the PD. It contains detrital zircon grains with a Gondwanan provenance. However, cores of nine detrital grains gave LA-ICPMS ages between ca. 450 to 320 Ma. Metamorphic rims gave ages of ca. 280 Ma. The youngest detrital ages constrain the Poplar Mtn. Gneiss to a Carboniferous age, and require an Alleghanian tectonic contact between the arc rocks and the core rocks of the PD. The 607 Ma age of the Dry Hill Gneiss is indistinguishable from Avalonian basement, but also overlaps in age with Ganderian granites. A sample of the Partridge Fm from the BHA yielded a small (25 dated grains) detrital zircon population that includes Ordovician grains, presumably derived from arc volcanism, and Neoproterozoic grains suggesting a Gondwanan source. New evidence indicates that the SFA was built on a Gondwanan fragment preserved in the Moretown Fm, which also contains abundant ca. 607 Ma detrital grains. After collision of the SFA with Laurentia in the Early Ordovician, a west-dipping subduction zone developed under the newly accreted SFA and Moretown terrane. At least that portion of the BHA located in MA and southern NH. formed above this new subduction zone. Thus, although the BHA preserves evidence for a Gondwanan basement it may have formed along the Laurentian margin in the Late Ordovician. The Dry Hill Gneiss in the Pelham dome has been previously proposed to represent a Ganderian or Avalonian sliver thrust beneath the BHA. However, another possibility is that the Dry Hill Gneiss represents basement to the Moretown terrane. Viable models must include formation of a Carboniferous extensional or transtensional basin on a formerly accreted terrane, and thrusting of the Dry Hill Gneiss and BHA over these young rocks.

A Newly Identified Gondwanan Terrane in the Northern Appalachian Mountains: Implications for the Taconic Orogeny and Closure of the Iapetus Ocean: REPLY

Francis Macdonald, J. Ryan-Davis, R. Coish, James Crowley, and *Paul Karabinos*

Geology 43, 360, 2015, doi: 10.1130/G36575Y.1

There is no abstract for this paper.

History of Science

Who is Collaborating with Whom?
Part I. Mathematical Model and Methods for Empirical Testing

Hildrun Kretschmer, *Donald deB. Beaver*, Bulent Ozel,Theo Kretschmer,

Journal of Informetrics, 9 (2) (April 2015): 359-372

There are two versions in the literature of counting co-author pairs. Whereas the first version leads to a two-dimensional (2-D) power function distribution; the other version shows three-dimensional (3-D) graphs, totally rotatable around and their shapes are visible in space from all possible points of view. As a result, these new 3-D computer graphs, called "Social Gestalts" deliver more comprehensive information about social network structures than simple 2-D power function distributions. The mathematical model of Social Gestalts and the corresponding methods for the 3-D visualization and animation of collaboration networks are presented in Part I of this paper. Fundamental findings in psychology/sociology and physics are used as a basis for the development of this model.

The application of these new methods to male and to female networks is shown in Part II. After regression analysis the visualized Social Gestalts are rather identical with the corresponding empirical distributions (R2 > 0.99). The structures of female co-authorship networks differ markedly from the structures of the male co-authorship networks. For female co-author pairs' networks, accentuation of productivity dissimilarities of the pairs is becoming visible but on the contrary, for male co-author pairs' networks, accentuation of productivity similarities of the pairs is expressed.

Part II. Application of the methods to male and to female networks

Journal of Informetrics, 9 (2) (April 2015): 373-384

The theoretical approach of the mathematical model of Social Gestalts and the corresponding methods for the 3-D visualization and animation of collaboration networks are presented in Part I. The application of these new methods to male and female networks is shown in Part II. After regression analysis the visualized Social Gestalts are rather identically with the corresponding empirical distributions (R2 > 0.99). The structures of female co-authorship networks differ markedly from the structures of the male co-authorship networks. For female co-author pairs' networks, accentuation of productivity dissimilarities of the pairs is becoming visible but on the contrary, for male co-author pairs' networks, accentuation of productivity similarities of the pairs is expressed.

Three-dimensional visualization and animation of emerging patterns by the process of self-organization in collaboration networks

Hildrun Kretschmer, *Donald deB. Beaver*, Theo Kretschmer

Scientometrics 2015; 104(1): 87-120 (online 5 April 2015)

The "Social Gestalt" model is a new parametric model visualizing 3-D graphs, using animation to show these graphs from different points of view. A visible 3-D graph image is the emerging pattern at the macro level of a system of co-authorships by the process of self-organization. Well-ordered 3-D computer graphs are totally rotatable and their shapes are visible from all possible points of view. The objectives of this paper are the description of several methods for three-dimensional modelling and animation and the application of these methods to two co-authorship networks selected for demonstration of varying 3-D graph images. This application of the 3-D graph modelling and animation shows for both the journal "NATURE" and the journal "Psychology of Women Quarterly" that at any time and independently on the manifold visible results of rotation, the empirical values nearly exactly match the theoretical distributions (Called "Social Gestalts") obtained by regression analysis. In addition the emergence of different shapes between the 3-D graphs of "NATURE" and "Psychology of Women Quarterly" is explained.

Mathematics and Statistics

Knot Projections with a Single Multi-Crossing
Colin Adams with Thomas Crawford, *Benjamin Demeo '15,* Michael Landry, MurphyKate Montee, Seojung Park, Saraswathi Venkatesh, Farrah Yhee

Journal of Knot Theory and Its Ramifications, Vol. 24, No. 3, 1550011(30 pages), 2015.

Bounds on Ubercrossing and Petal Number for Knots
C. Adams, O. Capovilla-Searle*, J. Freeman '15,* D. Irvine, *S. Petti '15,* D. Vitek, A. Weber, S. Zhang

Journal of Knot Theory and Its Ramifications, Vol. 24, No. 2, 1550012 (16 pages), 2015.

The End of Mathematics
Colin Adams

Mathematical Intelligencer, Vol. 36, No. 3, 20-212, 2014.

Motivational Seminar
Colin Adams

Mathematical Intelligencer, Vol. 36, No. 4, 19-21, 2014.

Zombies and Calculus: An Excerpt
Colin Adams

Mathematical Intelligencer, Vol. 37, No. 1, 78-82, 2015.

Zombies and Calculus
Colin Adams

Princeton University Press, October 2014.

Calculus, 3rd Edition
Colin Adams with Jon Rogawski

W.H. Freeman, 36, December 2014.

Zombies and Calculus I and II
Colin Adams with Jon Rogawski

NOVA, produced by Ari Daniel, September 2014

Navigation in Tree Spaces
Satyan Devadoss with J. Morava

Advances in Applied Mathematics, 67, 75-95, 2015.

The orientable cover of the moduli space of real genus zero algebraic curves with marked points is a compact aspherical manifold tiled by associahedra, which resolves the singularities of the space of phylogenetic trees. The resolution maps planar metric trees to their underlying abstract representatives, collapsing and folding an explicit geometric decomposition of the moduli space into cubes. This decomposition endows the resolving space with an interesting canonical pseudometric.

Convex Polytopes From Nested Posets
Satyan Devadoss with S. Forcey, S. Reisdorf, P. Showers

European Journal of Combinatorics, 43, 229-248, 2015.

Motivated by the graph associahedron KG, a polytope whose face poset is based on connected subgraphs of G, we consider the notion of associativity and tubes on posets. This leads to a new family of simple convex polytopes obtained by iterated truncations. These generalize graph associahedra and nestohedra, even encompassing notions of nestings on CW-complexes, but fall in a different category altogether than generalized permutohedra.

Polyhedral Covers of Tree Space

Satyan Devadoss with D. Huang, D. Spadacene

SIAM Journal of Discrete Mathematics, 28, 1508-1514, 2014.

We construct the space of phylogenetic trees from local gluings of classical polytopes, the associahedron and the permutohedron. Its homotopy is also reinterpreted and calculated based on polytope data.

Stats: Data and Models, 4th Edition

Richard De Veaux with Paul Velleman and David Bock

Pearson, January 2015.

A Generalized Family of Multidimensional Continued Fractions: TRIP Maps

Thomas Garrity, with Krishna Dasaratha, Laure Flapan*, Chansoo Lee '12,* Cornelia Mihaila, *Nicholas Neumann-Chun '14,* Sarah Peluse, Matt Stoffregen

International Journal of Number Theory, Vol. 10, 2151, 2014.

Most well-known multidimensional continued fractions, including the M\"{o}nkemeyer map and the triangle map, are generated by repeatedly subdividing triangles. This paper constructs a family of multidimensional continued fractions by permuting the vertices of these triangles before and after each subdivision. We obtain an even larger class of multidimensional continued fractions by composing the maps in the family. These include the algorithms of Brun, Parry-Daniels and G\"{u}ting. We give criteria for when multidimensional continued fractions associate sequences to unique points, which allows us to determine when periodicity of the corresponding multidimensional continued fraction corresponds to pairs of real numbers being cubic irrationals in the same number field.

Cubic Irrationals and Periodicity Via a Family of Multi-Dimensional Continued Fraction Algorithms

Thomas Garrity, with Krishna Dasaratha, Laure Flapan*, Chansoo Lee '12,* Cornelia Mihaila, *Nicholas Neumann-Chun '14,* Sarah Peluse, Matt Stoffregen

Monatshefte für Mathematik, Vol. 174, Issue 4, 549-566, August 2014.

We construct a countable family of multi-dimensional continued fraction algorithms, built out of five specific multidimensional continued fractions, and show a real number is a cubic irrational precisely when its multidimensional continued fraction expansion with respect to at least one element of the countable family is eventually periodic. We interpret this result as the construction of a matrix with entries of non-negative integers such that at least one of the rows is eventually periodic if and only if the chosen real is a cubic irrational. This result is built on a careful technical analysis of certain units in cubic number fields and our family of multi-dimensional continued fractions.

Review of Spherical Tube Hypersurfaces, by Alexander Isaev

Thomas Garrity

Bulletin of the American Mathematical Society, Vol. 51, No. 4, 675-685, 2014.

A review of Isaev's text and an overview of CR geometry.

Electricity and Magnetism for Mathematicians: A Guided Path from Maxwell's Equations to Yang-Mills

Thomas Garrity

Cambridge University Press, 2015.

This text is an introduction to some of the mathematical wonders of Maxwell's equations. These equations led to the prediction of radio waves, the realization that light is a type of electromagnetic wave, and the discovery of the special theory of relativity. In fact, almost all current descriptions of the fundamental laws of the universe can be viewed as deep generalizations of Maxwell's equations. Even more surprising is that these equations and their generalizations have led to some of the most important mathematical discoveries of the past thirty years. It seems that the mathematics behind Maxwell's equations is endless. The goal of this book is to explain to mathematicians the underlying physics behind electricity and magnetism and to show their connections to mathematics. Starting with Maxwell's equations, the reader is led to such topics as the special

theory of relativity, differential forms, quantum mechanics, manifolds, tangent bundles, connections, and curvature.

Multiple Comparisons of Marginal Probabilities Following GEE Estimation
Bernhard Klingenberg

Proceedings of the 30th International Workshop on Statistical Modelling, Linz 2015.

Newman's conjecture in various settings
Steven Miller (with Julio Andrade and Alan Chang)

Journal of Number Theory 144, 70-91, 2014.

We explicitly determine the Newman constants in various function field settings, which has strong implications for Newman's quantitative version of RH.

A Message From Professor Steven Miller, A SLICE OF Pi
Steven Miller

Palmdale High School Math Department News Letter, volume 2, issue 5, pages 1 and 7, November 2014.

Discussion of Math Riddles for High School students.

Generalized Ramanujan Primes
Steven Miller (with Nadine Amersi, Olivia Beckwith, Ryan Ronan and Jonathan Sondow)

Combinatorial and Additive Number Theory, CANT 2011 and 2012 (Melvyn B. Nathanson, editor), *Springer Proceedings in Mathematics & Statistics*, 1—13, 2014.

We generalize the notion of Ramanujan primes and prove many properties, and conjecture others.

Finding and Counting MSTD Sets
Steven Miller (with Geoffrey Iyer, Oleg Lazarev and Liyang Zhang)

Combinatorial and Additive Number Theory, CANT 2011 and 2012 (Melvyn B. Nathanson, editor), Springer *Proceedings in Mathematics & Statistics*, 79-98, 2014.

We give new constructions and results of generalized MSTD sets, including among other items results on a positive percentage of sets having a given linear combination greater than another linear combination, and a proof that a positive percentage of sets are k-generational sum-dominant.

Most Subsets are Balanced in Finite Groups
Steven Miller (with Kevin Vissuet)

Combinatorial and Additive Number Theory, CANT 2011 and 2012 (Melvyn B. Nathanson, editor), *Springer Proceedings in Mathematics & Statistics*, 147-157, 2014.

We show that if we take subsets of larger and larger finite groups uniformly at random, then not only does the probability of a set being sum-dominated tend to zero but the probability that $|A + A| = |A - A|$ tends to one, and hence a typical set is balanced in this case.

Gaussian Behavior in Generalized Zeckendorf Decompositions
Steven Miller (with Yinghui Wang)

Combinatorial and Additive Number Theory, CANT 2011 and 2012 (Melvyn B. Nathanson, editor), *Springer Proceedings in Mathematics & Statistics*, 159-173, 2014.

We prove Gaussian behavior for generalized Zeckendorf decompositions arising from certain recurrences.

The Expected Eigenvalue Distribution of Large, Weighted d-regular Graphs
Steven Miller (with *Leo Goldmakher*, Cap Khoury and Kesinee Ninsuwan)

Random Matrices: Theory and Applications 3, no. 4, 1450015 (22 pages) 2014.

We compute the limiting spectral measure for weighted ensembles arising from d-regular graphs.

Pythagoras at the Bat

Steven Miller (with Taylor Corcoran, *Jennifer Gossels '13*, *Victor Luo '14* and *Jaclyn Porfilio '15*)

Book chapter in Social Networks and the Economics of Sports (organized by Victor Zamaraev), Springer-Verlag, 2014.

This survey article describes some of the advances and successes in modeling and using the Pythagorean won-loss formula.

The n-Level Density of Dirichlet L-Functions over F_q[T]

Steven Miller (with Julio Andrade, Kyle Pratt and Minh-Tam Trinh)

Communications in Number Theory and Physics 8, no. 3, 1—29, 2014

We compute the n-level density of Dirichlet L-functions in the function field.

A Message From Professor Steven Miller, A SLICE OF Pi

Steven Miller

Palmdale High School Math Department News Letter, volume 2, issue 7, page 1 and 7 additional remarks online, December 2014

Discussion of Math Riddles for High School students.

Surpassing the Ratios Conjecture in the 1-level density of Dirichlet L-functions

Steven Miller (with Daniel Fiorilli)

Algebra & Number Theory Vol. 9, No. 1, 13—52, 2015

We compute the 1-level density for Dirichlet L-functions, computing lower order terms beyond square-root cancellation and showing how various conjectures influence the level of support computable.

The James Function

Steven Miller (with Christopher N. B. Hammond and Warren P. Johnson)

Mathematics Magazine 88, 54—71, 2015

We explore a set of natural conditions for a won-loss formula, and determine the class of functions which satisfy these.

Gaps Between Zeros of GL(2) L-Functions

Steven Miller (with Owen Barrett, Brian McDonald, Ryan Patrick, Caroline Turnage-Butterbaugh and Karl Winsor)

Journal of Mathematical Analysis and Applications 429, 204—232, 2015

We prove there are infinitely many zeros at least sqrt(3) times the average spacing for GL(2) L-functions, as well as similar results on gaps smaller than the average spacing.

Benford Behavior of Zeckendorf Decompositions

Steven Miller (with *A. Best '15*, P. Dynes, *X. Edelsbrunner'16*, B. McDonald, C. Turnage-Butterbaugh and M. Weinstein)

Fibonacci Quarterly 52 (2014), no. 5, 35—46, 2014.

We prove that the distribution of summands in Zeckendorf decompositions satisfy Benford's law.

Gaussian Behavior of the Number of Summands in Zeckendorf Decompositions in Small Intervals

Steven Miller (with *A. Best '15*, P. Dynes, *X. Edelsbrunner '16*, B. McDonald C. Turnage-Butterbaugh and M. Weinstein)

Fibonacci Quarterly 52, no. 5, 47—53, 2014

We extend previous Gaussian results to smaller intervals.

Generalizing Zeckendorf's Theorem: The Kentucky Sequence

Steven Miller (with M. Catral, P. Ford, P. Harris and D. Nelson)

Fibonacci Quarterly 52, no. 5, 68—90, 2014.

Previous studies on generalized Zeckendorf decompositions required the first coefficient in the recurrence relation to be a positive integer; we explore the consequences arising from a sequence with first term zero.

Benford's Law: Theory and Applications

Steven Miller, Editor

Princeton University Press, 2015.

This is the first interdisciplinary book on Benford's law, with 19 chapters on diverse areas such as accounting, auditing, economics, finance, gambling, imaging, medicine, natural sciences, psychology, statistics, and voting. I wrote the introductory chapter, a chapter on 'Fourier Analysis and Benford's Law' (parts written with recent SMALL students *Xixi Edelsbrunner '16,* Karen Huan'16, *Blake Mackall '16*, Jasmine Powell and Madeleine Weinstein), and a chapter on 'Application of Benfords Law to Images.'

Optimal City Hierarchy: A Dynamic Programming Approach to Central Place Theory

Thomas J. Holmes, Wen-Tai Hsu, and *Frank Morgan*

J. Econ. Theory 154, 245-273, 2014.

We place cities of various sizes on the line to minimize set-up and transportation costs, and we provide a dynamic programming solution. We show that there must be one and only one immediate smaller city between two neighboring larger-sized cities. Often the smaller city takes a "central place" halfway between the next larger cities, but not always.

Bubbles and Tilings: Art and Mathematics

Frank Morgan

Proc. Bridges, 2014.

The 2002 proof of the Double Bubble Conjecture on the ideal shape for a double soap bubble depended for its ideas and explanation on beautiful images of the multitudinous possibilities. Similarly recent results on ideal tilings depend on the artwork.

Academics Must Be Williams Top Priority

Frank Morgan

Williams Record, May 7, 2014.

Williams: Inclusive or Exclusive?

Frank Morgan

WilliamsAlternative.com, May 2014.

Arithmetic Properties of Generalized Rikuna Polynomials

Allison Pacelli with Z. Chonoles, *H. Hausman '12*, *S. Pegado '11*, F. Wei

Mathematiques de Besancon: Algebre et Theorie des Nombres, 1, 19-33, 2014.

On Rationally Ergodic and Rationally Weakly Mixing Rank-One Transformations

Cesar E. Silva with Irving Dai, Xavier Garcia, and Tudor Padurariu

Ergodic Theory and Dynamical Systems, 35, No. 4, 1141-1154, 2015.

We study the notions of weak rational ergodicity and rational weak mixing as defined by Jon Aaronson in 1977 and 2012. We prove that various families of infinite measure-preserving rank-one transformations possess or do not posses these properties, and consider their relation to other notions of mixing in infinite measure.

On Li-Yorke Measurable Sensitivity

Cesar E. Silva with Lucas Manuelli and *Jared Hallett '14*

Amer. Math. Soc., 143, No. 6, 2411-2426, 2015.

The notion of Li-Yorke sensitivity has been studied extensively in the case of topological dynamical systems. We introduce a measurable version of Li-Yorke sensitivity, for nonsingular (and measure-preserving) dynamical systems, and compare it with various mixing notions. It is known that in the case of nonsingular dynamical systems, conservative ergodic Cartesian square implies double ergodicity, which in turn implies weak mixing, but the converses do not hold in general, though they are all equivalent in the finite measure-preserving case. We show that for nonsingular systems, ergodic Cartesian square implies Li-Yorke measurable sensitivity, which in turn implies weak mixing. As a consequence we obtain that, in the finite measure-preserving case, Li-Yorke measurable sensitivity is equivalent to weak mixing. We also show that with respect to totally bounded metrics, double ergodicity implies Li-Yorke measurable sensitivity.

Subsequence Bounded Rational Ergodicity of Rank-One Transformations

Cesar E. Silva with Francisc Bozgan, Anthony Sanchez, *David Stevens '14* and Jane Wang

Dynamical Systems, 30, No. 1, 70-84, 2015.

We show that all rank-one transformations are subsequence boundedly rationally ergodic and that there exist rank-one transformations that are not weakly rationally ergodic.

Spectral Properties of Random and Deterministic Matrices

Mihai Stoiciu

Math. Model. Nat. Phenom., Vol. 9, No. 5, 270-281, 2014.

The CMV matrices are unitary analogues of the discrete one-dimensional Schrödinger operators. We review spectral properties of a few classes of CMV matrices and describe families of random and deterministic CMV matrices which exhibit a transition in the distribution of their eigenvalues.

Improving Cross-Validated Bandwidth Selection Using Subsampling-Extrapolation Techniques

Qing Wang and Bruce Lindsay

Computational Statistica & Data Analysis 89, 51-71, 2015.

Cross-validation methodologies have been widely used as a means of selecting tuning parameters in nonparametric statistical problems. In this paper we focus on a new method for improving the reliability of cross-validation. We implement this method in the context of the kernel density estimator, where one needs to select the bandwidth parameter so as to minimize L2 risk. This method is a two-stage subsampling-extrapolation bandwidth selection procedure, which is realized by first evaluating the risk at a fictional sample size m (m <= sample size n) and then extrapolating the optimal bandwidth from m to n. This two-stage method can dramatically reduce the variability of the conventional unbiased cross-validation bandwidth selector. This simple first-order extrapolation estimator is equivalent to the rescaled "bagging-CV" bandwidth selector in Hall and Robinson (2009) if one sets the bootstrap size equal to the fictional sample size. However, our simplified expression for the risk estimator enables us to compute the aggregated risk without any bootstrapping. Furthermore, we developed a second-order extrapolation technique as an extension designed to improve the approximation of the true optimal bandwidth. To select the optimal choice of the fictional size m given a sample of size n, we propose a nested cross-validation methodology. Based on simulation study, the proposed new methods show promising performance across a wide selection of distributions. In addition, we also investigated the asymptotic properties of the proposed bandwidth selectors.

Robust Thresholding for Diffusion Index Forecast

Qing Wang and *Vu Lee '14*

Economics Letters 125, 52-56, 2014.

In this paper we propose a new methodology in improving the Diffusion Index forecasting model (Stock and Watson, 2002) using hard thresholding with robust KVB statistic for regression hypothesis tests (Kiefer, Vogelsang, and Bunzel, 2000). The new method yields promising results in the context of long forecasting horizons and existence of serial correlation. Numerical comparison indicates that the proposed methodology

can improve upon the existing hard thresholding methods and outperform the soft thresholding methods (Bai and Ng, 2008) when applied to a real data set that forecasts eight macroeconomic variables in the United States.

A General Class of Linearly Extrapolated Variance Estimators

Qing Wang and *Shiwen Chen '14*

Statistics & Probability Letters 98, 29-38, 2015.

A general class of linearly extrapolated variance estimators was developed as an extension of the conventional leave-one-out jackknife variance estimator. In the context of U-statistic variance estimation, the proposed variance estimator is first-order unbiased. After showing the equivalence between the Hoeffding decomposition (Hoeffding, 1948) and the ANOVA decomposition (Efron and Stein, 1981), we study the bias property of the proposed variance estimator in comparison to the conventional jackknife method. Simulation studies indicate that the proposal has comparable performance to the jackknife method when assessing the variance of the sample variance in various distributions. An application to half-sampling cross-validation indicates that the proposal is more computationally efficient and shows better performance than its jackknife counterpart in the context of regression analysis.

Physics

"US Patent Application, Methods for Alerting Polypeptide Expression "

Daniel P. Aalberts, Greg Boel and John Hunt, co-authors

"Transformed composite sequences for improved qubit addressing"

Merrill, J. T., Doret, S. C., Vittorini, G., Addison, J. P., and Brown, K. R.

Phys. Rev. **A *90***, 040301 (2014)

Selective laser addressing of a single atom or atomic ion qubit can be improved using narrow-band composite pulse sequences. We describe a Lie-algebraic technique to generalize known narrow-band sequences and introduce sequences related by dilation and rotation of sequence generators. Our method improves known narrow-band sequences by decreasing both the pulse time and the residual error. Finally, we experimentally demonstrate these composite sequences using 40Ca+ ions trapped in a surface-electrode ion trap.

"Quantum mutual information of an entangled state propagating through a fast-light medium"

Kevin M. Jones, McElfresh Professor of Physics, and others

Nature Photonics (2014)

It is widely accepted that information cannot travel faster than c, the speed of light in vacuum. Here, we investigate the behaviour 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.

"Comparing resolved-sideband cooling and measurement-based feedback cooling on an equal footing: Analytical results in the regime of ground-state cooling"

K. Jacobs, H. I. Nurdin, F. W. Strauch, and M. James

*Physical Review **A 91***, 043812 (2015)

We show that in the regime of ground-state cooling, simple expressions can be derived for the performance of resolved-sideband cooling—an example of coherent feedback control—and optimal linear measurement-based feedback cooling for a harmonic oscillator. These results are valid to leading order in the small parameters that define this regime. They provide insight into the origins of the limitations of coherent and measurement-based feedback for linear systems, and the relationship between them. These limitations are not fundamental bounds imposed by quantum mechanics, but are

due to the fact that both cooling methods are restricted to use only a linear interaction with the resonator. We compare the performance of the two methods on an equal footing—that is, for the same interaction strength—and confirm that coherent feedback is able to make much better use of the linear interaction than measurement-based feedback. We find that this performance gap is caused not by the back-action noise of the measurement but by the projection noise. We also obtain simple expressions for the maximal cooling that can be obtained by both methods in this regime, optimized over the interaction strength.

"Equipartitions and a distribution for numbers: A statistical model for Benford's law"

J. R. Iafrate, S. J. Miller, and F. W. Strauch

Physical Review E (forthcoming)

A statistical model for the fragmentation of a conserved quantity is analyzed, using the principle of maximum entropy and the theory of partitions. Upper and lower bounds for the restricted partitioning problem are derived and applied to the distribution of fragments. The resulting power law directly leads to Benford's law for the first digits of the parts.

"Searching for dilepton resonances below the Z mass at the LHC"

Isaac Hoenig, Gabriel Samach, and David Tucker-Smith

Phys. Rev. **D 90**, 075016 *(*2014*)*

We consider LHC searches for dilepton resonances in an intermediate mass range, 10--80 GeV. We adopt a kinetically mixed Z' as an example of weakly coupled new physics that might have evaded detection at previous experiments but which could still be probed by LHC dilepton spectrum measurements in this mass range. Based on Monte Carlo simulations, we estimate that existing data from the 7 and 8 TeV LHC could be used to test values of the kinetic mixing parameter ε several times smaller than precision electroweak upper bounds, provided an appropriate analysis were carried out by one of the experimental collaborations.

"States that "look the same" with respect to every basis in a mutually unbiased set"

Ilya Amburg '14, Roshan Sharma '13, Daniel M. Sussman '07, and William K. Wootters

J. Math. Phys. **55***,* 122206 *(*2014)

A complete set of mutually unbiased bases in a Hilbert space of dimension d defines a set of d+1 orthogonal measurements. Relative to such a set, we define a MUB-balanced state to be a pure state for which the list of probabilities of the d outcomes of any of these measurements is independent of the choice of measurement, up to permutations. In this paper we explicitly construct a MUB-balanced state for each prime power dimension d for which d = 3 (mod 4). These states have already been constructed by Appleby in unpublished notes, but our presentation here is different in that both the expression for the states themselves and the proof of MUB-balancedness are given in terms of the discrete Wigner function, rather than the density matrix or state vector. The discrete Wigner functions of these states are "rotationally symmetric" in a sense roughly analogous to the rotational symmetry of the energy eigenstates of a harmonic oscillator in the continuous two-dimensional phase space. Upon converting the Wigner function to a density matrix, we find that the states are expressible as real state vectors in the standard basis. We observe numerically that when d is large (and not a power of 3), a histogram of the components of such a state vector appears to form a semicircular distribution.

"The rebit three-tangle and its relation to two-qubit entanglement"

William K. Wootters

J. Phys. A: Math. Theor. **47**, 424037 (2014)

The three-tangle is a measure of three-way entanglement in a system of three qubits. For a pure state, it can be understood as the residual entanglement not accounted for by pairwise entanglements between individual qubits. Here we define and evaluate the analogous quantity for three rebits (that is, binary systems in the real-amplitude variant of quantum theory). We find that the resulting formula is the same as in the complex case, except that an overall absolute value sign is missing. As a result, the rebit three-tangle can be negative, expressing the possibility of non-monogamous entanglement in real-amplitude quantum theory (for entanglement based on the convex-roof construction). We then relate the entanglement among three rebits to the entanglement of two qubits, by re-expressing the two-qubit state as a three-rebit state in the ubit model.

Psychology

Change in Children's Externalizing and Internalizing Behavior Problems: The Role of Defense

Mechanisms

Phebe Cramer

Journal of Nervous and Mental Disease 203, 215 – 221, 2015.

This study investigates the relation of defense mechanisms to children's externalizing and internalizing behavior problems, as assessed from mothers' report at age 9 and 12 years. The results showed that the defense of Identification predicted a decrease in externalizing behaviors between age 9 and 12 years. In contrast, the use of projection was related to fewer internalizing behaviors at both ages.

Adolescent Parenting, Identification, and Maladaptive Narcissism

Phebe Cramer

Psychoanalytic Psychology 32, 381 – 402, 2015.

The presence of two types of maladaptive narcissism --- grandiose and vulnerable – was studied in a group of 23-year-olds and was related to the parenting styles of their mothers and their fathers when the 23-year-olds were 18. The findings showed that father's parenting style was related to the presence of grandiose narcissism at age 23, whereas mother's parenting style was related to vulnerable narcissism. In both cases, parenting involving responsiveness and permissiveness was related to lower narcissism scores, whereas authoritarian parenting was related to higher levels of narcissism. In addition, participant sex interacted with the defense of identification in predicting narcissism.

Defense Mechanisms: 40 Years of Empirical Research

Phebe Cramer

Journal of Personality Assessment 97, 1 – 9, 2015.

This article reviews research on defense mechanisms carried out over the past 40 years with children, adolescents, adults, and psychiatric patients. Both experimental and observational studies are included.

25 Years of Family Therapy Research: Progress and Promise

L. Heatherington, M.L. Friedlander, V. Escudero, G. Diamond & W.M. Pinsof

Psychotherapy Research (25th Anniversary Special Issue) 25, 348-364, 2015.

Objective: In this article we describe and assess the state of the science on systemic psychotherapies. In the quarter century since the first issue of *Psychotherapy Research* was published, considerable progress has been made. There is an increasingly solid evidence base for systemic treatments, which includes a wide range of approaches to working conjointly with couples and families. Moreover, there are exciting new developments that hold promise for explicating the dynamic processes of therapeutic change in couple and family systems. Method: We begin by explaining how we view "systemic therapies" as different from individual approaches and then summarize what we have learned in the past 25 years about this set of treatments, how we have learned it, and what we have yet to learn. Results and Conclusions: We consider current trends in research on outcomes and change process mechanisms, and end with speculations about what lies ahead in the interrelated domains of systemic research and practice.

Relationship Satisfaction of HIV+ Ugandan Individuals with HIV- Partners

E. Pasipanodya & *L. Heatherington*

AIDS Care 27, 675-678, 2015.

The challenges of relational coping with a chronic illness are well documented in the literature on couples and chronic illnesses, but there is significantly less research on the psychological aspects of couple relationships and HIV, particularly in international contexts. Coping with the uncertainty of illness progression, family planning, disclosure to friends and family, social isolation and stigma, fear of transmission, sexual intimacy, changes to social and physical functioning, and receiving and providing care pose special challenges for individuals with discordant HIV statuses. This study examined the correlates of relationship satisfaction in HIV+ individuals whose partners were HIV- in a sample of Ugandan women and men seeking treatment at a community clinic.

Relationship satisfaction was predicted by couple identity, and levels of relationship satisfaction and relational identity were inversely associated with depression and self-perceived burden among HIV+ individuals in HIV-discordant relationships. This suggests that relationship qualities such as closeness and intimacy can serve as both a defense and source of dissatisfaction in a relationship.

Lessons Offered, Lessons Learned: Reflections on How Doing Family Therapy can Affect Therapists

L. Heatherington, M.L. Friedlander & G.M. Diamond

Journal of Clinical Psychology 70, 760-767, 2014.

Only in working conjointly with couples and families do therapists literally witness clients struggling to improve their most intimate relationships. In writing this article, we realized that, in true systemic fashion, not only have many of our clients benefited from working with us, but also we have learned some invaluable lessons from them. Indeed, practicing couple and family therapy gives therapists many opportunities to learn about themselves, especially when it is done thoughtfully. In this article, we reflect on myriad ways in which couples and family therapy has affected each of us personally -- as individuals, as partners, as parents, as adult children in our families of origin, and as educators.

Research Based Change Mechanisms: Advances in Process Research

M.L. Friedlander, *L. Heatherington*, & V. Escudero

In T. L. Sexton & J. Lebow (Eds.), *Handbook of Family Therapy* (4th ed.). New York: Routledge (2015)

(Chapter: no abstract)

The Social Psychology of False Confessions

S. Kassin

Social Issues and Policy Review 9, 24-49, 2015.

Inspired by DNA exoneration cases and other wrongful convictions of innocent people who had confessed to crimes they did not commit, and drawing from basic principles of social perception and social influence, a vast body of research has focused on the social psychology of confessions. In particular, this article describes laboratory and field studies on the "Milgramesque" processes of police interviewing an interrogation, the methods by which innocent people are judged deceptive and induced into confession, and the rippling effects of these confessions on judges, juries, lay and expert witnesses, and the truth-seeking process itself. This article concludes with a discussion of social and policy implications—including a call for the mandatory video recording of entire interrogations, blind testing in forensic science labs, and the admissibility of confession experts in court.

False Confessions: Causes, Consequences, and Implications for Reform

S. Kassin

Policy Insights from the Behavioral and Brain Sciences 1, 112-121, 2014.

In recent years, DNA exoneration cases have shed light on the problem of false confessions and the wrongful convictions that result. Drawing on basic psychological principles and methods, an extensive body of research has focused on the psychology of confessions. This article describes the processes of interrogation by which police assess whether a suspect is lying or telling the truth and the techniques used to elicit confessions from those deemed deceptive. The problem of false confessions emphasizes personal and situational factors that put innocent people at risk in the interrogation room. Turning from the causes of false confessions to their consequences, research shows that confession evidence can bias juries, judges, lay witnesses, and forensic examiners. Finally, empirically based proposals for the reform of policy and practice include a call for the mandatory video recording of interrogations, blind testing in forensic crime labs, and use of confession experts in court.

"I'd Know a False Confession if I Saw One": A Constructive Replication with Juveniles

C.R. Honts, *S. Kassin* & R. Craig

Psychology, Crime and Law 20, 695-704, 2014.

We report two experiments concerning the ability of laypersons to assess the credibility of confessions given by incarcerated juveniles. Participants were 401 college students who were asked to make 3208 true or false judgments and confidence estimates of the juveniles' confessions. Judgment accuracy was poor across two experiments averaging 52.8% correct with the participants showing a small truth bias in their judgments. Audio and video presentation modes resulted in more accurate judgments than did transcripts. Participants were moderately confident in their accuracy judgments and confidence was sometimes weakly associated with accuracy. A believability index developed from judgments and confidence consistently showed significant, but small, differences in the evaluations of true and false confessions with audio and video presentation, but not with transcripts. Our results suggest that, as with adults, a high degree of caution is necessary when evaluating confessions given by juveniles.

"Midnight Confession": The Effect of Chronotype Asynchrony on Admissions of Wrongdoing

K.C. Scherr, J.C. Miller, *S.M. Kassin*

Basic and Applied Social Psychology 36, 321-328, 2014.

Confession evidence is highly incriminating in court. Using a recently developed experimental laboratory paradigm, the current study examined the influence of chronotype (i.e., the time of day at which individuals are at peak levels of psychological and physiological functioning) and time of day (7:30 a.m. or 7:30 p.m.) on the confession decisions of 60 participants. Morning larks and night owls were recruited to participate either in the morning or in the evening. Results supported a dispositional hypothesis that owls would make more confessions than larks and the interactional synchrony hypothesis that owls are more likely to confess when tested in the morning. This interaction was obtained for both high-seriousness and low-seriousness transgressions. These results suggest that chronotype asynchrony may constitute a significant person x situation risk factor for false confessions and the wrongful convictions that often follow.

Gandhi, Vows, and the Psychology of Self Control

K.N. Kirby

Gandhi Marg, 2014.

Throughout his life M. K. Gandhi stressed the virtue of self control and the critical role of private vows in attaining self control. In this article I review Gandhi's views on vows and self control, describe the Ainslie-Rachlin delay-discounting theory of self control, and show that many of Gandhi's insights and the experiences he reported are consistent with our current scientific understanding. The discounting theory provides a quantitative account of why self control is so difficult, why private vows help, and why we can be motivated to obey our vows even during periods of temptation. Within this framework I also describe some ways we might control—as Gandhi advised—our thoughts, tastes, and desires. Finally, I discuss Gandhi's view of the relationship between means and ends, and explain how the goal of being a self-controlled person could motivate individual acts of self control as means to that end.

Retrieval Attempts Enhance Learning, but Retrieval Success (Versus Failure) Does Not Matter

N. Kornell, P.J. Klein & K.A. Rawson

Journal of Experimental Psychology: Learning, Memory, and Cognition 41, 283-294, 2015.

Retrieving information from memory enhances learning. We propose a 2-stage framework to explain the benefits of retrieval. Stage 1 takes place as one attempts to retrieve an answer, which activates knowledge related to the retrieval cue. Stage 2 begins when the answer becomes available, at which point appropriate connections are strengthened and inappropriate connections may be weakened. This framework raises a basic question: Does it matter whether Stage 2 is initiated via successful retrieval or via an external presentation of the answer? To test this question, we asked participants to attempt retrieval and then randomly assigned items (which were equivalent otherwise) to be retrieved successfully or to be copied (i.e., not retrieved). Experiments 1, 2, 4, and 5 tested assumptions necessary for interpreting Experiments 3a, 3b, and 6. Experiments 3a, 3b, and 6 did not support the hypothesis that retrieval success produces more learning than does retrieval failure followed by

feedback. It appears that retrieval attempts promote learning but retrieval success per se does not.

Highlighting and Its Relation to Distributed Study and Students' Metacognitive Beliefs

C.L. Yue, B.C. Storm, *N. Kornell*, & E.L. Bjork

Educational Psychology Review 27, 69-78, 2015.

Use of highlighting is a prevalent study strategy among students, but evidence regarding its benefit for learning is mixed. We examined highlighting in relation to distributed study and students' attitudes about highlighting as a study strategy. Participants read a text passage twice while highlighting or not, with their readings either distributed or massed, and followed by a week-delayed test. An overall benefit of highlighting occurred, with highlighting being especially beneficial with massed readings of the passages. Importantly, highlighting did not impair knowledge of non-highlighted information. Interestingly, those students reporting that they did not think highlighting was beneficial or were unsure about its benefits actually benefitted more from highlighting than did students who were pro-highlighting. Overall, our results indicate that under some conditions, highlighting can be a beneficial study strategy for learning and argue for students being trained in how to optimize the potential benefits of their highlighting behavior.

Mixing Topics While Studying Does Not Enhance Learning.

H. Hausman '12 & N. Kornell

Journal of Applied Research in Memory and Cognition 3, 153-160, 2014.

According to a recent survey, it is common for students to study two topics at the same time using flashcards, and students who do so virtually always keep the topics separate instead of mixing flashcards together (Wissman, Rawson, & Pyc, 2012). We predicted that mixing might be a relatively easy way to increase learning efficiency because mixing increases the spacing between repetitions of a given item, and spacing enhances long-term learning. We compared two conditions: in the mixed condition, participants alternated on each trial between studying anatomy terms and Indonesian translations. In the unmixed condition they studied one topic and then the other. Items were interleaved within item-type in both conditions. Mixing did not have reliable effects when participants studied flashcards in a single day (Experiments 1 and 2) or on two different days (Experiments 3 and 4). Thus, the results seem to dis-confirm two sets of beliefs: students' universal belief that mixing flashcards is undesirable and cognitive psychologists' belief that doing so should be encouraged.

Is Focusing on Unknown Items While Studying a Beneficial Long-Term Strategy?

N. Kornell & K. Flanagan

Journal of Cognitive Psychology 26, 928-942, (2014).

The amount students learn is influenced by the decisions they make while they study. Prior research shows that when people decide what to study (and what not to), they almost universally prioritise information they do not know over information they do know. We found that focusing on unknown items was beneficial when memory was tested immediately after studying, but not when memory was tested after a delay of one or two weeks. These findings support a model in which studying unknown items causes many items to rise above a recall threshold, which results in a short-term advantage, but also leaves the items vulnerable to forgetting. Studying known items, by contrast, moves items farther above threshold, such that they remain above threshold for longer. These findings have implications for students and teachers who want to maximise long-term learning.

Expecting to Teach Enhances Learning and Organization of Knowledge in Free Recall of Text Passages

J.F. Nestojko, D.C. Bui, *N. Kornell* & E.L. Bjork

Memory & Cognition 42, 1038-1048, 2014.

The present research assessed the potential effects of expecting to teach on learning. In two experiments, participants studied passages either in preparation for a later test or in preparation for teaching the passage to another student who would then be tested. In reality, all participants were tested, and no one actually engaged in teaching. Participants expecting to teach produced more complete and better organized free recall of the passage (Experiment 1) and, in general, correctly answered more questions about the passage than did participants

expecting a test (Experiment 1), particularly questions covering main points (Experiment 2), consistent with their having engaged in more effective learning strategies. Instilling an expectation to teach thus seems to be a simple, inexpensive intervention with the potential to increase learning efficiency at home and in the classroom.

Young Children Bet on Their Numerical Skills: Metacognition in the Numerical Domain

V.A. Vo, R. Li, *N. Kornell*, A. Pouget & J.F. Cantlon

Psychological Science 25, 1712–1721, 2014.

Metacognition, the ability to assess one's own knowledge, has been targeted as a critical learning mechanism in mathematics education. Yet the early childhood origins of metacognition have proven difficult to study. Using a novel nonverbal task and a comprehensive set of metacognitive measures, we provided the strongest evidence to date that young children are metacognitive. We showed that children as young as 5 years made metacognitive "bets" on their numerical discriminations in a wagering task. However, contrary to previous reports from adults, our results showed that children's metacognition is domain specific: Their metacognition in the numerical domain was unrelated to their metacognition in another domain (emotion discrimination). Moreover, children's metacognitive ability in only the numerical domain predicted their school-based mathematics knowledge. The data provide novel evidence that metacognition is a fundamental, domain-dependent cognitive ability in children. The findings have implications for theories of uncertainty and reveal new avenues for training metacognition in children.

Goal-Directed Action is Automatically Biased Towards Looming Motion

J. Moher, J. Sit & J-H Song

Vision Research, in press.

It is known that looming motion can capture attention regardless of an observer's intentions. Real-world behavior, however, frequently involves not just attentional selection, but selection for action. Thus, it is important to understand the impact of looming motion on goal-directed action to gain a broader perspective on how stimulus properties bias human behavior. We presented participants with a visually-guided reaching task in which they pointed to a target letter presented among non-target distractors. On some trials, one of the pre-masks at the location of the upcoming search objects grew rapidly in size, creating the appearance of a "looming" target or distractor. Even though looming motion did not predict the target location, the time required to reach to the target was shorter when the target loomed compared to when a distractor loomed. Furthermore, reach movement trajectories were pulled towards the location of a looming distractor when one was present, a pull that was greater still when the looming motion was on a collision path with the participant. We also contrast reaching data with data from a similarly designed visual search task requiring keypress responses. This comparison underscores the sensitivity of visually-guided reaching data, as some experimental manipulations, such as looming motion path, affected reach trajectories but not keypress measures. Together, the results demonstrate that looming motion biases visually-guided action regardless of an observer's current behavioral goals, affecting not only the time required to reach to targets but also the path of the observer's hand movement itself.

Target Selection Bias Transfers Across Different Response Actions

J. Moher & J-H Song

Journal of Experimental Psychology: Human Perception and Performance 40(3), 1117-1130, 2014.

Target selection is biased by recent experience. For example, a selected target feature may be stored in memory and bias selection on future trials, such that objects matching that feature are "primed" for selection. In the present study, we examined the role of action history in selection biases. Participants searched for a uniquely colored object. Pretrial cues indicated whether participants should respond with a keypress or a reach movement. If the representation of the feature that biases selection is critically bound with its associated action, we would expect priming effects to be restricted to cases where both the response mode and target color are repeated. However, we found that responses to the target were faster when the target color was repeated, even when the response switched from a reach to a keypress, or vice versa. Priming effects were even observed after "no-go" trials in

which a response was withheld, and priming effects transferred across response modes when eye movement recordings ensured that participants did not saccade to the target. These results demonstrate that target features are represented in memory separately from their associated actions and can bias selection on subsequent trials even when a different mode of action output is required.

Decision-Making Thresholds are Dynamically Adjusted to Account for Motor Costs Associated with Changes of Mind

J. Moher & J-H Song

Journal of Vision 14(8), 1-13, 2014.

The motor system is tightly linked with perception and cognition. Recent studies have shown that even anticipated biophysical action costs associated with competing response options can be incorporated into decision-making processes. As a result, choices associated with high energy costs are less likely to be selected. However, some action costs may be harder to predict. For example, a person choosing among apples at a grocery store may change his or her mind suddenly about which apple to put into the cart. This change of mind may be reflected in motor output as the initial decision triggers a motor response toward a Granny Smith that is subsequently redirected toward a Red Delicious. In the present study, to examine how motor costs associated with changes of mind affect perceptual decision making, participants performed a difficult random dot–motion discrimination task in which they had to indicate the direction of motion by reaching to one of two response options. Although each response box was always equidistant from the starting position, the physical distance between the two response options was varied. We found that when the boxes were far apart from one another, and thus changes of mind incurred greater redirection motor costs, change-of-mind frequency decreased while latency to initiate movement increased. This occurred even when response box distance varied randomly from trial to trial and was cued only 1 s before each trial began. Thus, we demonstrated that observers can dynamically adjust perceptual decision-making processes to avoid high motor costs incurred by a change of mind.

A Systematic Review of the Efficacy of Cognitive Behavioral Therapy for Treating and Preventing Perinatal Depression.

L.E. Sockol

Journal of Affective Disorders 177, 7-21, 2015.

Background: Cognitive behavioral therapy (CBT) is an empirically supported treatment for treating and preventing depression that has been widely studied in perinatal populations. Previous meta-analytic reviews of CBT interventions in this population have not investigated potential moderators of treatment efficacy specific to this type of therapy. Method: Forty randomized and quasi-randomized controlled trials assessing the efficacy of CBT during pregnancy and the first year postpartum were included in the meta-analyses. Change in depressive symptoms from pre-treatment to post-treatment was assessed in both treatment and prevention trials, and the difference in prevalence of postpartum depressive episodes was assessed in prevention trials. Characteristics of included studies, interventions and samples were assessed as potential moderators of effect sizes. Results: CBT interventions resulted in significant reductions in depressive symptoms compared to control conditions in both treatment and prevention studies. In prevention studies, individuals who received CBT had significantly lower rates of postpartum depressive episodes compared to control conditions. In both treatment and prevention trials, interventions initiated during the postpartum period were more effective than antenatal interventions. In prevention trials, individually-administered treatments were more effective than group interventions and greater reductions in depressive symptoms were found in studies that included higher proportions of nonwhite, single, and multiparous participants. Limitations: The methodological quality of included studies varied widely among studies eligible for inclusion in the meta-analysis. Conclusions: There is strong evidence that CBT interventions are effective for treating and preventing depression during the perinatal period. Further methodologically rigorous studies are needed to further investigate potential moderators of treatment efficacy.

Maternal Attitudes, Depression and Anxiety in Pregnant and Postpartum Multiparous Women

L.E. Sockol & C.L. Battle

Archives of Women's Mental Health, 2015.

The Attitudes Toward Motherhood (AToM) Scale was developed to assess women's beliefs about motherhood, a specific risk factor for emotional distress in perinatal populations. As the measure was initially developed and validated for use among first-time mothers, this study assessed the reliability and validity of the AToM Scale in a sample of multiparous women. Maternal attitudes were significantly associated with symptoms of depression, even after controlling for demographic, cognitive, and interpersonal risk factors. Maternal attitudes were also associated with symptoms of anxiety after controlling for demographic risk factors, but this association was not significant after accounting for cognitive and interpersonal risk factors. Compared to primiparous women from the initial validation study of the AToM Scale, multiparous women reported lower levels of social support and marital satisfaction. The relationships between cognitive and interpersonal risk factors and symptoms of depression and anxiety were comparable between multiparous and primiparous women.

Women's Participation in the Association for Behavioral & Cognitive Therapies

L.E. Sockol & M. Girouard

ABCT Women's SIG: Official Newsletter of the ABCT Women's Issues in Behavior Therapy Special Interest Group, 2014.

While women are under-represented in many academic fields, women have earned the majority of doctoral degrees in psychology for nearly 30 years, and nearly three-quarters of recent doctoral degree awardees in clinical psychology are now women. Despite advances in representation, other gender disparities persist, such as under-representation in leadership positions and lower tenure rates. This study investigated the participation of women in various roles in the annual meeting of the Association for Behavioral & Cognitive Therapies. While women's overall participation in the conference was comparable to the demographics of the organization (50% female), women were significantly over-represented as poster authors and significantly under-represented as clinical roundtable panelists and mini workshop leaders. There was a significant increase in women's participation as symposium discussants, symposium panelists, and poster authors from 1998 through 2013. Finally, women were significantly under-represented as recipients of awards and in leadership positions.

Normal Personality Traits, Rumination and Stress Generation Among Early Adolescent Girls

C.B. Stroud, E.E. Sosoo '13 & S. Wilson

Journal of Research in Personality, in press.

This study examined associations between personality and stress generation. Expanding upon prior work, we examined a) the role of Positive Emotionality (PE), Negative Emotionality (NE), and Constraint (CON), and their lower-order facets, as predictors of acute and chronic interpersonal stress generation; b) whether personality moderated effects of rumination on stress generation; and c) whether personality increased exposure to independent (uncontrollable) stress. These questions were examined in a one-year study of 126 adolescent girls (*M* age = 12.39 years) using contextual stress interviews. NE predicted increases in acute and chronic interpersonal stress generation, but not independent stress. NE, CON and affiliative PE each moderated the effect of rumination on chronic interpersonal stress generation. These effects were driven by particular lower-order traits.

SIG Spotlight: Clinical Psychology at Liberal Arts Colleges SIG.

C.B., Stroud, E.S., Sheets, J.H., Shih, C.A. Schofield & D.G. Friedman-Wheeler

The Behavior Therapist, in press.

This article describes the ABCT special interest group—Clinical Psychology at Liberal Arts Colleges—that Catherine Stroud founded to promote research in clinical psychology at liberal arts colleges.

Family Therapy

J. Lebow & *C.B. Stroud*

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Family therapy, once viewed as a radical departure from the focus on the individual, is now widely practiced in clinical psychology and other disciplines. Indeed, couple and family interventions are used to treat a myriad of difficulties and are the leading treatments for a number of presenting problems and disorders. Moreover, these approaches have accumulated considerable research support. After defining couple and family therapy, this chapter will review the history and key accomplishments the treatment approach; the main principles and; and research investigating these models. In addition, strengths, limitations and future directions will be discussed.

Effects of Neonatal Fluoxetine Exposure on Behavior Across Development in Rats Selectively Bred for an Infantile Affective Trait

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Infants born to women with depressive symptoms are at higher risk for insecure attachment and behavioral problems. Thus current medical practice is to continue psychotropic medication of pregnant women with depression despite concerns about its behavioral teratology. There are few animal studies focused on long-term behavioral effects of prenatal antidepressant exposure; in addition, studies have not looked at individual differences in baseline affective state as a source of response variability. In this study, fluoxetine, a selective serotonin reuptake inhibitor (SSRI), was administered to male and female rat pups from postnatal days 2 to 7 to model exposure to antidepressants in the human third trimester. Four behavioral measures were conducted from the neonatal to adult age periods in Low and High lines selectively bred for their rate of ultrasonic vocalizations after brief maternal separation. Neonatal fluoxetine administration decreased distress calls in both lines, but to a greater extent in High line rats than Low line. Neonatal fluoxetine also impaired motor coordination in neonates. Neonatal fluoxetine administration decreased social behavior in both juvenile and adult subjects. Fluoxetine-related reductions in anxiety behavior were not observed at the two older ages. As expected, High line subjects displayed more anxiety behavior than Low line subjects at all three test ages. These results suggest that there are may be significant behavioral consequences of antidepressant use during late pregnancy on offspring maternal attachment and social behavior, with implications for increased risk of autism spectrum disorders.

Communal Nesting Exerts Epigenetic Influences on Affective and Social Behaviors in Rats Selectively Bred for an Infantile Trait

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Communal Nesting (CN) is a mouse model of early social enrichment during pregnancy and lactation. In this study, a rat model of CN was developed to determine if CN exerts an epigenetic effect in rats selectively bred for an infantile affective trait (high and low rates of ultrasonic distress calls). High and Low offspring from CN groups were compared to standard reared (SN) offspring on five measures of social and affective behavior at three critical ages. A differential effect of the CN paradigm on High and low lines was seen in measures of anxiety and arousal, but not in measures of depression or social behavior. Neonatal CN subjects emitted fewer distress calls than SN subjects when separated from their dams, and the High line subjects were more affected by the CN procedure. As juveniles, CN subjects showed increased social behaviors in tests of juvenile parenting and play compared to SN subjects. In adulthood, CN differentially increased the activity of Low line subjects. All CN subjects displayed less anxiety behavior in an open field compared to SN subjects; High line subjects were more anxious than Lows. CN reduced immobility and increased attempts to escape on the Porsolt forced swim task relative to SN subjects. These results extend the usefulness of this early enrichment paradigm from mice to rats, and found some rodent species differences in outcomes dependent on the behavioral test. They also emphasize the importance of social contact during pregnancy and lactation on offspring's optimal development across behaviors and ages.

Effects of Neurokinin-1 Receptor Inhibition on Anxiety Behavior in Neonatal Rats Selectively Bred for an Infantile Affective Trait

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Interest in understanding the etiology and developing new treatments for anxiety disorders in children and adolescents has led to recent studies of neurotransmitters not traditionally associated with neural pathways for fear and anxiety. The binding of the neurotransmitter Substance P (SP) to its neurokinin-1 (NK1) receptor may be a crucial component in mediating the anxiety response. While previous studies using rodent models have documented the anxiolytic effects of SP antagonists, the role of individual differences in affective temperament has not yet been examined in studies of drug response. This study used intracerebroventricular injections of the NK1 antagonist Spantide II at concentrations of 10 and 100 pmol to examine the consequences of blocking the SP-NK1 pathway in High and Low line rats selectively bred for high or low levels of ultrasonic distress calls after a brief maternal separation. Affective temperament was a significant factor in determining drug response. Spantide II resulted in a significant reduction of distress calls in subjects in the High anxiety line, while Low line subjects with low affect temperament were resistant to the drug. These data indicate that the SP-NK1 pathway could be an important therapeutic target for the treatment of various stress disorders, but drug response might be influenced by the individual's state anxiety or history of chronic stress.