Report of Science

at

Williams College

2015-2016

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

Williamstown, Massachusetts

Front Cover Image:

Thin section Gigapan photomicrograph of a garnet, chloritoid, chlorite schist from Jamaica, Vermont. The field of view is approximately 20 by 30 mm, and parallel polarized light was used for illumination. The photo was created with the automated thin section imaging system at Williams College developed by Paul Karabinos, Michael Taylor, and Larry George. The automated microscope stage moves by precise increments to capture hundreds of individual high-magnification photographs, which are then stitched together to create a 1.89 Gigapixel image. The Gigapan image makes it possible to view an entire thin section at once or to zoom into small areas to view details at high magnification.

The gray area is a large garnet crystal that overgrew chloritoid and chlorite grains. The parallel alignment of the inclusions formed during an episode of deformation before the garnet grew. After garnet growth, a later deformation event created micro-folds in the matrix surrounding the garnet. The mineral inclusions in garnet escaped the younger deformation because they were sheltered by the rigid crystal.

Thin sections are made from slices of rock that are 40 mm long, 25 mm wide, and 30 microns thick. Polarized light passes through optically anisotropic minerals and creates interference colors diagnostic of different minerals. Mineral textures in thin sections record information about the formation and history of rocks.

You can view Professor Karabinos' entire Gigapan collection http://gigapan.com/profiles/Stretchedpebble/galleries

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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Ground has been broken on the new science building south of the Morley Science Labs (photos taken August and October 2016). This building will primarily house research labs, offices, and support space for the Biology, Chemistry, and Physics departments. Construction is expected to be complete by Spring of 2018.

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. Construction has now begun on a new science center addition which 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 2016 had 536 graduates, with 263 majors in a science or mathematics discipline. Approximately 25% of students in 2016 have expressed interest in careers in scientific research. The quality of the College's science programs has nurtured this interest and this year 56 students were inducted into Sigma Xi as associate members, after being nominated by faculty and reviewed by members of the Williams College chapter of Sigma Xi. Williams College has become a leader in the training of future scientists with more than 50 students going on to Ph.D. programs in science each year. As a result of this commitment, Williams has ranked first among predominantly undergraduate institutions in students receiving NSF pre-doctoral fellowships, averaging about 7 per year over the past ten years. We attribute this success to an energetic faculty and staff dedicated to providing an excellent educational experience and to the many research opportunities available to Williams students at both advanced and introductory levels.

It has long been recognized that a positive undergraduate research experience is the single most important inspiration for future scientists. As documented in this report, more than 250 students were engaged in science research with Williams faculty this year. Many students conducted independent research projects during the academic year with 81 completing theses and 193 were engaged in full-time research with Williams science faculty during the summer of 2016. 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. In the past five years, Williams faculty members were awarded 37 NSF grants totaling $5,301,975 and 3 NIH grants totaling $1,026,639. 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 three-year grant primarily supports 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 Henry Luce Foundation, the Clare Boothe Luce research scholars grant increases the number of female students at Williams who declare majors in the physical sciences (astrophysics, computer science, geosciences, mathematics/statistics, and physics) and increases 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 supports the Clare Boothe Luce scholars program with funds for a second year of honors theses related research and funds programmatic enhancements such as visits from CBL professors, cohort-building events during the academic year, and 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 is now in its 29th 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 Mathematics Meetings 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 non-mathematical 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 400-level tutorials. Every course changes from year to year to emphasize the latest concepts and to introduce and integrate new techniques and instrumentation used in modern biological research. Although the biology major is specifically designed to provide a balanced curriculum in the broader context of the liberal arts for any interested student, it is also an excellent preparation for graduate studies in medicine and life sciences.

The **Biochemistry and Molecular Biology (BIMO)** Program is designed to provide students with an opportunity to explore living systems on the molecular level. Biochemistry and molecular biology are dynamic fields that lie at the interface between biology and chemistry. Current applications range from the diagnosis and treatment of disease to enzyme chemistry, developmental biology, and the engineering of new crop plants. After completing the introductory biology and chemistry courses and organic chemistry, a student would normally take the introductory course in the program: Biochemistry I – Structure and Function of Biological Molecules (BIMO 321) and Biochemistry II Metabolism (BIMO 322). These courses, taken in conjunction with courses in genetics and molecular genetics, establish a solid background in biochemistry and molecular biology. The advanced courses and electives available from the chemistry and biology department offerings encourage students' exploration of individual interests in a wide variety of topics. A senior capstone course, Topics in Biochemistry and Molecular Biology (BIMO 401), gives students the chance to explore the scientific literature in a variety of BIMO related

research areas. Completion of the BIMO Program provides exceptional preparation for graduate study in all aspects of biochemistry, molecular biology, and the medical sciences.

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

Computers 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 either Introduction to Computer Science (CSCI 134) or Diving into the Deluge of Data (CSCI 135). 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 2,600-acre 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 nonmajors.

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 **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 nonmajor students. Courses are grouped into the areas of behavioral neuroscience, cognitive psychology, developmental psychology, social psychology, clinical psychology, and psychology of education. After completing Introductory Psychology (PSYC 101), majors take Research Methods and Statistics (PSYC 201), in which they learn the tools used to generate knowledge in psychology, and at least three 200 level courses, which are comprehensive surveys of each of the subfields. 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 2016 Offerings

ASTR 12 Mars (and now, Pluto)!-A Passion for Planets

This course, meant for non-majors, will deal with scientific, historical, and literary aspects of the planets Mars and Pluto. We will look at how the exploration of Mars and Pluto challenged the preconceptions of scientists and the public alike, and shattered paradigms.

It will be based on the content of the instructor's book A Passion for Mars: Intrepid Explorers of the Red Planet (2008), and also, on his experiences participating in NASA's New Horizons mission to Pluto in 2015.

Mars: Dreamers and space scientists, engineers and biologists, backyard astronomers and artists have devoted their lives-sometimes at the expense of their careers-to the quest for Mars. Over half a century, they have transformed the Red Planet from a projection of our wildest fantasies into an even more amazing real place of spectacular landscapes, beguiling mysteries, and fantastic possibilities-as an abode for life, and even as a second home for humanity. In A Passion for Mars, Andrew Chaikin, who covered Mars exploration as a science journalist and took part in the first Mars landing, chronicled this epic quest and the enduring dream of going there.

Pluto: In 2015, NASA's New Horizons mission gave humans their first close-up look at the much maligned "ninth planet" Pluto. Andrew Chaikin participated in the mission and is now writing a book about the adventure. In this course we will discuss Pluto's controversial demotion from planetary status by the International Astronomical Union, as well as the incredible scientific discoveries that have been made about this distant, icy world by the New Horizons mission. We will also consider the possibility that there may be thousands planets in our solar system—many of them possibly like Pluto—instead of the 8 planets recognized by the International Astronomical Union.

CHEM 16 Glass and Glassblowing

This course provides an introduction to both a 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 will find the course most rewarding. The class is open to both artistically and scientifically oriented students.

CHEM 17 Combinatorial Organic Chemistry: Distributed Drug Discovery

This course provides an introduction to combinatorial research through the lens of peptide-based drugs, a class of molecules that has shown promising activity in anti-bacterial and anti-malarial studies. Using solid phase synthesis, students will generate a library of related and novel compounds. Skills to learn/practice will include standard organic laboratory techniques, combinatorial library design, analytical methods of characterization, literature searching and evaluation, and biochemical assessment of the compounds. Students are expected to attend lab 3 afternoons (T-R, 1-4) and a 1 hour meeting (TBD) each week. Outside of class time, students will analyze, interpret, and report their data in order to determine the next course of action. This course is designed as an introduction to research. While we will use organic chemistry techniques, we will focus on the process of research; students with minimal chemistry background are encouraged to enroll.

CSCI 12 Stained Glass Tiling

This course combines medieval craftsmanship with contemporary geometry. Each student will build a piece of stained glass using colored glass tiles that fit together to form two or three-dimensional tiling patterns. Students will 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 an original work of art. The course includes a field trip to see hand-painted stained glass in North Adams and southern Vermont. Exhibition of work on the last day of Winter Study is mandatory. Instructional sessions on the use of tools and safe handling of materials are included where necessary.

CSCI 14 Creating a Roguelike Game

Before World of Warcraft, before Diablo, before the Legend of Zelda and the Nintendo Entertainment System, before fancy graphics cards and computer mice, there were text terminals and there was Rogue. Created around 1980 by Michael Toy, Ken Arnold, and Glenn Wichman at U.C. Santa Cruz, this wildly popular video game "wasted more CPU time than anything in history." [Dennis Ritchie] and spawned an entire genre, known as 'roguelikes'. Roguelikes in the original style are created and played to this day, and many of the game design concepts and principles that Rogue pioneered can be found in modern games outside the genre. In this course we'll study (and play) some roguelikes, discuss what does and doesn't work and why, and work in small teams to design, plan, and code our own. Creating the game will require a lot of time writing code, but we'll also bring in game design, software design, user experience, project management, models and tools for collaboration, and various topics and realms related to game programming (AI, procedural content, complex data structures, persistence, help systems, etc.). In class students will do exercises, participate in discussions, give presentations, and provide feedback to each other as well as write code. Outside class students will meet with each other, do various writing assignments, and spend a lot more time coding. By the end each team will have a complete, working game that showcases their particular interests and goals.

CSCI 16 Web and Application Development in Meteor

We use web and mobile applications every day, but building them is a daunting task. It doesn't need to be. Over the last few years, it has gotten easier to build web applications, even for people with no previous experience. In this winter study, you will learn how to build those applications.

You'll be learning using a new curriculum developed in-house that teaches modern best practices. We will be using MeteorJS (http://meteor.com) for teaching, so you'll get firsthand experience with the latest web development technology. And because we're a small team, you'll have significant influence over the the substance and pace of learning of the materials.

Whatever your current level of ability, you will build and deploy multiple modern web applications during this winter study.

ENVI 16 Cheese Making and the Benefits of Value-added Production in Small Scale Agriculture

This course will look at the structures and strategies that drive Cricket Creek Farm and help sustain it with value added production, specifically cheese making. Students will be introduced to the science and art of producing artisanal cheese through a combination of hands-on lessons and lectures/discussions. Additionally, the course will examine the reasons why cheese is produced at Cricket Creek Farm, and how value-added products generally are a means to small-farm viability.

Course material will include handouts, prescribed online reading, and other multimedia. Students will participate in group work to complete a final project. Student should expect to spend some time outside of the course hours to complete readings and group work. The final group project will be an examination of an aspect of value-added production. The project may take the form of a paper or presentation to the class and general public. The focus of the piece will be on value added products and the relevance to the local food movement.

ENVI 25 Sustainable Agriculture in California

Students will gain hands-on experience with the diversity of agricultural practices in Central Coast of California on a variety farms from vineyards in San Luis Obispo County in the south through the winter vegetable, livestock, and diversified farms in the Salinas Valley and Santa Cruz region in the north. We will examine agriculture on different scales, from small single-person farms to large operations operated by corporations. We will experience a diversity of approaches within various crops, contrasting and comparing biodynamic and organic approaches with other forms of conservation agriculture and conventional petrochemical-intensive methods of producing food. The course will include participating in the Ecological Farming (EcoFarm) Conference in Pacific Grove, CA.

This field course will be structured to give students as much hands-on experience as possible by engaging them in work experiences in exchange for interviewing the farm operators and touring the facilities. For the most part we will be lodged in yurts, bunk-houses, and similar accommodations, and working under whatever weather conditions we encounter.

GEOS 12 Geology of the National Parks

A vicarious trip through a variety of national parks in the US and Canada to appreciate the geological basis for their spectacular scenery. Areas to be included will be selected to portray a wide range of geological processes (volcanism, desert and coastal erosion, mountain-building, glaciation, etc.). The group will meet most mornings during the first two weeks for highly illustrated classes, supplemented by the interpretation of topographic and geologic maps and by out-of-class study of rock samples. Readings will be from a paperback text (PARKS AND PLATES) as well as short publications by the U.S. Geological Survey and various natural history associations linked to the parks. The second part of the month will involve independent study and preparation of an oral report about the geology of a park or monument of the student's choice. The oral reports during the last week will be comprehensive and well illustrated, using PowerPoint, maps, samples, and other reference materials pertinent to the geology of the subject area. A detailed outline and bibliography will be distributed by the presenter at the time of the report.

MATH 11 A Taste of Austria

This course introduces students to elements of the Austrian culture around the turn of the 19th century up to today. Students will learn and prepare presentations about significant contributions to the arts and sciences from Austrians such as musician Gustav Mahler, artist Gustav Klimt, scientist Karl Landsteiner or poet Stefan Zweig. Other activities include learning how to dance the Viennese waltz composed by Johann Strauss (in case you want to attend Austria's main annual society event, the Opernball in Vienna) or how to prepare Wienerschnitzel or bake Sachertorte (the delicious cake offered by the Hotel Sacher in Vienna). If time and weather permits, we will also pursue typical Austrian winter activities such as downhill or cross country skiing, sledding or skating.

The course will be conducted mainly in English, with some German intermingled.

MATH 12 LEGO Adventures in Learning

This course is a modification of two previous winter studies I have done on the Mathematics of LEGO bricks. Similar to that, we will use LEGO bricks as a motivator to talk about some good mathematics (combinatorics, algorithms, efficiency); however, instead of trying to build a SuperStar Destroyer in a world record time, we instead will partner with local schools to design and execute small units for students at various grades. Partner schools include the Williamstown Elementary School and hopefully Mt Greylock Regional High School.

MATH 14 Malaria and Public Health: Past and Future

Malaria, an infection caused by Plasmodium parasites and transmitted by Anopheles mosquito, remains a significant cause of mortality and morbidity. Nearly half the world population is at risk of infection and over 200 million cases occur each year, with nearly a million resulting in death. In this course, we will explore the biology of the parasites and their hosts and discuss the major strategies currently being pursued to control and eliminate the disease including drugs, vaccines and vector control. We will examine the complex role of malaria in the course of human history and highlight challenges faced in the ongoing endeavor for elimination and eradication.

Students will be asked to write a 10-page paper on a topic relating to malaria and to present on their topic during the final week of class. There will be readings for each class and regular in-class participation is expected.

MATH 18 Wavelets and Image Processing

Image processing arises in a variety of problems such as adding filters to Instagram pictures and analyzing satellite pictures. In this class we will cover the basics of image processing and focus on one of the main mathematical techniques used: wavelets. During the course, we will explore one of the most magical aspects of image processing - image compression - and will learn the modern compression algorithm JPEG 2000 and see how it drastically reduces the size of pictures without losing much detail.

Students will be asked to either write a 10-page paper on the mathematics of image processing or write a computer program that implements image processing techniques that we will learn. During the last week of class students will present their projects.

MATH 19 Our Singular Universe?

The Universe, fascinating and wrapped in mystery. We are not sure where it came from, when or where it began, what is it made of, or where or when (if ever) will it end. In fact, up until Albert Einstein formulated his famous theory of general relativity,

time and space were thought of as being separate quantities, not intertwined together into what we now call space-time. In this winter study we discuss the most well-known theories for understanding the nature of the universe: general relativity, quantum mechanics, and superstring theory. The first two aim at explaining large and respectively small structures in the universe, such as galaxies and stars, and atoms and quarks. Although many predictions from general relativity and quantum mechanics have turned out to be true, these theories appear to be incompatible. However, string theory, the newest of them all, says that they are not just compatible, but that one cannot stand without the other. Through readings, videos, and discussions, we look at how this reconciliation may occur and what are some of its possible implications. Another fascinating on-going debate concerns the nature of black holes. Are they singularities on the fabric of space-time? In mathematical models of physical processes, singularities are, more often than not, regarded as a manifestation that your model is somewhat incomplete, although there actually are physical quantities out there which become undefined before our own eyes. Does all this mean that our universe is ill-natured? or could it be that black holes and singularities are natural features of it? In addition to these questions, we also discuss concepts such as the beginning of time, the eleven dimensions, parallel universes, a theory of everything, and dark matter and gravity.

PHYS 10 Light and Holography

This course will 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 will 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 will meet 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, will conduct an independent project in holography approved by the instructor. Attendance at lectures and laboratory is required.

PHYS 14 Electronics

Electronics are indispensable parts of modern laboratory work throughout the sciences. this course will cover the basics of analog electronics circuits, including transistors and operational amplifiers, and will briefly introduce digital circuits. Class will include a mixture of lab, lecture, and discussion, providing ample opportunity for hands-on experience. Students will build and test a variety of circuits chosen to illustrate the kinds of electronic devices and design problems a scientist is apt to encounter. In the last week, students will design and build a final project, or will write a 10-page paper.

PHYS 16 3-D CNC Machining: CAD, CAM and Multi-axis Milling

Advanced manufacturing technology is the foundation of many products that affect our lives and our economy. Sophisticated tools for design and fabrication have become widely available and lower in cost. In this course, we will use state-of the-art 3D CAD (computer-aided design) software to model a variety of objects. Using CAM (computer-aided manufacturing) software, we will prepare models for machining. We will fabricate objects from metal and plastic using the Haas CNC Mill in the Bronfman Science Shop with up to 5-axis simultaneous machining capability.

To gain further understanding of the impact of advanced manufacturing on jobs and the economy, we will visit several companies and institutions in New England that use advanced manufacturing technologies to create parts for industries such as aerospace and medical devices. At the conclusion of the class students will present their work in an “open-house” session in the machine shop.

PHYS 18 Wood and Woodturning

Woodturning - the use of a lathe to sculpt cylindrically symmetric objects from wood - dates to antiquity, with turned objects appearing in furniture, architecture, and art through the ages. This course will introduce the basic concepts of woodturning, including lathe and tool safety, tool selection, and techniques for shaping both side grain and end grain. We will use gouges, chisels, and scrapers to turn a variety of projects like finger tops, carving mallets, bowls, pens, etc. from several different species of wood. Along the way we will also discuss several topics related to wood and

woodworking such as sharpness and sharpening, the metallurgy of hardening and tempering, moisture and wood movement, and forestry. We will meet for at least 12 hours weekly for lecture, discussion, turning demonstrations, and individual work on projects. Students will also complete short outside readings and research for a final paper.

No previous experience is required; however, students with patience, good fine-motor skills, and some imagination will find the course most rewarding.

PSYC 16 The Prisoner

The US criminal justice system makes thousands of life-changing decisions every day. How does it work? How could it be better? What does it do to prisoners? What is the point of prison? We will address these large questions by asking more questions. Is the death penalty effective? Why are so many people incarcerated in the US? What are the major problems in our criminal justice system: racial/ethnic bias? inaccurate eyewitness testimony and false confession? torture and abuse? outdated legal procedures? juries? perverse incentives for prosecutors, police, judges, etc? What is prison like? What effect does solitary confinement have? What do we want prison to accomplish (prevent future crime? punishment?)? What does it actually accomplish? Are there more effective ways of preventing recidivism (e.g., swift and sure punishment)? What happens when an innocent person is incarcerated and an effort is made to set them free? What is life like after prison? The students in this class will be the conductors. Students will lead discussions and help choose the readings/ videos/podcasts etc. Student will be expected to do a couple of hours of homework per day. In addition to class discussion, students will pick a specific question in consultation with the professor and write a 10-page paper about it.

The Science Center

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.

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.

2016 Summer Science Research Funding Sources

Contributors	Number of Students Supported
Arnold Bernhard Foundation Summer Fellows Program	28
Clare Boothe Luce Scholarships for Women in Science	8
Class of 1951	6
Computer Science Department	1
Freeman Foote Fund - Geosciences	1
Geology Summer Internship Program	1
Joint Quantum Institute - Physics	1
Louis 1950 Summer Science Research Fellowship	1
Lowe 1940 Summer Science Research Fellows	1
Lowe 1973 Chemistry Fellowships	7
Markgraf JH 1952 Fellowships	6
John & Louise Finnerty Fund for Applied Mathematical Research	5
McDonnell Foundation	1
MIT NASA	1
National Institute of Standards and Technology (NIST)	1
NSF/NIH grants to individual faculty	17
Research Corporation for Science Advancement - Physics	1
Sherman Fairchild Foundation	15
SMALL Program	21
Somers B&L 1948 Physics Internships	2
Summer Science Program Alumni	7
Synnott TW 3rd 1958 Physics Internships	2
Wege-Markgraf Chemistry Fellowships	11
Whitehead Scholars Program - Biology	3
Williams Science Center Funding	21
Williams Bicentennial Psychology Scholarship	2
Total number of 10-week stipends	**171**

2016 Summer Science Students and their Faculty Advisors

Astronomy

Anneliese Rilinger	Karen Kwitter

Biology

Seema Amin	Dan Lynch
Josselyn Barahona	Damian Turner
Josselyn Barahona	Damian Turner
Francesca Barradale	Tim Lebestky
Nigel Bates	Hank Art
Mark (Jake) Bingaman	Steve Swoap
Osama Brosh	Luana Maroja
Graham Buchan	Tim Lebestky
Michelle Buncke	Lois Banta
Christopher Carley	David Smith
Michael Chen	Manuel Morales
Ivy Ciaburri	Heather Williams
Lane Davis	Joan Edwards
Lane Davis	Joan Edwards
Cesar Dominguez	Dan Lynch
Williams Duke	Matt Carter
Rebecca Gorelov	Dan Lynch
Yanira Guerra	Dan Lynch
Jacques Guyot	Joan Edwards
George Hunkele	Damian Turner
Ye Rem (Jeremiah) Kim	Luana Maroja
Jonah Levy	David Smith
Amanda Lugo	Heather Williams
Peter Lugthart	Hank Art
Niko MacDougall	J. Edwards / L. Maroja
Tsaina Mahlen	Manuel Morales
Esmeralda Navarro	Dan Lynch
Jack Page	Hank Art
Adam Resnick	Lois Banta
Diana Sanchez	Manuel Morales
Andrew Scharf	Heather Williams
Nicole Tanna	Lois Banta
Kelly Tellez	Tim Lebestky
Jacob Verter	Damian Turner
Jacob Verter	Damian Turner
Alonso Villasmil Ocando	Dan Lynch
Sean Wang	Manuel Morales
Stella Worters	Dan Lynch

Center for Environmental Studies

Sean Dory	D. Dethier / J. Racela

Chemistry

John Ahn	Amy Gehring
Chinoso Anokwute	Chip Lovett
Alexia Barandiaran	Amy Gehring
Benjamin Bui	Enrique Peacock-Lopez
Paige Chardavoyne	David Smith
Hannah Cole	Sarah Goh
Matt Davies	Sarah Goh
Laura Elmendorf	Patrick Barber
Matthew Goss	D. Richardson / J. Thoman
Michael Green	Chip Lovett
Jonathan Hall	D. Richardson/J. Thoman
Emily Harris	Patrick Barber

Justin Harris	Anne Skinner
Tony Huang	Jimmy Blair
Walker Knauss	Patrick Barber
Taylor Knoble	Jay Thoman
Hanson Koota	Sarah Goh
Cindy Liao	Chip Lovett
Si Hou Lon	Enrique Peacock-Lopez
Jose Lopez	Chris Goh
Alexi McAdams	Patrick Barber
Oscar Merino	Chip Lovett
Erica Myers	Enrique Peacock-Lopez
James Rasmussen	Patrick Barber
Anna Ringuette	Chris Goh
Robert Rowledge	Enrique Peacock-Lopez
Richard (Alex) Ruberto	Chip Lovett
Caroline Ryan	D. Richardson / J. Thoman
Carl Sangree	D. Richardson / J. Thoman
Hanna Shebert	Jimmy Blair
Larissa Silva	Chris Goh
Josemaria Silvestrini	Chris Goh
Uygar Sozer	Chris Goh
Roshny Vijaykar	D. Richardson / J. Thoman
Brandon Vuong	Chip Lovett
Suyee Win	Patrick Barber
Alan Zhang	Jay Thoman

Computer Science

Katherine Blake	Jeannie Albrecht
Miranda Chaiken	Stephen Freund
Matheus Cruz Correia de Carvalho Souza	Stephen Freund
Benjamin Drews	Bill Lenhart
Julia Goldman	Tom Murtagh
Nola Gordon	Brent Heeringa
Zander Majercik	Bill Lenhart
Anya Michaelsen	Brent Heeringa
Anjali Pai	Jeannie Albrecht
Rehaan Vij	Tom Murtagh
Dawn Wu	Jeannie Albrecht
Linda Zeng	Mary Bailey

Geosciences

Brian Coakley	Phoebe Cohen
Kyrien Edwards	Ronadh Cox
Jordan Fields	David Dethier
Jordan Fields	David Dethier
Chen-Yi Hung	Lisa Gilbert
Didier Jean-Michel	Paul Karabinos
Didier Jean-Michel	Paul Karabinos
Krystina Lincoln	Bud Wobus
Matthew Marcarelli	Bud Wobus
Timothy Nagle-McNaughton	Ronadh Cox
Marco Vallejos	Ronadh Cox
Noah Williams	David Dethier

Mathematics & Statistics

Andre Archer	Julie Blackwood
Paul Baird-Smith	Diana Davis
Jaeho Choi	Alejandro Sarria
Peter Cohen	S. Miller/E. Palsson
Katherine Cordwell	S. Miller/E. Palsson
Leonardo Di Giosia	Frank Morgan
Rebecca Durst	S. Miller/E. Palsson

Madeleine Elyze	Cesar Silva
Alyssa Epstein	S. Miller/E. Palsson
Elijah Fromm	Diana Davis
Johan Gaebler	Cesar Silva
Oscar Gonzalez	S. Miller/E. Palsson
Jahangir Habib	Frank Morgan
Anand Hemmady	S. Miller/E. Palsson
Magda Hlavacek	S. Miller/E. Palsson
Ngoc Yen Chi Huynh	S. Miller/E. Palsson
Sumun Iyer	Diana Davis
Rose Kaplan-Kelly	Colin Adams
Alexander Kastner	Cesar Silva
Lea Kenigsberg	Frank Morgan
Nitin Anantha Krishna	Alejandro Sarria
Kiran Kumar	Colin Adams
Chung Hang Kwan	S. Miller/E. Palsson
Isaac Loh	Cesar Silva
Adam Lott	S. Miller/E. Palsson
Nicole Magill	Alejandro Sarria
Branndon Mariscal	Alejandro Sarria
Eliza Matt	Julie Blackwood
Ondrej Maxian	Julie Blackwood
Michael Moore	Colin Adams
Anna Neufeld	Julie Blackwood
Colin Okasaki	Julie Blackwood
Juan Ortiz Rhoton	Cesar Silva
Carsten Peterson	S. Miller/E. Palsson
Dylanger Pittman	Frank Morgan
Vadim Semenov	Cesar Silva
Brandon Shapiro	Colin Adams
Aaditya Sharma	S. Miller/E. Palsson
Carsten Sprunger	S. Miller/E. Palsson
Shruthi Sridhar	Colin Adams
Emma Talis	Julie Blackwood
Yen Nhi Truong Vu	S. Miller/E. Palsson
Roger Van Peski	S. Miller/E. Palsson
Vidya Venkatesh	Steven Gerrard
Joshua Wakefield	Colin Adams
Xiaoyu Xu	Cesar Silva
Zirui Zhou	Cesar Silva
Weitao Zhu	Frank Morgan

Williams-Mystic

Kathleen Swoap	Mike Nishizaki

Neuroscience

Patrick (Daniel) Gainey	Martha Marvin
Candy Lu	Martha Marvin
Rodsy Modhurima	Martha Marvin
Miriam Semmar	Martha Marvin

Physics

Samuel Alterman	Bill Wootters
Ian Banta	Dave Tucker-Smith
Iona Binnie	Catherine Kealhofer
William Fung	Charlie Doret
Derek Galvin	Catherine Kealhofer
Eli Hoenig	Tiku Majumder
Intekhab Hossain	Daniel Aalberts
Nikolaus Howe	Daniel Aalberts
Sierra Jubin	Charlie Doret
William Kirby	Fred Strauch
Michael May	Fred Strauch
Ashay Patel	Kevin Jones

John “Jack” Scaletta	Kevin Jones
Alex Semendinger	Dave Tucker-Smith
Sarah Stevenson	Charlie Doret
Nathaniel Vilas	Tiku Majumder
Bingy Wang	Tiku Majumder
Daniel Wong	Daniel Aalberts
Hallee Wong	Tiku Majumder

Psychology

Kendall Bazinet	Ken Savitsky
Claire Bergey	Safa Zaki
Julia Cheng	Kate Stroud
Griffin Colaizzi	Nate Kornell
Garcelle Coldros	Nate Kornell
Syed Hussain Fareed Bukhari	Lauren Williamson
Gabrielle Gauthier	Jeremy Cone
Elijah Hale	Jeff Moher
Jae Hyun Jeong	Susan Engel
Aria (Hyo Jung) Kim	Lauren Williamson
Benjamin Lin	J. Cone / M. Moher
Calvin Ludwig	Jeff Moher
Velia Moran Olivas	Laurie Heatherington
Jose Rivera-Aparicio	Mariko Moher
Jean Elizabeth Salisbury	Amie Hane
Isabella Salmi	Safa Zaki
Abigail Soloway	Amie Hane
Lauren Steele	Betty Zimmerberg
Gabriela Suarez	Amie Hane
Hayley Tartell	Lauren Williamson
Hayley Tartell	Lauren Williamson
Katherine Wardlaw	Jeremy Cone

Summer Science Research Poster Session: August 12, 2016

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
Daniel Wong	Daniel Aalberts	Optimizing mRNA for high protein expression
Rose Kaplan-Kelly, Michael Moore, Brandon Shapiro, Shruthi Sridhar, Joshua Wakefield	Colin Adams	Cusp Invariants: Dense or Knot?
Anjali Pai, Katherine Blake, Dawn Wu	Jeannie Albrecht	Visualizing Power and Energy Usage
Nigel Bates, Peter Lugthart, Jack Page	Henry Art	The Secret Life of Trees: Quantifying Carbon Sequestration in the Beinecke Stand
Nicole Tanna, Adam Resnick, Michelle Buncke	Lois Banta, Janis Bravo	Defense Against the Dark Arts: A.tumefaciens T6SS ‘wand’ disarms host plants but fails as an invisibility cloak
Andre Archer, Eliza Matt, Colin Okasaki	Julie Blackwood	Modeling Coral Reef Ecosystems
Emma Talis, Ondrej Maxian, Anna Neufeld	Julie Blackwood, Lauren Childs	Understanding Zika Dynamics: Sex, Mosquitoes, and Gender
Will Duke	Matt Carter	Optimizing DREADDs to Investigate the Effect of AgRP Neuron Stimulation on Sleep
Brian Coakley	Phoebe Cohen	Searching for Fossils in the S1 Section of Wynniatt Formation Carbonates
Maoli Vizcaíno	Phoebe Cohen	Morphology of putative tintinnid fossils from the Tsagaan Olom Group, Mongolia
Benjamin Lin, Jose Rivera-Aparicio	Jeremy Cone, Mariko Moher	Representations of visual features in sorting tasks
Katie Wardlaw & Gabby Gauthier	Professor Jeremy Cone	Matters Order: Order Effects on Impression Formation
Tim Nagle-McNaughton	Ronadh Cox	Inland migration of coastal boulder deposits on Inishmaan, Ireland
Ezekiel King Phillips	Rónadh Cox	Monitoring evolution of lavakas (gullies) in the Alaotra-Mangoro district of eastern Madagascar using 20th century air photos and 21st century orthoimagery
Paul Baird-Smith, Elijah Fromm, Sumun Iyer	Diana Davis	Tiling Billiards on Triangle and Two-Square Tilings
Hallee Wong, Derek Galvin, Iona Binnie	Charlie Doret, Tiku Majumder	780nm and 940nm Diode Laser Construction

Sierra Jubin, Sarah Stevenson, Will Fung	Charlie Doret	Gotta Catch an Ion: Towards Coherent Control of 40Ca+
Sierra Jubin, Sarah Stevenson, Will Fung	Charlie Doret	Gotta Catch an Ion! Towards Trapping and Coherent Control of Ionized Calcium-40
Lane Davis	Joan Edwards, David Smith	The influence of mowing on the abundance and diversity of fall-blooming Asteraceae and their pollinators
Miranda Chaiken	Stephen Freund	It was the Best of Locks, It was the Worst of Locks
Matheus Cruz Correia de Carvalho Souza	Stephen Freund	Optimizing race detection: Field shadow location compression
Anya Michaelsen and Nola Gordon	Brent Heeringa	Relating Images for Long-Term Visual Recognition
Derek Galvin, Iona Binnie	Catherine Kealhofer	Production of Tungsten Nanoemitters for Ultrafast Electron Diffraction
Anneliese Rilinger	Karen Kwitter	Understanding the Bright-End Cutoff of the Planetary Nebula Luminosity Function
Francesca Barradale, Kelly Tellez, Graham Buchan	Tim Lebestky	Investigating the Role of the Dopamine Receptor on Optomotor Response and Grooming Behavior in Drosophila
Alexander Majercik, Benjamin Drews	William Lenhart	Construction of Small Trees with Convex Obstacle Number Four
Cindy Liao, Alex Ruberto, Michael Green, Chinonso Anokwute, Brandon Vuong, Oscar Merino	Chip Lovett	Combatting Bacterial Resistance to Antibiotics
Stella Worters and Esmeralda Navarro	Daniel Lynch	To kill a physcomitrella patens: A tale of two toxins, myriocin and ceramides, and their associated structural changes and perturbation of sphingolipids in moss
Seema Amin	Daniel Lynch	The Changes in Gene Expression of Phosphorus and Non-phosphorus Containing Lipids in Response to Phosphate Deficiency in Physcomitrella Patens
Nathaniel Vilas, Eli Hoenig, Bingyi Wang	Tiku Majumder	Precise Measurement of Hyperfine Splittings in Group IIIA Atoms Using Two-Step Laser Spectroscopy
Osama Brosh	Luana Maroja, David Smith	Hedging Bets and the Pattern of Sibling Group Membership in Populations of the Chorus Frog Pseudacris Maculata
Daniel Patrick Gainey	Martha Marvin	Inducing Targeted DNA Methylation in Danio Rerio
Rodsy Modhurima	Martha Marvin	Anxiety-like Behavior in Zebrafish

Peter Cohen, Max Hlavacek, Carsten Sprunger, Paula Burkhardt, Kevin Yang, Jonathan Dewitt, Nhi Truong, and Roger Van Peski	Steven J. Miller, Eyvindur Ari Palsson	Random Matrix Theory: Checkerboard Matrices and Limiting Spectral Distributions
Katherine Cordwell, Alyssa Epstein, Anand Hemmady, Aaditya Sharma, Yen Nhi Truong Vu	Eyvindur Palsson, Steven Miller, Stefan Steinerberger	Some Bounds on Integer Complexity
Katherine Cordwell, Max Hlavacek, Chi Huynh Ngoc Yen, Carsten Peterson, Yen Nhi Truong Vu	Steven J. Miller, Eyvindur A. Palsson	Summand Minimality of Generalized Zeckendorf Representations \\ of Non-Negative Linear Recurrence Relations
Oscar E. Gonzalez	Steven J. Miller	Beyond Endoscopy
Rebecca Durst, Max Hlavacek, Chi Huynh	Steven J. Miller, Eyvindur A. Palsson	Classification of All Crescent Configurations on 4 and 5 points
Calvin Ludwig & Elijah Hale	Jeff Moher	Audibly received, unread smartphone messages impair visual search performance
Michael Chen, Diana Sanchez	Manuel Morales	Lagged Effects of Herbivory and Mutualism on Performance and Oviposition for the Treehopper Publilia concava
Leo DiGiosia, Jay Habib, Lea Kenigsberg, Dylanger Pittman, Weitao Zhu	Frank Morgan	Isoperimetry and Manifolds with Density
Weitao Zhu, Lea Kenigsberg, Leo DiGiosia, Dylanger Pittman, Jay Habib	Frank Morgan	Minimizing Perimeter with Density
Julia Goldman and Rehaan Vij	Thomas Murtagh	A NAND-memory File System Design Based on Easily Recyclable Logs
Robert Rowledge	Enrique Peacock Lopez	Modeling Light's Yearly Effect on Melatonin, Serotonin, and the Relationship with Seasonal Affective Disorder (SAD)
Sean Dory and Jake Foehl	Jay Racela	The Spruces Heavy Metal Extraction and Analysis
Nitin Krishna, Jaeho Choi, Nicole Magill, Branndon Mariscal	Alejandro Sarria	On the L^p regularity of solutions to the generalized Hunter-Saxton system
Madeleine Elyze, Alexander Kastner, Juan Ortiz Rhoton, Vadim Semenov	Cesar Silva	On Ergodicity and Conservativeness of Product Transformations
Johann Gaebler, Xiaoyu Xu, Zirui Zhou	Cesar Silva	Partially Bounded Transformation Has Trivial Centralizer
William M. Kirby	Frederick Strauch	Efficient Quantum Compiling
Michael May	Frederick Strauch	The Dirac Equation from Quantum Cellular Automata
Ian Banta, Alex Semendinger	David Tucker-Smith	Electroweak Baryogenesis with a Minimal Extension to the Standard Model

Jacob Verter, George Hunkele	Damian Turner	Lung resident memory lymphocytes associated with chronic inflammation in allergic asthma
Valeria Sosa Garnica, Connor Mulhall, Diego Gonzalez, Meaghan Boucher, Isiah Thompson, Annie Gagnon	Lindley Wells	Teach To Learn 2016
Greg Ferland	Nick Stroud, Lindley Wells	The Effects of Science Teaching on Undergraduate Students
Amanda Lugo	Heather Williams	Familiarity breeds contempt: Responses to local song dialects
Andrew Scharf	Heather Williams	Why do some song features replace others?
Ivy Ciaburri	Heather Williams	Exploring the Source of Variation in House Finch Song
Samuel B. Alterman	William K. Wootters	Does the Boltzmann distribution emerge from a thermal correspondence principle?

Summer Science Research Colloquia 2016

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
Daniel Aalberts, Physics	I'm so over-expression
Damian Turner, Biology	Distribution and Compartmentalization of Immune Cells in the Human Body
Phoebe Cohen, Geosciences	The oldest fossil evidence of biomineralization: co-evolution of Earth and Life at work
Hank Art, Biology	The Natural and Unnatural History of 'Sensing Place: Reflecting on Stone Hill'
Karen Kwitter, Astronomy	Mommy, Where Did I Come From?
Frank Morgan, Math	Soap Bubbles and Hong Kong
Jeff Moher, Psychology	Ignoring distractio – hang on, someone just texted me
Patrick Barber, Chemistry	Lanthanide Ions and Luminescence: It's Illuminating!

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-ninth summer in 2016, 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 under- represented groups in the sciences. Since 1991, SSP has received additional funding from a biological sciences grant from the Howard Hughes Medical Institute. This grant contributed support for several SSP components, and has provided summer research stipends for SSP 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.

2016 Pre-First Year Summer Science Program Participants

Students

Elvira Alonso Rivera
Andrea Alvarez
Jonathan Carrasco-Noriega
Jeromy DiGiacomo
Azar Dixit
Javier Esparza
Kwasi Fahie
Joseph Flores
Michael Gao
Dietrich Hartman
Konnor Herbst
Wendy Hernandez
Astia Innis
Yang Lee
Nicholas Madamidola
Noah McCoy
Dylan Millson
Christopher Ochoa
Inaya Payne-Wilks
Janeth Rodriguez
Anastasia Tishena
John Velez
Andres Villasmil Ocando
Morgan Whaley
Gabrielle Wolfe

Faculty

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

Tutors

Cesar Dominguez
Josemaria Silvestrini
Anthony Simpson
Ogechukwu Uwanaka

Summer Science Lab Program

For the last eighteen 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 2016 eleven Williams College and four MCLA students taught elementary students through hands-on experiments, which explore scientific processes. Hailing from eighteen different towns, seventy-two 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

Chino Anokwute ‘19
Seema Amin ‘18
Alexia Barandiaran ‘19
Diego Gonzalez ‘18
Reuben Kaufman ‘19
Ned Lauber ‘18
Oscar Merino ‘19
Connor Mulhall ‘17
Esmeralda Navarro ‘19
James Rasmussen ‘19
Valeria Sosa Garnica ‘19
Isiah Thompson (MCLA)
Annie Gagnon (MCLA)
Meaghan Boucher (MCLA)
Naseema Amin (MCLA)

Williams Faculty

Dave Richardson
Chip Lovett

Local Teachers

Stephen Bechtel - Director
Tim Hermann - Lead Teacher
Asvelt Nduwumwami '13
Sarah Bellofatto

And 72 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 2015-2016 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, Chris Goh, Associate Professor of Chemistry, presented, "Catalysis: Promoting Chemical Transformations. Expanding a chemist's tool chest to design novel materials." In March, Elizabeth Kolbert, Class of 1946 Environmental Fellow-in-Residence at the Center for Environmental Studies, presented "The Sixth Extinction," based on her Pulitzer Prize-winning book of the same name. 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 Zachary Armet.

One of the primary purposes of Sigma Xi is to recognize graduating science students who have demonstrated exceptional ability and promise for further contributions to the advancement of scientific research. These students are elected as associate members of Sigma Xi and are inducted into the society at a ceremony during commencement weekend. On Class Day, the chapter honored 56 newly elected associate members from the Class of 2016 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.

2016 Associate Sigma Xi Inductees

Biology	Penny Sun	Kai Wang	Gabriel K. Staton
Bethany C. Berry	Hector A. Trujillo	**Geosciences**	Roger Vargas
Julia T. Carroll	**Chemistry**	Caroline E. Atwood	**Physics**
Rachel A. Essner	Melissa C. Cendejas	Joshua P. Harrington	Allison L. Carter
Aubrey W. Kenefick	Dylan J. Freas	Mary E. Ignatiadis	Sau Man Cheng
Moon Hyung Kim	Tony P. Huang	Spencer W. Irvine	Bijan H. Mazaheri
Soomin Kim	Young Sun Lee	Abigail A. Kelly	Ashwin Narayan
Catherine C. Landers	Miguel A. Mendez	Christina H. Seeger	John C. Russell
Sierra M. McDonald	Lauren A. Moseley	Laura K. Stamp	Ariel L. Silbert
Conor L. Mook	Jessica G.K. O'Brien	Caroline White-Nockleby	**Psychology**
Ashley Ngo	Carly K. Schissel	**Math & Statistics**	Kathryn A. McNaughton
Laura C. Partida	Megan A. Steele	Emmanuel H. Daring	Mai Mitsuyama
Elise V. Pitmon	Douglas R. Wassarman	Gregory J.H. Kehne	Silvio Resuli
Reid A. Pryzant	**Computer Science**	Peter M. McDonald	Sarah T. Wieman
Anna R. Ryba	Tong Liu	Alexander D. Meyer	Chanel W. Zhan
Emily K. Shea	Matthew J. McNaughton	Mia C. Smith	

Academic Year Science Lunch Colloquia 2015-2016

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 2015-2016 academic year.

Presenter	**Title**
Tiku Majumder	Welcome and Introductions
Joan Edwards, Biology	The Flower's-eye View: New Ways to Look at Pollinators
Lee Park, Chemistry, Sara LaLumia, Economics	Quantitative Resources Team
Leo Goldmakher, Math/Stats	From paper folding to primes
Safa Zaki, Psychology	Made you look: Using computational models and eye-tracking to understand category learning
Dick De Veaux, Statistics	How Fast do 100 year olds slow down? — Modeling the effect of Age on Performance in Running and Swimming
Duane Bailey, Computer Science	Computational Tails from the Devil's Workshop
Christina Olsen, Class of 1956 Director, WCMA and Kevin Murphy, Eugénie Prendergast Curator of American Art, WCMA	Williams College Museum of Art
Adam Romero, Environmental Studies	"From Oil Well to Farm"
Luana Maroja, Biology	A two part presentation: update on the cricket genetic map and "the mouse study"
Markes Johnson, Geosciences	Tectonic decapitation of a massive Pliocene delta system (Isla del Carmen, Baja California, Mexico)
Marek Demianski, Astronomy	First direct detection of gravitational waves
Courtney Wade, Dir. of Institutional Research	Visualizing Williams Data
Lee Park, with guest Eugene Korsunskiy	What is "Design Thinking"? How can we apply this to curriculum design and pedagogy? Does this approach fit with a liberal arts education?
Mike Nishizaki, Williams Mystic	Coastal marine organisms in an age of climate change: responses to environmental uncertainty.
Julie Blackwood, Mathematics	Coral reefs: management, alternative stable states, and math
Kevin Jones, Physics	Faster than a speeding bullet? Kid's stuff. Faster than light!
Lee Park and Karen Swann	Classroom Climate in STEM courses - some feedback collected by CDC and other student groups
Phebe Cramer, Psychology	What Happens When Narcissists Grow Older?
Tim Lebestky, Biology	TBD

Teaching to Learn

Over the past two years, 49 Williams students from various class years and majors have participated in the NSF Teaching to Learn program designed to Improve Undergraduate Science Education Through Engagement in K-7 Science. This is coordinated by staff in the Center for Learning in Action. This project will take place over four years, from 2014-2018, with NSF funds totaling $810,876.00. During the school year, undergraduates are assigned to work in a K-7 classroom at either Brayton or Greylock Elementary school to teach for a two-hour block each. During the summer three undergraduates participate in a nine week internship during which they revise and develop science curriculum for the upcoming school year based on the Next Generation Science Standards. The undergraduates work alongside project staff, teachers from the North Adams district, and science faculty from MCLA to to revise and develop science units. Over the past two years roughly 400 elementary students have been served by this program, 450 science lessons have been taught, and Williams students have led over 800 hours of science teaching.

The majority of research on undergraduate science education focuses on the impact of various instructional techniques on students' learning of science. Less understood are the roles of undergraduates' understanding of and attitude toward science in shaping science course-taking and persistence in science majors. The Teach to Learn project aims to address this gap in research by investigating the impact of science teaching experiences on undergraduate students. The project will accomplish this by engaging students in an experience to develop and teach science lessons in K-7 classrooms in the North Adams School District. This experience is expected to (1) deepen undergraduates' understanding of the nature of science, (2) increase their ability to explain science concepts to non-specialists, (3) increase their confidence in their own ability in science, (4) create a "community of science learners" that can sustain pursuit of further science coursework, and ultimately (5) lead to more science course taking and higher retention in science majors.

Student and Staff participation 2014-2016

Students:			
Bushra Ali	Diego Gonzalez	Connor Mulhall	Jaqueline Serrano
Fatima Anaza	Sola Haye	Austin Nguyen	Valeria Sosa-Garnica
Eduardo Avalos	David Hourin	Daishiro Nishida	Adrienne Strait
Daisy Banta	Matthew Jang	Cynthia Okoye	Grace Sullivan
Derrick Bonafilia	Mpaza Kapembwa	Ashay Patel	Darla Torres
Ivy Ciaburri	Jeremiah Kim	Apshara Ravichandran	Rachel Waldman
Leslie Chae	Elizaveta Lavrova	Moiz Rehan	Bingyi Wang
Christina Chen	Gabrielle Llagan	Alia Richardson	Joyce Wang
Olivia Daniels	Aaron Maruzzo	Jose Rivas-Garcia	Chanae Williams
Hadley DesMeules	Maryanne Masibo	Ryan Roels	Zachary Wood
Greg Ferland	Lauren Moseley	Megan Rogers	Dawn Wu
Claudia Forrester	Tobias Muellers	Abigail Sanchez	Greg Zaffino
Andrea Garundo			
Staff:			
Jean Bacon	Lindsay Osterhoudt	Leslie Rule	Jennifer Swoap
Chris Himes	Molly Polk	Nick Stroud	Lindley Wells

Astronomy Department

Faculty of the Astronomy Department included Karen Kwitter, Ebenezer Fitch Professor of Astronomy and Chair; Jay Pasachoff, Field Memorial Professor of Astronomy and Director of the Hopkins Observatory (on leave, spring semester); Marek Demianski (Visiting Professor of Astronomy, spring semester); and Steven Souza, Senior Lecturer in Astronomy. Bryce Babcock, continues to serve as Associate of the Hopkins Observatory.

Jay Pasachoff observed the total solar eclipse of March 9, 2016, from Ternate, Indonesia. He prepared a first discussion of the results in a paper for the Solar Physics Division of the American Astronomical Society held in Boulder, Colorado, in May/June 2016. The paper is joint with *Daniel Seaton '01*, who has recently moved to Boulder to head a solar spacecraft telescope on a NOAA satellite to be launched in November, and with Alphonse Sterling of NASA's Marshall Space Flight Center. Pasachoff was joined in Indonesia by *Robert Wittenmyer '98* of the University of New South Wales and others.

Pasachoff, with *Allison Carter '16*, Ron Dantowitz of the Dexter Southfield School, and other colleagues, had 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. Pasachoff worked on scientific papers on the astronomical data and also jointly with former Fulbright visitor Marcos Peñaloza-Murillo and Michael T. Roman of the University of Michigan on a paper based on terrestrial-atmospheric temperature and pressure measurements. Images and other information about eclipse efforts appear at *http://totalsolareclipse.org.*

The Pasachoff studies focus on the solar corona which is now past its appearance that corresponded to the maximum of the solar-activity cycle. In addition to Seaton and Dantowitz, he has been collaborating with researchers at the Astronomical Institute of the Slovak Academy of Sciences, and the Aristotle University of Thessaloniki, Greece.

For the forthcoming August 21, 2017, eclipse, Pasachoff received research grants from the Solar Terrestrial Program of the Atmospheric and Geospace Sciences Division of the National Science Foundation and from the Committee for Research and Exploration of the National Geographic Society. Extensive planning for science and outreach is under way.

Pasachoff is Chair of the International Astronomical Union's Working Group on Solar Eclipses, which is joint between the heliophysics and education/outreach interdisciplinary divisions of the IAU, and is a member of the Eclipse2017 Task Force of the American Astronomical Society.

As part of his sabbatical at the California Institute of Technology Planetary Sciences Department, Pasachoff observed the May 9, 2016, transit of Mercury across the face of the Sun from the Big Bear Solar Observatory in California, where he collaborated with a number of colleagues from various universities and institutes. In addition to smaller instruments, they used the 1.6m New Solar Telescope with adaptive optics. A video of close-up results can be viewed at http://bbso.njit.edu.

The scientific aspects of their investigations include the black-drop effect, verifying the previous explanation by Schneider and Pasachoff based on spacecraft observations that it results from a combination of the extreme solar limb darkening and the telescopes' point-spread function. Their work was coordinated with observations at the Dunn Solar Telescope Sacramento Peak Observatory of the National Solar Observatory led by *Kevin Reardon '92*, now on the NSO staff, and Dantowitz; and with Alphonse Sterling of NASA for spacecraft observations from Hinode's Solar Optical Telescope and XRT (X-Ray Telescope). See observations posted at http://transitofvenus.info.

At Williams in the summer and fall and Caltech in the spring, 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 Sickafoose, on studying the atmosphere of Pluto and other aspects of the outer solar solar system through the method of stellar occultations. They observed a major Pluto occultation of a relatively bright star (12th magnitude) on June 23, 2015, from Canterbury University's Mt. John Observatory in Tekapo, New Zealand, with Pasachoff, Babcock, *Rebecca Durst '17,* and *Tina Seeger '16*; and with coordinated observations by MIT collaborator Michael Person aboard NASA's SOFIA (Stratospheric Observatory for Infrared

Astronomy) airplane with its 2.5-m telescope flying from nearby Christchurch. The work is supported by a grants to Williams and to MIT from NASA's Planetary Astronomy Program. The Pluto observations were especially timely, given the flyby of NASA's New Horizon's spacecraft on July 14, 2015, so up-to-date ground-based observations of the state of Pluto's atmosphere were important for planning and remain important for placing the spacecraft observations into long-term context. Pasachoff attended the receipt of the flyby spacecraft data at the Johns Hopkins University Applied Physics Laboratory in Maryland.

Pasachoff continued his work on the overlap of art and astronomy with Roberta J. M. Olson, curator of drawings at the New-York Historical Society. They worked with Stephen Nowlin, director of the Williamson Gallery at the Art Center/College of Design in Pasadena to plan an exhibition on eclipse-related art and artifacts for the summer of 2017, overlapping with the eclipse summer. Pasachoff and Olson are arranging to publish a book on several hundred works of art related to astronomy.

Pasachoff attended and delivered papers at the General Assembly of the International Astronomical Union held in Honolulu for two weeks in August 2015. He continued as Chair of the Working Group on Solar Eclipses of the International Astronomical Union's as part of the IAU's newly reorganized Division structure, and was elected to the Organizing Committee of the History of Astronomy commission, in which he is also a member of the Johannes Kepler Working Group. He continues as U.S. National Liaison to the successor IAU commission on Education and Development of which he is a past president. Following his correction of a historical error in the crowdsourced naming of exoplanets and their parent stars arranged by the IAU, he has been added to the Executive Committee Working Group (EC-WG) of the IAU: "Public Naming of Planets and Planetary Satellites" (2016-).

Pasachoff's historical posting of a brief biographical note about Kepler was permanently affixed to a wall of the Smithsonian's National Air and Space Museum in Washington, DC, alongside a plaque about Galileo and a diorama about Tycho Brahe. Pasachoff was Chair (2013-2015) of the Historical Astronomy Division of the American Astronomical Society, and is now serves as chair of the prize committee. Pasachoff continues as representative of the American Astronomical Society to the American Association for the Advancement of Science's Astronomy Division.

In January 2016, Pasachoff attended the meeting of the American Astronomical Society in Orlando, FL. He attended the AAS's Division of Planetary Sciences meeting in November 2015 in National Harbor, MD, and the Solar Physics Division's May/June 2016 meeting in Boulder, CO. He also gave two eclipse-related papers at the 228th meeting of the AAS in San Diego, CA in June.

Pasachoff continued 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, and they are coauthors of an *Astrophysical Journal* paper using their Hubble results to test a method for detecting spots analogous to Jupiter's Great Red Spot on exoplanets (http://www.eclipses.info and http://www.transitofvenus.info).

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 physical-science book reviewer for The Key Reporter, the Phi Beta Kappa newsletter. He continues as advisor to the children's magazine *Muse*. He and Naomi Pasachoff, Research Fellow at Williams College, arranged a special issue of the children's magazine *Dig Into History* about solar eclipses and their history.

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

In June, Pasachoff brought the three new Astronomy majors to the Palomar Observatory and the student workshop on the Zwicky Telescope Facility that uses the wide-field Schmidt telescope, the 60" telescope,

and the 200" telescope (for 50 years the world's largest) on Palomar Mountain. *Marcus Hughes '18* and *Tim Nagle McNaughton '18* participated in the ZTF workshop preceding the Palomar Observing, including visits to the 100" telescope on Mt. Wilson and the Big Bear Solar Observatory. They were joined by Taylor Knoble '18 for the Palomar 200" observing. ZTF is headed by Asst. Prof. of Astrophysics Mansi Kasliwal of Caltech, who got her start in research with Pasachoff through the Keck Northeast Astronomy Consortium when when she was a sophomore at Bryn Mawr.

Marek Demianski has been visiting professor at Williams more than a dozen times, replacing Profs. Pasachoff and Kwitter during their sabbaticals and other 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 the upper-level non-major cosmology course, Astronomy 330 and the astronomy survey course's semester on the solar system, Astronomy 102.

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). Their latest paper on this work was published in the Astrophysical Journal in June 2015, with Kwitter's thesis student *Kerry Hensley '14* as co-author. *Anneliese Rilinger '17*, Kwitter's honors student, will be working on additional GTC data as well as data from planetary nebulae in the Large Magellanic Cloud obtained with the 8-meter Very Large Telescope in Chile.

Kwitter has arranged for Williams to be part of a consortium of small colleges that has entered into a three-year agreement for purchasing time on the 3.5-m and 0.5-m telescopes at Apache Point Observatory in Sunspot, NM. She and Souza will continue to observe remotely from campus with students.

Kwitter continued work with colleagues on their Hubble Space Telescope project to study the structure and composition of PNe in the Milky Way. In particular ultraviolet spectroscopic data reveals abundant ions of elements like carbon, which are difficult to detect in the optical region. The resulting ratios of carbon to nitrogen and to oxygen supply important constraints on the processes of evolution and nucleosynthesis inside PN parent stars. The latest papers from this collaboration were published in the Astrophysical Journal in April 2015.

Kwitter was appointed this year to the van Biesbroeck Award Committee of the American Astronomical Society; the award honors extraordinary service to the field. Kwitter continues to serve on the International Astronomical Union's Working Group on Planetary Nebulae. She continued as the coordinator for the summer intern program of the Keck Northeast Astronomy Consortium (KNAC). Kwitter was the meeting organizer for the KNAC Student Research Symposium, held at Williams on October 16-17, 2015, and Souza edited the Proceedings. In June 2016 she attended the 228th meeting of the American Astronomical Society in San Diego, and the KNAC faculty meeting at Wellesley College.

Kwitter served on the Scientific Organizing Committee for the Focus Meeting on Planetary Nebulae held at the XXIX International Astronomical Union's General Assembly in Honolulu, HI, August 2015 and for IAU Symposium 323: "Planetary nebulae: Multi-wavelength probes of stellar and galactic evolution," to be held in Beijing in October 2016.

Steven Souza conducts and supervises the astronomy observing program, indoor labs, and daytime observing. He hosted observatory visitors, including planetarium groups, alumni, Summer Science Program participants, Camp Vision (visually impaired) students, MCLA STEM Academy students, Mt. Greylock HS students, Science Blast 2016 participants (also MGHS students), Family Days attendees, Monument Elementary School 4th and 5th graders. North Adams Public Library astronomy program participants, Science Camp participants, 9/27/15 lunar eclipse visitors, 5/9/16 Transit of Mercury visitors, and numerous student previews and prospective students. He continues to maintain and improve the observatory, and has secured funding for a major upgrade to the 0.6m DFM telescope in 2016,

modernizing the control system and enabling remote operation. Souza also assisted Middlebury College with their 2015 telescope upgrade. He also once again upgraded the astronomy department computer systems by deploying a new department server and ~20 "new" trickle iMac workstations. He acts as department liaison with OIT and Facilities, and continued to advocate for, and work with the administration on, reducing the impact of campus lighting on observing.

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 *Hallee Wong '18* and KNAC summer research exchange student Aylin Garcia Soto (Wesleyan '18), whose research work resulted in a presentation entitled "Short-Term Variability in NGC 1960" at the Keck Northeast Astronomy Consortium (KNAC) Student Symposium at Williams College in October 2015. He continued research observations both locally and remotely using the 0.5-m ARCSAT telescope at Apache Point Observatory in New Mexico. Souza attended the KNAC Student Symposium in November 2015, and the 228th meeting of the American Astronomical Society in San Diego in June 2016 where he presented a poster on his research.

Astronomy Colloquia

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

Off-Campus Astronomy Colloquia

Jay M. Pasachoff

"Public Education and Outreach for Observing Solar Eclipses and Transits"IAU General Assembly, Honolulu, Hawaii, August 2015

"John Bevis's 18th-century Atlas Celeste: An Oft-Overlooked Treasure"
Ninth Meeting on the Inspiration of Astronomical Phenomena, INSAP IX, London, August 2015

"A Central Flash at an Occultation of a Bright Star by Pluto Soon Before New Horizons' Flyby"
Division of Planetary Sciences meeting, National Harbor, Maryland, November 2015

"Haze in Pluto's atmosphere: Results from SOFIA and ground-based observations of the 2015 June 29 Pluto occultation"
Division of Planetary Sciences meeting, National Harbor, Maryland, November 2015

"Central Flash Analysis of the 29 June 2015 Occultation"
Division of Planetary Sciences meeting, National Harbor, Maryland, November 2015

"The Lunar Profile and Baily's Beads at Solar Eclipses"
Division of Planetary Sciences meeting, National Harbor, Maryland, November 2015

"The Lunar Profile and Baily's Beads at Solar Eclipses"
Division of Planetary Sciences meeting, National Harbor, Maryland, November 2015

"Ground-based Light Curves Two Pluto Days Before the New Horizons Passage"
AGU meeting, San Francisco, December 2015

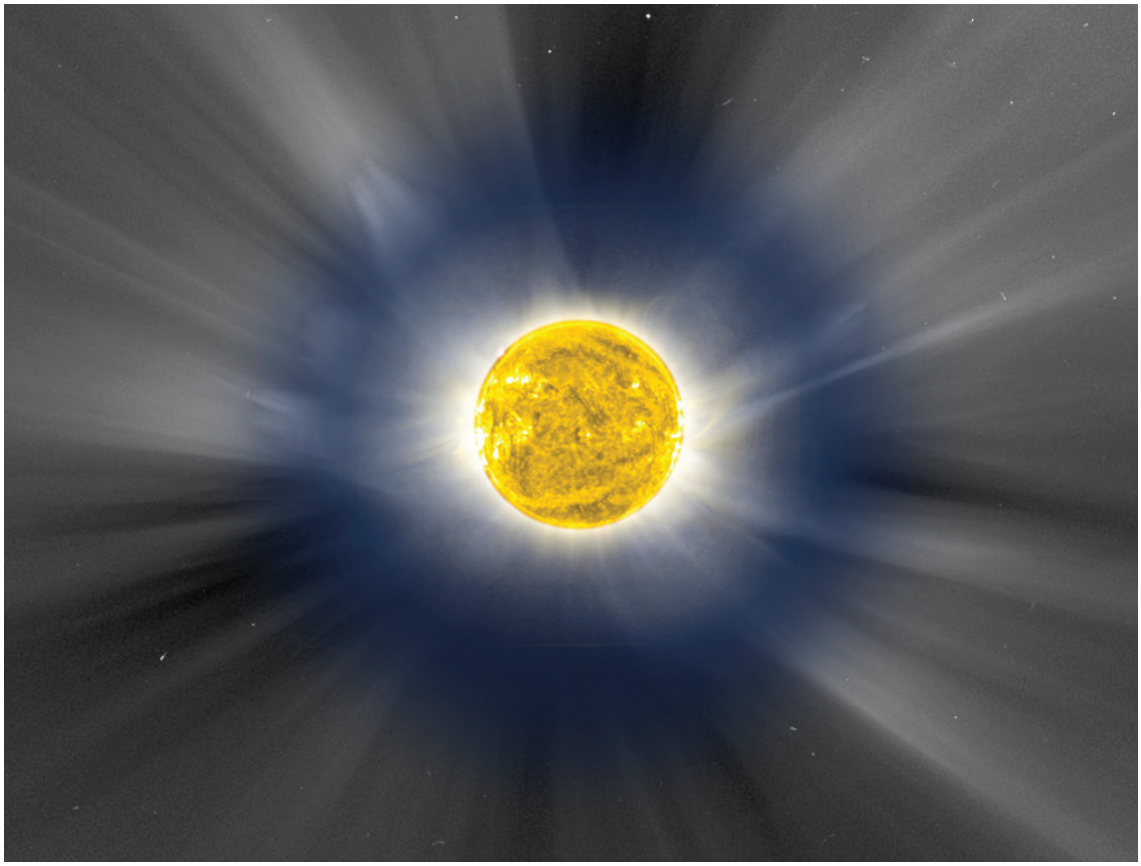
"Occultation Evidence for Haze in Pluto's Atmosphere in 2015 at the New Horizons Encounter"
AGU meeting, San Francisco, December 2015
Institut Teknologi Bandung (via Skype), March 2016

Steven P. Souza, A. Garcia Soto, and H. Wong

"Hour-Scale Variability in NGC 663 and NGC 1960"
228th Meeting of the American Astronomical Society, San Diego, CA, June 2016

Post-Graduation Plans of Astronomy Majors

Name	Plans
Christina H. Seeger	AmeriCorps/Geoscientist internship at Mt. Rainier National Park in Washington



Biology Department

Working closely with the many interdisciplinary programs on campus: The BIMO Program, the Neuroscience Program, the Environmental Studies Program, the BiGP Program and the Public Health Program, the Biology Department's goal is to provide students with the opportunity to do hands-on, one-on-one research with a professor in addition to offering state of the art academic courses. To that end the department had 23 honors students working in faculty labs this past year. Of these, 16 were inducted into the Sigma Xi Honors Society. For the academic year 2016-2017, the department has 33 students who will be doing honors work. The department is committed to providing a positive research and learning experience for all biology students. As a result of this commitment, several of our students were awarded grants or fellowships to pursue their studies after graduation. *Catherine Landers '16* received a Stratton Fellowship to further her studies. The department also has approximately 44 students doing summer research, either here at Williams or off campus. *Rebecca Gorelov '18* and *Alonso Villasmil Ocando '18* will be working at the Whitehead Institute. Funding for summer research comes from various sources including individual research grants and Division funding. At least half of the biology faculty has outside research funding from either NSF or NIH. This funding allows many students to travel to professional meetings throughout the year giving poster presentations on their research at Williams.

Each year at graduation, the Biology Department awards prizes to several outstanding majors. Rachel Essner, Penny Sun and Emily Shea each received the Benedict Prize in Biology. Aubrey Kenefick received the Dwight Botanical Prize. Patricia Ho received the Conant-Harrington Prize for exemplary performance in the biology major, and Reid Pryzant received the William C. Grant, Jr. Prize for demonstrating excellence in a broad range of areas in biology.

This year the biology department welcomes one new faculty member, Pei-Wen Chen. Pei-Wen starts in the Fall 2016 semester as Assistant Professor. Pei-Wen comes to us following her one-year term position as Assistant Professor at Grinnell College. She did her post-doctoral research at National Cancer Institute, National Institutes of Health in the laboratory of Paul Randazzo. Her research has examined the mechanism by which Arf GTPase activating proteins (Arf GAPs) regulate integrin-based protein-lipid complexes, focal adhesions as well as the related functions including cell migration and cancer cell invasion. She did her graduate work at the Albert Einstein College of Medicine in the laboratory of Glenn Kroog. Her graduate work focused on signaling events from a mitogenic G protein coupled receptor and how the activated receptor modulates the activity of focal adhesion proteins. At Williams her research will focus on understanding the role of Arf GAPs in regulating dynamics of membrane and actomyosin networks and its contribution to cancer invasion and metastasis

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 *Aubrey Kenefick '16, Breanna Nguyen '16* and *Jacob Kim '16,* along with *Ruby Froom '17*, *Adam Resnick '17,* and post-doctoral fellow Janis Bravo, pursued this line of investigation. This research is funded by a three-year individual research grant to Professor Banta totaling $462,000 from the National Science Foundation. At the annual international Crown Gall Conference, held this year in Indianapolis, IN, Janis Bravo presented a poster and Lois Banta presented a talk on this research.

During the fall semester, Professor Banta taught a junior/senior-level elective in Microbiology. In the lab component of this literature-based course, the students explored microbial diversity in soil from ponds and agricultural sites locally and in California, and characterized unknown bacterial species isolated from a variety of artisanal cheeses. As part of a semester-long focus on the contributions of the bacterial communities in the animal gut to human health, immune system development, and obesity, students also compared the microbial composition of feces from a variety of animals. In the spring, Professor Banta taught a sophomore-level tutorial called "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 taught a Winter Study course "Documenting Stories of Escape and Survival." The seven students in the course traveled to New York and Washington DC to conduct videotaped interviews with members of the Estonian diaspora who fled in 1944 to avoid the brutality of Stalin's second invasion of the Baltic countries. This project was a collaboration with the Estonian Unitas Foundation and documentary film-makers Jim and Maureen Tusty; the edited videos will appear on the Unitas website (kogumelugu.ee/en) and will serve as an educational resource. Under Professor Banta's leadership, the Gaudino Fund also organized or co-sponsored public talks by environmental writers/activists Terry Tempest Williams and Michael Pollan. During this academic year, Professor Banta was a reviewer for the National Science Foundation,*The Plant Journal, Molecular Plant Pathology, Cell Host and Microbe, Applied and Environmental Microbiology, Computational Biology and Chemistry,* and *Frontiers in Microbiology*. Within Williams, she served on 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.

Assistant Professor **Matt Carter** was awarded a three-year grant from the National Institutes of Health for $361,000 to explore the neural basis of food intake and appetite suppression. His lab continues to study neurons that regulate food intake and sleep/wake architecture. This year he worked with three thesis students (who also worked during the summer science session): *Rachel Essner '16*, who studied the role of AgRP neurons in overcoming appetite suppressing compounds; *Brian Levine '16*, who studied the role of AgRP neurons in affecting sleep/wake behaviors; and *Conor Mook '16* who studied the role of arcuate nucleus neurons in the physiology of torpor. Matt also worked with two independent study students, *Olivia Meyerson '16* and *Natalie Bernstein '16,* and a lab technician, *Theresa Legan '14*. Matt gave talks at the Gordon Research Conference: Frontiers in Catecholamine Function and at the University of Illinois, Chicago. He presented a poster with *Manasi Iyer '14* at the 45th Annual Meeting of the Society for Neuroscience and two posters with *Kelsey Loy '15*, *Alison Smith '15*, and *Nitsan Goldstein '15* at the 49th Annual Winter Conference on Brain Research. In the classroom, Matt taught Neural Systems and Circuits (Biol 311) and Physiology (Biol 205). Matt continues to serve as an ad hoc reviewer for scientific journals such as *Science Signaling* and *Nature Neuroscience* and granting agencies, most recently serving on a grant review panel for NIDDK. Within Williams, Matt served on the Faculty Steering Committee.

Lecturer, **Derek Dean**, Luana Maroja, *Katie Westervelt '16*, *Brent Bomkamp '15,* and *Sarah Cottrill '15*, along with collaborator David Deitcher at Cornell University, authored a research paper in *Genes, Genomes, Genetics*. In this manuscript, they solved an 80-year old mystery, mapping a mutation that causes disrupted wing structure in the fruit fly to the responsible gene and they began to uncover the cellular processes responsible for the phenotype. The gene was initially mapped in the Genetics class at Williams, and so all students in the class had the experience of mapping an unknown mutation, thus participating in a process that a graduate student or post doc would undergo if mapping a gene. Additional experiments were done by the authors of this paper in order to expand the story. Dean, Westervelt, and *Ye Rem Kim '18* have continued through the spring of 2016 to investigate the cellular processes that the wavy gene regulates. Evidence currently indicates that wavy affects wing structure by controlling levels of autophagy, a wide-

ranging process in biology by which cells degrade components of their cytoplasm. The authors are grateful to the Division III and Psychology Research funding provided by the College, as it was essential to the research and publishing the manuscript. We hope to have a second paper on this topic submitted by the fall.

During this past year Professor **Dan Lynch** taught one section of The Cell (BIOL 101) in the fall and the lecture section of Biochemistry II Metabolism (BIMO/BIOL/CHEM 322) in the spring. 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 function and metabolism. Students working in his lab over the year included *Seema Amin '18, Cesar Dominguez '17, Yanira Guerra '17, Esmeralda Navarro '19,* and *Stella Worters '18*. Based on a previous collaboration with the Swoap lab, Lynch co-authored a paper published in American Journal of Physiology. He also served as a reviewer for the journal *Plant Physiology*.

Professor Joan Edwards began a three-year term as Chair of the Biology Department on 1 July 2015. She taught a Field Botany and Plant Systematics (Biology 220) in the spring 2016. In the summer of 2015, Professor Edwards worked with *Peter Luthgart '18* and *Will Duke '17* to study pollinators in the field at Isle Royale Wilderness National Park. The focus of the project was to film insect visitors to flowers of the same species at different microsites in order to document near complete records of visitors over the flower's entire bloom and compare visitors to flowers of the same species at different locations. They also collected data on arctic plant populations. For some sub-populations, this is the 18th year of data collection. During the academic year, Professor Edwards worked with *Elizabeth Jacobsen '16* and *Natalia Miller '18.* Together they worked on two projects: 1) maintaining the greenhouse populations of different species of *Oxalis* for study of their explosive seed dispersal and 2) scoring videos taken during the previous summers.

Professor Edwards published two papers over the past academic year. The first was published in 2015 in the *Journal of Pollination Ecology* with *G.P. Smith '13* and *M.H.F. McEntee '14*. This paper reports a very exciting new method where we can record near-complete records of visitors to flowers over their entire bloom. To our knowledge, this has never been done before. The findings from these studies are markedly changing the way pollination systems are viewed. The second was published in April 2106 in *Proceedings of the Royale Society* with a number of collaborators including *J. E. Hancock '11*. This paper shows that as CO_2 has risen in the atmosphere, the C/N ratios in pollen have also increased. This has important implications for the health of pollinators as pollen is a main source of protein for bees and other insect visitors.

Professor Edwards gave a talk at the Entomological Society of America Pacific Branch annual meeting in Honolulu, Hawaii. She was an invited speaker in the symposium: *Bringing Natural History Into Focus: Utilizing Modern Resources for High Throughput Observational Data*. Her talk was entitled: *The Flower's Eye View: New Ways to look at Pollination.* In the Fall, she also gave a Bronfman Science lunch talk with the same title.

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 student *Hector Trujillo '16* used fluorescence microscopy and designed novel chimeric receptors to investigate the cellular placement of the DNA sensing TLR9. Joining Hector in the laboratory were *Alexia Barandiaran '19, Minwei Cao '17,* and *Roya Huang '17*. Work was presented at the 2015 Gordon Research Conference on Molecular Mechanisms of Membranes.

Professor Engel taught BIOL 101 The Cell in the fall and led the capstone senior seminar course of the Biochemistry and Molecular Biology concentration in the spring.

This year, Assistant Professor **Tim Lebestky** taught Biol 101 in the fall semester and Biol 310 in the spring. He and his thesis student, *Elise Pitmon '16* presented the labs research at the Drosophila Neuroscience Conference at Cold Spring Harbor Labs in the Fall. This year, Lebestky published a paper in *Genes, Brain, and Behavior* with three student researchers (Elise Pitmon '16, Gabrielle Stevens '15 and Greg Kehne '16) and Michael Taylor from the science shop. The manuscript for a second paper has also been submitted to *Genes, Genomes, and Genetics* which features the work of four thesis students in the Lebestky lab. Research this year in the Lebestky lab was carried out

by two thesis students, Soomin Kim and Elise Pitmon, as well as three research assistants, *Sofia Roitman '16, Kelly Tellez '17,* and *Micaela Dickinson '19*. Projects included the investigation of dopaminergic regulation of daytime sleep in Drosophila as well as the characterization of the Dopamine Receptor mutants in visuolocomotor arousal and optomotor responses. Professor Lebestky was invited to give lectures at UC-Merced, Florida Atlantic University, and Amherst College in 2016. He was also awarded funding for research through the Hellman Foundation.

Assistant Professor **Luana Maroja** has been promoted to associate professor. Maroja was on maternity leave during the Fall 2015 and taught Evolution (BIOL305) in the Spring 2016. She advised two honor students: Laura Partida and Katie Bennett. Maroja co-authored two papers from work related to *Heliconius sp.* butterfly wing color evolution and one with Derek Dean in the Biology department related to a project started in the Genetics (BIOL202) fly lab. During summer 2016, Maroja will be working with three summer students (*Osama Brosh '17, Jeremiah Kim* and *Nico McDougall '17*). Osama and Nico will be continuing as honor students in the upcoming academic year. This June Prof. Maroja, Osama Brosh and David Smith (Biology) presented results on reproductive strategies on Chorus frogs in the Evolution meeting in Austin Texas. Maroja and rising senior *Patrick Gainey '17* also presented results on the cricket genetic map.

Associate Professor **Claire Ting** taught Life at Extremes: Molecular Mechanisms (BIOL 414) in the fall semester and 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.

Professor Claire Ting taught a capstone course in the fall semester on Genome Sciences: At the Cutting Edge (BIOL 430T), which explored how developments in metagenomics (genomic studies of entire communities of microorganisms in natural environments, such as the open oceans), metatranscriptomics (studies of genome wide changes in expression and mRNA levels in natural communities of organisms), and proteomics have integrated and revolutionized the field of biology. In the spring semester she taught the Biology Department core course, The Organism (BIOL 102). Through lectures, discussions of original research papers, and laboratories, this course encouraged students to explore how one cell becomes a multicellular organism through the process of development and how evolution results in the rich biological diversity on earth.

During the year, Professor Ting continued to pursue her research on photosynthesis in the ecologically important marine cyanobacterium, *Prochlorococcus sp*. This blue-green bacterium is one of the most abundant photosynthetic organisms on the planet and is an important carbon sink. Research in her laboratory aims to establish how differences at the genomic level translate into physiological advantages in photosynthetic capacity and in tolerance to environmental stress. The striking dissimilarities her laboratory has discovered in photosynthesis and stress response genes, as well as in photosynthetic performance and cellular architecture, suggest the evolution of distinct physiological strategies in response to selective pressures in the open oceans. Her group has also conducted field work in the Sargasso Sea, which is an open ocean region where *Prochlorococcus* thrives.

Undergraduate students who participated in research in her laboratory this past year included *Reid Pryzant '16*, who continued as a research assistant. Reid's research goals include extending our understanding of *Prochlorococcus* from the laboratory to the open oceans and examining how environmental selection impacts microbial populations at different depths in the water column. Using a range of computational methods he developed to study the Ting Lab's genomic, metagenomic and metatranscriptomic data sets, Reid characterized how key microorganisms shape the composition and functional landscape of the Sargasso Sea. In addition, *Penny Sun '16* and *Julia Carroll '16* joined the Ting Lab to conduct their senior honors thesis research. Penny and Julia investigated the physiological responses of *Prochlorococcus* to light and characterized how photosynthetic capacity is impacted at different growth irradiance levels. They also examined the DnaK/DnaJ family of molecular chaperones in *Prochlorococcus* and other microorganisms. They discovered that the *dnaK1*

gene has been lost in the *Prochlorococcus* lineage, and that the remaining *dnaK2* and *dnaK3* genes are likely to differ in their regulation of expression.

Professor **Heather Williams** taught Neuroscience (NSCI 201) in the fall. She also taught the Neuroscience capstone course (NSCI 401), which focused on human speech and animal vocal communication. In the spring, she taught Animal Behavior (BIOL 204). She continued her research on cultural evolution of bird song, visiting the Kent Island Field Station in the Bay of Fundy with *Ivy Ciaburri '17* and *Anna Ryba '16*. Anna continued her work as an honors thesis, modeling the invasion of new song features and their impact on population dialects, a project pursued in collaboration with Julie Blackwood of the Mathematics Department.

Class of 1960 Scholars in Biology

The Biology Department continued to participate in the Class of 1960 Scholars program. The department invited Dr. Jack Bateman of Bowdoin College and Dr. Kai Zinn of the California Institute of Technology to be Class of 1960's Scholar speakers.

Andrew Scharf	Christine Reed	Delaney Smith
Erika Chang	Jacques Guyot	Kreszentia Laino
Naomi Currimjee	Rebecca Gorelov	Syed Hussain U Fareed Bukhari
Ye Rem Kim	Adam Resnick	Funmilayo Adejobi
Jacob Verter	Jung Min Suh	Maria Vicent Allende
Maria Guzman	Michael Chen	Ronak Dave
Roya Huang	Yanira Guerra	

Biology Colloquia

Matt Carter, Assistant Professor of Biology
"Strategies for designing and delivering a scientific presentation"

Jack Bateman, Bowdoin College
"Interchromosomal interactions and nuclear organization in *Drosophila melanogaster*"

Yaowu Yuan, University of CT
"Developmental Genetics of Pollinator-associated Floral Traits"

Michael Goldstein, Cornell University
"Emergence of Complex Communication from Simple Interactions: Lessons from Songbirds and Human Infants"

Roman Yukilevich, Union College
"Zooming in on rapid speciation in *Drosophila*: What drives inter-fertile, sympatric taxa to speciate?"

David Weinshenker, Emory University
"Norepinephrine-Dopamine Interactions Underlying Addiction and Arousal"

Rachel O'Neill, University of CT
"The dark matter of genomes: understanding the forces and conflicts that drive genome change"

Russell Debose-Boyd, UT Southwestern Medical Center
"Mechanisms controlling degradation of HMG CoA reductase, the rate-limiting enzyme in cholesterol synthesis"

Biology Alumni Research Reunion with Carrie Tribble '13, Theresa Ong '09 and Erin Troy '01.
Panel Discussion about science careers/grad school followed by a poster session

Michael Krashes, NIH
"Hunger-drive motivational state competition"

Michael Levy, University of Pennsylvania
"Socio-spatial studies of Chagas Disease in Peru"

Alison Brody, University of Vermont
"Putting the below-ground above-ground in plant-animal interactions"

Kai Zinn, California Institute of Technology
"Control of synaptic connectivity by an interacting network of cell surface proteins"

Off-Campus Biology Colloquia

Joan Edwards
"The Flower's Eye View: New Ways to look at Pollination" Entomological Society of America Pacific Branch Annual Meeting, Honolulu, HI, April 2016

Luana Maroja and *Daniel Gainey '17*
"Non-introgressing loci in *Gryllus firmus* and *G. pennsylvanicus* map to the X chromosome"**,** Evolution 2016 convention, Austin, TX, June 2016

Luana Maroja, *Osama Brosh '17*, and David Smith
"Hedging bets and the pattern of sib group membership in Chorus frog populations", Evolution 2016 convention, Austin, TX, June 2016

Post-Graduation Plans of Biology Majors

Name	Plans
Victor Arechiga	undecided
Helena Barber	undecided
Katherine Bennett	Venture for America Fellow at GenomOncology
Bethany Berry	undecided
Alexander Beschloss	Bioengineering Lab at Massachusetts General Hospital as a Student Researcher for 1 year prior to applying to medical school.
Julia Carroll	Volunteering in the Washington D.C. area and attending graduate school after a gap year.
Christina Chen	Working as Research Project Coordinator at the Harvard Wyss Institute for Biologically Inspired Engineering
Tendai Chisowa	University of Cambridge PhD Clinical Biochemistry
Raza Currimjee	Queen Mary School of Law London LLB
Daquan Daly	Full-Time Biology Teacher and Assistant Track Coach at Woodberry Forest School in Woodberry Forest VA
Micaela Dussel	undecided
Rachel Essner	I will be working as a Research Specialist in Dr. Zachary Knight's lab at the University of California San Francisco (UCSF). The lab studies the neural circuits controlling homeostatic behaviors such as hunger thirst and thermoregulation.
Dylan Freas	Graduate School in Chemistry at CalTech.
Racquel Gibson	undecided
Natalie Gill	undecided
Meagan Goldman	Digital Marketing Associate at Bounce Exchange in New York NY
Jacqueline Harris	Teach for America in NYC
Patricia Ho	Research Technician at the Dana Farber Cancer Institute and the Broad Institute
Joyce Huang	undecided
Elizabeth Jacobsen	American Geophysical Union as a production intern for the summer and will then pursue a career in science writing. I also intend to begin working towards an MA in Science Writing at Johns Hopkins University beginning fall semester.
Sophia Jannetty	Electrophysiology Research Associate at Hydra Biosciences in Cambridge MA
Carolina Jaramillo	Bioethics Research Fellow at the Mayo Clinic in Minnesota.
Aubrey Kenefick	I will be moving to California to work in a plant pathology lab at UC Davis
Diane Kim	undecided
Hyung Kim Moon	undecided
Soomin Kim	I'm working as a Research Technician at Dana-Farber Cancer Institute in the Ritz Lab.
Catherine Landers	Next year I will work as a Research Associate at the Broad Institute in Cambridge MA.
Brian Levine	Associate at Close Concerns San Francisco CA
Katherine Litman	Applying to medical school.

Julia Matejcek	undecided
Eleanor McClements	undecided
Sierra McDonald	undecided
Kathryn McNaughton	Sara S. Sparrow Fellow in Clinical Neuroscience at the Yale Child Study Center.
Alexander Meyer	Ph.D. in Applied Mathematics University of California Davis
Conor Mook	Research Associate Biological Engineering at Intrexon in San Francisco CA.
Abigail Morss	undecided
Ashley Ngo	Staff Research Associate in Kevin Shannon's Lab at UCSF
Breanna Nguyen	Post-Bac Position in the Colbert Lab (NIAMS/NIH)
Chibueze Nwakeze	undecided
Laura Partida	I'll be taking a gap year and working as an Assistant Learning Teacher for the JET program in Japan for a year
Valeria Pelayo	undecided
Elise Pitmon	Attending UCONN for graduate school in their Biomedical Sciences specifically Neuroscience Ph.D program
Lindsey Precht	undecided
Reid Pryzant	PhD in Computer Science Stanford University
Shazeen Rattansi	undecided
Anna Ryba	Working in a neuroscience lab at NIH as part of the Postbac IRTA program
Lacey Serletti	I will apply to medical school next year; in the meantime I am going home finishing my prerequisites at a local university and volunteering as a coach for my high school cross country team
Shea Emily Serletti	Research Associate in the Cancer Program at the Broad Institute; Cambridge MA
Talia Simon	Public Finance Analyst at Citigroup New York
Galen Squiers	undecided
Penny Sun	I will be working for 2 years as a Research Technician in the Hung Lab (Infectious Disease) at the Broad Institute.
Stephanie Sun	undecided
Madelynn Taylor	Clinical research (women's health) in San Francisco.
Hector Trujillo	Ph.D. in Plant and Microbial Biology University of California Berkeley
Zoe Trutner	Associate Consultant at Clarion Healthcare LLC in Boston MA
Ogechukwu Uwanaka	Tufts University School of Medicine
Kathleen Westervelt	undecided
Sarah Wieman	Sarah Wieman will be a research assistant at the Center for Anxiety and Traumatic Stress Disorders at Mass General Hospital which will allow her to continue to conduct integrative clinical research. She plans to pursue a doctorate in clinical psychology.
Daniel Yoo	undecided

Chemistry Department

The 2015-2016 academic year was a busy one for the Chemistry Department. The graduating class of 2016 had a record number of 53 chemistry majors, with 18 of these students completing senior thesis research projects. Unfortunately we bid farewell to Professor Dieter Bingemann, who after 14 years in the Chemistry Department as a physical chemist, decided to take a position in his home country of Germany. Assistant Professor Rebecca Taurog is also leaving the department. We wish them both the best of luck with all of their endeavors.

We are particularly proud of our seniors and their accomplishments. Each year, individual students are recognized with departmental awards. In the Class of 2016, the John Sabin Adriance prize went to *Luxi Qiao* for outstanding work throughout her chemistry career. The James F. Skinner prize was awarded to *Dylan Freas* for his distinguished achievement in chemistry and future promise as a researcher. The Leverett Mears prize went to *Taylor Jackvony* in recognition of both her abilities in chemistry and her future in medicine. *Douglas Wassarman* was awarded the American Chemical Society Connecticut Valley Section Award for his sustained scholastic excellence. *Carly Schissel* was awarded the American Institute of Chemists Student Award for outstanding scholastic achievement, *Austin Paul* was the recipient of the ACS Analytical Chemistry Award, *Christina Chen* received the ACS Undergraduate Award in Inorganic Chemistry, *Irene Lim* was awarded the Frank C. Goodrich 1945 Award, and *Tony Huang* was presented with the ACS Division of Organic Chemistry Award.

Over the course of the academic year, a number of additional awards were presented to undergraduate chemistry students for outstanding scholarship. *Josemaria Silvestrini '19* and *Alan Zhang '19* received the CRC Awards as the outstanding students in CHEM 151 and CHEM 155, respectively. *Francesca Barradale '19* was presented with the Raymond Chang First-Year Chemistry Award for her exceptional work in CHEM 153. Recognized for their achievement in organic chemistry, *Daniel Brandes '18* received the Polymer Chemistry Award and *Jonathan Meng '18* was the recipient of the Harold H. Warren Prize.

During the summer of 2016, approximately 35 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, the National Science Foundation, Research Corporation, the College Divisional Research Funding Committee, the J.A. Lowe III '73 summer research fund, the J. Hodge Markgraf '52 Summer Research Fund, the Wege-Markgraf Fund, and Summer Science Program funds.

Visiting Professor **Patrick Barber** spent the summer of 2015 hosting five students in his laboratory: *Stella Worters '18, Jacques Guyot '17, Alexi McAdams '18, L. David Jaramillo '17,* and *Melissa C. Cendejas '16.* Together they furthered two projects focused on the development of lanthanide ion complexes for mercury and arsenic sensing and biological imaging. The summer's work culminated in a poster presentation at the ACS meeting in Boston, MA (Melissa, David, Jacques, and Professor Barber attended). In the fall, Melissa continued and focused on the synthesis of gemini surfactants for biological imaging as a thesis project and was joined by *Miguel Mendez '16* who pursued the synthesis of lanthanide ion complexes for mercury and arsenic sensing for his thesis. Four additional students, *Suyee Win '17, Laura Elmendorf '17, James Rasmussen '19,* and *Oscar Marino '19* joined the lab to work on these projects. In the spring, another student, *Hannah Weinstein '18,* along with James and Oscar pushed forward a new project designing ionic liquids for the biomimetic mineralization of metal salts using shrimp shells. All three were able to successfully synthesize and characterized two new ionic liquids each. David returned from study abroad in the spring and continued his project of synthesizing gemini surfactants for lanthanide ion complexes and presented this research at the local ACS undergraduate symposium in April. In addition to teaching *Instrumental Methods of Analysis* (CHEM 364) and *Inorganic and Organometallic Chemistry* (CHEM 335) again this academic year, Professor Barber received a grant from the NSF-sponsored Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS) program to attend a workshop on renewable energy with the goal of developing course materials for *Materials* Chemistry (CHEM 336) planned for fall 2016.

Assistant Professor **Jimmy Blair** enjoyed a productive research sabbatical for the 2015-16 academic year. Professor Blair and his students develop inhibitors of bacterial histidine kinases, which are enzymes involved in cellular signaling and are promising targets for the development of novel antibiotics. Professor Blair spent the year in his lab at Williams following up on promising leads discovered by his past research students. *Tony Huang '16* and *Doug Wassarman '16* joined Professor Blair for the year to work on their honors thesis projects. Tony's work focused on developing histidine kinase inhibitors using "click chemistry" methods to generate 1,4- and 1,5-biaryl triazole compounds, and his library of 20+ compounds should keep future students busy with uncovering their mode of action. Doug began a fragment-based drug discovery project and adapted a new assay (the ThermoFluor method) to measure inhibitor binding to two different histidine kinases. In March Tony, Doug and Professor Blair traveled to San Diego, CA, to present their work at the American Chemical Society national meeting. Professor Blair and his students thank the generous support of the Williams College Divisional Research Funding Committee, the Dean of the College and the Skinner Travel award for financial support of Tony and Doug's trip. This year, Professor Blair was awarded a fellowship from The Hellman Fellows Fund, which he will use to begin an X-ray crystallography project to uncover the molecular interactions governing how small molecule inhibitors bind to histidine kinases. Finally, Professor Blair joined the Harvard University Chemical Biology program for their annual retreat in the spring, where he served as an invited panelist to discuss career opportunities at small liberal arts colleges.

Professor **Amy Gehring** enjoyed working with many different students this year, both in her capacity as Chair of the Chemistry Department and through teaching in the biochemistry curriculum. In the fall, Gehring taught *Biochemistry I – Structure and Function of Biological Molecules* (BIMO/BIOL/CHEM 321) to a record-sized group of 80 students. In the spring, she taught one of two sections of the capstone course for the Biochemistry and Molecular Biology (BIMO) concentration, *Topics in Biochemistry and Molecular Biology* (BIMO 401). It is great to see so much interest and enthusiasm amongst the students for the study of biochemistry. Gehring also continued serving as the chair of the BIMO program, where highlights of the year included hosting seminars by distinguished scientists Dr. Rachel O'Neill from the University of Connecticut and Dr. Russell DeBose-Boyd from the University of Texas Southwestern Medical Center.

Gehring also enjoyed fostering student enthusiasm for biochemistry research through the pursuit of projects in her lab. The Gehring lab continued its long-standing work 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 biosynthesis of molecules with important applications in medicine. Over the summer of 2015, Gehring was joined in this research by *Alexandra (Ali) DeSousa '16*, *Liza Lavrova '18*, *Lia Lee '17*, *Brian Leland '16*, and *Megan Steele '16* (an Allison Davis Research Fellow). They all continued their research during the academic year; Brian and Megan as honors thesis students, Ali as a spring-semester independent study student, and Liza and Lia for work-study. They were joined in the lab by fellow thesis students *Cecilia Castellano '16* and *John Chae '16* as well as work-study students *John Ahn '18*, *Selena Castro '17*, *Adam Calogeras '18*, and *Si Hou Lon '19*. John Chae, Cecilia and Ali focused on a project to understand the role of a phosphodiesterase enzyme in the regulation of antibiotic production by *S. coelicolor*. John Chae explored the substrate specificity of this enzyme, while Cecilia and Ali examined the *in vivo* effects on antibiotic production of either deletion or overexpression of the corresponding gene. John Ahn, Lia and Selena pursued plasmid construction and protein purification experiments to obtain the necessary substrates for the phosphodiesterase specificity studies. Brian studied the role of sigma factor genes, which encode important regulators of gene expression in bacterial organisms, in the developmental events of the *S. coelicolor* life cycle. Scanning electron microscopy was a particularly useful and exciting technique for this project. Adam assisted Brian in this research beginning as a Winter Study course *Introduction to Research in Biochemistry* (CHEM 18). Megan continued her long-standing research to understand the relationship of *whiJ*-like genes to each other and to define their role in sporulation in *S. coelicolor*. Liza and Si Hou participated in this project as well. Finally, Liza continued the group's collaboration with Prof. Peacock-Lopez on a project to visualize oscillations in bacterial gene expression

via fluorescence microscopy.

Gehring also participated in the broader scientific community by presenting a poster at the 5th ASM Conference on Prokaryotic Biology and Cell Development in Washington, DC during summer 2015. She also served as a reviewer for the journals *Applied and Environmental Microbiology*, *Microbiology* and *BBA Proteins and Proteomics*.

Associate Professor **Christopher Goh** taught *Introductory Concepts of Chemistry* (CHEM 151) in the fall semester, and a lab section of *Advanced Chemical Concepts* (CHEM 256) in the spring. Research in the field of transition-metal mediated homogeneous catalysis was advanced with *Jose Lopez '17* and *Jackson Barber '18* who continued work on iron-catalyzed epoxidations of alkenes. The designs of these catalysts are based on iron-containing enzymes. During the academic year, *Dylan Freas '16* expanded the set of catalysts available. Joining him in the lab as a senior thesis student was *Christina Chen '16* who initiated a project on metal-binding polymers as models for metal storage proteins in cells. Over Winter Study, *Daniel Brandes '18*, *Julie Geng '19* and *Alan Zhang '19* were part of the research team, and *Uygar Sozer '17* contributed as a work study student during the spring semester. The students made the lab an active and fun place.

Associate Professor **Sarah Goh** spent the summer of 2015 working with incoming thesis student *Jessica O'Brien '16*, outgoing *Dylan Barber '15*, along with *Lindsey Vandergrift '16* and *Hannah Cole '17*. The lab's research continues to be focused on polymers for drug delivery applications. Professor Goh attended the National American Chemical Society's fall meeting, where she gave a talk on the group's current research into self-assembling amphiphilic copolymers and their antioxidant activity. She also met up with former Chemistry Ephs *Sara Turner '11* and *Charles Seipp '11*, who were attending the conference, as well as *Michael Girouard '13*, *Bryn Falahee '13*, and *Moses Flash '15*, who are currently located in the Boston area. Professor Goh is also involved in creating a web portal for polymer education in the undergraduate curriculum. She presented this work at the National American Chemical Society's spring meeting in San Deigo, CA where there were many Ephs in attendance (see photo)! Thesis student *Luxi Qiao '16* gave an oral presentation on her research as well. Professor Goh taught *Polymer Chemistry* (CHEM 348) in the fall and *Introductory Organic Chemistry* (CHEM 156) in the spring. This year she was also given the Nelson Bushnell '20 Faculty Award in recognition of excellence in teaching and writing.

Professor **Lawrence J. Kaplan** taught four 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 Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS) with his colleagues Professors Jerry Smith of Georgia State University, David Collard of Georgia Institute of Technology and Patricia Hill of Millersville University. Since its founding fifteen years ago, the cCWCS 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. 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 cCWCS continues to develop a series of Communities of Scholars. With the workshops and their alumni serving as the nucleus, the Communities will continue to develop high-quality course content and pedagogy; propagate the use of successful teaching strategies; and provide discussion venues such as online discussion boards and video conferencing. The website for the Forensic Science Scholars Community, launched in 2010 continues to be expanded and updated with many more members and more educational resources.

Kaplan taught a weeklong cCWCS workshop in forensic science during the summer of 2015 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, Administrative Assistant, and Penny Sage, Technical Assistant, both in the Chemistry Department, assisted Kaplan in the organization and instruction of the workshop.

Kaplan attended the 251st National Meeting of the American Chemical Society in San Diego, CA in

March 2016 where he participated in a National Science Foundation sponsored symposium and presented a paper *Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS): Developing Scholarly Communities to Transform Undergraduate STEM Education.* He also attended an NSF conference in Washington in April and presented a poster entitled, *Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS): Forensic Science at Williams College.*

With a number of colleagues, who are alumni of the forensic science workshop, he published a paper detailing the scope of the workshop in the *Journal of Chemical Education.*

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 12,000 compounds and have now found a total of 18 compounds that inhibit the SOS response. Summer research students who worked on this project included *Elizabeth Gootkind '16, Taylor Jackvony '16, Young Sun Lee '16, Galen Squiers '16, Alonso Villasmil '18,* and *Miranda Villanueva '18*. Taylor Jackvony and Young Sun Lee continued as senior thesis students for the academic year. Professor Lovett also supervised work study research students *Chinonso Anokwute '19, Samantha Avila '16, Quinnton Cooper '19, Jennyfer Galvez '18, Charles Laurore '18, Lauren McCall '17, Richard Alex Ruberto '17, Galen Squires '16, Edgar Vega '16, Alonso Villasmil '18, Miranda Villanueva '18, Brandon Vuong '19*, and *Alison Wong '19*.

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 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** completed her second year as Associate Dean of Faculty this year, which she enjoyed very much. She taught the lectures for CHEM 153 in the fall semester (and is grateful to Sarah Goh and Laura Strauch who ran the laboratory portion of the course). She also ran her problem solving sessions for the summer science program (SSP) in the summer of 2015. She'll run those again for the 2016 SSP program. After that, she'll be heading off to Seoul Korea for a sabbatical during the 2016-2017 academic year, which she'll spend in a lab in the Chemistry Department at Ewha University.

During the 2015-16 academic year Professor **Enrique Peacock-López** taught in the fall *Physical Chemistry: Quantum Mechanics and Kinetics* (CHEM 361), *Physical Chemistry: Thermodynamics* (CHEM 366), and *Computational Chemistry and Molecular Spectroscopy* (CHEM 368T). In these courses, Peacock-López extended the use of MATHEMATICA and Python to solve problems in Physical Chemistry and computational chemistry.

During the summer Peacock-López, in collaboration with Professor Manuel Morales, of the Biology Department and supported by the grant "*Dynamics in an Herbivore-protection Mutualism*" funded by the National Science Foundation, extended his work on the Morales model of mutualism. The proposal has been funded for the 2015-2018 period for an amount of $244,117, and it supported summer research for *Sam Swire '17* and *Uygar Sozer '17* on pattern formation in the Morales model, and dynamics of an alternative model of mutualism. Another two students worked in the Peacock-López lab funded by Williams College. While *Lauren Moseley '16* initiated her work on chemical self-replication and analyzed the differences

between first and second order self-replication, Emily Silva developed a twelve months discrete seasonality model.

The academic year was a busy time with two thesis students (*Lauren Moseley '16* and *Stanley B. T. Ewala '16*), and a couple of independent research students (*Gregory Stone '16* and *Varun Sharma '16*). Continuing her summer work, Lauren studied competitive self-replication for second order systems, and the dynamics of alternate kinetics for first and second order systems. In contrast, Stanley started his work on reversible glycolysis, and he extended the Li-DosReis-Peacock model for glycolysis. In particular, Stanley implemented the model by adding the regulated desphosphorylation of fructose-1,6-bisphosphate yielding the first simple reversible model of glycolysis-gluconeogenesis. In one of the independent research projects, Greg proposes a dynamic model of the Complement that includes the classical and the alternative pathway. The mathematical model tracks the concentration of each component in the cascading system as a function of time. Of special interest to this investigation are the concentrations of C3b and C1 because of their relevance to the pathogenesis of systemic lupus erythematosus (SLE). The pathways of the complement system converge to produce C3b, which acts as an opsonin. A widely published theory on the pathogenesis of SLE implicates the body's inability to metabolize immune complexes. Since C3b acts as an opsonin and binds to immune complexes to promote their ingestion by macrophages, the ability to determine how the concentration of C3b in time depends on certain parameter values and initial conditions is of great interest. Additionally, lowered concentrations of C1q have been correlated to the occurrence of SLE. Therefore, the capacity to determine how the complement cascade is altered by lowered concentrations of C1q is also of great interest. Finally, Varun analyzed the dynamics of the four variable Morales model.

During spring semester Peacock-Lopez dedicated some time to study non-fickian diffusion and self-replicating peptide networks. Artificial peptide networks have been synthesized at Ben-Gurion University by Professor Gonen Ashkenazy's group, and in collaboration with Nathaniel Wagner, Peacock-López analyzed the smallest closed peptide network that shows bi-equilibrium. Last April, Peacock-Lopez presented preliminary results at the 29th meeting of the Israel Society for Astrobiology and the Origin of Life, at Ben-Gurion University.

While continuing with his research, Professor Peacock-López, Gisela Demant, 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 Gisela 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 has served as reviewer for the *National Science Foundation, Eureopean Journal of Physics, Journal of Chemical Physics, Chaos, International Journal of Bifurcation and Chaos*, *Nonlinear Dynamics, and Journal of Chemical Education.*

During the 2015-2016 academic year, Professor **David Richardson** enjoyed a mini-sabbatical in the fall semester, remaining on campus. He idled his research lab, supervising only a single work-study student (*Nallely Lopez '18*) throughout the year, and concentrated on developing new research projects, writing and several departmental service projects. During this time, he completed two manuscripts detailing many years of collaborative work (with Professor Jay Thoman) involving selective, zinc-mediated deuteration of iodofluorocarbons. In a second collaboration with Professor Jay Thoman he also supervised the summer 2015 research work of *Matthew Goss '17* and *Linda Shin '17* which was directed at measuring PCB levels in 3 species of trout collected from the Hoosic River. He also completed a structure determination problem involving extensive NMR and x-Ray crystallographic analysis of an anti-cancer agent that was part of the senior honors thesis project of *Dylan Griswold '15*.

Professor Richardson continued his supervision and maintenance of the Department's 500 MHz nuclear magnetic resonance spectrometer, overseeing an upgrade of its workstation, R_f console, preamps, probe, and operating system. After many months of planning and preparation, this project was completed during Spring Break. He also served the Department by participating fully in the process of planning for extensive renovations to teaching and research

spaces in the Morley Science Lab that will be part of the upcoming science building project. As part of this project he worked together with Professors Chris Goh and Larry Kaplan to review, purchase and oversee the installation of new IR, GC-MS and LC-MS instruments that will be coordinated with the Morley renovations. In related work, he served on the Department's hiring committee tasked with filing our new "Instrumentation Specialist" position.

Professor Richardson served as a reviewer for the *The Journal of Fluorine Chemistry*, and he reviewed an introductory organic chemistry textbook for Oxford University Press. He also reviewed a pair of grant applications to the American Chemical Society's Petroleum Research Foundation.

Professor Richardson's teaching responsibilities for the year were limited to a single laboratory section in CHEM 156 (*Organic Chemistry, Introductory Level*) in spring 2016. In the month of July he taught the Chemistry laboratory portion of the Williams College Summer Science Program for traditionally underrepresented groups in the sciences and, together with Professor Chip Lovett, he hosted the Department's Summer Science Camp program for local 4th and 5th graders. He also served on the Board of the One World Conservation Center as the group's Secretary.

Anne Skinner, Senior Lecturer emerita, continued her research program on dating fossils related to human evolution with work on the age of human occupation in Tanzania. Her focus this year was a study of Mumba Cave and nearby Lake Eyasi. This area has evidence of technological variability that needs to be dated to correlate it with other East African sites. In other projects, one of her summer students analyzed teeth from a site in Sudan where it appears primitive technology lasted for a very long time. The ESR dates conflict with this interpretation of the tools, but more samples are needed. She made two presentations at the EPR Biodose 2015 meeting at Dartmouth College; *Terrance Mensah '17* also gave an oral presentation. She is an associate editor for the proceedings. Recently she has been a reviewer for articles in *PLOS, Quaternary Geochronology* and *Radiation Measurements*.

Professor **Tom Smith** spent his eighteenth 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 independent research student *Katie Cavanaugh '16* continued work toward the synthesis of a new cytotoxic marine natural product, enigmazole A. *Carly Schissel '16* completed the final steps of the total synthesis of jerangolid D. Professor Smith taught *Intermediate Organic Chemistry* (CHEM 251) and *Synthetic Organic Chemistry* (CHEM 342) and completed his first year as a member of the Committee on Appointments and Promotions.

In her third year at Williams Assistant Professor **Becky Taurog** continued to develop her laboratory's research program. Professor Taurog followed up on work begun by *Ian Outhwaite '17* in the summer of 2015, and continued by Ian with help from *Graham Buchan '17* and *Osama Brosh '17* through 2016. The goal of the project is to explore the movements that the enzyme cobalamin-independent methionine synthase (MetE) undergoes in order catalyze the synthesis of the essential amino acid methionine. One method the laboratory is utilizing to do this is electron paramagnetic resonance, which allows the distances between chemical labels attached to MetE to be measured. Ian had previously used computer models to determine prime locations to attach pairs of spin labels to MetE. The students used genetic manipulations along with a special strain of *E. coli* to make MetE mutant proteins with pairs of unnatural amino acids (acetyl-phenylalanine) incorporated at those specific locations. The unnatural amino acids were then chemically linked to spin labels. Electron paramagnetic resonance studies were performed by our collaborators at the National Biomedical Center for Advanced Electron Spin Resonance Technology at Cornell University. Data were collected for MetE when no substrate is present, when each of the two substrates is bound individually, and when both substrates are bound. To corroborate these data, Professor Taurog has been working with researchers at Princeton University, who are characterizing the size and shape of MetE under the same set of conditions using small-angle X-ray scattering.

In the spring semester, Professor Taurog taught chemistry majors in *Enzyme Kinetics and Mechanism* (CHEM 324). In this advanced seminar-style course, the students delved into the current understanding of enzymes, and how these proteins can catalyze chemistry very specifically and rapidly, often

increasing rates of chemical reactions on the order of 100 million-fold compared to the uncatalyzed rate.

Professor Taurog also taught 44 students in a course for non-science majors entitled *AIDS: The Disease and Search a Cure* (CHEM 115). This was her first time teaching this course and she truly enjoyed the opportunity to engage students who did not consider themselves to be "science people" on topics ranging from biochemistry to immunology. The class also considered some of the scientific challenges that HIV continues to present, as well as the progress that has been made since AIDS was first described over forty years ago.

Professor **Jay Thoman** taught *Principles of Modern Chemistry* (CHEM 155) and *Advanced Chemical Concepts* (CHEM 256) during the past year. While he has taught the laboratory sections for these courses, this was his first time being the lecturer and lab coordinator in each case. During January 2016, he once again taught *Glass and Glassblowing* (CHEM/ ARTS 16).

During summer 2015, Thoman continued worked with Professor Dave Richardson on long-term monitoring of PCB pollution in the Hoosic River watershed. Thoman and Richardson were joined by *Matthew Goss '17* and *Linda Shin '16* in refining the analysis methods and analyzing trout collected by volunteer anglers. Goss presented this work at the annual meeting of the Hoosic River Watershed Association, October 17, 2015. Thoman also worked with Geosciences professor David Dethier and *Stephen Mayfield '16* to analyze water at the '66 Environmental Center, especially with respect to copper content. The '66 Environmental Center hopes to meet the Living Building Challenge (LBC). As part of the LBC, the center must supply its own water, and not rely on town water. To this end, water is collected from the roof of the building and treated for use as potable water. Mayfield worked with Environmental Analysis Lab Technician Jay Racela, *Caroline Atwood '16, Taylor Knoble '18,* and *Sean Wang '18* during the summer and during January to measure water flows and chemical content. The end result is Mayfield's chemistry thesis.

(L to R) Emma Pelegri O'Day '12, Cameron Rogers '12, Mary Beth Anzovino '06, Professor Jimmy Blair, Luisa Hammond '16, Professor Sarah Goh, Talia Loewen '12, Doug Wassarman '16, Tony Huang '16, and Hanson Koota '17 at the American Chemical Society Conference in San Diego, CA, March 2016.

Class of 1960 Scholars in Chemistry

We continued to participate in the Class of 1960 Scholars Program, with three distinguished scientists visiting campus to present a seminar and meet with our students during the 2015-2016 academic year. Professor Alexander Statsyuk from Northwestern University, Dr. Erin Whitney ’96 from the Alaska Center of Energy and Power, University of Alaska, and Professor David Case of Rutgers University were our Class of 1960 Scholars Program speakers. As part of this program, the students participate by attending a preliminary meeting with a Chemistry Department faculty member to discuss some of the research papers by the seminar speaker, attend the seminar/discussion, and then are given an opportunity for further discussion with the visiting scientist at an informal reception or dinner. The students for 2016 are:

Hannah Cole

Erica Myers

Luis (David) Jaramillo

Uygar Sozer

Chemistry Colloquia

Professor Patrick Barber, Williams College
“The f-elements: Coordination Chemistry, Spectroscopy, and Crystallographic Studies of the Illuminating and Radioactive”

Professor David Case, Rutgers University, Class of 1960 Scholars
“Bridging the Divide: All Atom Molecular Dynamics Simulations of Biomolecular Crystals”

Professor Marion Emmert, Worcester Polytechnic Institute
“Breaking Strong Bonds and Recovering Rare Earths: Adventures in Sustainable Chemistry”

Professor Elizabeth Landis ’05, College of the Holy Cross
“Molecular Monolayers as Functional Interfaces on Nanoporous Gold”

Professor Graham Peaslee, Hope College
“Using Ion Beam Analysis to Shape US Public Health Policy: Big Science from a Small Lab”

Professor Tanya Schneider ’94, Connecticut College, Charles Compton Lectureship
“Spying on the Enemy: Investigating and Inhibiting Bacterial Quorum Sensing”

Professor Alexander Statsyuk, Northwestern University, Class of 1960 Scholars
“The Ubiquitin System: Center Stage for Chemical Biology and Medicine in 2015-2100”

Dr. Sara Turner ’11, Living Proof, Inc.
“Stylish Molecules: The Design and Development of Polymers for Personal Care Products”

Professor Karen Wassarman ’85, University of Wisconsin
“6S RNA, A Global Regulator of Transcription in Bacteria”

Professor Matthew Whited, Carleton College
“Stoichiometric and Catalytic Reactions Exploiting Metal/Silicon Cooperation”

Dr. Erin Whitney ’96, Alaska Center for Energy & Power, University of Alaska, Class of 1960 Scholars
“Solar Photovoltaic Energy in Alaska: Not Such an Oxymoron”

Off-Campus Chemistry Colloquia

Katherine Aubrecht, Erik B. Berda, Kevin A. Cavicchi, Philip J. Costanzo, Gregory J. Gabriel, Christopher Goh, Sarah L. Goh, Scott T. Iacono, Sarah E. Morgan, and Daniel Savin
"Online Resources for the Polymer Education Community", poster
251st ACS National Meeting, San Diego, CA, April 2016

Patrick S. Barber, *Miguel Mendez '16, Stella Worters '18, Alexi McAdams '18, Melissa Cendejas '16,* and *Jacques P. Guyot '17*
"Lanthanide Complexes for Environmental and Biological Imaging"
250th American Chemical Society's National Meeting & Exposition, Boston, MA, August 2015

Dylan J. Freas '16, Claire A.L. Lidston '15, and Christopher Goh
"Biomimetic Iron Catalysts of a Family of BPMEN Ligands for Alkene Epoxidation"
Connecticut Valley Section of the American Chemical Society Undergraduate Symposium
Mount Holyoke College, South Hadley, MA, April 2016

Sarah L. Guillot '13 and Christopher Goh
"Atom transfer radical polymerization of styrene using copper complexes of polydentate pyridine-amine ligands"
BRIC (Boston Regional Inorganic Conference), Clark University, Worcester, MA, February 2016

Sarah L. Goh, *Todd A. Brenner '14, Dylan M. Barber '15,* and *Luxi Qiao '16*
"Polyphenols for Antioxidant Delivery"
250th ACS National Meeting, Boston, MA, August 2015

Matthew Goss '17, Linda Shin '17, and David Richardson
"PCB Levels in Brown Trout from the Hoosic River"
Hoosic River Watershed Association's "State of the River" Conference, Williamstown, MA, Oct. 2015

David L. Jaramillo '16, Laura Elmendorf '17, Alexi McAdams '18, and Patrick S. Barber
"Gemini Surfactant-Based Lanthanide Ion Complexes for Bioprobe Applications"
Connecticut Valley Section of the American Chemical Society Undergraduate Symposium, Mount Holyoke College, South Hadley, MA, April 2016

Larry Kaplan
"Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS): Forensic Science at Williams College"
2016 TUES/CCLI PI Conference, Washington, DC, April 2016

Larry Kaplan, David Collard, Patricia Hill, and J. C. Smith
"Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS): Developing Scholarly Communities to Transform Undergraduate STEM Education"
Curricular Innovations in Undergraduate Chemical Education Impacted by NSF Symposium, 251st National Meeting of the American Chemical Society, San Diego, CA, March 2016

Enrique Peacock-López
"Chemical Self-replication and Complex Dynamics in Open Systems"
29th Meeting of the Israel Society for Astrobiology and the Origin of Life, Ben-Gurion University, Be'er Sheva, Israel, April 2016

Luxi Qiao '16 and Sarah L. Goh
"Synthesis and Characterization of NIPAM and Acrylic Acid-based Polymer-lysozyme Conjugates"
251st ACS National Meeting, San Diego, CA, April 2016

Anne R. Skinner
"New Dates for Mumba Cave"
EPR Biodose 2015, Dartmouth College, Hanover, NH, October 2015

Thomas E. Smith
"Asymmetric Methods for the Synthesis of Pyran-Based Natural Products"
Pacifichem 2015: The International Chemical Congress of Pacific Basin Societies, Honolulu, HI, December 2015

Post-Graduation Plans of Chemistry Majors

Samantha Avila	Unknown
Christopher Bravo	Associate, Parthenon-EY, Boston, MA
Anthony Brooks	Model Risk Associate, PNC Bank, then to medical school, Thomas Jefferson University
Cecilia Castellano	Lab Technician, Brigham and Women's Hospital, Boston, MA
Jorge Castro	Unknown
Katherine Cavanaugh	Ph.D. in Chemistry, University of Connecticut
Melissa Cendejas	Ph.D. in Chemistry, University of Wisconsin-Madison
Kyung Jun (John) Chae	In-house Director, Empower House, ENoK, Chicago, IL
Christina Chen	Research Project Coordinator, Wyss Institute for Biologically Inspired Engineering, Boston, MA
Tendai Chisowa	M.Phil., Cambridge University, Dr. Herchel Smith Fellowship
Abigail Dalzell	Unknown
Alexandra DeSousa	Research Assistant, Brigham and Women's Hospital, Boston, MA
Vy Duong	Coordinator for International Relations, The Japan Exchange and Teaching Program, Japan
Stanley Ewala	M.D., Icahn School of Medicine at Mount Sinai
Naomi Fields	Clinical Research Coordinator, Medical Practice Evaluation Center, MA General Hospital, Boston, MA
Dylan Freas	Ph.D. in Chemistry, California Institute of Technology
Luisa Hammond	Applying for jobs in California
John Hammond	Unknown
William Hardesty-Dyck	Unknown
Tony Huang	Ph.D. in Chemical Biology, Harvard University
Taylor Jackvony	M.D., University of Connecticut
Kimberly Kiplagat	Unknown
Logan Lawson	Teach for America, Hartford, CT
Young Sun Lee	Ph.D. in Chemistry, University of Wisconsin-Madison

Brian Leland	Dental School
Irene Lim	Unknown
Stephen Mayfield	Unknown
Meilu McDermott	Unknown
Miguel Mendez	Applying for environmental chemistry positions in Washington, DC
Lindsey Moran	Unknown
Lauren Moseley	Fulbright Scholar, Turkey
Elizabeth Noh	Research Study Assistant in Medicine-Allergy & Immunology, Boston Children's Hospital, Boston, MA
Jessica O'Brien	Ph.D. in Chemistry and Biochemistry, University of Delaware
Emmanuel Ocampo	Unknown
Natasha Pangarkar	Unknown
Austin Paul	Software Developer, IBM, Marlborough, MA
Luxi Qiao	M.Phil. in Clinical Neuroscience, Cambridge University, Dr. Herchel Smith Fellowship
Nicholas Scaglione	Unknown
Carly Schissel	Ph.D. in Chemistry, Massachusetts Institute of Technology
Temair Shorty	Teach for America, Shiprock, NM
Chloe Snow	Associate Teacher, Success Academy, New York, NY, then to medical school
Eugene Song	Community Residence Counselor, McLean Hospital, Belmont, MA
Megan Steele	Research Assistant, Beth Israel Deaconess Medical Center, Boston, MA
Christopher Stefanik	Dean's Fellow, Yale-NUS College, Singapore
Gregory Stone	Unknown
Helen Tang	Research Associate, Broad Institute, Cambridge, MA
Hector Trujillo	Ph.D. in Plant and Microbial Biology, University of California, Berkeley
Lindsey Vandergrift	Research Technician, MA General Hospital, Boston, MA
Edgar Vega	Unknown
Douglas Wassarman	Ph.D. in Chemical Biology, University of California, San Francisco
Knox Young	Unknown
Chanel Zhan	Unknown

Computer Science Department

2015-2016 marked another exciting year in the Computer Science Department. Student interest in computer science grew across the curriculum with record enrollments in our introductory, core, and elective courses. The department hosted two world class speakers: Turner Whitted, inventor of the ray tracing algorithm behind most modern CGI films, and Douglas Hofstadter, writer and Pulitzer prize winner of *Gödel, Escher, Bach*. The department also sponsored and hosted events from Google and Facebook that featured alumni *Josh Ain '02* and *Joshua Geller '14*.

In October, *Melanie Subbiah '17, Tafarii McKenzie '16, Lisa Liu '16, Olivia Gordon '17, Kelly Wang '16, Jamie Lesser '17* and *Pamela Mishkin '16,* attended the Grace Hopper Celebration of Women in Computing. Also attending the conference in Houston, TX were faculty members Jeannie Albrecht and Andrea Danyluk. In addition, Jamie Lesser won first place in the undergraduate ACM student research competition hosted at the conference. Continuing her successful year in research, Jamie also served as posters chair for the ACM Symposium on Interactive 3D Graphics and Games.

The department was noticeably more active in outreach activities this year. *Matthew McNaughton '16, Emily Roach '16,* and *Leslie Chae '16,* participated in the Williams Elementary Outreach iTeam, a pilot program of the Center for Learning in Action. They worked with students at Brayton Elementary in North Adams for "The Hour of Code," to introduce young students to what coding is and get them excited. The students had limited educational experiences with computers and computer science.

This year Associate 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 Class of 1966 Environmental Center on campus. The newly renovated and expanded building is 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, Devin Gardella '16,* and *Jamie Lesser '17* on a system for monitoring and visualizing energy usage in the Environmental Center, focusing specifically on the kitchen. They developed a prototype visualization that displays both power and energy usage for kitchen appliances in an intuitive and aesthetically pleasing way. They conducted several user studies to measure the effectiveness of the visualization, and obtained very promising results. Albrecht plans to fully deploy the system in the building this summer with *Anjali Pai '19, Katherine Blake '19,* and *Dawn Wu '18.*

Albrecht also supervised *Matt McNaughton's '16* honors thesis this year. For his thesis, Matt added new features to the Kubernetes Cluster Manager. Kubernetes is an open source project based out of Google. It aims to help manage compute resources in cluster environments to improve efficiency and reduce waste. The state of Kubernetes prior to Matt's thesis took a naïve approach to auto-scaling—that is, increasing (or decreasing) the amount of computing power assigned to a given service based on the workload. Matt incorporated additional functionality to allow for prediction in this context. Given the extensions he added to the code, rather than reacting to a sudden change in workload and resource utilization, Kubernetes can now predict (based on past performance) when more or less resources are needed, and preemptively adjust the allocated resources to maintain a more consistent quality of service.

Professor **Duane Bailey**, *Alex Paseltiner '16* and *Pamela Mishkin '16* joined Margaret Wertheim and Christina Simmons from the Institute for Figuring to install an abstract piece at Mass MOCA. The project, which involved folding more than 5000 business cards into individual cubes, is motivated by circuit board design.

Diwas Timilsina '16 worked with Prof. 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 reduce total power costs. Bailey and Timilsina have developed techniques to use single-lane ("faux") vector processors to reduce the power necessary to execute programs composed of long-running loops.

Tony Liu '16 and Bailey investigated the computational power of novel, bio-reminiscent irregular cellular automata. Cellular automata harness small bits of computation with grids of communication. Traditionally, these grids have been regular meshes. In this work, Liu and Bailey investigated the efficacy of cellular computations coordinated using aperiodic and irregularly connected meshes. The problem is motivated by a conjecture that plant leaves coordinate respiration through local exchange of gases. Surprisingly, they demonstrated that computation robustness improves with the introduction of limited amounts of randomness.

Bailey mentored Adly Templeton, of Mount Greylock Regional High School, who spent the year experimenting with evolving life structures in artificial chemistry systems. Templeton's work may give us insight into how real biological systems exhibit evolutionary pressure through genetic mutation.

Bailey, Liu, Timilsina, and Templeton, along with *Riwaz Poudyal '18*, investigated the structure of curling number sequences. Their experiments led to long-running and intensely parallel enumerations of "rotten" and "active" sequences, managed by several hundred coordinated processors that continuously ran for over eight months. The data led them to a fundamental new way of thinking about the structure of the sequences, motivated by aperiodic tiling theory.

Professor Bailey and artist Debora Coombs have been working on an exhibit of three dimensional paper and glass constructions that highlight a variety of features of the Penrose tiling. The tiling, which is aperiodic in two dimensions, is the projection of a regular structure from five-space. Their artwork seeks to demonstrate this relationship. Bailey and Coombs also collaborated with Institute For Figuring artists Margaret Wertheim and Christina Simmons in the construction of fractal and circuit-motivated structures built from folded business cards. The exhibit opened in May at Mass MOCA.

Professor **Andrea Danyluk** was on sabbatical for the academic year. She spent the fall semester at NYU as a Visiting Scholar and was back at Williams for the spring. While in New York, she devoted time to learning new techniques in Natural Language Processing as well as research at the intersection of computer science and social science that concerns itself with the dynamics of online social spaces.

Danyluk continued her research in machine learning, specifically in the areas of classifier learning and their applications. She supervised the work of two honors students, *Pamela Mishkin '16* and *Lauren Yu '16*. Pamela's work was concerned with online news discussion forums, focusing specifically on the New York Times comment space. Among other things, she applied machine learning and natural language processing methodology in an effort to learn a classifier that would automatically determine whether a comment submitted to the Times was suitable for posting or whether it should be screened out. Lauren's work was broadly concerned with building computational systems to faithfully simulate the playing of music. Specifically, she used machine-learning techniques to induce models of the way a violinist or violist would control the bow in order to play music expressively. Danyluk also worked with *Reid Pryzant '16* on an independent study project investigating "deep learning" methods and their application to problems in bioinformatics.

Danyluk 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 responsibilities are to administer an undergraduate research grant program, as well as to run undergraduate research mentoring programs at various events. She also speaks at mentoring programs for graduate students, and early- as well as mid-career researchers, and co-organized a workshop for new educators at the annual ACM Technical Symposium on Computer Science Education. She was a reviewer for several conferences and publications, including the International Conference on Machine Learning.

Professor **Stephen Freund** focuses on tools to help programmers find defects in software, particularly in the area of multithreaded software designed to run, for example, on multicore processors. He is also exploring scalability-oriented optimizations that

enable programmers to more easily design code that is both safe and efficient to execute on many processing cores.

Freund published two papers on his work. The first, "Shadow State Compression for Precise Dynamic Race Detection," examines how to improve the performance of algorithms for finding data race errors (occurring when multiple tasks access the same memory location without proper coordination). The new technique takes advantage of memory access patterns commonly found in concurrent programs to reduce the amount of computation the analysis must do to detect data races. This paper resulted from the work of two thesis students, *James Wilcox '13* and *Parker Finch '14*. The second paper, "Cooperative Types for Controlling Thread Interference in Java," summarizes and concludes a long line of work on cooperative concurrency, a programming methodology developed to reduce the complexity of multithreaded software.

Last summer, Freund worked with a number of summer research students. *Yitong Tseo '17* and *Alexander Majercik '17* participated in a new project on optimizing locks, the most common programming mechanism by which different parts of a computer system coordinate their access to shared data. In addition, *David Moon '16* spent last summer improving the memory usage in a data race detection tool. Freund also advised David on his senior thesis titled "Specifying and Enforcing Synchronization Disciplines in Multithreaded Programs." That thesis presents a new framework for specifying and enforcing how locks and other synchronization disciplines are used in multithreaded programs.

In addition to teaching courses on compiler design and programming languages, Freund advised an independent study on advanced compilation techniques undertaken by *Austin Paul '16, Eli Goldstein '16,* and *Danny Smith '16*. This study examined various compiler optimizations, emerging trends in programming language and compiler design, and compiling for concurrency.

For the second year, **Brent Heeringa** chaired the Computer Science department. In the fall, he taught Theory of Computation and in the spring he taught Algorithm Design and Analysis. Both these courses had enrollments of around 40 students. Heeringa was also thesis advisor to *Kai Wang '16* who studied psychologically-inspired representations of music suitable for learning Bach chorales with deep learning techniques like convolutional and recurrent neural networks. With Jeannie Albrecht, Heeringa developed a new work-study course for first-year students participating in the well-established summer science program.

Heeringa continued his collaboration with Nate Kornell (Psychology) on recognition codes, which transform arbitrary pieces of information into representations that are human-friendly. Working with *Nola Gordon '17* and *Russell Jones '17* this past summer, Heeringa ran several related experiments on Amazon Mechanical Turk. Heeringa gave a talk on this work at Union College in the fall. A working version of the system is available at www.mindburnr.com.

Heeringa also continued collaborating with Bill Lenhart. Together the two computer science colleagues showed that a natural string packing problem was computationally intractable and developed an approximation algorithm that finds a provably good solution–one that is never more than one-third smaller than optimal. The pair plan to expand and submit their work for publication soon.

In January Heeringa attended the Symposium on Discrete Algorithms. Also in January, he was featured in a Teach It Forward capital campaign video highlighting the department. In May, Heeringa represented the department in the annual Science Blast program, which aims to showcase research in the sciences to 11th grade students at the local high school.

Professor **Bill Lenhart** continued pursuing his interests in graph drawing and computational geometry, focusing mainly 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 known results and efficient algorithms for the extensively-studied class of planar graphs can be extended to these broader classes. Work with colleagues Giuseppe Liotta and Fabrizio Montecchiani from the *Univeritatà degli Studi di Perugia* resulted in a paper *On Partitioning the Edges of 1-Planar Graphs*, in which the authors were able to establish that every optimal 1-planar graph admits a partition into two planar graphs, one of which is maximal and the other of which is planar of maximum degree 4.

The paper has been submitted for publication to the journal *Theoretical Computer Science.*

Bill also continued to work with 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. We plan to continue working on this and related problems in the coming year.

Professor **Morgan McGuire** taught two new courses in film and media studies this year. The Visual Media Revolution tutorial investigated topics such as voxel graphics, 3D printing, and virtual reality. Cinematography in the Digital Age was a large studio course on creating short films and understanding the technology behind them, accompanied by a film series at Images cinema.

McGuire advised *Sam Donow's '16* thesis on fast ray tracing and *Jamie Lesser's '17* research on the optical properties, which won the ACM undergraduate research award at the Grace Hopper conference. He has continued to collaborate with *Dan Evangelakos '15* (at NVIDIA) and *Mike Mara '12* (at Stanford University).

Williams had a great graphics research presence at the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games in Redmond, MA in February. McGuire and Mara each presented a paper, Evangelakos presented a poster, and Lesser was on the organizing committee as posters chair. McGuire and Lesser also attended the ACM SIGGRAPH annual conference together in July 2015, and in June 2016, McGuire and Mara attended the Annecy Animation Festival, High Performance Graphics, and Eurographics Symposium on Rendering conferences together to learn about new work and present their own.

Professor **Tom Murtagh** continues to investigate file system designs that are more compatible with the performance characteristics of NAND memory devices. Currently available solid state drives, which are based on NAND memory, have been designed to imitate traditional disk interfaces so that they can be used in place of disks without changing system software. Because the software views the NAND memory as a disk, it makes data placement decisions optimized for disk device rather than for the constraints of NAND memory. Tom has developed an approach that extends techniques used in log structured file systems by having the system maintain multiple logs simultaneously. Such an organization promises to reduce the overhead associated with space reclamation by the file system. This summer, Tom will be working with *Rehaan Vij'18* and *Julia Goldman '18* to complete an experimental implementation of such a file system and evaluate its performance.

Class of 1960 Scholars in Computer Science

Amelia L. Archer '17	Stephanie Liu '17	Emily A. Roach '16
Kyle S. Cheng '16	Tong (Tony) Liu '16	Melanie S. Subbiah '17
Samuel A. Donow '16	Matthew J. McNaughton '16	Adly Templeton (High school senior)
Devin P. Gardella '16	Pamela F. Mishkin '16	Diwas Timilsina '16
Nola J. Gordon '17	Dong Hwan (David) Moon '16	Kaleb Y. Tseo '17
Russell K. Jones IV '17	Reid A. Pryzant '16	Kai Wang '16
Jamie R. Lesser '17	Jose Rivas-Garcia '17	Lauren J. Yu '16
Siyao Liu '16		

Computer Science Colloquia

Evan Sandhaus ‘02
“How to Build a TimesMachine”, September 2015

Henry M. Walker ‘69“MyroC 3.0: A C-based Project for using Robots in CS2: Design Approaches and Techniques to Implement Robot Commands”, October 2015

Turner Whitted, UNC Chapel Hill
“How Advanced Displays Will Re-define Computer Graphics”, October 2015

Wojciech Jaroz, Dartmouth College
“Mastering the Interaction of Light & Matter: From Real to Virtual, and Back Again

Frederich W. Strauch, Williams College
“A bit about qubits: quo vadis quantum computer?”, November 2015

Joydeep Biswas, UMass Amherst
“The Quest for Robust, Reliable, Autonomous Mobile Robots”, November 2015

John Foley, UMass Amherst
“Learning to Extract Local Events from the Web”, December 2015

Heather Pon-Barry, Mount Holyoke College
“Spoken Language in Human-Robot Interaction / MaGE Program”, February 2016

Ameet Soni, Swarthmore College
“Machine Learning Approaches for Computational Biology”, March 2016

Matthew Ginsberg, CEO Connected Sicgals, Inc.
“Fast Subpixel Feature identification – OR – How I got Mark Cuban to Incest in My Sports-Related Startup”, April 2016

Douglas Hofstadter, Indiana University
“A Tale of Luck and of Pluck: The Fortuitous Discovery, Forty-two Years Ago, of the Hofstadter Butterfly”, April 2016

Sorelle Friedler, Haverford College
“Biased Data, Biased Algorithms: Detecting and Preventing Discrimination in Machine-Learned Decisions”, April 2016

Dan Licata, Wesleyan University
“Computer-checked Programs and Proofs”, April 2016

Christopher Chabris, Union College
“Collective Intelligence, Individual Intelligence, and Social Intelligence”, April 2016

Off-Campus Computer Science Colloquia

Jeannie Albrecht

"Creating New user Experiences with IoT"
Grace Hopper Convention, October 2015

"P2P Systems Overview"
US Patent and Trademark Office Tech Fair, July 2015

Andrea Danyluk

"Publishing Your Research"
CRA-W Grad Cohort Meeting, San Diego, CA, April 2016

"Working With Colleagues"
New Educators Workshop at SIGCSE 2016, Memphis, TN, March 2016

Morgan McGuire

"Master Class on Virtual Reality"
Vicarious Visions, May 26, 2016

"Film and Media Studies"
Taylor University, April 19, 2016

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

Morgan McGuire and Shawn Rosenheim

"Ex Machina"
Images Cinema, May 28, 2015

Melanie Subbiah '17, Tafarii McKenzie '16, Lisa Liu '16, Olivia Gordon '17, Kelly Wang '16, Jamie Lesser '17 and *Pamela Mishkin '16* pose with Professors Jeanie Albrecht and Andrea Danyluk at the Grace Hopper Celebration of Women in Computing Conference.

Post-Graduation Plans of Computer Science Majors

Name	Plans
Leslie Chae	Undecided
Kyle Cheng	Software Engineer, Epic Systems, Madison, WI
Samuel Donow	Hudson River Trading LLC, New York, NY
Alexander Ellison	Data Engineer, Denodo Technologies, Palo Alto, CA
Gordon Finnie	Undecided
Devin Gardella	Software Engineer, Amazon Web Services, Seattle, WA
Rick Gentry	Software Engineer, Ebay, San Francisco, CA
Olivia Gordon	Instructor, iD Tech Camps, Seattle, WA
Noah Grumman	Undecided
Patrick Johnson	Undecided
Mia Knowles	Graduate Student in Computer Science at Sacred Heart University, Fairfield, CT
Nina Kumar	Undecided
Matt LaRose	Software Engineer, Duolingo, Pittsburgh, PA
Joel Lee	Implementation Consultant, Fast Enterprises, Denver, CO
Siyao Liu	Undecided
Tony Liu	Watson Health Software Engineer, IBM, Cambridge, MA
Jonas Luebbers	Undecided
Blake Mackall	Undecided
Bijan Mazaheri	Herchel Smith Fellowship, University of Cambridge, UK
Tafarii McKenzie	Software Developer at ThoughtWorks Inc., New York, NY
Matt McNaughton	Software Engineer, Flatiron Health, New York, NY
Pamela Mishkin	Undecided
David Moon	Undecided
Nigel Munoz	Undecided
Alex Paseltiner	Undecided
Austin Paul	IBM, Marlborough, MA
Kevin Persons	Associate Analyst/Programmer, Regional Economic Models Inc., Amherst, MA
Reid Pryzant	PhD candidate, Stanford University, CA
Emily Roach	Middle School Computer Science Teacher, Ravenscroft School, Raleigh, NC
Alexis Savery	Software Engineer, Google, Mountain View, CA
Michael Shaw	Cyber Risk Consultant, Deloitte, New York, NY
Daniel Smith	Undecided
Mohamed Soussi	Software Engineer, Daycation, Miami, FL
Diwas Timilsina	Software Engineer, C3IoT, Redwood City, CA

Geosciences Department

The department marks a couple of significant milestones this year. Bud Wobus completed his 50th year of teaching at Williams, which we celebrated with current students at the year-end barbeque and with former students at the annual Geosciences alumni reception during Alumni Reunion in June. In addition to his Golden Jubilee Geosciences flannel shirt and cake complete with mineralogical pun, both courtesy of the graduating senior class (see photos), Bud was presented with a compilation of alumni memories. We also unveiled Bud's gift to the department: the first published geological map of Williamstown, which has been framed and will hang in the Geosciences Department in perpetuity. And as David Dethier prepares to retire—phasing out over the next two years—we are getting ready to welcome his successor, José Constantine, who will become our new geomorphologist later this summer. We are delighted that there will be two years of overlap between David and José, giving them a chance to teach together and letting David pass on at least some of his vast store of local knowledge.

With the Annual Geological Society of America Meeting in Baltimore, Maryland, in October, a contingent of our students were able to attend the meeting. *Henry Barker '18*, *Joshua Harrington '16*, *Spencer Irvine '16*, *Abigail Kelly '16*, *Christina Seeger '16*, *Laura Stamp '16*, and *Will Wicherski '15* gave poster presentations at the meeting. At the annual American Geophysical Union meeting in San Francisco in December, *Alice Chapman '15* and *Caroline White Nockleby '17* gave poster presentations of their research work. In March, *Mary Ignatiadis '16* and *Laura Stamp '16* both gave talks on their research at the New England Geological Society of America meeting. Mary also gave a short talk and poster presentation at the annual Keck Geology Consortium symposium at Oberlin College.

Maoli Vizcaino '17 and *Sasha Langesfeld '17* were awarded the Lauren Interess Fellowship and spent part of the summer studying glaciers on the Columbia Icefield learning about the history of the glacial formations and gathering firsthand evidence of global warming.

We had seven senior thesis students this year. Presentations of their work were given on Monday, May 13, at the annual Senior Thesis Day (see section on Geosciences Student Colloquia). *Christina Seeger '16* won the Freeman Foote Prize for best presentation of a senior honors thesis, *Laura Stamp '16* was given the David Major Prize for outstanding Geosciences senior, and she also was awarded the American Mineralogist Undergraduate Award from the Mineralogical Society of America, which recognizes the member of the senior class with the most outstanding record of scholarship and research in Mineralogy and Petrology.

This year we graduated 16 seniors, whom we will miss. But our upcoming classes (16 rising seniors and 13 new junior majors) are an energetic and diverse bunch, and we look forward to working with them all. As always at this time of year, we are looking forward to the summer research period. Six rising seniors will begin thesis work, working in areas as varied as Iceland, Colorado and Japan, and we also have a number of underclassmen doing on-campus research.

Assistant Professor **Phoebe Cohen** spent the summer of 2015 doing field and lab work with Williams students. She traveled to Western New York with *Abby Kelly '16* and *Henry Barker '18* to examine evidence of the late Devonian mass extinction event. Abby spent the remainder of the summer in the Cohen lab working on these samples for her thesis research, while Henry continued on the work of *Laura Stamp '16* on biomineralized fossils from the Yukon. *Spencer Irvine '16* spent much of the summer in the Cohen Lab as well, working on his thesis research on vase-shaped microfossils from the Yukon. In the fall, Phoebe took all three students to the Geological Society of America meeting in Baltimore, MD, where all presented posters on their research. Phoebe also mentored *Maoli Vizcaino '17* on her Allison Davis Fellowship project on organic walled fossils from the Cryogenian of Mongolia.

Phoebe was on sabbatical during the academic year, so her time was spent working on research, mentoring her thesis students, and writing. Phoebe submitted a grant on the Late Devonian extinction to the Petroleum Research Fund, which was successfully funded this spring. Phoebe also received the W. Storrs Cole Memorial Research Award from the Geological Society of America to support her ongoing work on

the earliest fossil evidence of biomineralization.

This summer, Phoebe will again have a full lab as *Maoli Vizcaino '17* works on her senior thesis research, *Brian Coakley '18* continues Henry Barker's work on Yukon microfossils, and *Ezekiel King-Phillips '17* divides his time between his Mellon Mayes Fellowship and work in the Cohen lab on this research project, continuing the work of *Abby Kelly '16*.

This year, Phoebe served as a reviewer for the National Science Foundation and the journal Geology. She also continued her role as the Social Media Coordinator for the Paleontological Society and served on the advisory committee for Cornell University's Department of Earth and Atmospheric Sciences.

Associate Professor **Mea Cook**'s students *Alice Chapman '15* and *Caroline White-Nockelby '17* presented a poster at the American Geophysical Union annual meeting in San Francisco, California. The presentation was co-authored by *Paul de Konkoly Thege '14* and *Jeffrey Rubel '17*, and was on matching volcanic ash layers in sediment cores from lakes and the deep sea using the chemistry of glass shards in the ash. Radiocarbon dates were measured at the matching ashes in order to infer how radiocarbon was distributed in the ocean in the past and what the ocean circulation and climate were like at the time. This ongoing project is funded by the National Science Foundation, and comprised Paul's and Caroline's senior honors theses, Alice's independent study, and Jeffrey's summer 2015 project. Four research assistants, *Tiffani Castro '19, Natasha Baranow '18, Akuku Makori '17,* and *Jorge Castro '16*, 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 reviewed manuscripts for 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** finished up her four-year stint as a Science Editor for the Geological Society of America journal *Geology* but continues to serve on the Editorial Board and as a member of the society's Publications and Ethics Advisory Committee. She also continues as chair of the department. In Fall 2015 Rónadh received an NSF grant to fund another three years of work on coastal boulder deposits, and this grant brings into the project numerical wave modelers from University College Dublin and physical modelers from Queens University Belfast. This international group will convene in the Aran Islands this summer and plan their collaborative approach moving forward. Work this year by *Josh Harrington '16* (numerical modeling of wave amplification: thesis) and *Tim Nagle-McNaughton '17* (creation of 3D structure-from-motion models of boulder deposits: independent research) is part of this next phase, designed to increase our understanding of how coastal boulder deposits form and evolve. With *Tina Seeger '16,* Rónadh investigated the geomorphology of Jupiter's moon Io. Tina's thesis used Galileo imagery to investigate the relationship between mountain erosion and volcanic activity. In addition, *Zeke King Phillips '17* put the final touches to a GIS database documenting 20th century evolution of lavakas in northeastern Madagascar.

The work of Rónadh and her students was featured in Creedon's Wild Atlantic Way, a documentary-travelogue program on Ireland's national television station (RTÉ). Rónadh and students presented work at the Geological Society of America national meeting in Fall 2015, and Rónadh also presented results at the European Geosciences Union meeting in Spring 2016. She co-led a workshop at GSA on the publications process (What's Your Problem, What's Your Point). In June she will lead a field seminar in the Aran Islands, introducing international collaborators to this classic coastal boulder deposit locality. Thesis student *Kyrien Edwards '17* (who is a Geosciences-Japanese double major) will spend the summer in Japan, kicking off another international collaboration, with Kasuhisa Goto at Tohouku University. Kyrien's project will involve field and wavetank studies of tsunami transport of boulders and will specifically address the question of whether tsunami can build organised boulder ridges.

Professor **David Dethier** continued his research with students from Williams College and Keck projects, focusing mainly on the measurement of hydrogeochemical processes at several sites, and on 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 *Will Ouimet '01* (University of Connecticut), Dethier worked during July with *Mary Ignatiadis '16* on a Keck

project that emphasized Holocene and Anthropocene geomorphic change in Connecticut. He also worked with *Caroline Atwood '16* on a hydrologic study and *Stephen Mayfield '16* on drinking water chemistry at the new Environmental Center at Williams. Dethier, Ouimet and Jim Kaste (College of William and Mary) continued investigations of Front Range erosion rates using field measurements and meteoric and in-situ cosmogenic ^{10}Be and bomb-isotope (ex. ^{137}Cs) techniques.

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 served as Chair of the Kellogg Building Committee from 2010 to 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://env-center.williams.edu/. Dethier and his students are continuing hydrologic studies of the building and surrounding grounds.

During the summer of 2015, Associate Professor **Lisa Gilbert** had a successful field season at Barn Island Marsh in Stonington, Connecticut. Her thesis student Molly Weiner (Williams-Mystic S14; University of Rochester '16) presented their co-authored work on marsh resilience in October at the Geological Society of America Annual Meeting in Baltimore. This summer *Caroline Hung '19* will be a research assistant at Williams-Mystic to continue the project. Gilbert is also advising CES Intern *Charley Wyser '17* (Williams-Mystic F15) on an environmental psychology project.

Gilbert continues her work with the NSF-funded effort to improve interdisciplinary teaching for a sustainable future through InTeGrate. She is developing teaching materials on Systems Thinking with colleagues from Carleton College and the University of Maine. She also led a workshop for an international group of faculty at the American Geophysical Union Fall Meeting, San Francisco called "Teaching Geoscience in Society: Building Relevance and Interest in the Geosciences by Adding InTeGrate Resources to Your Class."

Emeritus professor **Markes Johnson** attended the "Twelfth International Workshop on Palaeontology in Atlantic Islands" at Ville de Port on Santa Maria Island in the Azores, July 19-25, 2015, where fieldwork on Pliocene carbonate stratigraphy was continued from the previous year. Together with Research Scientist Gudveig Baarli, Johnson attended the Fifth International Rhodolith Workshop at the University of Costa Rica in San José, Costa Rica July 27-30, 2015, where they made presentations on research conducted in the Cape Verde Islands. In November, Prof. Johnson visited Loreto in Baja California Sur (Mexico) to lay the groundwork for a spring break 2016 field excursion with students from the Geosciences Department in conjunction with the tutorial course on Gulf of California Geology and Ecology Systems (GEOS 254T) taught during the spring semester. Ten out of the dozen students taking the course accompanied Markes and Gudveig from March 19 to April 2 for a camping and hiking trip on Islas Coronados and Carmen in the Loreto Bay National Marine Park. The course text (Gulf of California Coastal Ecology: Insights from the Present and Patterns from the Past) was issued by Sunbelt Publications (San Diego, CA) on January 1, 2016, just in time for the spring term. Generous support for the excursion came from the Freeman Foote Field Trip Fund for the Sciences, established by Dr. Joseph Lintz '42. Concurrently with the Williams tutorial course, Markes offered a lecture course for the Berkshire County Osher Lifelong Learning Institute, which met for a series of 10 power-point presentations in Clark Hall (April 13 to May 11). During the third week of May, Markes went on a book and lecture tour to San Diego in promotion of his Sunbelt book.

Professor of Geosciences **Paul Karabinos** continued research on his grant from the National Science Foundation to support an educational initiative: GEODE- Google Earth for Onsite and Distance Education. This collaborative effort involves a dozen geoscientists, computer specialists, and cognitive psychologists. Its goal is to create a comprehensive set of demonstrations, exercises and tools for instructors to use in a wide variety of educational settings.

Karabinos attended the national meeting of the

Geological Society of America in Baltimore, Maryland, in October, 2015, where he gave two presentations: "The Enduring Impact of E-An Zen on Taconic Geology" and "Combining Rectified High-Resolution Gigapan Images and an Interactive Strain Program to Test the Rf-Phi Method for Analysis of Conglomerates."

Karabinos attended the Northeastern Section of the Geological Society meeting in Albany, New York, in March 2016, where he organized a theme session entitled: "Integrating Complimentary Records of Paleozoic Orogenies in the Appalachians, Bridging the Foreland and Hinterland." He also gave a presentation: "Evidence for the Evolving Plate Geometry in the Taconic Hinterland of the Northern Appalachians and Implications for Foreland Basin Deposits." He was also co-author on three presentations: "Detrital Zircon Constraints on the Age of the Granville Dome Mantling Sequence", "Taconic Basin Formation and Magmatism in New England and Newfoundland", and "Integrating Foreland and Hinterland Data: Toward a Greater Synthesis of Appalachian Tectonics and Orogenesis."

Karabinos published an article in Journal of Structural Geology with Declan De Paor (Old Dominion), Mladen Dordevic (Old Dominion), Barbara Tewksbury (Hamilton), and Steven Whitmeyer (James Madison), entitled "The Fold Analysis Challenge, a Virtual Globe-Based Education Resource."

Prof. **Bud Wobus** completed his 50th year of full-time teaching at Williams during 2015-16. For the 30th year he represented Williams on the governing board of the 18-college Keck Geology Consortium, which he helped to found in 1986. He attended both of the meetings of the Keck board, at the annual meeting of the Geological Society of America in Baltimore in the fall and at the annual Keck Geology Symposium at Oberlin in the spring. At GSA he also organized a reunion of Williams alumni and current students and faculty at the meeting, repeating the process at the fall gathering of the American Geophysical Union in San Francisco in December. At both meetings he was co-author, with several members of the Keck board, of papers about mentoring within the Consortium. During Winter Study he again offered his bi-annual Geology of the National Parks (GEOS 014) for first-year students, with six of the eleven participants continuing in Geosciences courses during the spring and following fall. He organized the department's lecture series (including Class of 1960 Lecturers) around the theme of "Magmatic Systems": see department colloquia for speakers and titles.

In September he led a geology hike on Stone Hill for the Clark Art Institute in conjunction with their Van Gogh exhibition. At the Rocky Mountain GSA section meeting in Idaho in May he co-authored a paper on Icelandic basalts presented by last year's senior thesis student, *Nell Davis '15*, now in graduate school at the Univ. of Idaho. During Reunion Weekend in June he will lead his annual campus walk, "Williams Rocks," and host a gathering of Geosciences alumni at his home. Later in the summer he will lead a trip for Williams alumni to Switzerland, his 40th trip in the Alumni Travel program that began with his Colorado offering in 1981.

He will advise two senior thesis students next year who will begin their research this summer. *Krystina Lincoln '17* will study pyroclastic volcanic deposits and tephrastratigraphy as part of a 6-student Keck Consortium project in Iceland, and *Matt Marcarelli '17* will begin a study with Wobus in Colorado investigating the tectonic setting and geochemistry of 1.4-billion-year granite plutons in the Front Range.

Class of 1960 Scholars in Geosciences

Jordan Fields
Spencer Irvine
Didier Jean-Michel
Martin Keenan
Michaela Levine
Krystina Lincoln
Matt Marcarelli
Christina Seeger
Laura Stamp
Caroline White-Nockleby
Noah Williams

Geosciences Colloquia

James Lawford Anderson
"Probing the Depth of Batholiths from Crustal Ascent in Core Complexes to Descent in the Sierras"

David Hawkins, Wellesley College
"Incremental Construction of a Subvolcanic Magma System: Geology and U-Pb Geochronology of the

Vinalhaven Intrusion, Maine"
Meagen Pollock, The College of Wooster

"Subglacial Pillow Lavas"
Frederic Dias, University College Dublin, Ireland
"Extreme Ocean Waves: Their Generation, Observation, and Impact"

José Constantine, Cardiff University
"Unraveling the Origins of Meandering Rivers"

Gabrielle David, Boston College
"Fluvial Wood: an Agent of Geomorphic Diversity"

Joseph Levy, Univ. of Texas Institute for Geophysics
"There Will Be Mud: Rapid Landscape Change in Antarctica"

Sheila Seaman, Univ. of Massachusetts, Amherst
"Supervolcanos: Past, Present, and Future"

Douglas Hollett '76, Department of Energy, Geothermal Technologies Office
"Hot Rocks: The Continuum from Natural Geothermal Systems to Engineering the Earth"

Professor Bud Wobus celebrating his 50th year of teaching at the 2016 senior class picnic...He's not done yet!

Geosciences Student Colloquia

Abigail Kelly ’16 and Caroline White-Nockleby ’17
“Aquifers, Bones, and Caves: The ABC’s of the Southwest’s Paleoenvironments”

Sasha Langesfeld ’17 and Maoli Vizcaino ’17
“Glaciers in the Canadian Rockies”

Caroline Atwood ‘16
“The Water Balance and Hydrology of the Class of ’66 Environmental Center”

Joshua Harrington ’16
“Modeling Non-Linear Storm Wave Behaviour for Coastal Boulder Transport in the Aran Islands, Ireland”

Mary Ignatiadis ’16
“Changes in Sediment Transport and Present-Day Carbon Storage Due to Historic Charcoaling Activity in Litchfield, CT”

Spencer Irvine ’16
“Not Just Flowers: Vases in the Neoproterozoic”

Abigail Kelly ’16
“Tiny Fossils from a Big Extinction: Microfossil Assemblage Variation Through the Kellwasser Event of the Late Devonian”

Christina Seeger ’16
“The Geomorphology of Mountains on Io”

Laura Stamp ’16
“Detrital Zircon Constraints on the Age of the Granville Dome Mantling Sequence”

Caroline White-Nockleby ’17
“Tephronchronology as a Tool to Constrain Surface Reservoir Age in the Deglacial Bering Sea”

Off-Campus Geosciences Colloquia

Phoebe Cohen

"Digging Deeper into the Proterozoic Fossil Record of Eukaryotes"
Univ. of Connecticut Center for Integrative Geosciences Dept. Seminar, December 2015

" Apatite for Construction: the Oldes Fossil Evidence of Biomineralization"
Pomona College, March 2016
Amherst College, May 2016

Rónadh Cox

"Coastal Erosion and Storms"
Mount Greylock Regional High School, March 2016

Lisa Gilbert

"Citizen Science Aboard the Charles W. Morgan"
Mystic Seaport, July 2015

"Teaching with InTeGrate Materials in a 2YC Environment: Natural Hazards and Risks"
Earth Educators Rendezoaus, Colorado, July 2015

"On-going Geologic Activity of Hawai'i"
Pine Point School, February 2016

"Hurricanes and Sea Level Rise on the New England Coast"
Sea Education Association, March 2016

"Monitoring Environmental Change on the Connecticut Shore"
Eastern Connecticut State University, April 2016

Markes Johnson

"Tale of Two Islands (Islas Cerralvo and Carmen): Increased Hurricane Activity in the Gulf of California"
Loreto Exploration Club, Loretao, Baja California Sur, Mexico, November 2015

"The Geopark Concept and Sustainable Ecotourism in the Gulf Of California"
Eco-Alianza de Loreto, Loreta, Baja California Sur, Mexico, March 2016

"Coral reefs in the Gulf of California: Temporal Record of Changes in Climate and Sea Level"
Scripps Oceanographic Institute, La Jolla, CA, May 2016

"Tectonic Decapitation of a Pliocene Delta System on Isla del Carmen (Baja California Sur, Mexico): Shadows of Former and Future Hurricane Activity in the Gulf of California"
San Diego Geologists' Association, San Diego, CA, May 2016

"Let's Go Baja!: Following Ed Ricketts and John Steinbeck to the Sea of Cortéz"
San Elijo Lagoon Conservancy, San Diego, CA, May 2016

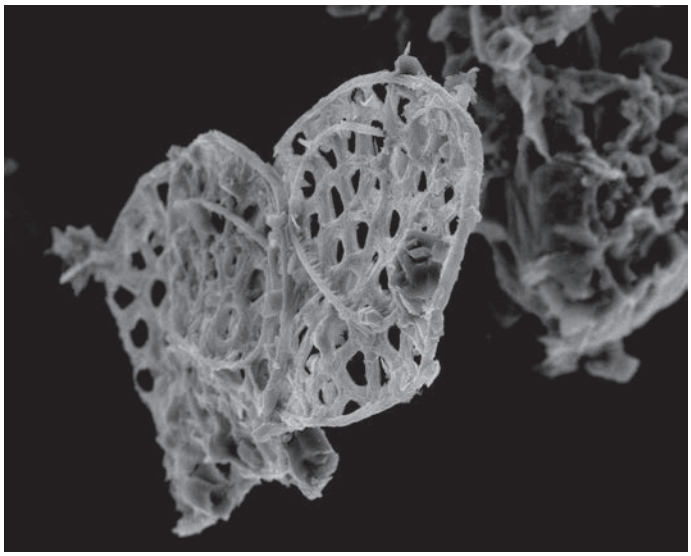
"Recent Rhodolith Deposits Stranded on the Windward Shores of Maio (Cape Verde Islands): Historical Resource for a Local Economy"
Fifth International Rhodolith Workshop, University of Costa Rica, July 2016

R. A. Wobus

"From Shore to Shore: the Geological Story of Stone Hill"
Clark Art Institute, September 2015

Post-Graduation Plans of Geosciences Majors

Kelsey P. Adamson	Working at Vaynermedia in New York City
Caroline E. Atwood	Post-grad research program assistant developer for Williams College (summer 2016)
Julia T. Carroll	Volunteer at local shelters; graduate school in one year
Jorge A. Castro	Environmental consulting; graduate school
Joshua P. Harrington	Undecided
Ailan S. Hurley-Echevarria	Work in the renewable energy field
Faye T.A.S.E. Hussain	Swimming in the Olympics in Brazil; management consulting work
Mary E. Ignatiadis	Connecticut Fund for the Environment (summer); undecided
Spencer W. Irvine	Undecided
Abigail A. Kelly	Smithsonian Tropical Research Institute, Panama (Mollusc paleontology)
Michaela B. Levine	Research Analyst at Industrial Economics, Inc.
Cody E. Remillard	Teaching Middle/High School science at Ben Gamla Prepatory Academy in Hollywood, FL
Eliza E. Rorabaugh	Undecided
Christina H. Seeger	Geoscientists in the Parks Internship program at Mt. Rainier National Park; grad school in planetary geology
Laura K. Stamp	Univ. of Colorado, Boulder, grad school (MS in Geology)
Luis A. Urrea	Teaching high school science in Texas



Scanning electron microscopy image of a 810 million year old biomineralized fossil from the Yukon, Canada. Based on new work by Professor Cohen and colleagues, this fossil and others like it represent the oldest evidence of intentional biomineralization in the fossil record.

Mathematics and Statistics Department

Frank Morgan served as chair his last year at Williams, before heading off to destinations unknown. FrankFest, a conference in his honor, attracted over 100 current and former colleagues and students. The invited speakers included three of his former research students: math stars Ivan Corwin and Michael Hutchings, and *Jonathan Lovett '04*, Obama speech writer and creator of the network TV show "1600 Penn."

Also departing: Satyan Devadoss, to become Fletcher Jones Professor of Applied Mathematics at the University of San Diego, and newly married Eyvi Palsson and Lauren Childs, for tenure-track jobs together at Virginia Tech. Two visitors will be staying for another year: Alejandro Sarria and Bolin Fellow and alumna *Haydee Lindo '08*.

Susan Loepp is the new chair. Bernhard Klingenberg has been promoted to full professor, and Julie Blackwood and Brianna Heggeseth have been reappointed as assistant professors.

A record-breaking seven new faculty will be arriving next year: two new mathematics assistant professors Pamela Harris and alumnus Ralph Morrison; two new statistics assistant professors Daniel Turek and Laura Tupper; two new visitors Payem Tabrizian and alumna *Diana Davis '07*; and a new Bolin Fellow and SMALL alumnus Cory Colbert. This coming year we'll be hiring two more mathematics faculty.

In summer 2017 we move into temporary quarters at Bascom House for three years while Bronfman is demolished and replaced.

We are now the second largest department in the College, with a record 200 majors, behind only Economics (213). The number of inductees into Mu Sigma Rho, the statistics honor society, has risen from 3 in 2014 to 19 in 2016. We have a record-breaking 46 students in our SMALL research program this summer.

We are very proud of the accomplishments of our majors: Rosenberg Prize for outstanding senior: *Greg Kehne '16, Peter McDonald '16*, and *Mia Smith '16;* Morgan Prize in applied mathematics: *Alex Meyer '16*; Kozelka Prize in statistics: *Bryan Jones '16* and *Kelly Kung '16*; Wyskiel Prize in teaching: *Mia Smith '16*; Beaver Prize in citizenship: *Roger Vargas '16*; Goldberg Prize for best colloquium: *Alex Kling '16* and *Olivia Meyerson '16*; Colloquium Attendance Prizes: *Ashwin Narayan '16* and *Sarah Fleming '16*; Witte Problem-solving Prize: *Blake Mackall '16*; 1st Benedict Prize for outstanding sophomore: *Anna Neufield '18* and *Harry Zhang '18*; 2nd Benedict Prize: *Sumun Iyer '18, Andrew Scharf '18,* and *Weitao Zhu '18*; Williams students participated in many math competitions this school year. Our team, lead by *Granger Carty '18, Zhiqi Li '19, Gregory Kehne '16* and *Sam Donow '16* defended the Green Chicken at Middlebury. On the William Lowell Putnam Mathematical Competition, our team, consisting of *Blake Mackall '16, Gregory Kehne '16* and *Sam Donow '16*, placed in the top 50 in the nation, and the top two individual scores came from *Blake Mackall '16*, ranked 235.5, and *Ziqi Lu '18*, ranked 452.5. The turnout was great with over 1.5% of the campus taking the exam. Williams students also participated in the Virginia Tech Regional Mathematics Contest, the University of Rochester Math Olympiad, and the Rochester Institute of Technology competition.

We would like to thank the members of SMASAB (Students of Mathematics and Statistics Advisory Board): *Katherine Bennett '16, John Bihn '16, Ashwin Narayan '16, Mia Smith '16, Kathryn Grice '17, Nina Pande '17, Troy Sipprelle '17, Jay Habib '18*, and *Isabella Huang '18*.

Twenty-two high school students from across the country participated in Allison Pacelli's third annual summer Math Camp, learning number theory, writing proofs, attending guest lectures, and participating in problem-solving sessions.

One hundred forty four local 10th graders attended our annual MathBlast December 14. Students and teachers each chose three thirty-minute workshops by Williams faculty, ranging from soap bubbles to mathematical card tricks.

In summer 2015, **Colin Adams** had a group of six students working with him in the SMALL program, two of which were from Williams. The group worked on volume and determinant densities of hyperbolic knots, and produced two papers that have been submitted for publication.

During the academic year, Adams advised two thesis students, *Xixi Edelsbrunner '16,* who worked on ubercrossing projections of knots, and *Greg Kehne '16*, who worked on bipyramid decompositions of multicrossing projections of knots.

Adams gave a variety of presentations at various institutions, some research oriented, and some expository. With the help students and faculty from Williams and other schools, he put on humorous

math theater at the national math meetings in Seattle in January. In addition to work with students, he submitted several papers on hyperbolicity of knots and links including the paper "Generalized Augmented Alternating Links and Hyperbolic Volume."

Julie Blackwood completed her third year at Williams College. She taught two sections of Linear Algebra in the fall, one section of Differential Equations in the spring, and introduced a new 400-level tutorial on Mathematical Ecology in the spring.

Over the past year, Blackwood continued her research in mathematical ecology. *Alex Meyer '16,* her thesis student, worked on research related to white nose syndrome during the fall semester, and in the spring semester he began new work on understanding the spatial synchrony of periodical cicadas in the U.S. Blackwood had a paper accepted on the age-structured dynamics of pertussis in the journal *Epidemics*, and she began new research with Lauren Childs (Visiting Assistant Professor of Mathematics) on spatial management of Ebola virus. Over the past year, Blackwood has given several talks on these subjects and also became an editor for the journal *Natural Resource Modeling*.

Satyan Devadoss spent this year on leave at Harvey Mudd College, learning ways to balance a STEM foundation with a humanities education. His research is in the areas of topology and geometry, on which he gave several invited talks from coast-to-coast. He supervised thesis student *Mia Smith '16* at Williams as well as students at Harvey Mudd.

Devadoss was proud to represent Williams once again in the national stage, when he received the Haimo Teaching Award from the Mathematical Association at the Joint Meetings in Seattle.

Devadoss' collaboration with Bay Area artist Owen Schuh, on the cartography of phylogenetic trees, had its inaugural show at "Satellite Berlin" in Germany. He was also part of another work in this gallery, "Nulla Dies Sine Linea", which focused on how artists and scientists create.

Dick De Veaux continued his work in data mining and writing textbooks and gave a variety of talks, invited talks, keynote addresses and workshops on teaching and data mining throughout the World. He finished serving as the representative of the Council of Sections to the Board of Directors of the American Statistical Association and started his term as Chair of the section on Statistical Learning and Data Science.

Tom Garrity has continued his research in number theory. His review of Steven Weintraub's *Differential Forms: Theory and Practice* appeared in the *American Mathematical Monthly*. He put two preprints on the arxiv: "Stern Sequences for a Family of Multidimensional Continued Fractions: TRIP-Stern Sequences," with coauthors *Amburg '14*, Dasaratha, Flapan, *Lee '12,* Mihaila, *Neumann-Chun '13*, Peluse, and Stoffregen, and "On Gauss-Kuzmin Statistics and the Transfer Operator for a Multidimensional Continued Fraction Algorithm: the Triangle Map."

He spent most of July of 2015 at the Park City Mathematics Institute (PCMI) in Park City, Utah, where he gave three weeks of daily lectures. In January, 2016, in Seattle at the joint meetings of the American Mathematical Society and the Mathematical Association of America, he gave an MAA mini-course with Ryan Brown. He learned a great deal from his three thesis students*: Emmanuel Daring '16, Elizabeth Frank '16,* and *Peter McDonald '16*. He is looking forward to spending next year on sabbatical at the Institut de Recherché en Informatique Fundamental at the University of Paris-Diderot.

Leo Goldmakher continued his research in number theory and additive combinatorics with a number of collaborators, including Williams students *Vidya Venkatesh '17, Michael Tcherepashenets '17,* and *Gabe Staton '16*. He gave invited talks at Amherst College, Boston College, the Ohio State University, and the Maine/Quebec number theory conference. He also gave a local talk at the weekly Science Lunch on relationships between paper folding and prime factorization.

Brianna Heggeseth continued her research in the area of longitudinal data analysis. She supervised the summer research of *Alvaro Aleman '16* and presented their work comparing statistical methods that can detect what factors impact the development patterns over time on campus as well as at the Joint Statistical Meetings 2015. Additionally, she developed a more modern curriculum for and taught Multivariate Statistics in the fall in addition to co-teaching Statistics and Data Analysis with Dick De Veaux.

Heggeseth was on maternity leave during the spring semester and looks forward furthering her research during her upcoming academic sabbatical.

Stewart Johnson remains active in dynamical systems, focusing on massively parallel computing methods for scientific modeling. He is developing tools for assessing chaotic attractors in high dimensional spatial systems, and adapting classic methodologies to better understand how the spatial component of these dynamics impact our notions of chaos and predictability. This basic research furthers our understanding of spatially organized systems such as systems of neurons, grain boundaries in crystal

formation, and cellular tissue growth.

Bernhard Klingenberg's textbook (co-authored with Alan Agresti and Chris Franklin) *Statistics: The Art and Science of Data Analysis,* 4th edition, was published by Pearson in January 2016. It is meant as a textbook for a two-semester course on introductory statistics. Klingenberg also created the public website *ArtofStats.com/webapps* where various statistical concepts are illustrated using interactive web apps. Many of these apps can also be used to carry out basic statistical data analyses in the cloud. Klingenberg worked as a statistical consultant on a clinical trial on small bowl obstruction and helped Williams students from various disciplines with their statistical analyses in their theses. He also continued as an associate editor for the journal Statistical Modelling. In April, he gave a one-day short course on modeling longitudinal binary data at the City of Hope cancer research center.

Susan Loepp was on leaving during the 2015-2016 academic year. She focused on her research in commutative algebra, and she especially enjoyed working with fellow commutative algebraist *Haydee Lindo '08*, who was in her first year of two as a Gaius Charles Bolin Fellow in Mathematics at Williams.

Loepp had three papers appear in 2015-2016, all joint with former Williams undergraduates. In January, Loepp attended the Joint Mathematics Meetings in Seattle where she gave a talk on her research, attended many commutative algebra talks, and gave a presentation as part of a Mathematical Association of America panel. In the fall of 2015, Loepp agreed to serve for a second 5-year term as an associate editor for the *American Mathematical Monthly*. She continues to serve on committees for the Mathematical Association of America and the Association for Women in Mathematics.

In summer 2015, Loepp advised the Commutative Algebra research group as part of the department's SMALL program. The group was comprised of five undergraduates, including the three Williams students *Sarah Fleming '17, Peter McDonald '16,* and *Nina Pande '17*. The group produced two papers that include original results and they have submitted both papers to research journals in mathematics for consideration for publication.

Steven Miller received a three year individual NSF grant to continue his investigations in number theory and probability, and served as director of the Williams SMALL REU. He and his students published more than 10 papers and gave over 25 talks. He has continued his mathematical outreach activities, ranging from his successful math riddles page (http://mathriddles.williams.edu/), which is used in schools around the world, to writing computational modules for high school classes and giving continuing education lectures to junior high and high school teachers, to editing a book on the theory and applications of Benford's Law. With Eyvi Palsson he ran math puzzle night and continued our streak of >1% campus participation on the Putnam exam. He was the thesis advisor to *Lawrence Luo '16* (on "More Sums Than Differences Sets") and also expanded his involvement in using online resources in teaching; all his course lectures are available online through YouTube, as are many of his talks. He was on sabbatical in the spring, and used the time to finish a book on probability theory and first drafts on books on *Operations Research* and, with Stephan Garcia of Pomona College, a mathematical collection book celebrating the centennial of the Pi Mu Epsilon math honor society.

Frank Morgan spent his last year at Williams as chair and new editor-in-chief of the *Notices of the American Mathematical Society*, the largest publication in higher mathematics. Next year he heads into the unknown, exploring the Americas (including Havana) for his new home. Upcoming talks include Hong Kong, Sao Paulo, Rio, Buenos Aires, Alicante, Luminy, and Vienna. Meanwhile he is continuing work on optimal shapes, some with his 29th group of SMALL undergraduate research students this summer. The fifth edition of his *Geometric Measure Theory* book has just been published.

Allison Pacelli continued her work with Albany elementary school teachers and principals this year. She is part of a New York State Math & Science Partnership Grant aimed at increasing the mathematical knowledge and pedagogical effectiveness of K-2 teachers. She continues her teaching and research in algebraic number theory. The Williams College Math Camp, which she founded in 2013, is now in its fourth year. Alum *Michael Gold '14* is now assistant director for the camp.

Eyvindur (Eyvi) Palsson just finished his second year at Williams College. In the fall, he taught two sections of Calculus I. During Winter Study he taught and developed the class Wavelets and Image Processing. In the spring, he taught Applied Real Analysis as well as developed and taught the class Harmonic Analysis.

Palsson continued his research in harmonic analysis, geometric measure theory, and additive number theory. His paper on "Multilinear Generalized Radon Transforms and Point Configurations" with Loukas Grafakos, Allan Greenleaf, and Alex Iosevich appeared in *Forum Mathematicum* in the fall of 2015. Another paper "On a Group-theoretic Viewpoint of the Erdos-Falconer Problems and the Mattila Integral" with Allan Greenleaf, Alex Iosevich and Bochen Liu appeared in *Revista Matematica Iberoamericana* in the fall of 2015. He also submitted three papers with the SMALL group on Number Theory and Harmonic Analysis that he ran with Professor Steven Miller.

Palsson attended a special session on Geometric Aspects of Harmonic Analysis at the Joint Meeting of the AMS, EMS, and SPM in Porto, Portugal, where he also gave a lecture. He presented at an International Conference on Harmonic Analysis and Applications at the Graduate Center of the City University of New York, gave colloquium talks at Bard College and the University of Illinois at Urbana-Champaign, had seminar talks at Yale, University of Rochester and Colgate University, and spoke at the faculty seminar and colloquium here at Williams College.

With Steven Miller, Palsson ran math puzzle nights and math contests. Highlights included defending the Green Chicken from Middlebury College and the Putnam math team ranking in the top 50 nationally.

Palsson accepted a position at Virginia Tech and will leave Williams College after the spring semester of 2016 but not before he leads a summer research group in SMALL with Professor Steven Miller on Number Theory and Harmonic Analysis.

Cesar Silva's summer 2015 started with a visit from *Isaac Loh '15*, who had just completed a thesis with Silva. They completed several projects based on Loh's thesis and on work from SMALL 2014, and completed a paper that has been submitted for publication.

Silva taught Real Analysis and Measure and Ergodic Theory in fall 2015, and Real Analysis and Calculus II in spring 2016. He supervised *Roger Vargas '16* as a thesis student. He also taught in the Summer Science Program. He hosted his colleague, Emmanuel Roy, from the University of Paris XIII for a month in the fall. Silva took part in a Squares research group, a program organized by the American Mathematics Institute, and met for a week in November 2015 in San Jose, California. Silva attended several conferences, including the Ergodic Theory and Dynamical Systems Conference, in Bedlewo, Poland, in November 2015, where he gave a talk.

He was appointed associate editor of the *Notices of the American Mathematical Society* for the period January 2016 – December 2018. Together with Colin Adams they had a grant from the National Science Foundation to organize a conference at Williams in February, 2016 on the occasion of Frank Morgan's retirement.

Mihai Stoiciu taught Foundations in Quantitative Skills and Functional Analysis during the fall semester, Mathematics Immersion during Winter Study, and two sections of Multivariable Calculus during the spring semester of the academic year 2015-2016. During the year, he continued his research on spectral properties of random and deterministic operators. 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 recently published in *Involve - A Journal of Mathematics*.

Stoiciu was invited to present his research at the international conference, "The Fourth Najman Conference on Spectral Problems for Operators and Matrices," held in Opatija, Croatia in September 2015. He was also invited to give the Lenora Lecture in Mathematics at Oberlin College in January 2016 and the inaugural Eaves Lecture in Mathematics at University of Kentucky in February 2016. At Williams, Stoiciu gave a talk for high school students at the Williams MathBlast 2015 and a faculty seminar on his recent research in spectral theory.

Mathematics and Statistics Colloquia

Colin Adams, Williams College
- "Hyperbolic Knots for Fun and Profit"
- "Volume and Volume Density of Hyperbolic Knots and Links"
- "Why Knot" Osher Lifetime Learning Institute, Williams College, October 7 & 14, 2015

Taylor Arnold, Yale University
- "Guess Who? Learning Author Attributes from Unstructured Text"

Duane A. Bailey, Williams College
- "A Grammatical Interpretation of Curling Sequences"

Julie Blackwood, Williams College
- "The Role of Interconnectivity in Control of an Ebola Epidemic"

Lauren Childs, Williams College
- "Constrained Random Walks on Graphs as a Model for Antibody Affinity Maturation"

William Cipolli, University of South Carolina
- "Bayesian Nonparametric Multiple Testing"

Annalisa Crannell, Franklin & Marshall College
- "Math and Art: The Good, the Bad, and the Pretty"

John Cullinan, Bard College
- "Legendre Polynomials: From Mathematical Physics to Number Theory"

Richard De Veaux
- "How Fast Do 100 Year Olds Slow Down? – Modeling the Effect of Age on Performance in Running and Swimming"

Thomas Garrity, Williams College
- "On Multidimensional Continued Fractions"

Leo Goldmakher, Williams College
- "Primes in Additive Combinatorics"
- "Mock Characters and Finite State Machines"

Brianna Heggeseth
- "The Relationship Between Baseline Values and Change Over Time: How Easy it is to Get it Wrong!"

Roger Hoerl, Union College
- "The World is Calling: Should We Answer?"

Bernhard Klingenberg, Williams College
- "Multiple Comparisons of Marginal Probabilities"
- "Karl and Egon's Chi-Squared Statistic"

Michael Lawler, Berkshire Hathaway Reinsurance Group
- "The Value of Mathematical Training – in Theory and in Practice"

Haydee Lindo, Williams College
- "Trace Ideals and the Centers of Endomorphism Rings"

Susan Loepp, Williams College
- "Local Rings, Completions, and Prime Ideals"

Adam Lowrance, Vassar College
- "Alternating Tangle Decompositions"

Christopher Marx, Oberlin College
"Proving Delocalization for Quasi-Periodic Schrödinger Operators With Trigonometric Potentials"

Steven Miller, Williams College
"Applications of Harmonic Analysis in Number Theory"
"Extending Pythagoras"
"Benford's Law: Why the IRS Cares About Algebra and Number Theory (And Why You Should Too!)"
"Pythagoras at the Bat: An Introduction to Statistics and Modeling"
"Success and/or Significance, A Musician and Mathematician Discuss Beauty, Perfection and Faith in the Liberal Arts"

Kathryn Montovan, Bennington College
"Using Mathematical Modeling to Understand Animal Behavior"

Frank Morgan, Williams College
"Balls and Bubbles"
"*Notices*, Mathematics, and You"
"What is a Surface? From Calculus to Geometric Measure Theory"

Andrew Noble, University of California, Davis
"When Ecological Populations Behave Like Magnets: The Universality of Critical Transitions in Synchronization"

Ken Ono, Emory University
"The Legend and Legacy of Ramanujan"

Allison Pacelli
"Primes in Sequences"

Eyvindur Palsson
"Going the Distance"
"Crescent Configurations and Sharpness Examples for Triangles"

Emmanuel Roy, University Paris 13
"Introduction to Poisson Suspensions"

Cynthia Rush, Yale University
"Exploring the Relationship Between Regression and Information Theory"

Alejandro Sarria, Williams College
"The 3D Axisymmetric Euler Equations"

Cesar Silva, Williams College
"One Proof is Not Enough"

Stefan Steinerberger, Yale University
"Analysis Meets Number Theory: New Results and Mysteries"

Mihai Stoiciu
"Spectral Theory for Random Schrodinger Operators"

Laura Tupper, Cornell University
"Changes in the Wind: Depth Statistics and Distance Metrics for High-Dimensional Data"

Dr. Daniel Turek, University of California, Berkeley
"The NIMBLE Project and Efficient Markov Chain Monte Carlo Algorithms"

Mathematics and Statistics Student Colloquia

Alvaro Aleman ‘16
“Nonparametric Regression Using Penalized B-Splines”

Katherine Bennett ‘16
“The Rise of Graph Theory in Biological Networks”

Emily Berg ‘16
“Mathematical Modeling of Consumer Behavior”

Jonathan Berry ‘16
“Conway’s ZIP Proof”

John Bihn ‘16
“Tired of Linear Regression? Try Regression Trees!”

Sophie Chatas ‘16
“Stern’s Diatonic Sequence”

Kang-Yee Chyou ‘16
“Strategy in Games”

Julius Collado ‘16
“Tanh and Continued Fractions”

John Damstra ‘16
“The Banach-Mazur Game: Topology and Game Theory from the Scottish Book”

Samuel Donow ‘16
“When Can We Make Choices in Mathematics?: The Axiom of Choice and its Consequences”

Max Elgart ‘16
“Fractals and The Contraction Mapping Theorem”

Gregory Ferland ‘16
“Continued Fractions of Quadratic Irrationals”

Nicole Feshbach ‘16
“Math Madness: Ranking NCAA Basketball Teams”

Gordon Finnie ‘16
“The Uniqueness of Neural Networks”

Alexander Flick ‘16
“The abc Conjecture”

Jace Forbes-Cockell ‘16
“The Black-Scholes Equations”

Todd Ford ‘16
“Drawing a Straight Line: An Introduction to Mechanical Linkages and the Peaucellier-Lipkin Mechanism”

Eva Fourakis ‘16
“The Lewy Example”

Eli Goldstein ‘16
“The Kakutani Fixed Point Theorem and its Applications to Economic Theory”

Feixue Gong ‘16

"Intrinsically Linked and Knotted Graphs"

Merritt Harlan '16
"Modeling the Resiliency of Caribbean Coral Reefs"

Beau Horan '16
"Clustering and Pitch Identification in Baseball"

Karen Huan '16
"Pick Yourself Up! An Introduction to the Bootstrap"

Willem Humes '16
"An Investigation of the Waring Problem for Squares"

Ethan Jacobs '16
"Ultralimit Analysis and the Transfer Principle"

Logan Jester '16
"Markov's Monkeys"

Weiting Ji '16
"Using Confusion Graphs to Avoid Misunderstandings?"

Catherine Jiang '16
"Curious Cubic Curves: The Group Law on Cubic Curves"

Gregory Johnson '16
"Simulating Random Variables: The Accept-Reject Method"

Bryan Jones '16
"An Introduction to Spatial Autocorrelation With Airbnb Rental Price Data"

Benjamin Kaufman '16
"Abel and Equations of Degree 5"

Abraham Kirby-Galen '16
"Quadratic Reciprocity: An Updated Proof of Gauss' Golden Theorem"

Alexander Kling '16
"The log(2)/log(3) Dimension"

Kelly Kung '16
"Applying Statistics to Golf: Par vs. Birdie Putts"

Andrew Leary '16
"Beating the Sample Mean in 3-D: The James-Stein Estimator"

Joel Lee '16
"Computing the Trillionth Digit of Pi"

Maija Lindaas '16
"Modeling Movement to Music"

Blake Mackall '16
"The Funcertainty Principle"

Kanishka Malik '16
"Markov Chains"

Miles McCarthy '16
"Kelly Criterion for Wager Sizing"

Olivia Meyerson '16
"Fireflies, Crickets and Neurons: The Synchronization of Biological Oscillators"

Pamela Mishkin ‘16
“Elections on Graphs”

David Moon ‘16
“Circle Packing: From Cookie Cutting to Complex Analysis”

Ashwin Narayan ‘16
“Ideals of Operator Algebras: Combining Algebra and Analysis”

Yaroslav Nemenov ‘16
“Minimizing Regret When Playing Poker”

Christopher Owyang ‘16
“Zipf’s Law & the Mathematics of Coincidence”

Lucy Page ‘16
“Modeling Epidemics: The Impact of Individual Variation on Disease Extinction”

Michael Petrick ‘16
“Using Extreme Value Analysis to Study Once in a Lifetime Events”

Priscilla Pino ‘16
“Coexistence of Different Serotypes of Dengue Virus”

Daniel Potter ‘16
“The Mathematics of Change Ringing”

Matthew Radford ‘16
“Theory and Practice Behind Orthogonal Series Density Estimation”

Shadman Rahman ‘16
“The Old Japanese Theorem”

Jose Raventos ‘16
“Hamiltonian Graphs, Dirac’s Theorem and Applications”

Matthew Rock ‘16
“An Introduction to Artificial Neural Networks”

Alexis Savery ‘16
“Tetris is Hard”

Nicholas Scaglione ‘16
“Fair Division: An Exploration of Cake & Envy”

Amanda Siedem ‘16
“Matching Medical School Graduates to Residency Programs: Can We Make Everyone Happy?”

Jillian Stallman ‘16
“Picky Pandas and Meerkat Mayhem: Theory, Models and Applications of Allee Effects”

Michael Stone ‘16
“Rating and Ranking With Incomplete Information”

Matthew Tarduno ‘16
“Nash Equilibrium”

Jane Thompson ‘16
“An Introduction to Cloud Detection With Classification Trees”

Diwas Timilsina ‘16
“Gomory-Hu Trees and Their Applications”

Kristian Viggo Hoff Lunke ‘16

"Stochastic Models for Small Populations"

Jeffrey Wang '16
"Liouville Numbers: A Big and Small Set"

Howard Weiss '16
"Simple Continued Fractions"

Matthew Werner '16
"Comparison of the Hotelling's T-squared and Bonferroni Correction Methods"

Francis Worthington '16
"The First Sylow Theorem"

Sarah Wu '16
"Want to Spice up Your Life? Why Not With Calculus…of Variations!"

Jonathan Yin '16
"Bayesian Analysis and Applications"

Off-Campus Mathematics and Statistics Colloquia

Colin Adams

"The End of Mathematics"
Recreational Math Conference, Museum of Math, New York City, August 3, 2015

"Making Math Fun"
Macmillan/Scientific American Education Conference, New York, NY, August 4, 2015

"Mathematics Edutainement"
Mathfest, Washington, DC, August 5, 2015

"Blown Away: What Knot To Do When Sailing"
Boston College Topology/Geometry Seminar, October 29, 2015
Columbia University Teacher's College, New York, NY, November 16, 2015
CMC Anthenaeum, Claremont McKenna College, Claremont, CA, January 28, 2016
Sacred Heart University, Fairfield, CT, March 16, 2016
Central Michigan University, Mt. Pleasant, MI, March 29, 2016

"Volume and Determinant Density of Rational Links"
AMS Meeting, Rutgers University, New Brunswick, NJ, November 14, 2015

"Mathematically Bent Theater With "Mathematicus", Aftermath" and "A Pi Day Carol"
Joint Mathematics Meetings, Seattle, WA, January 8, 2016

"Volumes and Volume Densities of Hyperbolic Knots"
Topology/Geometry Seminar, Pomona College, Claremont, CA, January 28, 2016
Michigan State University, East Lansing, MI, March 30, 2016

Julie Blackwood

"Spatial Synchrony of Periodical Cicadas"
Rochester Institute of Techology
Colgate University

"From Rabies Transmission in Vampire Bats to Pest Management: Insights from Mathematical Models"
Bennington College

Satyan Devadoss

Colloquium
University of Texas, Austin
Westmont College
California State University, Fullerton
Occidental College
Loyola Marymount University

"Geometry Seminar"
University of Texas

"Atul Vyas Memorial Lecture"
Claremont McKenna College

"Biology Colloquium", "Michael Moody Lecture"
Harvey Mudd College

"Algebra-Number Theory-Combinatorics Seminar", "Topology Seminar"
Claremont Colleges

"Williams Association Speaker"
Ernie Wolfe Gallery

"Keynote Speaker"
MAA Southern California, Nevada Sectional Conference

"Algebraic and Topological Methods in Combinatorics", "MAA Teaching Award Presentations",
"Applied and Computational Topology"
Annual Joint Mathematics Meetings, Seattle, WA.

"Principal Speaker"
Institute of Environmental Sciences and Technology SoCal Meeting

"Plenary Speaker"
New American Colleges and Universities Conference

"Family Weekend Lecture"
Williams College

Richard De Veaux

"Human Performance and Aging"
Japan Discovery Conference, Tokyo, Japan, November 2015
Essex Meadows, Essex, CT, May 2015

"Intro Stats in the 21st Century"
New Zealand Association of Mathematics Teachers, Auckland, NZ, July 2015
UP-STATS 2016 Conference, Buffalo, NY, April 2016
Joint Statistical Meetings, Seattle, WA, August 2015
Columbia University, NY, April 2016

"Predictive Analytics Workshop"
London, England, October 2015
Frankfurt, Germany, October 2015
San Jose, CA, October 2015
Charlotte, NC, January 2016
San Diego, CA, February 2016
Atlanta, GA, March 2016
Princeton, NJ, May 2016

"Data Mining: Fool's Gold or the Mother Lode?"
Professional Night Speaker, AP Reading, Kansas City, MO, June 2015

"Presentation Skills Workshop"
Joint Statistical Meetings, Seattle, WA, August 2015

"Intro Stats for Future Data Scientists (with Brianna Heggeseth)"
CAUSEWEB E-COTS Conference, May 2016

Thomas Garrity

"Algebraic Geometry: Moduli Theory and Invariants"
Park City Mathematics Institute, July 2015

"Algebraic Geometry: A Problem Based Course", "Etudes of Questions: A New Approach for Writing Mathematics"
AMS-MAA January Meeting, Seattle, WA, January 2016

"Why are Mathematicians So Arrogant, and Why They Should Be; or, Why Mathematics is the Ultimate Structure of Reality"
Temple College, Temple, TX, March 2016

"On Expressing Numbers"
Simon's Rock College of Bard, Great Barrington, MA, April 2016

Leo Goldmakher

"Characters and Their Nonresidues"
Amherst College

Boston College
Ohio State University

"Mock Characters and Finite State Machines"
Maine/Quebec Number Theory Conference

Brianna Heggeseth

"The Relationship Between Baseline Factors and Change Over Time: How Easy It Is To Get It Wrong!"
Holy Cross College, October 2015

Stewart Johnson

"Non-Linear Games on a Grid"
Math Colloquium Series, Cal Poly Pomona, December 2015

Bernhard Klingenberg

"Multiple Comparisons of Marginal Probabilities Following GEE Estimation"
30th International Workshop on Statistical Modelling, Linz, Austria, July 2015

"Short Course on Modeling Categorical Longitudinal Data"
City of Hope Cancer Research Center, Pasadena, CA, April 2016

Susan Loepp

"Protecting Your Personal Information: An Introduction to Encryption"
Richard R. Bernard Lecture, Davidson College, September 2015

"Dimensions of Formal Fiber Rings"
AMS-AWM Special Session on Commutative Algebra, Joint Mathematics Meetings, Seattle, WA, January 2016

"Polynomials, Power Series and Cool Theorems Proved by Undergraduates"
Common Hour Talk, Davidson College, October 2015
Southwestern Undergraduate Mathematics Research Conference, Invited Speaker, Arizona State University, Tempe, AZ, February 2016

"What's Beyond the Curriculum?"
MAA Committee on the Undergraduate Program in Mathematics Panel Discussion, Invited Panelist, Joint Mathematics Meetings, Seattle, WA, January 2016

"To Detect Errors is Human, to Correct them Divine: Using Math to Correct Errors"
Norman Johnson Lecture Series, Wheaton College, March 2016

"The Hat Game"
Senior Seminar, Wheaton College, March 2016

Steven Miller

"Lessons Learned and Learning from Years of Experiential Classes"
Presentation to Delegation from a Hong Kong Liberal Arts College, June 3, 2015

"The Power of Multiple Proofs: Extending Pythagoras"
Williams Summer Science Talk, Williams College, June 30, 2015

"A Ramsey Theoretic Approach to Function Fields and Quaternions"
(given by *Megumi Asada '17* and Sarah Manski) University of Connecticut, July 28, 2015

"The Power of Multiple Proofs: Extending Pythagoras"
Hampshire College Summer Studies in Mathematics, July 28, 2015

"Panel Discussion on `A Lego Brickumentary'"
led discussion at Images (Williamstown, MA) after showing the documentary, August 8th and 9th, 2015

"Research Opportunities in Math and Science at Williams College"
panelist and organizer for summer prospective science students, August 14, 2015

"Pythagoras at the Bat: An introduction to Statistics and Modeling, Sample Math/Stats Class for Prospective Williams Students"
Wege Auditorium, August 14, 2015

"Sharpness Of Falconer's Incidence Theorem In Higher Dimensions"
(given by *Eli Goldstein '16* and Jonathan DeWitt), Young Mathematicians Conference, Ohio State, August 21, 2015

"Biases in Second Moments of Satake Parameters of L-Functions"
(given by *Megumi Asada '17*), Young Mathematicians Conference, Ohio State University, August 21, 2015

"Quaternionic Ramsey Theory"
(given by Sarah Manski and Gwyneth Moreland), Young Mathematicians Conference, Ohio State University, August 22, 2015

"Low-Lying Zeros of Families of L-Functions"
(given by Blaine Talbut and Gwyneth Moreland), Young Mathematicians Conference, Ohio State University, August 22, 2015

"A Twisted Second Moment for Automorphic L-Functions"
(given by *David Burt '17* and Blaine Talbut), Young Mathematicians Conference, Ohio State University, August 22, 2015

"One-Level Density for Cusp Forms of Arbitrary Level"
(given by Jonathan DeWitt), Young Mathematicians Conference, Ohio State University, August 22, 2015

"From M&Ms to Mathematics, or, How I Learned to Answer Questions and Help my Kids Love Math"
Maine-Quebec Number Theory Conference, October 3, 2015

"Biases in Moments of Satake Parameters and Models for L-function Zeros"
(with Kevin Yang), Maine-Quebec Number Theory Conference, October 3, 2015

"Large Gaps Between Zeros of L-Functions Associated to GL(2) Cusp Forms"
(given by *David Burt '17* and Blaine Talbut), Maine-Quebec Number Theory Conference, October 3, 2015

"A Ramsey Theoretic Approach to Finite Fields and Quaternions"
(given by Sarah Manski), Maine-Quebec Number Theory Conference, October 3, 2015

"From the Manhattan Project to Elliptic Curves"
Washington State University, October 12, 2015

"Benford's Law: Why the IRS Cares About Algebra and Number Theory (And Why You Should Too!)"
SACNAS, Washington, DC, October 2015
PME Induction Ceremony, Holy Cross College, April 20, 2016

"Careers in Academia"
Panelist at the 2015 Field of Dreams Conference, Birmingham, Alabama, November 7, 2015

"Biases in Moments of Satake Parameters and in Zeros Near the Central Point in Families of L-Functions, Computational Aspects of L-functions"
ICERM, Providence, RI, November 10, 2015

"Building YouTube University Brick by Brick"
AMS-MAA Special Session on Innovative Ideas in Enhancing Success in Mathematics Classes, Joint Meetings of the AMS-MAA, Seattle, January 6, 2015

"The Fibonacci Quilt Sequence: A Generalization of Zeckendorf Decompositions with Non-Uniqueness"
(presented by Dawn Nelson, joint with M. Catral, P. Ford and P. Harris), AMS Session on Number Theory II, Joint Mathematical Meetings, Seattle, January 7, 2016

"Balancing Responsibilities in Academia"
panelist at the 30th Automorphic Forms Workshop, Wake Forest University, March 7, 2016

"Biases in Moments of Elliptic Curve"
30th Automorphic Forms Workshop, Wake Forest University, March 8, 2016

"Success and/or Significance, A Musician and Mathematician Discuss Beauty, Perfection, and Faith in the Liberal Arts"
Veritas forum, Williams College, April 14, 2016

Frank Morgan

"Isoperimetric Problems with Density"
American Mathematical Society, Stony Book, NY
Preskensis Dinner, Framingham, MA

"Soap Bubbles and Mathematics"
Massachusetts College of Liberal Arts, North Adams, mA

"The Future of the AMS Notices"
Mathematical Association of America, Muhlenberg College
Lehigh University Geometry and Topology Conference

"Joel and Soap Bubbles"
JoelFest, University of California, Berkeley

Allison Pacelli

"Albany Math Content Workshops for K-2 Elementary School Teachers"
Albany, NY, October 16, December 18, 2015 & January 21, April 8 and May 20, 2016

"Building STEM Learning in Elementary Schools, A Workshop for Principals"
Albany Central School District, Albany, NY, October 23, 2015 (Part I) and January 20, 2016 (Part II).

Eyvindur Palsson

"Finite Point Configurations in Thin Sets"
Combinatorics Seminar, University of Rochester, February 2, 2016

"Multilinear Phenomena in Analysis and Related Areas"
Department of Mathematics Colloquium, University of Illinois, Urbana-Champaign, December 10, 2015

"A Look at the Distinct Distance Problem and Crescent Configurations"
Mathematics Colloquium, Bard College, December 8, 2015

"Finite Point Configurations and Multilinear Radon Tranforms"
Analysis Seminar, Yale University, December 1, 2015
Mathematics Department Seminar, Colgate University, October 15, 2015

"Finite Point Configurations"
Special Session on Geometric Aspects of Harmonic Analysis, Joint Meeting of the AMS, EMS and SPM, Porto, Portugal, June 12, 2015

International Conference on Harmonic Analysis and Applications, the Graduate Center of City University of New York, New York New York, June 2, 2015

Cesar Silva

"Weak Rational Ergodicity Does Not Imply Rational Ergodicity"
Ergodic Theory and Dynamical Systems Conference, Bedlewo, Poland, November 27, 2015

"Strict Doubly Ergodic in Nite Transformations"
AMS Special Session on Ergodic Theory and Dynamical Systems, North Dakota, April 16, 2016

Mihai Stoiciu

"Transition in the Microscopic Eigenvalue Distribution of Various Classes of Operators"
The Fourth Najman Conference on Spectral Problems for Operators and Matrices, Opatija, Croatia, September 2015

"Zeros and Eigenvalues on the Unit Circle: An Investigation of Random Orthogonal Polynomials and Their Associated Random Unitary Matrices"
Lenora Lecture in Mathematics, Oberlin College, January 2016

"Randomness, Well-Posedness, and Bertrand's Paradox"
Eaves Lecture in Mathematics, University of Kentucky, February 2016

Post-Graduation Plans of Mathematics and Statistics Majors

Alvaro Aleman	Working as a Data Analyst at Maguire Associates
Katherine Bennett	Working as a Fellow in the class of 2016 at Venture for America
Emily Berg	Working as an Analyst at DigitasLB's Boston office
Jonathan Berry	Assistant Coach for the Williams College Wrestling team
John Bihn	Working as an Analyst at Cornerstone Research in Boston
John Damstra	Working as a Research Assistant at the International Monetary Fund in Washington, DC, then applying to grad school
Emmanuel Daring	Teaching Fellow in mathematics and chemistry at St. George's School in Middletown, RI
Samuel Donow	Working as a Core Developer at Hudson River Trading LLC in New York City
Max Elgart	Working for the Investment Banking Division of Morgan Stanley in New York City
Gregory Ferland	Ski Bum in Salt Lake City, Utah
Nicole Feshbach	Working as an Associate at Triage Consulting Group in San Francisco
Jace Forbes-Cockell	Working as an Analyst at a Wealth Management firm
Eva Fourakis	Working in a psychology lab at Princeton University
Mary Gong	Pursuing a Ph.D. in Economics at MIT
Beau Horan	Pursuing a Sport Management MS/MBA dual degree at the University of Massachusetts, Amherst
Karen Huan	Working as a Consultant at Booz Allen Hamilton
Willem Humes	Working as a Hedge Fund Analyst at Appomattox Advisory in New York
Rachel Ji	Working at Credit Suisse in New York City
Logan Jester	Admitted into a graduate-level program called the Institute for Rowing Leadership (IRL), taking classes in fields such as biomechanics, coaching philosophy, and team management
Catherine Jiang	Working for an Economic Consulting firm in New York City
Gregory Kehne	Planning on attending Carnegie Mellon's Algorithms, Combinatorics, and Optimization Ph.D. program
Abraham Kirby-Galen	Teaching high school math at King's Academy in Madaba, Jordan
Alexander Kling	Working in Management Consulting for Bain and Company
Andrew Leary	Working as an Associate Consultant at Bain & Company in Boston
Joel Lee	Working as an Implementation Consultant at Fast Enterprises LLC in Denver
Lawrence Luo	Working as an Analyst at Appomattox Advisory, in New York City
Blake Mackall	Working on the Strats team in Investment Banking at Goldman Sachs

Peter McDonald	Working at Parthenon-EY
Alexander Meyer	Pursuing a Ph.D. in Applied Mathematics at the University of California, Davis
Ashwin Narayan	Pursuing a Ph.D. in Applied Mathematics at MIT
Christopher Owyang	Working as a Management Consultant at Oliver Wyman
Daniel Potter	Teaching music and/or math at an independent school
Jose Raventos	Working at Bain & Company
Mia Smith	Teaching upper high school math at the Williston Northampton School
Jillian Stallman	Abroad in Sweden, Spain, Ghana and Argentina on the Williams Chandler Fellowship, studying migration. Then planning on attending graduate school in economics.
Gabriel Staton	Pursuing a Ph.D. in Mathematics at the University of South Carolina, Columbia
Michael Stone	Working as an Analyst at Analysis Group in Boston
Matthew Tarduno	Working as an Economics Research Assistant at Stanford University
Jane Thompson	Working at a tech start up, Cognius in Cambridge
Roger Vargas	Pursuing a Ph.D. in Systems Biology at Harvard University
Jeffrey Wang	Pursuing a Ph.D. in Economics at Harvard University
Howard Weiss	Working as a Paralegal at Rose, Chinitz & Rose in Boston

Neuroscience

The Neuroscience Program continues to flourish, with a strong set of concentrators and faculty drawn from both the Biology and Psychology Departments teaching the courses specific to the program as well as a strong slate of electives. Heather Williams co-taught the core Neuroscience course and taught the senior capstone course and Animal Behavior; Lauren Williamson taught the core Neuroscience course and Brain, Behavior and the Immune system; Tim Lebestky taught Neural Development and Plasticity; Amie Hane taught Early Experience and the Developing Infant; Matt Carter taught Neural Systems and Circuits; Martha Marvin taught the core labs and supported many parts of the program.

Our students continue to conduct research with neuroscience faculty, exploring topics such as regulation of torpor by hypothalamic neurons (with Matt Carter) and the role of the immune system in regulating learning (with Lauren Williamson). Thirteen graduating seniors completed the neuroscience concentration in 2015. Lauren Claypoole completed a neuroscience thesis with highest honors, and eight other concentrators did neuroscience-related research for honors work recognized by the Biology and Psychology departments. Kathryn McNaughton was awarded the Patricia Goldman-Rakic Prize in Neuroscience for 2015.

Eleven students were named as Neuroscience Class of 1960s Scholars. The Neuroscience Class of 1960s Scholars program co-sponsored five speakers during the year. Ten students also attended the fall symposium on Neuroendocrine studies at the University of Massachusetts. *Shivon Robinson '11* came to visit from her graduate program at University of Pennsylvania and gave a talk during Winter Study about her research and her path from the Neuroscience Program to graduate school. She is currently studying the role of opioid drugs on motivation and depression, and her talk was well attended.

During National Brain Awareness Week (March 14-18), more than a dozen students participated in activities on campus and in the community to learn and teach neuroscience. Professor Williamson and six students visited Williamstown Elementary School 6th graders to introduce brain anatomy and function; in part by decorating swim caps with the lobes of the cortex. Students also hosted a brain-themed "stressbusters" event for their peers during the hectic week of midterms prior to Spring Break; the glucose and fun activities were appreciated by all. Headlining Brain Awareness week was *Dr. Christina Williams '75*, who returned to campus to give a talk for the community entitled "Neuroplasticity: How Food and Fitness Boost your Memory".

Professor Hane maintains a facebook page for the Neuroscience Program; it can be viewed at https://www.facebook.com/Williamsneuro, and provides information and pictures about activities such as brain awareness week, thesis presentations, and other neuroscience events and information.

Martha Marvin continues to refine and teach the laboratories for Neuroscience (NSCI 201). She again co-taught her Winter Study course, Project BioEyes, which trains Williams students to teach genetics and development to the 4th graders at Williamstown and Lanesborough elementary school. She also mentored three honors students and two research assistants this year. Research in the Marvin lab investigates stress responses and the development of the cardiovascular system.

The cardiovascular work focuses on signaling pathways that may be modified by environmental conditions. Small heat shock proteins protect animals from temperature stress. A member of this family called *hspb7* is necessary both to accurately designate the left side of an embryo, and to prevent overgrowth of heart valves. *Ashley Ngo '16, Naomi Currimjee '17* and *Christie Black '15* knocked out *hspb7* using the CRISPR/Cas9 system. We will soon be able to analyze homozygous mutants to better understand the role of this protein. Individuals respond differently to environmental challenges, possibly due to genetic variations in protective genes. Activity of Cox-2, the target of the anti-inflammatory drug Vioxx, is critical for embryonic heart valve development. *Ashley Ngo '16* found that simultaneous loss of both *hspb7* and Cox-2 activity is lethal, indicating that reduced *hspb7* makes embryos more vulnerable. Similarly, although estrogen has no effect on heart development by itself, *Jacqueline Harris '16* found that low levels of environmental estrogens potentiate birth defects through interactions with other developmental

pathways.

Early life stress in humans can cause long-lasting behavioral and physiological abnormalities associated with disorders such as depression and PTSD. *Tracey Kim '17* developed behavioral assays to distinguish between stressed, unstressed and Prozac-treated fish embryos so that they may be used to model changes in the stress response. *Bethany Berry '16* created mutation in *fkbp5*, a gene known to modulate the stress response. These mutant fish are predicted to have greater resilience to stress.

(For information about the activities of other Neuroscience faculty, please see the sections in their home departments: Biology for Carter, Lebestky and Williams, and Psychology for Hane, Sandstrom, Williamson, and Zimmerberg.)

Post-Graduation Plans of Neuroscience Concentrators

Bethany Berry	Research assistant, lab to be determined
Lauren Claypoole	Research coordinator, Center for Women's Mental Health, Massachusetts General Hospital
Madeline Epsten	Undecided
Brian Levine	Specialist at Close Concerns (translating diabetes research into practice)
Kathryn McNaughton	Sara S. Sparrow Clinical Neuroscience Fellow at Yale University
Conor Mook	Research Associate at Intrexon, San Francisco (vaccine development)
Sarah Pier	Hubbard Hutchinson Fellow in Theatre
Elise Pitmon	Ph.D. program in Neuroscience at University of Vermont
Abigail Pugh	Post-baccalaureate Pre-clinical Program in Communication Disorders at UMass Amherst
Luxi Qiao	Herchel Smith Fellowship at Oxford University / Fullbright research fellowship in Germany
Anna Ryba	Research assistant at the National Institutes of Health, spinal regeneration lab
Sarah Wieman	Research assistant at the Center for Anxiety and Traumatic Stress Disorders at Mass General Hospital
Laura Ureste	preparing for Physician's Assistant Master's program

Neuroscience Class of 1960s Scholars

Madeline Epsten '16	Brian Levine '16	Jacob Sperber '18
Hussein Fareed Bukhari '18	Kathryn McNaughton '16	Kelly Tellez '17
Marianna Frey '18	Conor Mook '16	Maria Vicent Allende '17
Sara Lehman '17	Anna Ryba '16	

Neuroscience Events and Colloquia

Fifteenth Annual Symposium of the Center for Neuroendocrine Studies, University of Massachusetts.
"**Promiscuous Molecules: Hormones, Immunity, and Evolution in the Brain",** Sept. 26 2015. Speakers: Tracy Bale (U. Penn), Staci Bilbo (Duke University), Colin Saldanha (American University), and Harold Zakon (University of Texas) - *attended by ten Neuroscience concentrators.*

Michael Goldstein, Cornell University
"Emergence of Complex Communication from Simple Interactions: Lessons from Songbirds and Human Infants", October 30, 2015

David Weinshenker, Emory University
"Norepinephrine-Dopamine Interactions Underlying Addiction and Arousal", November 13, 2015

Michael Krashes, NIH
"Hunger-drive motivational state competition", March 4 2015

Christina Williams, Duke University
"Neuroplasticity: How Food and Fitness Boost Your Memory", March 15, 2016

Kai Zinn, California Institute of Technology
"Control of synaptic connectivity by an interacting network of cell surface proteins", April 22, 2016

Physics Department

Having wrapped up another year serving as Dean of the College, Professor Sarah Bolton will leave to become President of the College of Wooster in Ohio. We congratulate Professor Bolton and thank her for her many important contributions to the Physics Department and to the College. She will be missed, and we wish her all the best.

It was a busy hiring season for the Physics Department. We will be delighted to welcome Drs. Catherine Kealhofer and Swati Singh as assistant professors in our department this coming fall. Dr. Kealhofer is an experimentalist who develops tools for generating ultrafast electron pulses, which can be used to probe the properties of materials with high resolution. Dr. Singh is a theorist who studies quantum phenomena in atomic, optical, and condensed matter systems. In the fall of 2017, we will welcome a third new assistant professor into our department, Dr. Kate Jensen, an experimental materials scientist.

Research with students continues to be a central activity of physics department faculty. In the summer of 2015, 17 students did research with physics faculty, and 18 are signed up to do research in the department this coming summer, including 10 students who plan to write senior honors theses. The year we were proud to learn that the American Physical Society selected *Ben Augenbraun '15* as winner of the 2015 LeRoy Apker Award. This national award is the highest honor for physics research by an undergraduate student in the United States. Only two winners are chosen each year. Ben worked with Prof. Tiku Majumder at Williams and is continuing his physics education as a graduate student at Harvard University.

Professor **Daniel Aalberts** was delighted to publish a paper in *Nature* this year. In the classroom, he developed *Condensed Matter Physics* (PHYS 451), and taught *Seminar in Modern Physics* (PHYS 151) and *Math Methods for Scientists* (PHYS/MATH 210). In his lab, *Bijan Mazaheri '16* completed an honors thesis RNA Macrostates and Macrokinetics, post-bac *Michael Flynn '15* worked on the MacroFold program to efficiently compute RNA folding states, and summer RA *Daniel Wong '17* designed synonymous mRNA sequences to increase protein expression. Aalberts also did science outreach presentations for the Williams College Children's Center.

The 2016-2016 academic year was all about electromagnetism for Assistant Professor **Charlie Doret**. Doret taught *Electromagnetic Theory* (PHYS 405T) during the fall followed by *Electromagnetism and the Physics of Matter* (PHYS 132) in the spring. Doret also pioneered a new winter-study course during January: *Wood and Woodturning* (PHYS 018). Taught to eight students, the course was centered on hands-on instruction at benchtop wood lathes set up in the Bronfman Science Center while also introducing a few topics from metallurgy and forestry.

The year was busy for Doret in the lab as he continued to work towards trapping atomic calcium ions for use in experiments on quantum simulation. This is where one quantum mechanical system is used to emulate the behavior of a second system. Such systems are challenging to study in the laboratory. Present efforts remain focused on construction of the experimental apparatus, with major contributions during the year from several students. *Sierra Jubin '17, Owen May '17,* and *Elena Polozova '17* spent summer 2015 working on the design and construction of the vacuum chamber in which ions will be trapped, an ion fluorescence imaging system, and a temperature-controlled isolation chamber for use in laser stabilization, respectively. Thesis student *Ariel Silbert '16* tied all of those pieces together and added additional electronics and software such that the lab is now ready to attempt to trap its first ions.

Ariel and Sierra accompanied Doret to the APS DAMOP conference in Providence, RI during late May, presenting a poster on their work in the lab. Ariel will be heading off to an internship at scientific service company E4Sciences where she will apply skills developed at Williams to problems in sustainable engineering and clean energy. Best wishes to Ariel!

The group will be picking up where Ariel left off during summer 2016. Sierra will be building upon her work from last summer, now as an incoming thesis student, and will be joined by *Will Fung '19*. After (hopefully!) trapping the group's first ions, summer work will shift towards design and assembly of digital electronics to be used in experiment control. *Sarah Stevenson '17* will begin senior thesis work in July after returning from study abroad in Germany. Doret will also be co-supervising *Iona Binnie '19* and *Derek*

Galvin ’18 at the start of the summer. Iona and Sam will be building new external-cavity diode lasers for use in *Quantum Physics* (PHYS 301) laboratory prior taking up work with newly arriving Assistant Professor Catherine Kealhofer.

McElfresh Professor of Physics **Kevin Jones** taught Quantum Physics (PHYS 301) in the fall and Vibrations, Waves and Optics (PHYS 202) in the spring. The accompanying lab plays an important part of these two courses as it works to prepare students for independent laboratory research.

Prof. Jones continues a long-standing research collaboration with the internationally acclaimed atomic physics research group headed by Dr. William Phillips of the National Institute of Standards and Technology. The group has recently moved (in large part) to new labs on the University of Maryland campus as part of the NIST/UMD Joint Quantum Institute. Jones will be spending the academic year 2016-17 there, continuing experiments on quantum enhancements to interferometry, quantum illumination and the propagation of quantum information through fast and slow light media. *Ashay Patel ’18*, who just completed Physics 202, is working with Jones for summer 2016 continuing work done in summer 2015 by *Anneliese Rilinger ’17*. Jones was able to obtain a grant from NIST to support another 202 graduate, *Jack Scallata ’18*, to work at NIST-Gaithersburg for the summer. Jones’ work is supported in part by a grant from the National Science Foundation.

Jones served on an outside review committee for Vassar College, reviewed National Science Foundation proposals and refereed papers for several major physics journals. Jones enjoyed sharing some of his recent research on in two lectures to an enthusiastic group from the OLLI adult education program run by Berkshire Community College.

During the 2015-16 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 planning and design for the exciting new science center project. In the fall he taught, *Mechanics and Waves* (PHYS 141), and this spring he taught *Statistical and Thermal Physics* (PHYS 302).

Majumder continued to pursue diode laser and atomic physics experiments in his research lab, teaming up with senior thesis students *Allison Carter ’16* and *Sauman Cheng ’16*, as well as postdoc Dr. Milinda Rupasinghe. The group is supported by a generous grant from the National Science Foundation. Allison will be headed to the University of Maryland to start a Ph.D. in physics this fall, while Sauman heads to Boulder, CO to begin a mechanical engineering Ph.D. program at the University of Colorado.

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). New results were obtained by both thesis students this year, and these are being written up for publication this summer. Incoming thesis students *Nathaniel Vilas ’17* and *Eli Hoenig ’17* will begin their research this June, and will be joined by sophomores *Bingyi Wang ’18* and *Hallee Wong ’18* during the summer of 2016.

A large group of students from both the Majumder and Doret groups attended this year’s DAMOP meeting in Providence, RI in May of 2016. At the meeting, two group posters were presented, and recent Majumder lab graduate, *Ben Augenbraun ’15* (currently at Harvard) was presented with the 2015 APS LeRoy Apker Award for his outstanding undergraduate research accomplishments. Ben also gave an invited talk on the thesis work that he completed at Williams (work that was continued this year by Allison Carter).

Professor **Jefferson Strait** and his students build and study optical fiber lasers that produce pulses of light less than 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 the physics of short pulses of light propagating in fiber, an essential element of high speed fiber optic communications.

During the summer of 2015 *Ashay Patel ’18* and

honors thesis student *Brian Cintrón '16* worked with Strait measuring the spectrum of a new fiber laser built the previous year. The bandwidth of the laser indicated that it could support pulses as short as 0.4 picoseconds. During the academic year, Brian built an erbium-doped fiber amplifier, boosting the output power of the fiber laser, enabling him to measure an autocorrelation of the pulses by two-photon absorption, a technique that allows one to infer the duration of pulses that are too short to measure with conventional electronics. Brian found that the pulses are approximately 0.8 picoseconds long, twice the minimum duration that the bandwidth could support. In his thesis Brian concluded that dispersion broadens the pulses. Future work will include modifying the fiber laser to compensate for this dispersion.

In recent years Strait has developed an interest in energy policy and technology. He has taught a course for non-science majors called *Energy Science and Technology*, covering electric power generation and distribution, and energy use in transportation, lighting, and buildings. In March he attended the 2016 Wind Energy Research Workshop at UMass Lowell in order to learn of current research in that field. He also served as a member of the Campus Environmental Advisory Committee

Strait served as the college's pre-engineering advisor. In May he attended the AALAC/NSF Engineering Connections Workshop in Saint Paul, Minnesota, to learn how liberal arts colleges provide pathways to engineering.

Associate Professor **Frederick Strauch** was on sabbatical during the 2015-16 academic year. During the summer and fall of 2015, he visited the Institute for Quantum Computing at the University of Waterloo and the Joint Center for Quantum Information and Computer Science (QuICS), a partnership between the University of Maryland and the National Institute for Standards and Technology.

Strauch continued his theoretical work in superconducting quantum circuits, quantum algorithms, and other applications to quantum information processing. His most recent work has addressed novel ways to encode, manipulate, and readout information in superconducting resonators and advanced coupling schemes for quantum logic operations on superconducting qubits and resonators. He has published work in Physical Review A (with students *Roshan Sharma '13* and Elena Polozova [now at MIT]). For the summer of 2016, he will be working with *Will Kirby '17* and *Michael May '17*.

In the fall, Professor **David Tucker-Smith** taught *Spacetime and Quanta* (PHYS 107), an introduction to special relativity and other topics in modern physics for non-majors. In the spring, Tucker-Smith taught *Gravity* (PHYS 418T), an upper-level tutorial on Einstein's general relativity. He greatly enjoyed teaching this course in tutorial format for the first time.

Tucker-Smith continued his research in theoretical particle physics. In the summer of 2015 He worked with summer students *Matt Radford '16* and *John Russell '16* studying the experimental signatures of two different extensions of the Standard Model of particle physics. John will continue this work as his senior honors project while Matt will continue his work as an independent study during the fall semester. John's thesis will develop strategies for using data from the Large Hadron Collider to search for a new "force carrier" particle that interacts preferentially with the top quark, the heaviest particle of the Standard Model. In the spring semester Tucker-Smith supervised *Maria Prado '17* in another particle physics independent study, in preparation for Maria's thesis work next year. During the summer of 2016, Tucker-Smith will work on research projects with *Alex Semendinger '18* and *Ian Banta '19*. In other activities, Tucker-Smith participated in a workshop on semiclassical probes of quantum field theory at the University of Massachusetts.

In the summer of 2015, Professor **Bill Wootters** worked with three students on two distinct projects. *Will Kirby '17* did a quantitative study of quantum entanglement: he identified an elegant entanglement inequality that is always preserved under "noisy" operations on single particles. Meanwhile *Jay Choi '17* and *Sam Steakley '17* started a new project in which they investigated a recently proposed method of approximating the quantum dynamics of a collection of interacting spin-1/2 particles. Approximation methods are important for this problem because the exact dynamical computation becomes exponentially more difficult as the number of particles increases. Jay and Sam's research, which was mostly numerical, laid the groundwork for the senior thesis project of *Ashwin Narayan '16,* who, in addition to doing further numerical tests, also proved rigorous theorems regarding the effectiveness of the new approximation

method. For certain kinds of interaction, Ashwin showed that even though the approximate solution sometimes veers far from the exact solution, there are specific observable quantities whose values the approximation gets exactly correct.

In the summer of 2016, Professor Wootters will work with *Sam Alterman '18*, to try to complete a project started a couple of years ago by *Becky Durst'17* and *Sarah Fleming'17*. The goal is to prove rigorously, for certain simple physical systems, an intriguing connection between quantum mechanics, classical mechanics, and statistical mechanics that Becky and Sarah identified numerically.

In addition to giving talks to audiences of physics students and faculty, Professor Wootters gave a public lecture on quantum nonlocality as a contribution to Sci-Tech Café, which is a regular series of popular lectures on science and technology held in Northampton, MA. Questions from the audience during the presentation stretched what would have been a twenty-minute talk into an hour and a half, with most of the questions—indeed some of the best questions—coming from children.

Class of 1960 Scholars in Physics

Allison L. Carter
Sauman Cheng
Brian Cintron
Bijan Mazaheri
Ashwin Narayan
John C. Russell
Ariel L. Silbert

Some products of the woodturning winter study class (*PHYS 18*)

Physics and Astronomy Colloquia

Miles Blencowe, Dartmouth College
"Mechanical Systems in the Quantum Regime"

Robin Blume-Kohout, Sandia National Laboratory
"Quantum computing and the War on Noise"

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

Matthew Evans, MIT Physics Department
"Gravitational Wave Detection with LIGO"

Michael Goldman, Harvard University
"Nature's Own Trapped Atom: Coherent Control of Atom-Like Defects in Diamond"

Gordon Jones '89, Hamilton College
"Fundamental Physics with Decaying Neutrons"

Kevin Jones
"Faster than a speeding bullet? Kid's Stuff. Faster than Light!"
Bronfman Science Center Lunch Talk, April 2016

Duane Lee '01, MIT Shanghai Astronomical Observatory
"Understanding the Nature of Chemical Abundance Ratio Distributions (CARDS) in Galactic Components and Dwarf Galaxies"

Reina Maruyama, Yale University
"DM-Ice17 Dark Matter Experiment at the South Pole"

Craig Martin, UMASS, Amherst
"Development of a Model System to Study the Co-transcriptional Folding of Large Structured RNAs in Biology and in Biotechnology"

Michael Person, MIT
"The Atmosphere of Pluto from Occultation Studies"

Elizabeth Petrik, Harvard
"The Search for the Electric Dipole Moment of the Electron"

Jonathan Petruculli, SUNY Albany
"Computational Phase Imaging"

Dr. Swati Singh, ITAMP, Harvard
"Coupling single quantum systems to spin baths"

Fred Strauch
"A bit about qubits: quo vadis quantum computer?"
Joint Physics & Astronomy and Computer Science Colloquium, November 2015

Scott Tenenbaum, SUNY Polytechnic Inst.
"sxRNA: A Trans-Regulated, miRNA Activated, Switch Technology"

David Tucker-Smith
"After the Higgs"
Summer Science Lunch, July 2015

Off-Campus Physics Colloquia

Daniel Aalberts

"RNA features controlling protein expression"
Talk at RNA2015, Benasque, Spain, July 2015

"Intuitive ways of visualizing RNA macrostates"
Talk at RNA2015, Benasque, Spain, July 2015

"How mRNA modulates gene expression"
Colloquium at Ohio State University, October 2015

"Liberal arts teaching as a career"
Ohio State University, October 2015

"RNA Secondary Structure Macrostates"
Poster Presentation (Bijan Mazaheri 16 and DPA) at The RNA Symposium, U. Albany, March 2016

"Synonymous mutations improve protein yield"
Poster presentation (*Daniel Wong '17* and DPA) at The RNA Symposium, U. Albany, March 2016

"Efficient sampling of RNA secondary structures"
Poster presentation (*Michael Flynn '15* and DPA) at The RNA Symposium, U. Albany, March 2016

Charles Doret

"Quantum Simulations with Trapped Calcium Ions"
Physics Dept. Colloquium, Amherst College, April 2016

Kevin Jones

"Is There a Cosmic Speed Limit?
Frontiers in Science lecture series sponsored by the Osher Lifelong Learning Institute (OLLI) of Berkshire Community College, held at Williams College , October 2015

"Can We Go Faster?"
Frontiers in Science lecture series sponsored by the Osher Lifelong Learning Institute (OLLI) of Berkshire Community College, held at Williams College , October 2015

Tiku Majumder

"Are we there yet: Clocks, Navigation, and Cold Atoms"
Williams College Campaign kickoff event, Palm Beach, FL, January 2016

"Precise measurement of the $8P_{1/2,3/2}$ state hyperfine splittings and isotope shift in ^{203}Tl and ^{205}Tl using two-step laser spectroscopy"
APS Division of Atomic Molecular and Optical Physics meeting, Providence, RI, May 2016

"Precise Measurement of the Indium $6p_{1/2}$-state polarizability using an Atomic Beam"
APS Division of Atomic Molecular and Optical Physics meeting, Providence, RI, May 2016

Fred Strauch

"Quantum Computing with Superconducting Resonator Qudits"
QuICS Seminar, October 2015

"Finding Faster Quantum Fourier Transforms"
KITP Workshop for Theorists at Undergraduate Institutions, University of California, Santa Barbara, June 2015

"Find Faster Quantum Fourier Transforms"
American University Department of Physics, October 2015

"Dephasing-induced Leakage in Superconducting Qubits"
American Physical Society March Meeting, Baltimore Maryland, March 2016

David Tucker-Smith

"Exotic decays of heavy B quarks"
A presentation to the ATLAS HQT working group, September 2015

William Wootters

"Einstein's spooky action at a distance"
Sci-Tech Café, Northampton, MA, January 2016

"Why does nature like complex probability amplitudes?"
Meeting of the Anacapa Society, KITP, Santa Barbara, June 2015

"Why does nature like the square root of negative one?"
Mount Holyoke College, January 2016
Amherst College, March 2016
City Tech, CUNY, March 2016

Post-Graduation Plans of Physics Majors

Name	Plans
Nicholas J. Brownrigg	Strategy consultant at Parthenon-EY in Boston
Allison L. Carter	Attending University of Maryland in the fall for a PhD in Physics
Sauman Cheng	Attending University of Boulder, CO for a PhD in Engineering
Brian A. Cintron	Internship at Bloomberg LP in Communications and PR Department
Alexander C. Ellison	Data Enginner with Denodo, a tech company in Palo Alto, CA
John H. Greenwald	Seeking employment
Joshua P. Harrington	Staff scientist at the environmental consulting firm RPS Iris Environmental
Benjamin M. Kaufman	Pursuing secondary school teaching opportnities
Bijan Mazaheri	Dr. Herchel Smith Fellowship at Cambridge, studying math, then PhD at Caltech
Ashwin Narayan	Attending MIT in the fall for a PhD in applied mathematics
Matthew N. Radford	Seeking employment
John C. Russell	Seeking employment
Mona Sami	Seeking employment
Ariel L. Silbert	Researcher at e4sciences, a company that provides sustainable engineering services
Mohammed D. Soussi	Software engineer at start up company, Daycation in Miami, FL

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 many opportunities to conduct research collaboratively with professors. These include empirical projects conducted within 300-level lab courses, work-study or research assistant positions, or in more formal independent studies. In 2015-16, seven students completed year long senior honors thesis research under the direction of a faculty advisor. 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 seventh year of the G. Stanley Hall Prize in Psychology, funded by a generous gift from the Chuzi family, parents of *Sarah Chuzi '07*, and given at graduation to a student who has demonstrated exceptional achievement in psychology. We were happy to award the prize to *Sarah Wieman '16* 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, as detailed below. We were thrilled to have two new faculty members in social psychology, Jeremy Cone and Laura Smalarz. Jeremy Cone's research examines a variety of important issues at the intersection of social and cognitive psychology, such as concerning nonconscious, or implicit, attitudes. Jeremy introduced *Social Judgment* (PSYC 342), to the Psychology Department. Laura Smalarz's research also concerns the intersection of social and cognitive psychology, specifically in the context of law and justice, such as concerning the influences on eyewitness identification. Laura has taken over teaching the very popular course, *Psychology and Law*, from Saul Kassin, whose retirement from Williams this year marked the conclusion of an enormously successful 35 years of teaching and research at Williams. During his years in the Psychology Department at Williams, Saul, the Massachusetts Professor of Psychology, rose to become one of most well-known and well-respected experts in psychology and law in the world. His research on the psychology of false confessions has had a profound impact not only on the academic scholarship in this area but also on the lives of numerous individuals who were exonerated based in part on Saul's research and/or testimony after spending years in prison for crimes they did not commit. Saul's teaching, scholarship, and mentoring made vital contributions to the Psychology department at Williams.

We were pleased to have our three visiting faculty stay on this year; Jeff Moher, teaching in cognitive psychology, Nicole Harrington, teaching in clinical psychology, and *Lauren Williamson '07*, teaching in neuroscience. 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.

Finally, we were delighted with the news that Marlene Sandstrom, Hales Professor of Psychology, was selected to be the Williams College's new Dean of the College, beginning in the 2016-17 academic year. This is a tremendous honor and great responsibility, and we know the College could not have made a better choice than Marlene.

Assistant Professor **Jeremy Cone** arrived at Williams in July of last year and has spent this year building the Implicit Cognition and Evaluation (ICE) Lab, which investigates the nature and development of relatively automatic, spontaneous, and unintentional social cognitive processes, including first impressions, attitudes, and intuitions. Three students, *Eva Fourakis '16, Madeline Epsten '16,* and *Emily Roach '16* joined the lab for the entire year, assisting in conducting studies exploring the role of persuasive messages on implicit attitude change as well as on implicit attitude generalization to novel objects. Additionally, Eva expanded her role in the lab in the Spring semester through the pursuit of an independent study on the role of construal processes in the development and change of implicit evaluations. *Kathryn Flaharty '18* joined the lab in the Spring semester, beginning work on a project exploring how facial cues interact with other information we learn about others to influence implicit responses. She will be continuing to work in the lab in the coming academic year.

In December, Cone published an article with Professor Ken Savitsky, *Jeffrey Rubel '17*, and former Williams faculty member Richard Eibach (now at the University of Waterloo) in the *Journal of Experimental Social Psychology* titled, "Haters are all the same: Perceptions of group homogeneity following positive vs. negative feedback." His work on rapid implicit evaluative change was also featured in *Scientific American Mind* in April.

In the Spring, he was invited to give a talk at the inaugural Judgment and Decision-Making Day held at the Carroll School of Management at Boston College titled "Singled Out: Biased selection for scrutiny alters third party responses to what that scrutiny reveals." He also co-chaired a symposium at the annual meeting for the Association for Psychological Science in Chicago on "New Evidence for Forming First Impressions Across the Lifespan." In the summer, he will give an invited talk at the "Psychology of Attitudes: Experience-Based versus Information-Based Attitude Processes" conference in Cologne, Germany titled "Changing Your Implicit Mind: New social-cognitive evidence for whether and how we can update our implicit first impressions."

Cone began serving as a Review Editor for the journal *Frontiers in Psychology*, as well as an ad-hoc reviewer for the *Journal of Experimental Social Psychology*. He will also serve as a reviewer for symposia submitted to this year's Society for Personality and Social Psychology (SPSP) annual conference. Finally, at Williams, he served on the Division III Research Funding Committee (DRFC) for the 2015-16 academic year.

Sadly, despite all of these positive developments, he is particularly unhappy to report that the ICE Lab got positively trampled this Spring in an inter-lab lawn game competition against the Smalarz lab, putting zero wins on the board over eight attempts. He will be anticipating a rematch next year after extensive training in the off-season.

Professor Emerita **Phebe Cramer** continued her research on the longitudinal study of personality development, studying especially defense mechanisms and narcissism. Based on this research, she published six new papers this year.

In July, she was invited to be a faculty member at a conference in Montreux, Switzerland where she presented her research work, and instructed the international participants on the use of her approach to assessing the presence of defense mechanisms in narrative material.

She 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.

This past year, **Susan Engel** completed a study, funded by the Spencer Foundation, titled: Does College Make Students More Thoughtful? *Chase Davenport '12, Kate Andersen '12, Jackie Lee '15, Hana Tomozawa '15* and *Candice Dyce '17* all worked on this project. As a companion piece to that project, Susan and *Irene Lim '16* conducted a yearlong interview study examining the impact of college on students who graduated 5-15 years ago.

Susan gave a keynote address on curiosity for The Conference on Learning and the Brain, as well as a series of community talks at various locations around the country, about the goals of education. She gave a talk at Mount St. Mary College, titled: Educating for

Happiness. She presented a paper on the development of children's ideas at a workshop titled Questions about Children's Questions, hosted by the Radcliffe Institute.

She published a paper titled "Can we talk? The Role of informal conversation in classrooms" in *Educational Leadership.*

She is an advisor to a project funded by the National Science Foundation being conducted at MIT, to see if social robots can foster narrative skills in 4-6 year olds. She is also advising a project called Math Talk, run by Omo Moses, Founding Director of the Young People's Project, designed to encourage parents to talk about math with their preschoolers.

The Program in Teaching events included presentations on home schooling, Montessori in the public sector, teaching creativity to middle schoolers, Philosophy for Kids, and Filmmaking with Students, among others.

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. Her honors students studied the individual and family psychological dynamics of concealment in LGBT+ individuals and the course of subclinical disordered eating and exercise behaviors and cognitions during the first year of college.

She published a study with *Ryan Jacoby '09,* and a chapter on research on change mechanisms in family therapy. With *Ellen Finch '16*, she wrote a successfully-funded grant for a pilot program in crowdfunding of scientific research, "What is True Recovery from Schizophrenia? Learning from Patients to Improve Outcomes Research." In November 2015, she presented "The therapeutic alliance in family therapy" as a panelist on the plenary, "Negotiating the therapeutic alliance" at the North American Society for Psychotherapy Research Regional workshop at the New School for Social Research, NY. At the June 2015 International Society for Psychotherapy Research Conference in Philadelphia, she was a panelist on two structured discussions: "The therapeutic relationship through different 'lenses': Expanding the scope of research and practice," and "*Psychotherapy Research*'s 25th Anniversary: How are the psychotherapy traditions evolving?" She was appointed to the Publications Board of the Society for the Advancement of Psychotherapy, for a three-year term, served on the Program Committee for the 2016 International Society for Psychotherapy Research Conference in Jerusalem, and as an external reviewer for the Adelphi University Undergraduate Psychology Program and Middlebury College Psychology Department.

Professor 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.* 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.

Associate Professor **Nate Kornell** continues his research on cognition, education, and self-regulated learning. He is funded from a $600,000 grant from the James S. McDonnell Foundation to study self-regulated learning. This year he was a consulting editor for *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 articles this year about how good learners are at evaluating both the amount they learn from studying and the amount they learn from their teachers.

This year, Visiting Professor **Jeff Moher** continued conducting research in his lab at Williams on human cognition, attention, and action. Several projects are ongoing that examine the role of distraction. For example, he is 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? Results from this work were presented in a conference last May, and will be presented this coming November. In addition, in collaboration with some colleagues from Johns Hopkins University, he began a project examining the brain mechanisms involved in learning to ignore irrelevant distractions over time. In this project, he is collecting electroencephalographic (EEG) data to examine electrical activity from the

brain. This method is non-invasive, involving the placement of electrodes along the surface of the scalp of human participants. It has been a great experience both for the undergraduates working in the lab and for the undergraduate participants to see real-time brain activity being recorded and analyzed in the lab. In addition, he has ongoing collaborations with colleagues at Brown University and Michigan State University.

Six undergraduate students have worked in the lab this year: *Hussain Bukhari '18, Christopher Lyons '17, Jane Dai '17, Alyza Ngbokoli '17, Austin Wruble '17,* and *Kenneth Park '17*. These students have played critical roles in collecting and analyzing data, along with providing creative input in designing and executing the above projects. Many of these students will be returning to the lab next year, including Jane, who will be doing a senior thesis. Moher also had two *Calvin Ludwig '18* and *Elijah Hale '19* working in the lab full time over the summer 2016 as part of the Williams Summer Science program.

Prof. Moher's other research activities over the past year have included the publication of several previous research projects in peer-reviewed journals, and presenting a talk on his research at the annual meeting of the Psychonomic Society (November 2015, Chicago, IL). Additionally, he attended the annual meeting of the Vision Sciences Society in St. Pete Beach, Florida, in May of 2016. He submitted two grant proposals for funding from private foundations, and is currently waiting to hear on the second proposal through the NARSAD Brain & Behavior research foundation. Finally, he was an ad-hoc peer-reviewer for a number of journals, reviewed conference submissions for the Cognitive Science Society, and became a Reviewing Editor and Frontiers in Perception Science.

Moher taught *Experimentation and Statistics* (PSYC 201) in both the Fall and the Spring. In addition to techniques he developed while teaching this course last year, he added a new component this year called "Track your own data." In this project, students were required to track, analyze, and present data from their own lives to the class. The assignment left a lot of room for creativity, and students came up with some very interesting ideas. The range of projects included examining patterns of social media use, tracking ticket sales patterns at the Williamstown theater and eating patterns at the cafeterias, determining what type of feedback is given most frequently by coaches, and examining the impact of web browsing on sleep patterns, to name a few. He looks forward to developing similar assignments in the coming year that allow students to apply the methods they learn in class directly to areas of interest outside the classroom.

Assistant Professor **Mariko Moher** focuses her research on the development of children's memory. This year, she worked closely with students to collect data and to present the lab's work. In the fall, she co-authored a presentation at the biennial meeting of the Cognitive Development Society with her former thesis student, *Alida Davis '14*. During the past year, *Becca Dunwoody '17, Ben Lin '17, Giulia McDonnell Nieto del Rio '18, Darla Torres '18,* and *Chris Zaro '19* worked with various local organizations (Berkshire Museum, Children's Museum of Science and Technology, Sand Springs Pool, Williamstown farmers' markets, among others) to work with children and examine how grouping impacts memory.

Last summer, Moher hosted a workshop at Williams College for cognitive development 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 Moher also served as a reviewer for *Cognition* and *Frontiers in Psychology*, and is a consulting editor for *Developmental Psychology*.

Professor **Marlene Sandstrom** studies children's social relationships. She is particularly interested in peer rejection, victimization, bullying, bystander behavior, aggressive behavior, popularity, and social influence. Professor Sandstrom spent the 2015-16 academic on sabbatical at Oxford University. During this time, she has been focusing on two primary projects: a book chapter on the peer context of relational aggression, and an empirical study of ostracism in childhood.

In addition to her own scholarship, Professor Sandstrom has served on the editorial board of *Journal of Youth and Adolescence* as well *Adolescent Research Review*. She has also been an ad hoc reviewer for a number of journals including *Developmental Psychology, Child Development, Journal of Abnormal Child Psychology,* and the *Journal of Early Adolescence.*

Professor **Noah Sandstrom** spent the 2015-2016 academic year serving as Director of the Williams-Exeter Programme at Oxford University. While in the UK, he 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 wellbeing. This collaboration led to a publication in the *Journal of Neurotrauma,* a presentation at a Williams Teach it Forward Campaign event in Boston, and a presentation to the Behavioural Neuroscience Unit at Oxford University. Professor Sandstrom attended the International Meeting on Steroids and the Nervous System in Torino, Italy in February 2015, as well as the Neuroscience School of Advanced Studies course on Cellular and Systems Mechanisms of Learning and Memory in May 2015. Professor Sandstrom will return to Williams during the summer and looks forward to teaching a newly developed tutorial on Neuroethics.

Assistant Professor **Laura Smalarz** began her first year in the Psychology Department at Williams College this fall. She set up her Psychology and Law research lab and worked together with students *Alex Stone '16*, *Ben Rosenblum '16,* and *Howie Weiss '16* on two research projects on eyewitness identification. She was appointed to the Research Advisory Board of the Innocence Project and has consulted with the Innocence Project's Strategic Litigation Unit and Policy Department on matters relating to eyewitness misidentification and false confession. She published two papers and a book chapter this year and presented her work at the Annual Meeting of the American Psychology-Law Society (AP-LS) in Atlanta.

Assistant Professor **Catherine Stroud** recently completed a 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. *Carey Marr '16* completed a senior honor thesis examining serotonergic vulnerability, early adversity, and stress generation. *Erin Curley '15* and Catherine presented their work on sexual activities, serotonergic vulnerability, and depression at the Annual Meeting of the Association for Behavioral and Cognitive Therapies (ABCT). Also, at ABCT Catherine and her colleagues presented their work examining the cortisol awakening response, interpersonal stress, and depression. In addition, Catherine and her colleagues presented their research exploring day-to-day links between diurnal cortisol and coping strategies at ABCT and the Society for Research on Child Development. Catherine and her colleagues published manuscripts documenting the contribution of recent stress and early adversity to trait-like individual differences in HPA axis activity in *Psychoneuroendocrinology* and *Developmental Psychobiology*, respectively. With *Jessica Fitts '12,* she published a paper examining the ways in which parents contribute to adolescents' use of rumination in the *Journal of Clinical Child & Adolescent Psychology*. She published research examining interpersonal style, emotion regulation, and sexual activity in the *International Journal of Sexual Health* with a colleague and three former students (*Stephanie Cardenas '14, Elizabeth Greiter '12,* and *Margaret Richmond '13)*. Catherine also co-authored a manuscript in *Journal of Abnormal Psychology* examining additive genetic risk, interpersonal stress, and depression in the, the findings of which were presented at three national conferences. a second manuscript was co-authored for *Journal of Affective Disorders* studying anxiety, depression, and negative anxiety response styles. Catherine has continued in her role as Associate Editor of *Family Process.*

Betty Zimmerberg continued her service as chair of the Psychology Department in the fall of 2015. In July, she attended the annual meeting of International Society for Developmental Psychobiology in San Sebastian, Spain. There she presented her research assisted by *Anika Mitchell '18* and *Lauren Steele '18* entitled "Early deprivation alters the development of affective and social behavior in rats selectively bred for an infantile trait." This research continued the Zimmerberg lab's epigenetic animal model that explores interactive effects of affective temperament and adverse conditions such as child neglect to better understand the deleterious effects of an early negative environment on brain development. In the summer of 2015, Lauren worked in the Zimmerberg lab on a joint project with Visiting Assistant Professor of Psychology *Lauren Williamson '07* and Alex Engel (Biology) on quantifying NK1 receptors. Other professional activities included serving on the Editorial Board of *Developmental Psychobiology,* and reviewing manuscripts for that journal as well as for several other neuroscience journals. Zimmerberg also continued her scholarship in neuroscience and art, writing an essay for a book entitled *Reframed: Perspectives on the Harvey R. and Madeleine P. Plonsker Collection.* This essay, "Constructing a Face," applied research findings in the neuroscience of face perception to the analysis of six works in the WCMA collection.

Psychology Colloquia

Wendy Silverman, Yale
"Improving Childhood Anxiety Treatment Outcomes by Involving Parents: How and for Whom?"

Sheldon Solomon, Skidmore
"Terror Management Theory"

Sue Hespos, Northwestern
"Concepts and Reasoning in Infancy"

Adam Galinsky, Columbia Business School
"From Glue to Gasoline: How the Same Processes that Bind People Together, Tear them Apart during Competition"

Nate Kornell
"Teaching Science Based on Cognitive Psychology Principles"
Talk delivered at Advances in Science Education

"The Science of Learning"
Talk delivered to Mt. Greylock students during Williams College Science Blast

Mariko Moher
"Infants' Abilities to Simultaneously Encode Multiple Ensembles"
Talk delivered during the Faculty Workshop Program at the Alliance to Advance Liberal Arts Colleges

Off-Campus Psychology Colloquia

Nate Kornell
"Why do Relatedness and Testing Influence Judgments of Learning: Heuristics or Beliefs?"
Poster presented with *Hannah Hausman '12* at the 56th Annual Meeting of the Psychonomic Society, November 2015

"Productive Struggle: Using Cognitive Science to Enhance Learning"
New York Chiropractic College, November 2015

"Why do Tests Enhance Learning?"
Middlebury College, November 2015

"Retrieval Attempts Enhance Learning Regardless of Time Spent Trying to Retrieve"
Paper presented with Kalif Vaughn at the 56th Annual Meeting of the Psychonomic Society, November 2015

"Lessons on How to Study: Evidence from Cognitive Psychology"
Annual meeting of the American Society of Plant Biologists, July 2015

Mariko Moher
"Young Children Automatically Access the Real-World Size of Objects"
Poster presented with B. Long, T. Konkle, G.A. Alvarez & S. Carey at the biennial meeting of the Cognitive Development Society, Columbus, OH, October 2015

"E Effects of Conceptual and Spatial Chunking Cues on Young Children's Working Memory"
Poster presented with *Alida Davis '14* at the biennial meeting of the Cognitive Development Society, Columbus, OH, October 2015

"Developmental Foundations of Memory"
Towson University, Towson, MD, December 8, 2015

"Developmental Foundations of Memory"
Hamilton College, Clinton, NY, December 10, 2015

Noah Sandstrom

"Hormones and Brain Damage"
Behavioural Neuroscience Unit, Oxford University, June 2015

"Sports, Concussion and Brain Injury"
Teach it Forward Campaign Event, Boston, MA, December 2015

Laura Smalarz

"Are eyewitnesses' Verbal Confidence Statements Related to Identification Accuracy?"
American Psychology-Law Society, Atlanta, Georgia, March 2016
Coauthors: Gary L. Wells and Yueran Yang

"Does the Confrontational Approach to Police Interrogation Mobilize Suspects with the Resources Needed to Resist Interrogative Influence?"
American Psychology-Law Society, Atlanta, Georgia, March 2016
Coauthors: Stephanie Madon, Max Guyll, Yueran Yang, and Curt More

Catherine Stroud

"Individual and Day-to-Day Differences in Coping Predict Diurnal Cortisol Patterns among Adolescent Girls"
Paper presented with M. Sladek & L. Doane at the biennial meeting of the Society for Research on Adolescence, Baltimore, MD**.** April 2016

"Additive Genetic Risk in the Serotonin System Interacts with Interpersonal Life Stress to Predict Depression"
Paper presented with S. Vrshek-Schallhorn, S. Mineka, R.E. Zinbarg, E.K. Adam, E.E. Redei, C. Hammen & M.G. Craske at the annual meeting of the Anxiety & Depression Association of America, Philadelphia, PA, April 2016

"Additive Genetic Risk in the Serotonin System Interacts with Interpersonal Life Stress to Predict Depression"
Paper presented with S. Vrshek-Schallhorn, S. Mineka, R.E. Zinbarg, E.K. Adam, E.E. Redei, C. Hammen & M.G. Craske at the annual meeting of the Association for Behavioral and Cognitive Therapies, Chicago, IL, November 2015

"Adolescent Sexual Activities and Depressive Symptoms: A Moderated Mediation Model of Serotonergic Vulnerability and Interpersonal Stress Exposure"
Poster presented with ***E.E. Curley '15*** & S. Vrshek-Schallhorn at the annual meeting of the Association for Behavioral and Cognitive Therapies, Chicago, IL, November 2015

"Does the Cortisol Awakening Response Interact with Acute Stress in Predicting Depressive Symptoms?
Paper presented with L.D. Doane & S. Vrshek-Schallhorn at the annual meeting of the Association for Behavioral and Cognitive Therapies, Chicago, IL, November 2015

"Rumination, Excessive Reassurance Seeking and Stress Generation Among Early Adolescent Girls"
Co-chair Oral Symposium; paper presented with ***E.E. Sosoo '13***, S. Wilson & ***E.E. Curley '15*** at the annual meeting of the Association for Behavioral and Cognitive Therapies, Chicago, IL, November 2015

"Rumination and Diurnal Cortisol Patterns in Adolescent Girls"
Paper presented with L.M. Hilt & L.D. Doane, at the annual meeting of the Association for Behavioral and Cognitive Therapies, Chicago, IL, November 2015

"Additive Genetic Risk in the Serotonin System Interacts with Interpersonal Life Stress to Predict

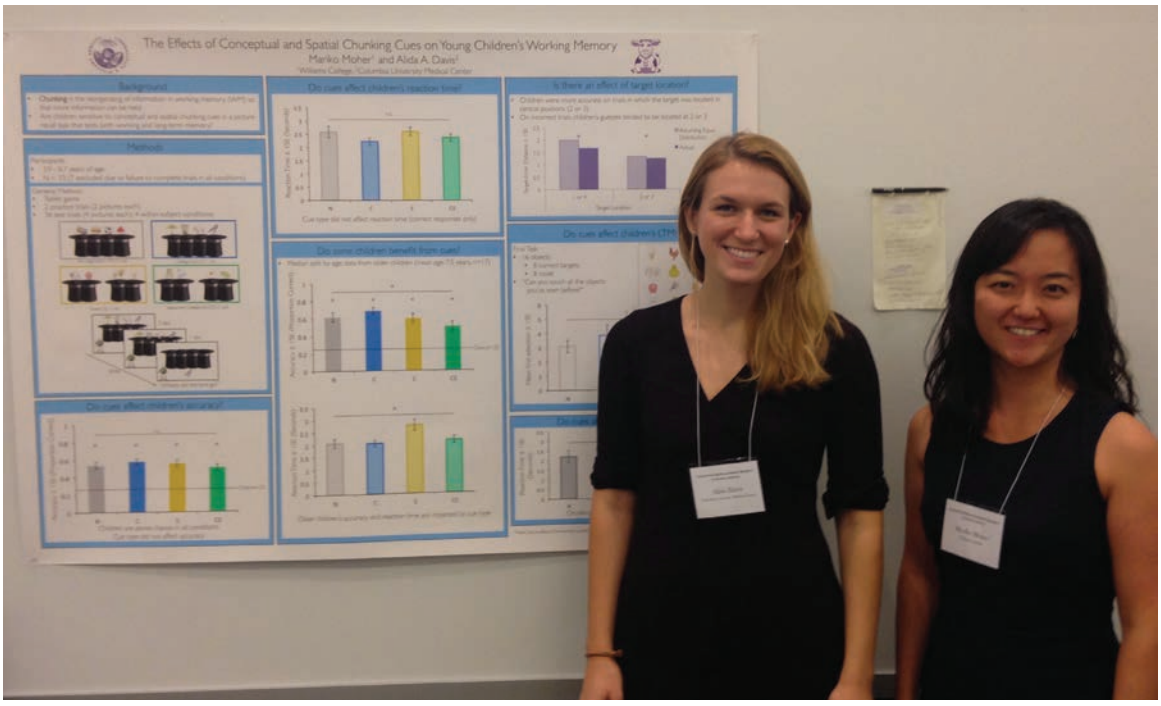
Depression”
Paper presented with S. Vrshek-Schallhorn, S. Mineka, R.E. Zinbarg, E.K. Adam, E.E. Redei, C. Hammen & M.G. Craske at the 2015 annual meeting of the Society for Research in Psychopathology, New Orleans, LA, October 2015

Betty Zimmerberg

“Early Deprivation Alters the Development of Affective and Social Behavior in Rats Selectively Bred for an Infantile Trait”
International Society for Developmental Psychobiology Annual Meeting, San Sebastian, Spain, July 21, 2015

Class of 1960 Scholars in Psychology

Claire Bergey ‘17	Min Kim ‘17	Silvio Resuli ‘16
Yvonne Bungei ‘17	Chris Leflore ‘16	Jesse Rodriguez ‘16
Julia Cheng ‘17	Chris Lyons ‘17	Scott Shelton ‘17
Olivia Clark ‘17	Carey Marr ‘16	Megan Steele ‘16
Lauren Claypoole ‘16	Kathryn McNaughton ‘16	Laura Ureste ‘16
Ellen Finch ‘16	Velia Moran Olivas ‘17	Sarah Wieman ‘16
Hanane Goelzer ‘17	Kyung Chan Park ‘17	Chanel Zhan ‘16
	Abigail Pugh ‘16	



Mariko Moher and *Alida Davis '14* present their poster at the biennial meeting of the Cognitive Development Society.

Post-Graduation Plans of Psychology Majors

Name	Plans
Brandon Acosta	Participating in a 10-month intensive study program at the Inter-University Center for Japanese Language Studies in Yokohama, Japan; this program is run by Stanford University
Alyssa Alden-Smith	Unknown
Graeme A Black	Working in private equity for Summit Partners in Boston
Sarah Brathwaite	Teaching at Blackstone Valley Prep Elementary School as part of the Teach for America program in Rhode Island
Lei S Brutus	Planning to work as a paralegal for a law firm in New York City
Lauren D Claypoole	Working as a Research Coordinator at Massachusetts General Hospital's Center for Women's Mental Health for the next two years
Katharine W Costantini	Working as an Outreach and Education Fellow with the Center for EcoTechnology in Northampton, MA
Lucy Davis	Moving to Boston to pursue a career in folk music (singing/songwriting) as well as possibly getting a degree in library science
Gabrielle Dibenedetto	Working as an assistant teacher at the Windward School, a school in New York for students with verbal learning disabilities
Tayler A Donze	Planning to find a position in Marketing and Sales
Libby Dvir	Hoping to go into either human resources or clinical psychology
Madeline J Epsten	Unknown
Andrea Estrada Bianchi	Hoping to work either in people management or the creative/design industry
Ricardo A Faillace	Teaching English in Madrid for the next year
Ellen F Finch	Working as a research assistant with Dr. Lois Choi-Kain at the Gunderson Residence at McLean Hospital in Belmont, MA, researching and disseminating new treatments for Borderline Personality Disorder; also hoping to attend clinical psychology graduate school in two years
Eva R Fourakis	Working in a psych lab at Princeton
Racquel E Gibson	Unknown
Kimberly A Golding	Interning at The New York Theater Workshop for the Summer, then moving to Berlin, Germany for three months to work in the theater. Afterwards, plans to work with a NYC non-profit theater
Emily G Grant	Unknown
Maya K Hart	Working as a Client Advocate at the Center for Appellate Litigation in NYC
Madeleine M Holker	Working in New York at HawkPartners, a marketing consulting firm
Phoebe K House	Working at the Family Resource Center in Lake Tahoe for a couple of years before applying to MSW programs
Noah I Klag	Working at an investment bank in New York
Zatio Kone	Working as a Customer Relations & Integrity Associate at DonorsChoose.org
Rachel L Krcmar	This summer, working with people with developmental disabilities at Camp Huntington; hopefully applying to medical school the following year
Nina L Kumar	Working in Offering Management at IBM Watson Health
Christopher I Leflore	Unknown

Crystal Lewin	Planning to play soccer professionally for a few years and then either work in MLS or in the film industry; hopes to one day start her own animal rescue organization
Jorge L Lopez	Working in corporate finance for Novartis Pharmaceuticals in East Hanover, NJ
Juana Manzanares-Torres	Unknown
Carey M Marr	Planning to continue in social psychology
Kathryn A McNaughton	Working as a Sara S. Sparrow Fellow in Clinical Neuroscience at the Yale Child Study Center
Mai Mitsuyama	Working as a Research Assistant at the Columbia University Medical Center in the Nurture Science Program
Katakyie Ofori-Atta	Working at Goldman Sachs in New York in the Securities division
Abigail M Pugh	Attending the Post-Baccalaureate Pre-Clinical Program in Communication Disorders at UMass Amherst
Silvio Resuli	Working at the Boston Center for Memory as a Research Associate
Jason A Ring	Unknown
Emily A Roach	Teaching middle school Computer Science and Video Editing at Ravenscroft School in Raleigh, NC
Jesse Rodriguez	Applying to medical school and working in research or as a medical scribe
Evelyn Rojas	Working as a Social Services Caseworker for the non-profit Heartland Alliance in Chicago assisting children and teens from Central America to find relatives here in the U.S or someone they can stay with so they can remain in this country
David A Rosas	Looking for a job in the Bay Area this year and will begin applying to medical school
Benjamin M Rosenblum	Unknown
Abigail Sanchez	Unknown
Nels A Snyder	Working in Chicago at Northern Trust Corporation on their corporate risk management team
Megan A Steele	Working as a research assistant at Beth Israel Hospital in the Neurology Department in the Scammell Lab; this lab studies the neurobiology of sleep, particularly cataplexy and narcolepsy
Alexandra E Stone	Working in consulting as a Solutions Analyst at Opera Solutions in Jersey City
Laura A Ureste	Taking the classes needed to apply for a masters program (Physician's Assistant/Associate) and also training to become a phlebotomist
Luis A Urrea	Teaching high school science in McAllen, Texas, as part of the 2016 Teach For America Corps
Annie L Vanwagenen	Joining Teach For America in New York
Howard J Weiss	Working as a paralegal at a Boston law firm named Rose, Chinitz & Rose
Sarah T Wieman	Working as a clinical coordinator at the Center for Anxiety and Traumatic Stress Disorders at Massachusetts General Hospital
Venson M Williams	Working at a home for people with mental illness, and ultimately planning to go into acting and playwriting
Jiuwei Yin	Unknown
Chanel W Zhan	Serving with AmeriCorps in Los Angeles

Abstracts from Student Theses

Biology

Modeling the Dynamics of Persistence and Extinction in Ecology

Alexander Meyer

Mathematical models are invaluable tools for ecologists. A well-constructed model not only holds predictive power, but also matches observations made in the field and sheds light on the mechanisms that underlie the complex interactions between organisms and their environment. Simulation allows researchers to conduct experiments in silico that would be impractical or unethical to conduct in the field, enabling ecologists and conservationists to forecast the outcomes of environmental management strategies prior to implementation. My investigation explores the mechanisms of species persistence and extinction in two unique examples: the lethal white-nose syndrome (WNS) epidemic decimating New England's bat populations, and the temporally/spatially synchronized emergences of periodical cicadas. In particular, I use models to determine the efficacy of several WNS control measures and to analyze the mechanisms that allow only one brood of cicadas to persist in a geographical area at the exclusion of all others.

The Effect of Pericentric Satellite Expression on Chromatin Stability in Cancer

Catherine Landers

Approximately fifty percent of the human genome is composed of repetitive DNA sequences. One class of these repeats is satellite DNA, which consists of high copy, tandemly repeated DNA elements that alone constitute about ten percent of the genome. Satellite repeats form large arrays that exist at the centric and pericentric regions of chromosomes and are typically maintained as heterochromatin. Broadly, pericentric heterochromatin is thought to be critical for centromere function and chromosome stability. Due to its critical location near the centromere, loss of pericentric heterochromatin may result in cellular instability and, ultimately, cell division defects. Cancer is characterized by aberrant cell division that can result from chromosomal instability (CIN). The location of satellites and the importance of maintaining pericentric heterochromatin suggest that satellites may be essential for genomic stability, and thus that mis-expression of satellites could contribute to CIN and cancer progression. Recent studies suggest that satellites are broadly overexpressed in most epithelial-derived cancers. One of these satellites, Satellite 2 (Sat2), is expressed in nuclear-restricted bodies in cancer cells, but is not expressed in noncancerous cells. In this study, we generated stable cell lines exogenously expressing satellite sequences. We report that in a stably expressing Sat2 cell line, Sat2 RNA formed into distinct nuclear bodies, similar to the pattern of endogenous Sat2 expression in cancer cells. Our results suggest that Sat2 expression is correlated with abnormal chromatin and cell division defects characteristic of cancer.

The Role of Prostaglandins in Zebrafish Heart Development

Ashley Ngo

Prostaglandins are small molecules that are most often associated with inflammation and pain, however recent studies suggest that they also play a role in the heart development of zebrafish. Prostaglandins are synthesized from arachidonic acid via the enzymes cyclooxygenase-1 and cyclooxygenase-2 (Cox-1 and Cox-2; Ricciotti and FitzGerald, 2011). Inhibition of Cox-2 prevents the formation of atrioventricular valves (AVV), which are necessary to prevent retrograde flow of blood (Xu et al., 2011). The opposite phenotype is observed when the small heat shock protein Hspb7 is knocked down (Springel, 2012). *hsp7* knockdowns have enlarged heart valve leaflets that lead to blood regurgitation. This enlargement is due to hypertrophy of the cells that constitute the leaflets, not increased cell proliferation (Wieman, 2014 unpublished data). The opposing phenotypes caused by Cox-2 inhibition and *hspb7* knockdown suggested a relationship between the two pathways. However, treatment of *hsp7* knockdowns with 10 or 15 uM of celecoxib did not rescue the enlarged heart valve phenotype. Therefore, it remains unclear whether prostaglandins and Hspb7 are involved in the same pathway of heart valve leaflet development.

Comparative Physiological and Genomic Studies of Prochlorococcus

Julie Carroll

Prochlorococcus, a small (0.5 – 0.7 μm diameter) marine cyanobacterium living in low-nutrient, open ocean areas, plays a crucial role in the environment as primary producers.As one of the smallest-known photosynthetic organisms, *Prochlorococcus* forms the base of the marine food chain. I hypothesize that *Prochlorococcus* strains have evolved specialized photosynthetic strategies that enable them to thrive under different environmental conditions. An important component of characterizing photosynthetic physiology involves examining how *Prochlorococcus* strains grow under different irradiance levels and comparing photosynthetic efficiencies. The strains I studied in my experiment belong to both deeply branched clades (SS120, MIT 9313, MIT 9303) and the large clade of recently differentiated lineages (MIT 9312). My results indicate that differences in genetic composition result in disparities in growth rates and photosynthetic efficiencies of theses *Prochlorococcus* strains when cultured at similar irradiance levels. My project also involved characterizing the genomic composition of two very closely related strains, MIT 9313 and MIT 9303. Although these two *Prochlorococcus* strains share high gene sequence conservation, the extensive chromosomal rearrangements that exist between these strains could generate differences in gene expression and physiology. My results indicate that unique genes (i.e., genes found only in one strain and not in the other) most frequently occurred in categories such as regulatory processes, metabolism, and cell wall/membrane biogenesis. Future studies may help show how specific differences in these genes could impact physiological ecology.

Exploring the Effect of Sublingual Immunotherapy on Lung TRM T Cells in Allergic Asthma

Patricia Ho

Sublingual immunotherapy (SLIT) is an effective new therapy for allergic asthma that induces a temporary tolerance to an asthma-triggering allergen through repeated sublingual exposure to the allergen. SLIT was administered to a murine model of allergic asthma induced by house dust mite (HDM) extract in order to determine if SLIT changes regulatory or inflammatory tissue-resident memory (TRM) T cell populations in the lungs. Mice sensitized to HDM demonstrated eosinophilic inflammation in bronchoalveolar lavage fluid following HDM challenge, and showed higher levels of both TRM CD4+ T cells and TRM Tregs in the lungs. HDM SLIT did not establish a clear decrease in lung inflammation, and no changes in TRM CD4+ or Treg levels were seen in the lungs, suggesting the need for an improved SLIT protocol in this model of asthma.

Plant Defense Pathways Respond to *Agrobacterium Tumefaciens* T6SS

Breanna Nguyen

Agrobacterium tumefaciens is a soil-borne plant pathogen that is the causal agent of crown gall disease in a wide variety of plant species. In addition to encoding a Type 4 secretion system that directly facilitates host infection, A. tumefaciens also encodes a Type 6 secretion system (T6SS), which secretes effectors that contribute to virulence. The Banta lab has data to suggest that Arabidopsis can both perceive the T6SS and mount defenses in response. To determine which specific plant defense pathways are involved in T6SS-triggered defenses and to identify a putative T6SS receptor, we developed and utilized a transient transformation assay to quantify the amount of bacterial DNA transferred into the host after WT or ΔT6SS A. tumefaciens infection. We then compared transient transformation of seedlings mutant for specific components of a defense pathway or for potential T6SS receptors to transformation of WT Arabidopsis thaliana (Col-0) to identify any significant differences.

We found that T6SS detection and T6SS-triggered defenses are not perceived at the level of the stomata but instead potentially after at the level of apoplastic defenses, and may be facilitated by RNS-mediated defenses but not by EFR, a lipopolysaccharide receptor (LPS) or CERK-mediated defenses. Furthermore, our transient transformation assays underscored the important role of co-receptor BAK1 in limiting transient transformation by mediating PAMP-triggered immunity. Additionally, an Arabidopsis ecotype, Ang-0, previously characterized as resistant to tumor formation appears to be insensitive to the T6SS. This finding was confirmed and extended by the result that expression of early defense genes, FRK1 and GST1, was not T6SS dependent in Ang-0 seedlings.

Dopaminergic Daytime Activity and Sleep Regulation in the Mushroom Body of Drosophila melanogaster

Elise Pitmon

Sleep is an important biological process for all animals. The investigation and characterization of sleep circuitry within the brain is important for understanding arousal and sleep disorders, such as insomnia and narcolepsy. The characterization of sleep circuitry may lead to important therapies for these disorders. Drosophila melanogaster have two main periods of sleep, one daytime and one nighttime, and the network of homeostatic regulation within Drosophila during sleep is not yet well characterized. Dopaminergic signaling has been shown to regulate sleep in the mushroom body in the Drosophila brain. Previous sleep studies have looked at total sleep averaged over the entire twenty-four hour day, but there may be differences between the sleep regulation that occurs during the daytime and the regulation occurring at night. Dopaminergic circuits in the brain are involved in many physiological processes including arousal, learning and memory, and other cognitive functions. I hypothesize that subsets of neurons within the mushroom body specifically regulate daytime sleep and activity. Our results indicate that restoration of the dopamine receptor DopR in subsets of neurons in the mushroom body is sufficient to rescue daytime sleep and activity. In addition, RNAi knockdown of DopR function within the same mushroom body neurons results in excessive sleep. Finally, activation of these neurons has dynamic effects on activity and sleep that are asymmetric depending on when activation occurs. These results support a distinct dopaminergic circuit responsible for the regulation of daytime sleep and activity, which is separate from nighttime regulation.

Stimulation of Hypothalamic AgRP or POMC Neurons Deepens and Lengthens Torpor in Mice

Conor Mook

Torpor is a physiological state characterized by large decreases in metabolism, heart rate, and body temperature that allows some small mammals to survive periods of low food availability by diminishing energy expenditure. Compounds such as ghrelin and leptin, which activate AgRP neurons and POMC neurons, respectively, have previously been shown to modulate torpor bouts in mice. The specific neural circuitry responsible for regulating torpor, however, is still largely unknown. Here, we show that optogenetic stimulation of AgRP neurons or POMC neurons is sufficient to increase torpor bout length and decrease both minimum body temperature and average body temperature in torpor without disturbing canonical torpor hysteresis. In addition, AgRP or POMC neuron stimulation induced changes in animals' descent into and emergence from torpor, as stimulated animals achieve lower body temperatures earlier in torpor and remain at lower temperatures until later in torpor. These results provide new insight into the neurobiology of torpor regulation and how these small mammals counter the challenges of low energy availability. Our findings open the door to the further study of neural regulation of the cardiac system and the development of novel therapies for disorders of energy homeostasis in humans.

Stimulation of AgRP Neurons Eliminates the Effects of Appetite Suppressing

Rachel Essner

The proper regulation of food intake depends on a balance in the activity of orexigenic (appetite promoting) and anorexigenic (appetite suppressing) brain regions, which respond to circulating factors in the bloodstream to affect food-seeking behavior. Endogenous anorexigenic hormones include amylin, secreted by the pancreas, and cholecystokinin (CCK), secreted by the small intestine. Exogenous compounds, such as lithium chloride (LiCl), a salt that creates gastric discomfort, and lipopolysaccharide (LPS), a bacterial cell wall component that induces sickness, have appetite-suppressing effects. Within the arcuate nucleus of the hypothalamus, agouti-related peptide (AgRP) neurons make up one key population of orexigenic neurons. Optogenetic stimulation of AgRP neurons increases food intake in mice; however, the effects of AgRP neuron activation during various conditions of appetite suppression are unknown.

Here, we tested the hypothesis that AgRP neuron stimulation would be sufficient to overcome the appetite suppressing effects of amylin, CCK, LiCl, and LPS. We optogenetically stimulated AgRP neurons following intraperitoneal (i.p.) injection of anorexigenic compounds, including amylin, CCK, LiCl, and LPS. As expected, following i.p. injection of saline, or in non-appetite suppressing conditions, AgRP neuron stimulation

induced a significant increase in food intake. AgRP neuron stimulation induced the same increase in food intake following i.p. injection of amylin, CCK, and LiCl, but not LPS. These results indicate that AgRP neuron stimulation is sufficient to overcome the appetite suppressing effects of amylin, CCK, and LiCl, but not those of LPS. Thus, in most cases, hunger signaling overrides the activity of anorexigenic brain regions. Future research should elucidate the precise mechanism by which LPS blocks AgRP neuron-induced food intake, as well as the mechanism by which AgRP neuron stimulation overcomes amylin, CCK, and LiCl induced appetite suppression. In addition, future research should increase the doses of amylin, CCK, and LiCl to determine whether there exists a threshold above which AgRP neuron activation can no longer overcome the appetite suppressing effects of these compounds.

Investigating Sequence and Context Influences on Nucleosome Positioning in *Saccharomyces cerevisiae*

Emily Shea

Nucleosomes are the fundamental packaging unit of DNA, consisting of 146 bp of DNA wrapped around a histone protein octamer. The presence of nucleosomes allows for the DNA to condense and fit into the nucleus, but also regulates access of proteins to the DNA. Because of its role in gene expression regulation, nucleosome positioning warrants study. We set out to investigate what determines nucleosome positioning: DNA sequence or gene context. Using yeast strains tagged with GFP-His5 at the 3' end of varied genes, we obtained nucleosome positioning data using MNase digestion and a qPCR tiling array of primer sets to amplify the nucleosomal fragments of DNA. We noted differences in nucleosome positioning when the GFP-His5 DNA sequence was placed in different genomic locations. In particular, we found that increasing distance from a promoter region led to more variability in nucleosome positioning and that genes with a lower expression level tended to have a different nucleosome architecture. Our data thus far leads us to the conclusion that nucleosome positioning is context-dependent rather than being wholly dependent on sequence. However, much future work, including repetition and expansion of our set of contextual factors, remains to be done. In understanding nucleosome positioning determinants, we can then move towards manipulating nucleosome positioning. Thus, this work could both benefit disease research that has implicated nucleosome positioning and also allow for more efficient endonuclease targeting in genome-editing technology.

AgRP Neuron Stimulation is Sufficient to Decrease the Quantity and Quality of Sleep in the Absence of Peripheral Hunger Cues

Brian Levine

Because sleeping and eating represent mutually exclusive yet essential behavioral states, the neural systems that regulate them must balance the need for sleep versus the need for food. To investigate the effect of stressing one of these homeostatic systems on the other, we tracked sleep/wake patterns of mice while artificially inducing hunger via optogenetic stimulation of agouti-related peptide (AgRP)-expressing neurons at the beginning of the inactive period. This hypothalamic neuronal population senses peripheral cues about nutritional/caloric deficits and subsequently increases food- seeking behavior. We demonstrate that AgRP neuron stimulation increases wakefulness at the expense of NREM and REM sleep, increases sleep fragmentation, and may alter the EEG power of NREM and REM sleep. Therefore, this study indicates that, in conditions of energy deficiency, the feeding homeostatic system temporarily overrides the sleep/wake homeostatic system. In this state, AgRP neuron activation confers an adaptive increase in wakefulness, facilitating an animal's search for food.

Landscape genetic structure of *Sagina nodosa* populations in Isle Royale, Michigan

Katherine Bennett

Isle Royale, Michigan, an isolated national park surrounded by Lake Superior, is a federally protected wilderness that serves as a long-term study site for several Williams college projects. For twenty years, one aspect of this work has been the sampling of *Sagina nodosa* var. *borealis*, a small flowering plant with a typically Arctic range. Long-term population monitoring in Isle Royale National Park has shown a population collapse of 37 to 64 percent on three sampled islands, leading us to hypothesize there would be significant changes in genetic diversity from "past" to "present" due to selective pressures of climate change and genetic bottleneck effect resulting from population collapse. Instead, I found there was a significant increase in inbreeding and

homozygosity from "past" (1997, 1998, and 2000) to "present" (2011 and 2014) cohorts, but there was no significant difference in allele frequency and no significant population genetic differentiation. I also studied spatial genetic patterns in 2011 and 2014 data using metapopulation and isolation-by-distance analyses, expecting to see water channels between islands acting as boundaries to gene flow, as well as an isolation-by-distance pattern seen in range-limited species. I determined there were only five genetically distinct subpopulations in the eight islands sampled in 2011, and only six in nine islands sampled in 2014. The "present" populations showed no significant isolation-by-distance patterns. Therefore, I propose that *S. nodosa* populations of Isle Royale did not demonstrate a genetic bottleneck in response to population collapse because of extensive gene flow between islands, which kept allele frequency and heterozygosity close to pre-collapse levels.

Prochlorococcus: a study of physiological and evolutionary differentiation

Penny Sun

Prochlorococcus is one of the smallest photosynthetic organisms (0.5-0.7µm) and dominates large, low-nutrient regions of the open oceans from the surface to 200 m within the 40°N to 40°S subtropical region. Thus, it is an excellent model system to study minimal genomes, ecological adaptation, and adaptive photosynthetic strategies. *Prochlorococcus* strains differ in significant ways and differences in their growth and stress responses and are especially important to understand due to their ecological significance and to the potential impacts of global climate change. It is unknown how *Prochlorococcus* will respond to increases in ocean temperature.

We hypothesize that *Prochlorococcus* strains have evolved distinct photosynthetic strategies and stress response mechanisms. In this study, we sought to understand the photosynthetic capabilities of strains that belong to two ecotypes: MED4 and MIT9313. We compared their growth rates at 10 µmol photons m^{-2} s^{-1} and found that MIT9313 grew significantly faster at this low irradiance level. We also compared MED4 growth at 20 µmol photons m^{-2} s^{-1} and 55 µmol photons m^{-2} $s^{-1}$and found that its growth was significantly different at each irradiance level: it grew faster as the irradiance level increased. Compared to previous data from our laboratory, this growth pattern differs between MED4 and MIT9313, as well as two other strains: MIT9312 and SS120. Each of these four strains, which belong to different ecotypes, was unique in their growth behaviors across a range of irradiance levels. Photosynthetic efficiency was also measured for MED4 at 20 µmol photons m^{-2} s^{-1} and compared to previous measurements of other strains at this irradiance level. Ultimately, MED4 and MIT9313 differed across measurements of photosynthetic capacity, reflecting their distinct photosynthetic strategies.

We also sought to gain insight into the stress responses of *Prochlorococcus* by examining the protein sequence, protein structure, chromosomal localization, and regional regulation of their DnaK chaperone proteins. First, we identified the DnaK proteins present in *Prochlorococcus* strains through comparisons with other closely related cyanobacteria. Our analyses indicated that DnaK1 has been lost in the*Prochlorococcus* lineage. DnaK2 and DnaK3 are preserved in the *Prochlorococcus*lineage, but ecotype distinctions can be visualized in their protein sequences, protein structures, and chromosomal localization. DnaK2 is the only DnaK protein in*Prochlorococcus* associated with a novel putative global stress regulatory region, the MARS box. DnaK3 is less conserved compared to DnaK2, but its retention in the genome and co-localization with a DnaJ and Hsp90 protein suggest that it is also performing a conserved function in the cell, though its expression is likely regulated by a different stress response pathway.

Agrobacterium tumefaciens Type VI Secretion System Components Impact Bacterial Motility and Limit Host Transient Transformation

Aubrey Kenefick

Agrobacterium tumefaciens is a common plant pathogen that causes crown gall disease on a wide variety of plants by releasing a small segment of DNA ("T-DNA") into hosts via the Type IV Secretion System (T4SS). In addition to the T4SS, these bacteria also possess a Type VI Secretion System (T6SS), which is capable of expelling toxic effector proteins into the extracellular environment or into proximal eukaryotic and prokaryotic cells. The Banta Lab has discovered that T6SS presence limits transient transformation (TT) by *A. tumefaciens* on *Arabidopsis* seedlings. Here, we examine the influence of various T6SS components

and effector proteins on bacterial behavior and TT processes. Here, we show that any mutation of the T6SS or its constituent substrates results in greater TT. We also demonstrate that functional mutations of T6SS machinery (but not effector proteins) result in decreased motility and altered colony morphology (on rich, neutral media). Finally, we show that two WT A. tumefaciens strains (58-3 and 530) exhibit differential motility levels and colony morphologies (in TT-mimic conditions), patterns of host defense gene elicitation, and TT capability. We propose that strain 58-3 harbors a genomic defect within an acidity/phosphate regulon (directly up- or downstream of the ChvG-ChvI two-component system). In all, these findings contribute nuance to a strong body of literature relating *A. tumefaciens* T4SS virulence, T6SS activity, and motility during TT; and, more broadly, relationships between TT, associated pathogen behavior, and tumorigenesis. These findings may prove useful in agricultural studies focused on plant-pathogen interactions.

Exploring the spatial-dependent function of endosomal Toll-like receptors

Hector Trujillo

Toll-like receptors are innate immune receptors capable of recognizing a wide variety off microbial elements, including cell wall components such lipopolysaccharide, motility elements like flagella, and even DNA and RNA. TLRs 7 and 9 are intracellular TLRs that have specific affinity for nucleic acids. Ligand recognition by TLR7 and 9 allow them to recruit signaling adaptor MyD88 to initiate a signal cascade that either results in the transcription of pro-inflammatory cytokines or type-I IFNs. The former is critical for recruiting more immune cells to the site of infection, while the latter arrests protein synthesis in response to viral infection. Transcriptional outputs of TLR7 and 9 activation seem to be spatially defined. That is, TLR activation from intracellular compartments such as the early endosome, the late endosome, or the lysosome related organelle determines whether pro-inflammatory cytokines are transcribed or type-I IFNs. Conflicting models suggest that pro-inflammatory cytokine signals and type-I IFN signals originate from the late endosome and early endosome or the lysosome related organelle and early endosome, or the late endosome and lysosome related organelle respectively. Epifluorescence microscopy shows that TLR7 and 9 most strongly co-localize with the late endosome compartments and not the early endosome, perhaps suggesting that no signaling originates from the early endosome. Before any model can be definitively proven, it would be important to see how TLR7 and 9 localization changes upon nucleic acid challenge. Using a way to synthetically localize and activate intracellular TLR signaling would be helping in describing this spatial dependent function.

Elucidating the Structure of CoT-1 Repeat RNA in situ”

Lacey Serletti

While classically much emphasis has been placed on the protein-coding portion of the genome, in reality this category accounts for only 2% of all genomic DNA. The remainder of the genome is transcribed into non-coding RNA, which has a variety of important regulatory and enzymatic functions. Approximately half of all noncoding DNA is comprised of repeat sequences. While once considered to be vestigial, repeat DNA is in fact transcribed. One such population of transcribed repeat DNA is CoT-1, a heterogeneous class of interspersed repeat DNA thought to be composed largely of long interspersed nuclear elements (LINEs). CoT-1 RNA is retained in the nucleus and associates with actively transcribed chromatin. Moreover, CoT-1 transcripts appear to coat their parent chromosome in cis much like XIST RNA. The consistent and particular localization of CoT-1 RNA in the nucleus seems to suggest a potential regulatory role for CoT-1, especially given the precedent for the functionality of other noncoding RNA. To begin to elucidate a potential function for CoT-1 RNA, we attempted to characterize its structure. First, a working protocol was established wherein live cells were treated with different RNases specific for certain RNA structures. Following the RNase treatment, RNA fluorescence in situ hybridization was used to detect the presence of CoT-1 RNA or L1ORF2 RNA, a particular LINE component of CoT-1. Using this methodology, we determined that the majority of CoT-1 RNA is single-stranded.

Prezygotic barriers between G. pennsylvanicus and G. firmus: The role of Female Cuticular Hydrocarbons in the Male Courtship Behavior

Laura Partida

Prezygotic barriers prevent two different species from mating. They minimize gene flow and prevent hybridization. Behavioral isolation, an early acting pre-zygotic barrier, is highly involved in preventing hybridization, and thus gene flow. Here I sought to test the relationship between male courtship behavior *of G. firmus* and *G. pennsylvanicus* crickets and the females' cuticular hydrocarbon (CHC) profile. I demonstrated that *G. firmus* males tend to promptly court females, whether conspecific or heterospecific, while *G. pennsylvanicus* males were selective. Additionally, principal component analysis identified four potential female profiles: *G. firmus*-like (F), *G. pennsylvanicus*-like (P), intermediate (Int), and male-like (ML). *G. pennsylvanicus* males were overall less likely to call and there were no differences in courtship between any female types. In contrast, *G. firmus* males did not show preference among F, Int, ML, but all of these were courted more than P females. Male-like females, which consist of several females of both species, are courted even if they are from the wrong species. Together these data suggest that male-like females may be the females involved in heterospecific mating.

Dopamine receptor is necessary for regulation of arousal in the optomotor response of *drosophila melanogaster*

Soomin Kim

The level of arousal in organisms is moderated by many neural systems, and dopamine in particular has been extensively researched on regarding its role in heightening arousal. Arousal also seems to have a threshold effect on attentional capacity, where too low or too high arousal levels result in a deficit on an animal's attention. To test this relationship we utilized an assay called Stampede Assay that can affect arousal levels through startle stimulus and test for visual attention through motion stimulus that elicits instinctive optomotor response from the fruit flies. Interestingly, it has been previously suggested that wildtype flies perform better in the optomotor performance when startled compared to when they are not startled; on the other hand, dopamine receptor mutant (DopR) flies do not show adequate optomotor performance regardless of startle stimulus. Thus, using the Drosophila melanogaster model system, we sought to investigate how the dopamine receptor mutation may affect arousal and attention. We hypothesize that 1) DopR flies will not show as robust an optomotor performance as that of wildtype flies due to dysregulation of arousal state and 2) the ellipsoid body of central complex will be able to rescue the mutant phenotype. Our results do indicate that 1) DopR flies do not perform as well in the Stampede Assay as the wildtype flies 2) DopR flies have lower arousal thresholds than wildtype flies and show higher velocity in response to external stimuli and 3) ellipsoid body GAL4 line moderately rescues the mutant phenotype. These results suggest the importance of DopR receptor in regulating arousal levels in relation to the optomotor response and point to the ellipsoid body as a possible candidate for this phenotype.

Developing a Mathematical Model for Cultural Change in a Songbird Population

Anna Ryba

Cultural structures arise from the combination of many individual learning processes, population movement subject to small, stochastic changes, and other - often random - processes. In a population of Savannah sparrows that nests on Kent Island, New Bruswick, a part of the relatively simple Savannah sparrow song - the buzz segment - has been shown to be extremely stable over time in direct contrast to other parts of the song. The standard Kent Island buzz was challenged by the introduction of a variant buzz, which managed to propagate in the singing population but eventually died out. I built and analyzed a mathematical model based on the biology of the Kent Island Savannah sparrow population to investigate the dynamics of this invasion. I asked whether or not a special concept of preferential learning is necessary to ensure the stability of a standard cultural form challenged by an invading variant, and found that, in fact, stochastic population processes are sufficient to

ensure the stability of the standard form. As Savannah sparrow song shares many key similarities with culture, this study extends the field of cultural evolution, emphasizing the fact that neutral population processes play an important role in determining stable cultural structures. Furthermore, the model I describe should serve as a valuable tool for broader exploration in the field of cultural evolution.

Agrobacterium tumefaciens Type VI Secretion System modulates defenses of *Arabidopsis* seedlings

Jacob Kim

The interaction between a pathogen and its host is complex, with both members trying to gain a competitive advantage over the other. Plants can detect molecules abundantly produced by invaders and induce a generalized defense response. For example, plants use the EF-Tu receptor (EFR) to recognize EF-Tu expressed by bacterial pathogens. The plant-pathogenic bacteria *Agrobacterium tumefaciens* expresses the Type VI Secretion System (T6SS) in an attempt to dampen the defense responses of its host. The T6SS injects its effectors into the host cell to dampen the innate defenses. In turn, the host cell may recognize the effector and trigger a defense response against its invader. In this thesis, we explored this interaction between *A. tumefaciens* and *Arabidopsis thaliana* seedlings, a model system of the host. We find that defense-related genes *FRK1* and *GST1* are temporally upregulated in the seedlings twice during 4 hours of infection by *A. tumefaciens* in an EFR-dependent manner. We also find that *WRKY29* is upregulated after 4 hours of infection by *A. tumefaciens*, while *WRKY62* shows no significant changes in expression. Furthermore, we find that the *A. tumefaciens* T6SS dampens the seedlings' ability to resist subsequent infections, but we were unable to identify the T6SS effector responsible.

Effects of Potential Teratogens on Heart Development in Zebrafish

Jacqueline Harris

Zebrafish heart valve development is influenced by a number of signaling pathways. Some of these pathways include the Notch, ErbB2, calcineurin/NFAT, and nitric oxide pathways. There is currently no known role of estrogen in heart valve development. Recently, in a transgenic estrogen-responsive zebrafish line 5xERE:GFP, it was found that GFP is expressed in heart valve precursors in response to estradiol. Although estradiol is not known to directly affect heart development, these findings suggest that estradiol may interact with other heart developmental pathways to shape the form and function of the valves. Therefore, dual treatments with estrogen and chemicals known to influence heart valve developmental pathways were used to see if estrogen interacted with these pathways. The dual treatment with DAPT, a Notch pathway inhibitor, and estradiol suggested that there is an interaction between these two pathways.

Endocrine disrupting chemicals like parabens are known to mimic estrogen activity. Many of these parabens like methylparaben and propylparaben are present in hair products that are applied to scarred scalps after hair relaxers or straighteners. It was also investigated whether these parabens induce similar reporter gene expression in comparison to a positive estradiol control, as well as whether a product containing these parabens has any influence on heart valve development.

Heart failure was indicated in these experiments by pericardial effusion, or the swelling of the pericardial cavity due to an abnormal excess amount of fluid. Pericardial effusion was observed in both the dual treatment with estradiol and DAPT, as well as in one of the diluted hair product samples. Thus, this data suggests that estrogen and endocrine disrupting chemicals like parabens may have an influence on heart development.

Creating a Knockout of *fkbp5* in a Transgenic SR4G Zebrafish (*Danio Rerio*) Using Crispr/Cas9

Bethany Berry

There are many neuropsychological disorders that have been linked to dysfunction of the hypothalamic-pituitary-adrenal (HPA) stress response axis. One gene in particular, *fkbp5*, has been shown, in the literature and from past experiments within the Marvin lab, to function in HPA axis regulation. More specifically *fkbp5* production inhibits the binding of glucocorticoids to the glucocorticoid receptor, decreasing the larger glucocorticoid mediated negative feedback loop. This is consistent across zebrafish, mice, and humans. This study set out to create an *fkbp5* zebrafish knockout using the CRISPR/Cas9 system. Loss of *fkbp5* would result in decreased stress reactivity. A mouse *fkbp5* knockout has already been made that exhibited a decreased response to stress. A

zebrafish knockout would add to the translational knowledge gained from the mouse by looking at *fkbp5* in the context of a model organism that has cortisol as its main stress hormone and a glucocorticoid receptor similar to that of humans. *fkbp5*-specific small guide RNAs (sgRNAs) were tested with Cas9 nuclease *in vitro* and *in vivo*. *In vitro*, effective sgRNAs were found that target Exon 5 and Intron 7. *In vivo*, effective sgRNAs were found that target Exon 5 and Exon 6. Both *in vivo* and *in vitro* the importance of optimizing the sgRNA concentration was found. Concentrations that were too high or too low were both ineffective at producing recombination. The *fkbp5* mutant zebrafish exhibited a phenotype in which they had no tail or had other significant physical malformations. It is unclear what caused these mutations, but it could be toxicity of the injected Cas9/sgRNA, non-specific effects of the mutant protein, or other effects of *fkbp5* not found in the mouse model. In the future, the current *fkbp5* mutants will be raised to produce a heterozygous F1 and a homozygous F2 generation that will be analyzed using qPCR and behavioral experiments. These experiments will help our understanding of *fkbp5*, glucocorticoid receptor activation and inhibition, as well as the HPA axis system as a whole.

Harnessing the CRISPR-Cas9 System to Induce Artificial Epigenetic Silencing in *S. cerevisiae*

Sierra McDonald

In eukaryotic nuclei, transcriptionally silent genes are generally located within heterochromatin, the complex of DNA and histone proteins that are sequestered from transcriptional machinery. Certain chemical modifications, such as H3K9me3, are enriched at the histone tails within heterochromatin. We were interested in whether inducing H3K9me3 at certain genes could cause them to become heterochromatic and exhibit transcriptional repression. We utilized the CRISPR-Cas9 system to localize CLR4, an H3K9 methyltransferase, to GFP-tagged genes in *S. cerevisiae*, an organism which lacks endogenous H3K9me3 machinery. We hypothesized that CLR4 would induce silencing of GFP. We were also interested in whether silencing could spread beyond the initial site of Cas9 localization, so we assayed for silencing in the presence of SWI6, a protein from *S. pombe,* that is thought to be required for spreading of silencing. Our preliminary flow cytometry and qPCR results show that CLR4 is capable of silencing at the transcriptional and translational level, but only when SWI6 is present. Additionally, the silencing activity appears to be dependent on the locus of the reporter gene, as we only observed it in certain strains. With SWI6, we also observed spreading of silencing downstream of the initial site of Cas9 localization. The ability to induce artificial epigenetic states could help increase our understanding of the mechanisms behind histone tail modification-induced silencing. Understanding these modifications is important, since there are many diseases with aberrant histone tail modification profiles.

Chemistry

Antibiotic Production In *Streptomyces Coelicolor* A3(2): An *In Vivo* Study Of The SCO6672 Phosphodiesterase

Cecilia Castellano

The *Streptomyces* genus is an important source of bioactive compounds and *Streptomyces coelicolor* A3(2) is a well studied model organism within the genus. *S. coelicolor* produces four antibiotic compounds, three of which were studied in this exploration. In particular, the biosynthesis of calcium-dependent antibiotic by *Streptomyces coelicolor* is accomplished by a multimodular enzymatic machine, a nonribosomal peptide synthetase (NRPS), that stiches together the antibiotic's amino acid building blocks.

In order for the NRPSs to be active so that the CDA peptide chain can grow, attachment of a 4'-phosphopantetheine (Ppant) arm to the NRPS carrier protein domains is required. Attachment of this arm is achieved by a phosphopantetheinyl transferase (PPTase), which, for CDA production in *S. coelicolor* is encoded by SCO6673. There are two other PPTases encoded in the genome with similar activating function. The gene just upstream from this PPTase is SCO6672, hypothesized to be a phosphodiesterase that can cleave the Ppant arm from the carrier protein domain via hydrolysis. This study focused on the *in vivo* function of SCO6672 in antibiotic biosynthetic gene mutants and PPTase gene mutant strains by studying antibiotic production in response to an overexpression of SCO6672. Because of a proposed interaction between other antibiotic biosynthetic production pathways and that for CDA, undecylprodigiosin (RED) and actinorhodin (ACT) production was also investigated.

Overexpression of SCO6672 increases RED antibiotic across all mutant strains; while it decreases ACT antibiotic production in all strains except for one biosynthetic gene mutant. These results suggest an interaction between the unique antibiotic production pathways.

The hypothesis that the SCO6672 cleavage functions in an editing mechanism in CDA production thus follows, and was explored through oxidative stress experiments meant to damage Ppant tethered biosynthetic intermediates. Overexpression of SCO6672 seems to rescue CDA production under environmental stress conditions, as SCO6672 strains overproduce CDA compared to the WT Control strain under oxidative stress conditions, suggesting the editing hypothesis. CRISPR/Cas9 technology was employed to improve the efficacy and efficiency of mutant construction, but this approach still needs to be optimized.

Synthetic Explorations of Phosphate-Based Anionic Gemini Surfactants for Luminescent Lanthanide Bioprobes

Melissa Cendejas

Luminescent complexes of lanthanide ions are becoming increasingly useful in the field of biological imaging. Because of the long emission lifetimes, sharp emission bands, and large Stokes shifts, lanthanide ion luminescence is ideal for use in elucidating cellular structures and processes. One challenge in developing lanthanide ion bioprobes is creating cell permeable complexes that maintain their luminescent characteristics. Gemini surfactants have been reported in the literature to be useful in cellular penetration and drug delivery. This thesis presents a review of the recent literature pertaining to luminescent lanthanide bioprobes (LLBs, as well as the efforts in the design and synthesis of phosphate-based anionic gemini surfactants as ligands for the sensitization of lanthanide ion luminescence. For this study we explored the design and synthetic modification of well-studied lanthanide ion ligands: dipicolinic acid (DPA) and 1,10-phenanthroline (phen). Though largely unsuccessful, the challenges of the proposed synthetic routes for the anionic gemini surfactants are discussed and an additional synthetic route is proposed for a cationic gemini surfactant based utilizing the phenanthroline moiety.

Characterizing the substrate specificities of phosphopantatheinyl transferases and SCO6672 in the antibiotic production pathways of *Streptomyces coelicolor* A3(2)

John Chae

The *Streptomyces* are a genus of filamentous Gram-positive, soil-dwelling bacteria that have a remarkable capacity to produce secondary metabolites. Collectively, their vast pool of secondary metabolites includes numerous antibiotics and bioactive molecules with wide ranges of applicability. A useful *Streptomyces* model organism for scientific investigations is *Streptomyces coelicolor* A3(2), whose genome has been fully sequenced. This particular species is known to produce five compounds with antibiotic activity: the red-pigmented tripyrrole undecylprodigiosin (RED), the blue-pigmented polyketide actinorhodin (ACT), the lipopeptide calcium dependent antibiotic (CDA), the cryptic polyketide (CPK), and the cyclopentanone methylenomycin. The biosynthetic pathways for the first four antibiotics involve two types of multimodular enzymatic systems: nonribosomal peptide syntethases (NRPSs) and/or polyketide synthases (PKSs). To properly function, these enzymes depend on the presence of 4'-phosphopantetheinyl (Ppant) cofactors covalently attached to their carrier protein domains. This phosphopantetheinylation is catalyzed by phosphoantetheinyl transferases (PPTases), and the *S. coelicolor* genome encodes three PPTases: RedU, AcpS, and SCO6673. It has been recently found that the *S. coelicolor* genome also encodes a phosphodieterase, SCO6672, which hydrolyzes the Ppant groups from carrier protein domains. SCO6672 is the only phosphodiesterase known to date that acts against carrier protein domains involved in antibiotic biosynthesis.

The objective of this study was to characterize the *in vitro* substrate specificities of the PPTases and SCO6672 by measuring PPTase and phosphodiesterase assays with various purified carrier protein domains. It was found that AcpS, SCO6673, and SCO6672 all have relatively relaxed substrate specificities and thus may be involved in multiple antibiotic biosynthetic pathways. In particular, SCO6672 could modify both holo-acyl carrier protein (ACP) and holo-peptidyl carrier protein (PCP) domains, though its catalytic activity appeared to be slightly faster and more efficient for the latter. However, the regulation of SCO6672 itself and the *in vivo* physiological role of SCO6672 are still largely unknown. With regard to its physiological role, two hypotheses are discussed: editing and negative regulation.

Toward Transition Metal Ion Encapsulation via Synthetic Polymer Micelle Environment

Christina G. Chen

Despite the scarcity of unassociated transition metal ions in the human body, metalloproteins are capable of obtaining the metal ion cofactors necessary for performing their ascribed functions. This feat is achieved with the assistance of soluble metal receptor proteins known as metallochaperones, which have extremely strong capacities for metal ion chelation. This ability may be attributed to the potential stabilizing effects of the secondary coordination sphere. This thesis is a proof-of-concept body of work in which an acrylic polymer backbone was functionalized with ligands that bind Cu^{2+}. With this as a model for the binding of metallochaperones, we established a synthetic and analytical work flow for the design of future metal-ion-chelating polymers.

The synthesis and characterization of seven acrylamide monomers is reported: *N*-(2-aminoethyl) acrylamide (L1), *N*-methoxyethyl acrylamide (L2), *N*-(2-pyridinylmethyl) acrylamide (L3), *N, N*-[(dimethylamino)ethyl] acrylamide (L4), *N, N*-[(diethylamino)ethyl] acrylamide (L5), *N, N*-[(dibutylamino)ethyl] acrylamide (L6), and *N*-acrylcysteamine (L7). The synthesis and characterization of two alkyl-acrylamide control monomers *N*-hexylacrylamide (nHex) and *N*-octylacrylamide (nOct), and three homopolymers *N*-[2-(diethylamino) ethyl] polyacrylamide (pDEEN), *N*-[2-(dibutylamino)ethyl]polyacrylamide (pDBEN), and poly(*N*-methoxyethylacrylamide) (pOMe) synthesized via RAFT polymerization are also reported. The Cu^{2+}- binding ability of these functionalized homopolymers were assessed and compared to that of a known copper chelator, ethylenediaminetetraacetic acid (EDTA). Homopolymers pDEEN and pDBEN successfully exhibited Cu^{2+} binding, but the binding ability of pOMe was not successfully established. Binding competition studies demonstrated that the binding of pDEEN and pDBEN to Cu^{2+} is reversible and weaker than the binding of EDTA to Cu^{2+}.

Further work on diblock copolymerization and inducing micelle formation is necessary to complete the workflow model and assess the ability of the functionalized micelles to bind target ions such as Cu2+ and ultimately, Cu+.

Constructing An Extended Higgins Model For Reversible Glycolysis In Streptomyces Coelicolor

Stanley Ewala

Like many other biological systems, glycolytic systems produce oscillations and these oscillations have been extensively studied in microorganisms such as *yeast* and *Escherichia coli. Streptomyces coelicolor* is notable because unlike most organisms where the rate determining steps in glycolysis are irreversible, the rate-determining steps in S. coelicolor glycolysis are reversible. So this bacterium introduces an entirely different biochemical scope to our understanding of glycolysis. *Streptomyces coelicolor* is a soil-dwelling actinomycete – a group of bacteria that produce a large number of antibiotics used in human and veterinary medicine

The Higgins model proposed in 1964 described glycolytic oscillations and in several sequential expansions, the original Higgins model has been modified to incorporate more molecular mechanisms, thus improving the accuracy of the model. We therefore continue to modify this model to describe the known biochemistry of the reversible glycolytic system of Streptomyces coelicolor. Our analyses shows that the overall macroscopic nature of oscillations depends on the value of each parameter, and oscillations only occur within strict limit cycles for particular parameters.

An in-depth analysis of the quality of each type of oscillations shows that even for given categories of oscillations such as chaotic oscillations, elaborately patterned and predictable miniscule changes occur and these microscopic changes determine the observed macroscopic character. Our model therefore offers a more elaborate depiction of microscopic and macroscopic oscillations, and has increased the overall understanding of glycolytic oscillations.

Exploring the Expoxidation of Alkenes Using Aromatic-Functionalized Derivatives of the [Fe(BPMEN)$(OTf)_2$]

Dylan Freas

Non-heme iron complexes function as efficient alkene epoxidation catalysts. In particular, biomimetic systems employing complexes containing the BPMEN ligand framework preferentially direct the reaction to form the desired epoxide product over the *cis*-diol in high yields. This thesis aimed to systematically tune the electronic properties of BPMEN by introducing a series of aromatic-functionalized substituents on the central amine

nitrogen atoms and to identify trends in reactivity of [Fe(BPMEN)$(OTf)_2$]-derived catalysts. An analysis of the various synthetic routes to these BPMEN-derived ligands are reported. Nucleophilic addition of a substituted aniline to an acyl chloride followed by subsequent reduction reliably produced the di- aniline intermediate, although nucleophilic substitution of the di-aniline to pyridine to form the target BPMEN-derived ligands gave rise to product mixtures. The synthesis and characterization of two derivatives of the [Fe(BPMEN)$(OTf)_2$] complex are also reported. These [Fe(L)$(OTf)_2$] complexes (L119, R = 4-Cl; L121, R = 3,4-Me_2) were employed as catalysts for the oxidation of *cis*-cyclooctene and 10-undecenoic acid, using hydrogen peroxide as an oxidant, and compared to the [Fe(BPMEN)$(OTf)_2$] standard. In general, the [Fe(L)$(OTf)_2$] catalysts exhibited little to no catalytic activity. It remains unclear whether this poor catalytic activity is inherent in the iron complexes or if experimental workflow must be improved. Future work is necessary to optimize ligand purification protocols and to fully characterize the [Fe(L)$(OTf)_2$] complexes by elemental analysis, X-ray crystallography, and cyclic voltammetry.

Development of Rapid, Modular Chemistry for the Synthesis of 1,4 and 1,5-diaryl-1,2,3-triazoles for Antibiotic Drug Discovery

Tony Huang

Because of growing bacterial resistance towards conventional antibiotics, it is critical that novel antimicrobial targets are explored. Histidine kinases (HKs), integral elements of two component systems (TCS), are promising targets as they are ubiquitous among bacteria and contain a number of conserved structural motifs. TCS serve crucial functions in bacteria, having been implicated in regulating growth, motility, and virulence. To widely inhibit multiple HKs, we believe targeting the highly conserved ATP binding domain is one strategy for developing a broad-spectrum antibiotic. Previous work in the Blair Lab found that biaryl-pyrazoles moderately inhibit HKs, but their synthesis proved inefficient, delaying exploration of novel motifs. We hypothesized that a biaryl-triazole scaffold, which can be readily accessed via click chemistry cycloaddition, is a suitable replacement for the biaryl-pyrazole scaffold due to similar spatial and electronic properties. To access this structure, both the classic CuAAC as well as base-catalyzed AAC were used to synthesize 1,4- and 1,5-diaryl-1,2,3-triazoles respectively. Reported in the work is an optimized route towards accessing structural analogs of our previously developed inhibitors of HKs. Although *in vitro* activity against CckA, our model HK that is essential to cell cycle progression in *Caulobacter crescentus*, was low for the library of triazoles synthesized this year, the presence of inhibition was promising. Efficient and highly yielding, this methodology will provide rapid access to a diverse set of molecules, facilitating future exploration of structure-activity relationships between these inhibitors and HKs.

Combating the Rise in Antibiotic Resistance: The Continued Search for Inhibitors of the Bacterial SOS System

Taylor Jackvony

Motivated by the rapid increase in bacterial resistance to antibiotics, this project is aimed at targeting the bacterial SOS system, which is involved in the two most common mechanisms by which bacteria acquire resistance to antibiotics: genetic mutation and horizontal gene transfer. Our lab is interested in specifically targeting two regulatory proteins of the system, LexA and RecA, due to the highly conserved nature of the interaction between these two proteins. Via a series of *in vitro* screening assays involving proteins purified from *Escherichia coli* cells and *in vivo* assays in *Bacilius subtilis*, cells, this project has continued the search for compounds capable of inhibiting induction of the SOS system in these two bacterial species. This year, we identified one new compound capable of inhibiting RecA-mediated LexA cleavage *in vitro*, and we determined the IC50 values for five compounds *in vivo.*

Identification and Characterization of Bacterial SOS System Inhibitors

Young Sun Lee

Despite the significant contribution of antibiotics in treating diseases, the effectiveness of antibiotics has been compromised by bacterial antibiotic resistance. Antibiotic resistance is unquestionably menacing to medical society; the emergence of multidrug-resistant organisms clearly demonstrates the severity of the threat. Researchers have been attacking the problem from different angles. Among multiple targets, the bacterial SOS system has arisen as a preeminently attractive one. Research has shown that the SOS system, a widely conserved DNA repair system in bacteria, has a direct link with antibiotic resistance and that turning off the system suppresses antibiotic resistance.

In an attempt to find a way to inhibit the SOS system, we focused on two proteins, LexA and RecA, that are not only products of the system but also function as a regulating switch. RecA-mediated LexA autocleavage results in transcription of SOS genes, which are associated with genetic mutagenesis and recombinational repair, the main mechanisms by which bacteria gain antibiotic resistance. We screened the Maybridge Chemical Library, a library composed of 14,400 compounds selected based on Lipinski's Rule of Five. The Lovett group has identified 14 effective inhibitors, five of which had expected IC50 values below 10 μM. My partner and I continued screening the library using an in vitro RecA-mediated LexA cleavage assay. At the same time, we obtained IC50 values of the five inhibitors with IC50 values below 10 μM. Four of these compounds turned out to have IC50 values around or below 5 μM, and we identified another effective inhibitor, 34H14.

Characterizing the Extracytoplasmic Function Sigma Factors of *Streptomyces coelicolor*

Brian Leland

Streptomyces is a genus of soil-dwelling, gram-positive bacteria, unique in their highly complex development and secondary metabolic processes, most notably their capacity for antibiotic production. In a microarray experiment of an *rsuA* mutant of *S. coelicolor* that fails to produce an aerial mycelium (NY415), we discovered that several extracytoplasmic functionsigma factors (*SCO1723, SCO0866, SCO3323* [*bldN],* and *SCO4409*) are more highly expressed in NY415 than in wild type. In order to better understand the impact of each of these sigma factors on the NY415 phenotype, we have created null mutants of all the aforementioned extracytoplasmic sigma factors, except *SCO4409* in wild type *S. coelicolor*. We ran various assays on each null mutant and performed light and scanning electron microscopy on them. We determined that the *SCO1723* and *SCO0866* null mutants have superficially identical phenotypes to wild type *S. coelicolor,* but scanning electron microscopy revealed that they present different spore aggregation patterns and spore lengths. The *SCO1723* mutant's spores additionally have a lower heat tolerance than the other spore samples. The *bldN* null mutant, like the NY415 mutant, does not sporulate and is delayed in its development. However, under the scanning electron microscope, we observed putative biofilm secretion at 10 days growth as well as sparse, highly deformed spore formation around this time. Additionally, attempts were made to isolate a *SCO4409* null mutant using CRISPR/Cas9 genome editing technology. The *SCO4409*-specific pCRISPomyces-2 plasmid was successfully created, and one colony has been isolated, mutation yet to be confirmed by PCR.

An Analysis of the Water Quality and Its Effect on the Williams College Class of ′66 Environmental Center: Quantification of Copper Concentrations Found in a Sustainable Building's Water System, and Its Potential to Bioaccumulate

Stephen Mayfield

The ′66 Environmental Center was opened to the general public in 2015. It was designed as a renovation and expansion of the historic Kellogg House, and was meant to meet the Living Building Challenge sustainable certification. As a result, the building is designed to be both energy neutral and water neutral. Due to the stipulations of the challenge, the south roof of Kellogg House was renovated with a copper portion to bear solar panels to meet the energy neural requirement, while the building also sports the first public water supply in the Commonwealth based on roof-captured rainwater.

The corrosion that precipitation would cause on this south roof were of interest to us due to the mobility of copper in acidic solutions, as well as the comparability between the concentrations observed in samples from the south roof and the north roof. In addition, downstream effects of the copper were of great concern; at concentrations below 2 mg/L copper is an essential micronutrient for many species of plants, while at concentrations above 1.3 mg/L, it becomes toxic to sensitive organisms such as humans. Due to adjacent vegetable gardens that will rely on this water, the bioaccumulation of the copper was another focus of my analysis.

Our study expanded from copper to include an assessment of other major cations and anions as a test of general water quality, as well as to test the effectiveness of the water system as a whole. Our findings showed that the potable water is well within the EPA guidelines of 1.3 mg/L for copper concentration in drinking water. Our investigation into bioaccumulation of copper was unsuccessful; however, with changes to the operations of the building, we can tentatively claim that the vegetables will not contain dangerous levels of copper.

Synthesis of Pyridine-Based Ligands for Sensitization of Ln(III) Complexes and Detection of Mercury and Arsenic

Miguel Méndez

Small molecule sensors have shown promise as successful detectors for metal ions in solution. Even with great success in this field, these sensors still suffer from a lack of sensitivity and short signal lifetimes, and furthermore, most can only be used within a laboratory setting. We believe the unique properties of the trivalent lanthanide ions and their subsequent complexes can be utilized as small molecule sensors to develop more effective detectors for the environmentally toxic metals arsenic and mercury. The goal of this thesis was aimed at the synthesis and characterization of pyridine-based ligands that could bind to both lanthanide ions and the target metal pollutants, As(III) and Hg(II). Asymmetric and symmetric synthetic pathways from dipicolinic acid (DPA) were used to try to integrate metal binding units bis(2-((2-(ethylthio)ethyl)thio)ethyl) amine and 2,3-dimercaptopropan-1-ol. Though there were many unsuccessful attempts in both pathways, a new symmetric pyridine-based ligand, bis((2,2-dimethyl-1,3-dithiolan-4yl)methyl)pyridine-2,6-dicarboxylate has been successfully synthesized and characterized by nuclear magnetic spectroscopy and mass spectrometry. Preliminary synthetic work has shown potential for accessing additional pyridine-based ligands, but additional progress is required to improve and modify the synthetic pathway. The following thesis discusses the background literature associated with small molecule sensors, as well as the experimental challenges and successes of the design and synthesis of pyridine-based ligands for the sensitization of lanthanide luminescence. Finally, the conclusions and future work needed to complete the project are outlined. We believe that the work detailed throughout lays the foundational synthetic work for the overall project goals of developing a luminescent lanthanide-based "turn-off" small molecule sensor for environmental imaging of mercury and arsenic.

A Dynamic Systems Approach to First and Second Order Chemical Self-Replication

Lauren Moseley

To further explore the origins of life, three chemical self-replicating models are mathematically defined and studied through the construction and analysis of mechanistic dimensionless equations—the First Order Model (FOM), the Second Order Model (SOM), and the Extended Second Order Model (ESOM). The computational program MATHEMATICA is used to visualize the oscillatory behavior of these systems and compare their capacities for sustained autocatalytic behavior. Next, a system composed of two identical SOMs is examined using MATHEMATICA to study the dynamic relationship between the two models amidst competition for a shared substrate. The resulting chemical oscillations and phase diagrams indicate that the SOMs coexist within the system, despite manipulations to intensify competition. Additionally, the amplitude of the competitive system's resulting chemical oscillations are determined by initial concentration of the competing substrates. Finally, a study of alternating dynamics is conducted to examine another method of inputting reagents into a system. Both sinusoidal and stepwise methods are successful in the creation of sustained chemical oscillations. The FOM displays more complex oscillatory behavior than the SOM when studied using both alternation methods.

RAFT Synthesis and Characterization of Cationic Triblock Copolymers and Anionic Drug Self-Assembly Studies

Jessica O'Brien

Micelles have many uses in drug delivery, especially those involving cationic-anionic interactions. Doubly hydrophilic cationic triblock copolymers were synthesized from 2-(dodecylthiocarbonothioylthio)-2-methylpropionic acid (DDMAT), poly(ethylene) oxide (PEG), and 2-(dimethylamino)ethyl acrylate (DMAEA). DDMAT was synthesized first, followed by DDMAT-PEG-DDMAT and DMAEA-PEG-DMAEA. Additionally, poly(acrylic acid) (PAAc) was synthesized from *tert*-Butyl acrylate and DDMAT. 1H-NMR provided both degree of polymerization and the molecular weight of polymers. IR confirmed that functional groups were conserved throughout the syntheses. Dynamic light scattering provided evidence that micelles formed in solution when copolymers were combined with a model anionic drug (PAAc); the micelles formed from cationic-anionic interactions. Radii size of 25 to 100 nm were considered micelles, while radii size larger than 100 were considered micellar aggregation. Finally, cell viability tests showed that micelles with DMAEA-PEG-DMAEA and PAAc, or either component added separately, did not affect the growth of cancerous cells, suggesting low toxicity. This provides evidence that the micelles may not be harmful to the human body.

Synthesis and Characterization of NIPAAm and Acrylic Acid-based Polymer-lysozyme Conjugates

Luxi Qiao

Enzymes' stability, affinity and specificity, efficiency, and reusability, distinguish them from small molecules drugs and make them ideal for pharmacological uses. However, there are some challenges such as sensitivity to heat and proteolytic digestions that prevent more prevalent uses of enzymes as drugs. One particularly interesting enzyme is lysozyme, which has been shown in the past to have anti-HIV, anti-tumor, and anti-bacterial properties. Here we used two techniques, EDC-coupling and HBTU- coupling, to conjugate lysozyme to a copolymer made up of two stimulus-sensitive monomers: *N*-isopropylacrylamide (NIPAAm) and acrylic acid (AA). NIPAAm is temperature responsive and AA is pH sensitive. The structure and stability synthesized conjugates were then evaluated using circular dichroism, dynamic light scattering, and other spectrophotometric methods. Lastly, *in vitro* bioactivities of the conjugates and enzymatic activity were evaluated. In summary, polymers showed thermoresponsive behavior. Bioconjugates were synthesized with good yields. In addition to exhibiting increased thermal stability and protection against proteolytic digestion, the conjugates, as with lysozyme, also showed selective bioactivity against cancerous cells.

Completing the Total Synthesis of Jerangolid D

Carly Schissel

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 contains structural similarities to another secondary metabolite of *S. cellulosum,* ambruticin, which is a well-known antifungal agent. Jerangolid D also shares a conserved genetic sequence of PKS enzymes, which could account for the shared structural components between jerangolids and ambruticins. This document highlights the progress towards and the ultimate completion of the total synthesis of jerangolid D. A cinnamaldehyde model system was employed to optimize and prepare for the final three steps in the synthesis. The complex aldol adduct was then synthesized via the diastereoselective thiazolidinethione-mediated aldol addition chemistry used previously in the synthetic scheme. Transacylation with potassium ethyl methylmalonate then allowed for the production of β-ketoester, and finally lactonization of the δ-hydroxy-β-ketoester and subsequent methylation by Me_2SO_4 prepared the final molecule, jerangolid D. Each of the three new molecules, as well as the three model system products, was characterized by ^{1}H NMR, ^{13}C NMR, COSY, HMQC, and ATR-IR. Direct comparison of spectra of synthetic jerangolid D with those of natural jerangolid D confirmed the completion of the synthesis.

Examination of *whiJ* homologs and their role in sporulation in *Streptomyces coelicolor* A3(2)

Megan Steele

Streptomyces coelicolor are complex soil bacteria with an unusual life cycle that involves the formation of a vegetative and an aerial mycelium and culminates in the dispersal of spores. Mutants that form the aerial mycelium but cannot produce the grey pigment associated with mature spores are called *whi* mutants. This work focused on one of the *whi* genes called *whiJ*, which is relatively poorly characterized. There are 3 genes in the *whiJ* locus: *whiJA (SCO4543), whiJB (SCO4542),* and *SCO4544.*

Although the relationships between the genes in the *whiJ* cluster have been studied extensively, the results of these experiments have often been inconclusive. The characterization of *whiJ*-like genes in *S. coelicolor* and other species of *Streptomyces* could inform the development of a possibly conserved mechanism of interaction between the genes in the *whiJ* family. Thus, the frequency and permutation of *whiJ* homologs in *S. coelicolor* and other species of *Streptomyces* was analyzed. Homologs of *whiJ* genes were found in almost every possible arrangement across the 19 species of soil-dwelling *Streptomyces* species that were analyzed. However, there were no *whiJ* homologs in any of the 16 marine-dwelling *Streptomyces* species that were examined.

Two models have been proposed to explain how the *whiJ* genes interact to mediate sporulation. It was hoped that examination of a paralogous set of genes would lend support to either model. The *E6* cluster was chosen because a mutant of the *E6A* paralog had the most severe phenotype. The goal was to create five different *E6* cluster mutants: *E6A,* Δ*E6B,* Δ*E6AB,* Δ*SCO2864,* and Δ*E6fullcluster.*

Since not all mutants were constructed, full analysis is not yet possible. Partial deletion of *E6A* delayed but did not ultimately disrupt sporulation. There were no significant differences in the spore length or the viability of the spores in response to heat stress between wild type and the *E6A* mutant. Multiple Δ*E6B* and Δ*E6AB* mutant

isolates were obtained, but analysis of the genome revealed that these strains apparently contained a mixture of "mutant" and "wild type" DNA. In the Δ*E6B* and Δ*E6AB* mutants there might be abnormalities in the chromosome partitioning process that causes each spore to receive multiple copies of the chromosome. There was significant variability in the *E6B* phenotypes; it is possible that these mutants had different ratios of "wild type" and "mutant" chromosomes.

Evaluating Inhibitor and Ligand Binding to Histidine Kinases Using ThermoFluor

Douglas Wassarman

In an effort to address growing the growing concern of antibiotic resistance, we investigate the development of new antibiotics that target the histidine kinases (HKs) of two-component signaling in bacteria. HKs present an appealing target due to their presence in most bacteria, critical roles in virulence, and conserved catalytic core. Previous work has shown that the structural conservation between the ATP- binding domains of Hsp90 and HKs facilitate the binding of Hsp90 inhibitors to HKs. We synthesized two compounds based on a small molecule shown to weakly bind Hsp90. We show that ThermoFluor can be used to detect the binding of ligands to both PhoQ and CckA, HKs from *Salmonella* and *Caulobacter*, respectively. We used ThermoFluor to measure the binding of these two molecules as well as known HK inhibitors to these HKs and found a preference for CckA binding.

Computer Science

Light-Probe Selection Algorithms for Real-Time Rendering of Light Fields

Samuel Donow

This thesis presents the data structures and algorithms necessary for approximating the plenoptic function in real-time using samples at a low spatial density called light probes. By computing the light into a few points in a scene in many directions, as well as distance from those key points to the scene, we can interpolate in order to reconstruct lighting information for the entire scene. The algorithm presented here is tunable with various heuristics for achieving desired results, as well as extensible, allowing other techniques from Computational Graphics to be brought to bear upon this new framework for answering general ray queries.

Computation in the Wild: Reconsidering Dynamic Systems in Light of Irregularity

Tony Liu

Dynamic, spatially-oriented systems found in nature such as plant cell arrays or ant colonies can produce complex behavior without centralized coordination or control. Instead, they communicate locally, with these local interactions producing emergent behavior globally across the entire system. The essence of these decentralized systems can be captured utilizing cellular automata (CA) modeling, and such models are utilized for investigating and simulating such natural systems. However, CA models assume spatial regularity and structure, which are certainly not present in natural systems. In fact, natural systems are inherently robust to spatial irregularities and environmental noise. In this work, we relax the assumption of spatial regularity when considering cellular automata in order to investigate the conditions in which complex behavior can emerge in noisy, irregular natural systems.

Predictive Pod Auto-scaling in the Kubernetes Container Cluster Manager

Mathew McNaughton

Recent increases in the volume and scope of computable tasks drive increases in the utilization of distributed systems, specifically cluster computing. Increases to efficient resource utilization (ERU) and quality of service (QoS) are essential to ensuring cluster computing can reliably and cost-effectively handle these new types of resource-intensive computing tasks. One predominant method for improving ERU and QoS is auto-scaling, which allocates applications running on a cluster exactly the resources they need. Kubernetes, a new open-source cluster manager from Google, successfully implements reactive horizontal auto-scaling, meaning Kubernetes uses the current resource utilization of the application to determine how to replicate applications across the cluster to ensure each application operates at a previously specified resource utilization level. We add predictive auto-scaling to Kubernetes, as we use predictions about future resource utilization to replicate

applications. While we find the addition of predictive auto-scaling does not universally improve the summation of ERU and QoS in representative trials, we highlight certain scenarios in which predictive auto-scaling is particularly beneficial. In short, this thesis presents users of Kubernetes, and cluster managers in general, an additional option for efficiently and reliably running their application. In doing so, we expand the realm of issues addressable through computing with distributed systems.

All the News That's Fit to Troll? Algorithmic Moderation of the New York Times Comment Section
Pamela Mishkin

As user comments become a standard offering of online news platforms, journalists and publishers have to learn to balance the tension between robust discussion and ensuring that user-generated content adheres to their journalistic standards in terms of honesty, civility, and style. This work considers how the New York Times has navigated this process, providing a high-level characterization of the New York Times comment space since its inception, focusing in particular on the period from July, 2011 through December, 2012. The thesis also considers patterns in rejected comments. Results suggest that the human editorial decisions are sufficiently subtle to prevent accurate classification solely on linguistic features. Other potential directions for employing user data to improve classification are discussed.

Specifying and Enforcing Synchronization Disciplines in Multithreaded Programs
Dong Hwan (David) Moon

Multithreaded programs are notoriously prone to race conditions. Programmers try to avoid race conditions by adopting various synchronization disciplines, which are simple policies for ordering thread access to shared memory. As these disciplines are left implicit, most existing methods for dynamic race detection can only verify whether a set of memory accesses are ordered, not whether they are ordered as intended.

This thesis presents a new framework for specifying and enforcing synchronization disciplines in multithreaded programs. We introduce a simple model for synchronization disciplines called a synchronization flow graph (SFG for short) which captures the dynamic behavior of a discipline in terms of ordered sequences of access modes. Disciplines for individual program variables can be declared as SFGs using a compact text-based specification grammar. We also present a corresponding technique for dynamically enforcing conformance to specified SFGs. This technique automatically refines each specified SFG into a corresponding Petri net, which is then simulated at run time to enforce conformance. We prove that execution conformance to any specified SFG implies race freedom, and that our enforcement technique is sound with respect to conformance.

Faux Vector Processor Design Using FPGA-Based Cores
Diwas Timilsina

Roughly a decade ago, computing performance hit a power wall. With this came the power consumption and heat dissipation concerns that have forced the semiconductor industry to radically change its course, shifting focus from performance to power e!ciency. We believe that Field programmable gate arrays (FPGAs) play an important role in this new era. FPGAs combine the performance and power savings of specialized hardware while maintaining the flexibility of general purpose processors (GPP). Most importantly, pairing an FPGAs with a GPP to support partnered computation can yield performance and energy e!ciency improvements, and flexibility that neither device can achieve on their own. In this work, we show that a GPP tightly coupled to a sequential vector processor implemented on an FPGA, called Faux Vector Processor (FVP), can support e!cient, general purpose, partnered computation.

Composing Bach-Style Chorales with Psychologically Realistic Representations
Kai Wang

We introduce a novel input representation, the Tonnetz, for learning polyphonic music with state-of-the-art recurrent neural network models. The Tonnetz, based on music theory and psychological evidence, partitions music note into a meaningful toroidal metric space, where geometric distance is correlated with musical distance. By mapping the Tonnetz into a 2D plane, we are able to apply convolutional neural networks on top of that to extract meaningful musical features. By combining such features with a more traditional 88-note input

representation, we create a hybrid, multicolumn neural network which we train on the set of John Sebastian Bach chorales. Preliminary experimental results have shown that using Tonnetz as an input representation provides noticeable improvement in performance for some aspects of the models. In particular, our Tonnetz-based neural network is able to learn datasets with more complex musical features than the baseline, and is particularly good at predicting the end of the musical piece—which is the most musically structured part. In additional to that, our model performs better in retrieving octave information—an important aspect of music.

Predicting Expressive Bow Controls for Violin and Viola

Lauren Yu

Though much progress has been made in building computational systems to faithfully simulate notes on a staff of sheet music, little is known about how to capture the artistic liberties professional musicians take to communicate a particular interpretation of those notes. Sheet music provides the outline for playing a particular piece, but it is ultimately up to the musician to extrapolate performance guidelines that both honor the composer's intent and present a reasonable interpretation of the work. Like text needing a reader to bring the words to life, a performer decides how to interpret a piece of music and determines how to make that interpretation a reality. In this thesis I present a new dataset of annotated sheet music with information about specific aspects of bow controls. I then present experiments for building and testing predictive models for these bow controls, as well as analysis that includes both general metrics and manual examination.

Geosciences

The Water Balance and Hydrologic Performance of the Class of '66 Environmental Center 2015-2016

Caroline E. Atwood

The water balance equation is a basic hydrologic relationship that can be used to evaluate the overall flow of water in and out of a system and to illuminate the hydrologic processes that produce the balance. The Williams College Class of '66 Environmental Center, located in Williamstown, MA, is currently seeking certification as a Living Building. The Living Building Challenge is a philosophy, advocacy and project certification tool developed by the International Living Future Institute, which promotes regenerative infrastructure in the built environment. I measured and estimated components of the year 2015-2016 water balance for the buildings and surrounding site of the Environmental Center, in order to evaluate the Center's performance under Living Building Challenge water imperatives. The project receives an annual average of 112 cm of precipitation and potentially loses 70 cm to evapotranspiration, leaving 42 cm available for storage and runoff. I used a color orthophoto and DEM base collected by a drone overflight as a map base and to classify the site into hydrologic units. I also measured water consumption by building occupants and production of effluent (blackwater). In addition, I used field observations and water-surface monitoring techniques to measure depth changes for the Environmental Center's storm water retention and infiltration structures in response to precipitation events. I found that the building projects a large annual surplus of water after all internal building needs are met. I also found that the site will have an annual surplus of water and estimated that 700m3 flowed offsite as surface runoff in 2015-16. In the future, I predict that the amount of offsite surface runoff will decrease because of the infiltration capacity of the site will continue to increase as vegetation become reestablished. Overall, my results indicate that Williams' College Environmental Center has already met, or is on track to meet in the near future, the Living Building Challenge water imperatives.

Modeling Non-linear Ocean Wave Amplification for Coastal Boulder Transport

Joshua P. Harrington

Numerical modeling is a powerful technique for exploring complex systems, like ocean waves, in a controlled environment. Coastal boulder deposits, like those previously examined by our lab in the Aran Islands, record wave power and can be used to estimate maximum wave sizes for past events. Simplified wave models, like linear wave theory, are often used in these boulder transport models, but such models do not capture important higher-order effects that can drastically increase wave heights. In this study, we modeled the behavior of 2D

wave trains using Euler's equations and observed the runup of these wave trains against a vertical barrier. Previous research has shown that wave trains passing over flat bathymetry can experience vertical runup up to 6x the initial wave amplitude for both long (125 times depth) and short (3 times depth) wavelength waves. We used a conformal mapping solution to Euler's equations to explore the vertical runup of such amplified wave trains after they passed over a single, sharp decrease in depth. This stepped bathymetry induced additional runup for long-wavelength waves, and these waves reached maximum runup heights up to 10x initial amplitude. Short-wavelength simulations were hampered by the limitations of Euler's equations for steep waves, and these simulations crashed before reaching previously reported runup values. Runup for short-wavelength waves over a flat bottom reached a maximum height of 4.25x the initial wave amplitude, and all short-wavelength simulations using stepped bathymetry recorded runup values less than this flat-bottom maximum runup height. For both long and short-wavelength waves, we observed runup values larger than the 2x initial amplitude predicted by linear wave theory. The additional runup for long-wavelength waves caused by variable bathymetry suggests that bathymetric affects could help ocean waves climb vertical cliffs and transport boulders well above high water. This study provides a better understanding of how ocean waves interact with simple bathymetry, and could help direct future experiments exploring the behavior of broken waves and boulder transport by ocean waves.

Charcoal-rich Mounds in Litchfield County Ct Record Widespread Hillslope Disturbance in the Iron Corridor from Mid 18th to Early 20th Centuries

Mary E. Ignatiadis

Charcoaling mounds constructed in northwestern Connecticut from the mid-18th to early 20th centuries fueled the region;s iron industry and continue to impact the landscape today. The total number (20,500) and high concentration of mounds (40-80 mounds km^{-2}) in Litchfield County suggests that they are important markers for the onset of the Anthropocene in this area, but the mounds have not been studied previously. We sampled soil profiles and made field and GIS-based measurements from four study areas that indicated the hillslope mounds represent a discrete pulse of downslope sediment transport and carbon sequestration.

The Abundance, Taxonomy, and Taphonomy of Vase-shaped Microfossils from the Callison Lake Formation, Yukon, Canada

Spencer W. Irvine

Vase-shaped microfossils (VSMs), interpreted as the remains of testate amoebae, are found in Late Tonian sedimentary rocks around the world. A new assemblage of VSMs has recently been described from the Callison Lake Formation in Yukon, Canada. Found in silicified black shale horizons as well as carbonate rocks, sedimentological data suggests these VSMs inhabited a lagoonal or shelf interior environment. Dated with Re-Os geochronology at 752.7 +/- 5.5 – 739.9 +/- 6.1 Ma, these microfossils are indicative of the early diversification of eukaryotic life prior to the Sturtian-age Snowball Earth event, and are roughly coeval with the diverse VSM assemblage from the Chuar Group of Grand Canyon, Arizona. Here we investigate the distribution and taxonomic and taphonomic variation of the Callison Lake VSMs. Fossil absolute abundance was determined by utilizing point counting techniques on petrographic thin sections. Photographs of each "count," coupled with high-magnification images of well-preserved and distinctive forms, were analyzed using ImageJ software to examine the morphological variation. In order to distinguish morphospecies we measured features such as test length, test width, aperture diameter, neck length, and concavity. We found that fossil abundances are as high as ~8% of counts per thin section, but vary dramatically across sections and horizons, declining to <1%, even between samples only 0.2 m apart. Among imaged, distinctive forms, vase-shaped and curved-neck morphospecies were found to be more abundant than hexagonal forms, which is consistent with assemblages from the Chuar Group. Additionally, analyses of well-preserved specimens reveal taxa comparable to those from the Chuar Group, as well as some previously undescribed morphospecies of VSMs. Overlapping species with Chuar Group VSMs include *Melanocyrillium hexodiadema, Cycliocyrillium simplex, Cycliocyrillium torquata, Bonniea dacruchares,* and *Bonniea pytinai*, while a long-necked vase and elongate curved-neck forms may represent new species of VSM. Elemental mapping done with energy dispersive X-ray spectroscopy (EDS) indicate that silicification is the most dominant preservation style, though fossils can

also be preserved with their original test wall, by authigenic mineralization, or in the carbonate horizons, be calcified. Preserved as mineralized casts or internal molds, the VSMs in this study serve to help reconstruct Late Tonian ecosystems before the Snowball Earth events, expand our understanding of the early diversification of eukaryotic life in the Neoproterozoic, and help assess the viability of VSMs as index fossils for the Late Tonian.

Microfossil Assemblage Variation Through the Kellwasser Events of the Late Devonian Mass Extinction

Abigail A. Kelly

The Kellwasser Events are globally expressed as two black shale horizons associated with the Late Devonian Extinction and the Frasnian/Famennian transition. The Kellwasser horizons have been interpreted as a signal of widespread marine anoxia correlated with the extinction interval. In Western New York, the Kellwasser horizons were deposited in the epeiric sea of the eastward-shallowing Appalachian Basin. While larger body fossils are mainly absent within the Kellwasser horizons, organic-walled microfossils, classified as acritarchs, are abundant and provide a nearly continuous record throughout the events.

In this study, we assess microfossil morphology, diversity, and abundance variation through Kellwasser Events. We sampled the Lower Kellwasser horizon at Hannover, NY and Hornell, NY, representing deeper and shallower marine paleoenvironments respectively. Additionally, we sampled the Upper Kellwasser horizon in Hannover, NY. In all localities, microfossil diversity is very low (relative to non-Kellwasser surveys of Devonian palynoflora), a trend indicative of ecological stress. The Upper Kellwasser horizon assemblages included only leiosphere fossils, and there was were no significant differences between assemblage morphologies and abundance trends between the Kellwasser horizon and the overlying Dunkirk formation, indicating that the environmental conditions of the Upper Kellwasser Event persisted after the event.

In contrast, we find that the microfossil assemblages of Lower Kellwasser Event show significant variation. This indicates that the Lower Kellwasser Event was more biologically significant than the Upper Kellwasser Event, adding support to similar findings in the Appalachian Basin (Bush et al., 2015), yet conflicting with the biological pattern in Europe. There is evidence that the Lower Kellwasser horizon was deposited during a transgressive-regressive cycle in sea level, and that algal bloom events and eutrophication are associated with both the sea level maximum and the peak in preserved organic carbon (symptomatic of marine anoxia). Algal bloom events and eutrophication may be a critical component of the anoxia associated the Kellwasser Events and the Late Devonian Mass Extinction, either contributing causally to the extinction or arising as a symptom of already-stressed ecological conditions.

The Geomorphology of Mountains on Io

Christina H. Seeger

On Io, the most volcanically active body in the Solar System, tectonic mountains exhibit a range of morphologies. It is hypothesized that there may be a link between these mountains and the active volcanic sites (particularly in depressions called paterae). However, all previous analyses of the spatial distribution of mountains and volcanic centers have ignored the morphologic differences among mountains. In order to evaluate the significance of these variations, we propose a classification scheme based on apparent mountain erosion. In this classification scheme, fresh mountains, characterized by sharp scarps and steep slopes, over time undergo gravitational relaxation, becoming less rugged, more lobate, and exhibiting signs of mass wasting. We observe very few fresh mountains on Io. This may be due to the fact that degradation rates are higher than formation rates, which allows us to propose an upper limit on mountain age. By evaluating mountain distribution in conjunction with these geomorphic categorizations, we suggest that mountains close to paterae tend to erode faster due to seismic-induced mass wasting, subsurface fluid movement, and slope oversteepening by volcanic ejecta.

Detrital Zircon Constraints on the Age of the Granville Dome Mantling Sequence

Laura K. Stamp

The Granville dome straddles the Massachusetts-Connecticut border in the Connecticut Valley trough and is considered part of the Ordovician Shelburne Falls arc. As mapped, it is cored by the Ordovician Collinsville

Formation, with an inner mantle of Devonian Goshen Formation and an outer mantle of Ordovician Cobble Mountain Formation, which has led to complex structural models of dome formation. Here I use zircon data from the Collinsville Formation to confirm that the Shelburne Falls arc formed on the Gondwanan-derived Moretown Terrane. I then test the assignment of the inner mantle rocks to the Goshen Formation by comparing detrital zircon from schist on the east flank of the dome and from an outcrop north of the dome mapped as Goshen Formation. U-Pb data from both samples show a dominant Laurentian component, a significant population at 550 to 650 Ma consistent with a Gondwanan source, a sharp Ordovician peak derived from arc-related rocks, and a sharp Early Devonian peak. These results are consistent with assigning the inner mantle rocks to the Goshen Formation, which has been dated in western Massachusetts at ca. 405 Ma by U-Pb zircon analysis of an interbedded volcanic tuff. The Goshen Formation zircon population is similar to those of the Silurian to Devonian Waits River and Gile Mountain Formations from the Connecticut Valley trough in Vermont (McWilliams et al., 2010), and by analogy I interpret the depositional environment of the Goshen Formation to be a continental slope environment in an intercontinental back-arc transitioning to a foreland basin. The basin was receiving detritus from multiple sources, indicating that Laurentia, peri-Gondwanan crust, Ordovician arc rocks, and late-Silurian to early-Devonian igneous sources were proximal to each other. To the north, the Goshen Dome in Massachusetts shows evidence of ultra-high-pressure metamorphism, and the Chester Dome in Vermont contains a high-strain zone. Based on the similar tectonic setting of the Granville Dome to the Goshen and Chester Domes and the kyanite identified in the Granville Dome, I propose high-pressure metamorphism and a tectonic boundary between the Collinsville and Goshen Formations. I suggest formation of the Granville Dome at ca. 380 Ma, constrained in part by an aplite dike of the same age in the Goshen Formation that indicates metamorphism and partial melting at ca. 380 Ma. Neither the Chester nor the Goshen Dome includes the Cobble Mountain Formation mantle, and therefore, the formation of the Granville dome appears to require an episode of Devonian back-thrusting of the Cobble Mountain Formation to bring it structurally above the Goshen Formation.

Tephronchronology as a Tool to Constrain Surface Reservoir Age in the Deglacial Bering Sea

Caroline C. White-Nockleby

In order to accurately calendar date marine carbon, it is necessary to constrain surface reservoir age, the apparent ^{14}C age difference between the atmosphere and surface ocean that results from incomplete equilibration of ^{14}C across the air-sea interface. Surface reservoir age is generally assumed to be constant at the preindustrial value, but evidence suggests it has varied through time by up to 1000 years. In this study I use tephrochronology, a method of correlating tephras across different environments to identify equivalent strata, as a tool to quantify reservoir and Benthic-Atmospheric age during the Bolling Allerod (14.7 – 12.9 kcal BP). I analyze major and trace elements using electron microprobe data and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) in candidate tephras from two marine cores from the Umnak Plateau, HLY02-02-51JPC and HLY02-02-55JPC. These sites are uniquely located under the "Bering Green Belt" region of high foraminiferal abundance, providing the opportunity to calculate the first high-resolution record of surface reservoir age in the subarctic Pacific. I identify two likely and two possible tephra matches between marine cores, and measure benthic-atmospheric age differences in these tephra by comparing ^{14}C ages of benthic and planktonic foraminifera. The Benthic-Atmospheric ages found are similar to previous Bolling Allerod ages measured in the North Pacific, but slightly smaller than the local preindustrial value. I also compare the tephra compositions to tephra in a core from Deep Lake, Sanak Island in the Eastern Aleutians (Misarti et al., 2012). I do not find any tephra matches between the marine and lacustrine environments. However, I calculate a surface reservoir age for a massive tephra in HLY02-02-55JPC that was previously matched (Chapman, 2015) to a tephra dated to 14.8 kcal BP from Sanak Island (Misarti et al., 2012). The surface reservoir age (929 ± 162 ^{14}C yr) is effectively the same as the surface reservoir age previously calculated between the matching massive tephra in HLY02-02-51JPC and Sanak massive tephra (934 ± 160 14C yr). This age is also similar to the average preindustrial value in the region (790 ± 130 ^{14}C yr). Ultimately, results presented here and future work on these tephras could help evaluate the accuracy of ^{14}C reconstructions of Pacific Ocean circulation throughout the deglaciation.

Mathematics & Statistics

Generalizations of Multidimensional Continued Fractions: Tetrahedron and k-Dimensional

Emmanuel Howard Daring

The decimal and continued fraction expansions of a number are periodic if and only if the number is rational or a quadratic irrational, respectively. Multidimensional continued fractions aim to replicate this property with different types of irrational numbers, partitioning a triangle to produce a periodic sequence if the coordinates of the point the sequence describes are at worst cubic irrationals in the same number field. In this paper, we redefine an existing multidimensional continued fraction algorithm which partitions the triangle. This new definition lends itself to being generalized to higher dimensions, partitioning any infinite n-th dimensional simplex to produce periodic sequences when the coordinates of a point are algebraic in the same number field of degree n + 1. We observe this generalization in action for the case n = 3, where the 3rd dimensional simplex is a tetrahedron.

Moves on Übercrossing Projections of Links

Xixi Edelsbrunner

Generally knot and link projections have crossings with two strands passing through. An übercrossing projection of a link L is a projection with exactly one crossing with any number of strands bisecting it. The übercrossing number $\ddot{u}$ is the least number of loops in any projection of L. We develop moves with which we can travel between übercrossing projections for a fixed knot. We also present a proof for a bound on braid index in terms of übercrossing number for link projections.

Blowing Up Toric Varieties With Multidimensional Continued Fractions

Elizabeth Frank

Because toric varieties are built up from convex geometry, there is a natural connection to be made with triangle partition maps, which are multidimensional continued fraction algorithms. Our motivation to explore this connection is showing that to resolve the curve $y^p=x^q$ we follow a path of blowups given by the continued fraction expansion of p/q. Dividing the triangle according to the Triangle Map turns out to be equivalent to blowing up an axis in C^3. We apply these blowups to resolving singularities of curves. We also discuss these blowups and blowdowns in terms of attracting or repelling curves toward or away from curves defined by a quadratic irrational or a pair of cubic irrationals with a periodic triangle sequence.

Bipyramid Decompositions of Multi-Crossing Link Complements

Gregory Kehne

Generalizing constructions of D. Thurston and C. Adams, we present a dual pair of decompositions of the complement of a link L into bipyramids, given any multi-crossing projection of L. When L is hyperbolic, this gives new upper bounds on the volume of L given its multi-crossing projection, which empirically approach a constant factor of the volume for typical petal and über knots. Additionally, this construction yields families of immersed surfaces in the complement of L, including a generalization of checkerboard surfaces.

Examining More Sum Than Difference Sets in Multiple Lattices

Lawrence Luo

The definition of a traditional MSTD set is a finite set $A \subset Z$ whose sumset, defined by $A+A = \{a_1 + a_2 : a_1, a_2 \in A\}$, is larger in cardinality than its difference set $A-A$, defined by $A-A = \{a_1 - a_2 : a_1, a_2 \in A\}$. We can view a MSTD set in two dimensions by making a polytope P whose lattice points form the elements from which a set A is constructed. The sumset and difference sets of A are then calculated by adding or subtracting the coordinates of the lattice points.

Thao Do, Archit Kulkarni, Steven Miller, David Moon '16, Jake Wellens, and James Wilcox '13 explored MSTD sets in $\mathbf{R}^D$ space with lattice points in $\mathbf{Z}^D$, for D > 0, generalizing previous results in $\mathbf{Z}$ by allowing the dilation of polytopes in $\mathbf{R}^D$. Instead of exploring MSTD sets in $\mathbf{R}^D$, we examine the frequency of such sets in the $\mathbf{R}^2$ space specifically.

To observe MSTD sets in two dimensions, we first take the five possible lattices in the Euclidean plane (square, rectangular, rhombic, parallelogramic, and hexagonal) and prove that every convex polytope in one lattice has a "strongly" equivalent convex polytope for each of the four other lattices that preserves its MSTD characteristics.

We investigate and discuss the importance of interior points for preserving the MSTD nature of balanced convex polytopes across lattices, and also discuss how a difference dominant convex polytope remain difference dominant when taking the boundary plus any combination of its interior points.

We also discuss efficient boundary constructions for generating larger MSTD densities, and offer conjectures on optimal boundary constructions for the square and hexagonal lattices.

We conclude with a discussion on the shortcomings of the code used to generate our experimental data.

Generalizing the Minkowski Function Using Triangle Partition Maps

Peter Morton McDonald, Jr.

In this paper, we present two previous attempts at generalizing the Minkowski Question Mark Function before presenting a framework for generalizing ?(x) to a family of 216 multidimensional continued fraction algorithms known as triangle partition (TRIP) maps. Furthermore, we place these 216 maps into 15 classes whose associated generalization of the Question Mark Function is related by a linear transformation and show for 7 of these classes that this function is singular.

Neuroscience

The Effect of Neonatal Inflammation on Neural Inflammation and Anxiety Behavior In Selectively-Bred Rats

Lauren D. Claypoole
(advisor: L. Williamson)

Disruptions in homeostasis, such as the induction of inflammation, occurring during the neonatal period of development often produce changes in the brain, physiology, and behavior that persist through the life span. This study seeks to investigate the potential effects that an immune challenge delivered during neonatal development would have on anxiety behavior and stress reactivity later in life within a selectively-bred strain of rat. The rats have been bred for multiple generations to display high anxiety-like phenotypic behavior and low anxiety-like phenotypic behavior. We set out to investigate the role of early life inflammation on neonatal and adult anxiety-like behavior, the neonatal central and peripheral immune response, and adult stress reactivity and examined each cohort in terms of line (High- or Low-line), inflammation treatment, and sex. Overall, we saw consistent differences between lines in terms of neonatal anxiety-like behavior, peripheral neonatal immune response to an inflammatory agent, adult anxiety-like behavior on the elevated zero maze behavioral paradigm (EZM), and adult anxiety-like behavior after stress induction. Furthermore, we also observed an effect of neonatal treatment in terms of neonatal peripheral response and adult anxiety-like behavior on the EZM. We also observed an effect of sex within the anxiety-like behavior of LPS-treated adults exposed to stress paradigm. The combined results shed light on the relationships between neural development, early-life inflammation and anxiety throughout the lifespan.

Physics

Precise Measurement of the Indium 6P1/2 Stark Shift Using Two-Step Laser Spectroscopy

Allison L. Carter

We have completed a measurement of the scalar polarizability of the 6P1/2 state of indium. Our results give a value of $\alpha 0 = 7688 \pm 41(\text{stat}) \pm 32(\text{sys})$ a03, which is in good agreement with the theoretically predicted value. We lock a 410 nm laser to the 5P1/2 → 6S1/2 transition and scan a 1343 nm laser across the 6S1/2 → 6P1/2 transition, with the lasers passing through both an atomic beam and a vapor cell. We have developed a new method of locking the 410 nm laser directly to the atomic beam transition, and we use single-tone FM

spectroscopy to obtain this locking signal. We also detect the spectrum from the 6S1/2 → 6P1/2 transition for a variety of applied electric fields in the atomic beam using two-tone FM spectroscopy. In the course of this experiment, we have also obtained a very precise measurement of the hyperfine splitting of the 6P1/2 state of 1267.0(2) MHz, for which the uncertainty is dominated by systematic effects. This value is an order of magnitude more precise than the previous measurement.

Measurement of the Hyperfine Structure of the 8P1/2 state in 203Tl and 205Tl Using Two-Step Laser Spectroscopy

Sauman Cheng

The hyperfine splitting of the 8P1/2 excited state in 203Tl and 205Tl, as well as the isotope shift within the 7S1/2 → 8P1/2 transition, have been measured using two-step laser spectroscopy. Our measured values for the hyperfine splittings are 780.5(5) MHz in 203Tl and 788.3(7) in 205Tl. The transition isotope shift of 203Tl relative to 205Tl was measured to be 450.3(1.0) MHz. Our value for the hyperfine splitting in 205Tl is in statistical agreement with the 1988 published value and very close to the 1993 published value, both of which quote comparable precision. Our value for the hyperfine splitting in 203Tl falls in the middle of the two most recently published values, as does our value for the level isotope shift in the 8P1/2 state. In our experiment, one laser was locked to the 6P1/2 (F = 1) → 7S1/2 (F' = 1) 378 nm transition, while a second, 672 nm red laser was scanned across the 7S1/2 (F = 1) → 8P1/2 (F'' = 0, 1) transitions. The two lasers were spatially overlapped inside a heated thallium vapour cell. Radio-frequency modulation of the red laser was used to create sidebands in the absorption spectrum to introduce a method of frequency calibration internal to the absorption spectra.

Amplifying a Modelocked Fiber Laser To Produce Ultrashort Pulses

Brian Cintron

This thesis presents the work to amplify a passively mode-locked all fiber laser used to produce ultrashort pulses. The fiber laser takes advantage of nonlinear effects, intrinsic to optical fiber, to create picosecond pulses. A fiber amplifier was built and added to the optical setup to increase the total peak power of the fiber laser, to record an autocorrelation through two photon absorption. The combined amplifier and laser produced spectra and autocorrelation pairs for varying polarization settings. According to the spectra we have the theoretical bandwidth to support pulses as short as 0.4 picoseconds. The results from the autocorrelation data tell us that our pulses are on average 0.8 picoseconds, which are the shortest pulses recorded in our lab. We believe dispersion broadens the pulses beyond the fourier transform limit.

RNA Macrostates and Macrokinetics

Bijan Mazaheri

We demonstrate that RNA has an exponential density of states, inducing a surprising separation of the average free energy from the minimum free energy. We argue that the resulting distribution of state probabilities calls for new partition function-based methods of analyzing RNA secondary structure states and kinetics. First we develop methods that define RNA macrostates, which consist of ensembles of structurally similar secondary structures. Next, we develop a partition function-based models of macrostates, and the transition region separating macrostates, to predict the relaxation kinetics.

Evaluating a Semi-classical Approximation for the Dynamics of Multi-particle Spin Systems

Ashwin Narayan

Exactly evaluating the time-dependent density matrix for a system of interacting spin-½ particles takes exponential time and is therefore computationally intractable. We attempt to rigorously evaluate an efficient semi-classical approximation algorithm ("the SPR method") introduced in Schachenmeyer et al. (2015) which calculates the time-evolved state of a system of spin-½ particles. The algorithm essentially rewrites the initial state of the system as the weighted average of cleverly chosen basis states, and classically evolves each basis state. We prove that for the Ising Hamiltonian with arbitrarily many particles, the single-particle restricted density matrices of the SPR approximation are exactly correct. We show the same result for the two particle Heisenberg Hamiltonian for a specific subspace of starting states. Both proofs are highly non-trivial (we have

not even been able to extend the Heisenberg proof to three particles, although simulations indicate the result still holds), and so we present some numerical results on the performance of the SPR method for various Hamiltonians and randomized starting states. The simulations reveal that, in general, the difference between the exact and approximate density matrices is quite large, so we focus on finding observables, $\hat{O}$, such that the expected value of $\hat{O}$ on the approximate state is close to the expected value of $\hat{O}$ on the exact state. Interestingly, even though the approximate and exact density matrices can be quite different, for all the Hamiltonians we considered, we found non-trivial observables for which the expected value of $\hat{O}$ on the approximate state was exactly correct. We conclude by laying out what we think would be fruitful next steps.

Phenomenology of a UV Complete Model for a Top-Friendly Z′

John C. Russell

We study the collider phenomenology of a UV complete model for a top-friendly Z′. In the model, Z′ couplings to the top quark are generated by mass mixing between the top quark and a new vector-like quark, T, which is directly charged under the U(1)'. We consider three Z′ production mechanisms at the LHC: Z′ production in association with a jet, Z′ production in association with $t\bar{t}$, and Z′ production via the decays of T in $T\overline{T}$ events. In the UV complete model, we find that the Z′ + jet production cross section is significantly smaller than as calculated in the literature in models without T. $T\overline{T}$ decays and $t\bar{t}Z'$ events produce Z′ at similar rates for $M_T \sim 1$ TeV with large top--T mixing. For smaller mixing, it is possible that T decays will be the only hope for detecting Z′ at the LHC. We use Monte Carlo simulations to develop and test methods for simultaneously reconstructing T and Z′ resonances in $T\overline{T}$ events. For $M_T = 1$ TeV and $M_{Z'} \leq 350$ GeV, both particles can potentially be discovered at the 14 TeV LHC after 30 fb-1 of integrated luminosity.

Implementation of an Experimental Setup for Trapping and Cooling 40Ca+

Ariel L. Silbert

We are working towards a goal of trapping 40Ca+ ions in a Paul trap. Once trapped these chains of ions will serve as an analog quantum simulator, which will be used to simulate and study heat transport in nanoscale systems. In order to trap ions, we need lasers to address the ions, a vacuum chamber to house the trap, and hardware and software to send voltage signals that are appropriate to create a trapping potential well. Previous work created a laser design and frequency stabilization scheme. It also developed magnetic field coils. We need these tools in order to control the electronic states of the ions. In our work, we have implemented these systems by working on creating and aligning them. We have also created a vacuum system to house and protect the trap. We have created voltage output software, a filterboard, and a helical resonator to send voltages into the trap. These tools account for most of the necessary experimental apparatus that we need to successfully trap calcium ions.

Psychology

Additive Genetic Risk from Five Serotonin System Polymorphisms and Stress Generation: Examining Early Adversity as a Moderator

Carey Marr

An emerging body of evidence suggests that greater serotonergic vulnerability renders individuals susceptible to stress generation or the tendency of vulnerable individuals to actively contribute to the occurrence of stress in their lives (Starr, Hammen, Brennan, & Najman, 2012, 2013). However, few studies have investigated whether early adversity moderates the influence of serotonergic vulnerability on stress generation. Moreover, most prior research has focused on acute (i.e., stressful life events), rather than chronic (i.e., ongoing life stress), stress generation. Prior work has also concentrated on one serotonergic polymorphisms (5-HTTLPR) and mostly observed the effects of singular, severe events of child adversity. To fill these gaps, the present study examined whether early adversity moderates the prospective associations between serotonergic vulnerability with each acute and chronic stress generation. In addition, I utilized a multilocus profile comprising five serotonergic polymorphisms to examine the additive effect of serotonergic vulnerability. In line with the stress generation

model (C. Hammen, 1991; Constance Hammen, 2006), the present study also examined whether serotonergic vulnerability and early adversity interacted to increase exposure to independent (i.e., uncontrollable) acute stress as well as both interpersonal and non-interpersonal stress generation. These questions were explored in a one-year longitudinal study of 129 early adolescent girls (M = 12.36 years) and their primary female caregivers using a multilocus profile to tap serotonergic vulnerability, and contextual objective stress interviews to assess chronic and acute stress generation, as well as early adversity. Findings indicated that early adversity moderated the relationship between serotonergic vulnerability and acute stress generation, with a pattern of effects consistent with the differential susceptibility model (Belsky, 1997a, 1997b), such that among adolescents with lower levels of early adversity, greater serotonergic vulnerability predicted decreases in acute stress generation over time, whereas among adolescents with higher levels of early adversity, greater serotonergic vulnerability predicted increases in acute stress generation over time. This moderation effect was not present, however, when examining non-interpersonal acute stress or acute independent stress. In addition, greater early adversity predicted increases in chronic stress generation over time, regardless of level of serotonergic vulnerability. Greater early adversity also predicted increases in independent acute stress. Clinical implications and future directions of research were discussed.

Mechanisms and Sex Differences in Neuroinflammatory Memory Deficits

Kathryn McNaughton

The immune system and the brain interact both to facilitate normal function in times of good health and also to respond to inflammatory stimuli in times of sickness. Specifically, in learning and memory tasks, immune overactivation is associated with impaired performance, while normal immune activation is associated with optimal performance. In one specific domain of memory, context discrimination memory, peripheral immune stimulation has been shown to impair performance on the context-object discrimination memory task in male rats. In order to evaluate potential sex differences in this task, as well as potential biological causes and correlates for the memory impairment, we evaluated the ability of peripheral immune stimulation to impair task performance in males and females. Next we examined whether treatment with interleukin-1 receptor antagonist (IL-1ra), a receptor antagonist for the pro-inflammatory cytokine IL-1β, was able to rescue the memory deficit. Finally, we examined microglial morphology and cytokine expression in the hippocampus to examine the neuroinflammatory status in the brain. Male rats displayed consistent memory impairment in response to LPS, and this impairment was not rescued by IL-1ra. Female rats displayed some memory impairments that were rescued by IL-1ra administration. While there were no differences in pro-inflammatory cytokine protein levels in the hippocampus, IL-1ra did affect microglia morphology in certain regions of the hippocampus. Together, these results suggest that sex differences exist in the ability of a peripheral immune stimulus to influence context discrimination memory, and that IL-1ra may be able to rescue that deficit. This study highlights the importance of sex differences in response to inflammatory challenges and identifies IL-1β as a potential mediator of memory impairments in context discrimination memory.

Family Nurture Intervention and Mother-Infant Social Engagement At Infant Corrected Age Four Months

Mai Mitsuyama

Previous research has established the importance of the mother-infant relationship and the positive effects of the Family Nurture Intervention (FNI) on quality of maternal caregiving, maternal anxiety and depression and infant neurodevelopment and social-relatedness (Amie A. Hane et al., 2015;Welch, Firestein, et al., 2015). No prior research has examined the sustainability of the effects of the FNI on dyadic functioning. Fifty-eight 4-month corrected age (CA) infants and their mothers participated in a follow-up study and completed the 10-minute mother-infant interaction. Of the 58 dyads, 25 were randomly assigned to Standard Care (SC) and 33 were randomly assigned to the intervention group (FNI). Second-by-second behavioral coding was used to determine the level of social engagement between the mother and infant. Infant gaze to mom and infant non-negative vocalization were coded to determine the *infant engagement* composite score. Maternal positive affect, maternal touch infant and maternal vocalization were coded to determine *maternal engagement* composite score. The means of the maternal engagement composite score and the infant engagement composite

score were used to compute the *dyad engagement* composite score. Significant FNI group-by-infant gender interactions effects revealed that SC males experienced significantly lower maternal engagement than control females. SC males experienced significantly less maternal engagement than FNI males. SC males also experienced significantly lower dyadic engagement than FNI males. These results illustrate the importance of early intervention, specifically with preterm males, to assist in the establishment of social engagement between preterm infants and their mothers.

Categorization and Cognitive Flexibility in Autism

Abigail Pugh

One fundamental cognitive process that has been implicated in autism spectrum disorders (ASD) is categorization, as early studies of autism reported a deficit in category learning (Klinger & Dawson, 1995). In this series of studies we aimed to determine whether a categorization deficit could be found in participants with an ASD and in participants with autistic traits. In Study 1, individuals with an ASD showed a significant deficit in category learning. In Study 2, individuals with high levels of autistic traits did not show a deficit in category learning. In Study 3, a cognitive flexibility demand was introduced in a categorization task, as this ability has been implicated as a potential deficit in ASD (Van Eylen et al., 2011). In contrast to previous studies, in Study 3, participants with high levels of autistic traits performed significantly better in the task than participants with low levels of autistic traits. Overall these results indicate that there is a deficit in category learning in individuals diagnosed with an ASD, but not in individuals with autistic traits.

The Joys of Being Hidden and the Disasters of Not Being Found: A Study on Concealment of Sexuality and Narrative Inconsistency in Queer Youths

Silvio Resuli

Queer individuals' intentional concealment of sexual orientation was separately assessed in the context of relationships to mother, father, siblings, friends, extended family members, and coworkers or fellow students. Concealment to father was predicted by conflictual dependence on the father in male participants, and by the perception of father's queerphobia in female participants. Concealment to mother was predicted by the perception of mother's queerphobia in male participants, and by the perception of mother's queerphobia, emotional dependence on the mother, and fusion with others in the family in female participants. Queer individuals' belief on whether or not their parents knew about their sexuality were assessed. Regardless of their gender, participants were more likely to report that their father did not know about their sexuality as participants' perception of father's queerphobia increased. Regardless of participants' gender, participants were more likely to report that their mother did not know about their sexuality in as participants' perception of mother's queerphobia increased, as their fusion with others in the family increased, and as their emotional dependence on their mother increased. Inconsistency in self-representation of sexuality, operationalized as the standard deviation of a queer individual's concealment levels across relationships, was computed. Different levels of locus of control, social anxiety, or emotional reactivity were not significantly predictive of different levels of inconsistency of self-representation. Implications for future research on queer individuals' wellbeing are discussed.

Family Nurture Intervention and Biobehavioral Responding to Maternal Still Face in Preterm Infants

Sarah Wieman

Being born prematurely and experiencing the bright, noisy, unpredictable, and painful medical procedures of the NICU environment violate fetal expectations of the warm, muffled, protected uterine environment. Preterm infants show dysregulated responses to stress that put them at risk for behavioral, mental, and physical health problems in childhood and adulthood. The Family Nurture Intervention (FNI) aims to establish the mother-infant connectedness while the infant is in the NICU. This thesis examines if the FNI helps support a healthier stress response in 4-month-old corrected age (CA) preterm infants by observing both physiological and behavioral responses to the Still Face Paradigm (SFP). Preterm infants in the FNI condition showed decreased heart rate across the entire still face paradigm compared to standard care infants. FNI infants also showed significantly less vocal distress during the still face episode and significantly more approach behaviors upon reunion. The

FNI infants also showed a higher degree of synchrony with their mothers, as the mothers also showed higher approach behavior upon reunion compared to the mothers with infants in standard care. These results indicate that the FNI decreases behavioral reactivity, increases behavioral regulation, and increases overall calmness in preterm infants. Future research should examine the behavioral and physiological responding of FNI infants compared to health full-term infants to determine if the FNI supports a stress response that matches that of infants born at term.

Disordered Eating-Related Cognitions And Behaviors During The First Year Of College: A Three-Wave Longitudinal Study

Chanel Zhan

Most studies of subclinical eating disorder symptoms among college students have not distinguished between *cognitions* (i.e., pertaining to attitudes, beliefs, feelings) and *behaviors* pertaining to disordered eating. Specifically, there is a dearth of research on how they change differentially over time. This study investigated behaviors and cognitions associated with disordered eating and exercise in a longitudinal sample of incoming college first-year students. Demographic factors (i.e., athletic participation, gender) and individual psychological factors (i.e., contingencies of self-worth, belief in the malleability of beauty) were examined as both concurrent predictors and prospective predictors of (a) disordered eating-related cognitions; (b) disordered eating-related behaviors; (c) disordered exercise-related cognitions; (d) exercise frequency. Students were assessed at three time points. Four hundred and three incoming first-year students (190 men, 211 women) were assessed one week prior to their arrival on campus (T1). Three months later (T2), 210 students (172 returning participants) were assessed; another three months later (T3), 214 students (163 returning participants) were assessed. Cross-sectional regression analyses revealed a positive association between disordered eating/exercise and the extent to which self-worth is contingent on appearance. In addition, athletic participation was found to be protective against disordered eating/exercise. The effect of gender was relatively weak, with the exception of disordered eating-related cognitions, which were more common in women. Longitudinal analyses using linear mixed modeling found that exercise-related cognitions became more disordered, on average, from T1 to T2, and there were no changes from T2 to T3. Eating-related cognitions and behaviors each became more disordered for individuals who based high levels of self-worth on others' approval at T1, whereas exercise frequency increased from T1 to T2 for college athletes, but decreased from T1 to T2 for non-athletes. Among those whose disordered eating-related cognitions and behaviors reliably changed from T1 to T2, changes were more likely to occur in the *disordered* direction. Students' subjective evaluations and explanations of changes in their eating and exercise habits/thoughts are considered for explanatory purposes. Implications and directions for future research are explored.

Abstracts from Presentations and Publications

Astronomy

The 1918 Eclipse Mural Series by Howard Russell Butler for the American Museum of Natural History and the Hayden Planetarium

Pasachoff, J. M., and R. J. M. Olson

Inspiration of Astronomical Phenomena VIII: City of Stars, insap.org, edited by B. P. Abbott (San Francisco: Astronomical Society of the Pacific), Astronomical Society of the Pacific Conference Series, vol. **501**, 2015

There is a rich trove of astronomical phenomena in works of art by artists from the greater New York area, a trend that is even more pronounced in the oeuvres of New York City residents through the present day. A case in point is the trio of oil paintings by artist (and former physics professor) Howard Russell Butler depicting total solar eclipses in 1918, 1923, and 1925 that are based on his own observations. They were long displayed in the former art-deco building of the Hayden Planetarium of the American Museum of Natural History, the location of this conference. (The Museum also has nine other Butler paintings, none of which are currently exhibited.) Since the eclipse paintings have been in storage for many years, these once famous works are now virtually forgotten. Based on our research as an astronomer who has seen sixty- two solar eclipses and an art historian who has written extensively about astronomical imagery, we will discuss Butler's Solar Eclipse Triptych to explore its place in the history of astronomical imaging.

Aeolus: An MCMC Code for Mapping Brown Dwarf and Other Ultra Cool Atmospheres

Karalidi, Theodora, Dániel Apai, Glenn Schneider, Jake R. Hanson, and Jay M. Pasachoff

Astrophyical Journal, **814**, 65. DOI: 10.1088/j0004-637X/814/65, 2015

Deducing the cloud cover and its temporal evolution from the observed planetary spectra and phase curves can give us major insight into the atmospheric dynamics. In this paper, we present Aeolus, a Markov–Chain Monte Carlo code that maps the structure of brown dwarf and other ultracool atmospheres. We validated Aeolus on a set of unique Jupiter Hubble Space Telescope (HST) light curves. Aeolus accurately retrieves the properties of the major features of the jovian atmosphere such as the Great Red Spot and a major 5 μm hot spot. Aeolus is the first mapping code validated on actual observations of a giant planet over a full rotational period. For this study, we applied Aeolus to J and H–bands HST light curves of 2MASSJ21392676+0220226 and 2MASSJ0136565+093347. Aeolus retrieves three spots at the top–of–the–atmosphere (per observational wavelength) of these two brown dwarfs, with a surface coverage of 21%±3% and 20.3%±1.5% respectively. The Jupiter HST light curves will be publicly available via ADS/VIZIR.

Trio of stellar occultations by Pluto One Year Prior to New Horizons's Arrival

Pasachoff, Jay M., Michael J. Person, Amanda S. Bosh, Amanda A. Sickafoose, 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

Astronomical Journal, **151**, 4 and 97, 2016

We observed occultations by Pluto, and attempted to observe occultations by its moon Nix and by 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 predictions were based on new USNO astrometry. We successfully detected occultations by Pluto of an R=18 mag star on 23 July (14:23:32 ± 00:00:04 UTC to 14:25:30 ± 00:00:04 UTC), with a drop of 5%, and of an R=17 star on 24 July (11:41:30 ± 00:00:08 UTC to 11:43:28 ± 00:00:08 UTC), with a drop of 3%, both with 20 s exposures with our frame-transfer Portable Occultation, Eclipse, and Transit System (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 and 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 on Las Campanas, the 4.1-m Southern Astrophysical Research Telescope (SOAR) on Cerro Pachön, the 2.5-m DuPont on Las Campanas, the 0.6-m SARA-South on Cerro Tololo of the Southeastern Association for Research in Astronomy (SARA), the MPI/ESO 2.2-m on La Silla, and the 0.45-m Cerro Calán telescope and 0.36 telescope in Constitución 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, but led to one detection with the Magellan/Clay Telescope on July 31 of the occultation of a previously unknown 15th-magnitude star, completing the trio of occultations successfully observed and reported in this paper.

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).

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.

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The Chemistry of Planetary Nebulae in the Outer Regions Of M31

R.L.M. Corradi, K.B. Kwitter, B. Balick, R.B.C. Henry, & Hensley, K.G. *(Williams '14)*

The Astrophysical Journal, **807, 181**, 2015

We present spectroscopy of nine planetary nebulae (PNe) in the outskirts of M31, all but one obtained with the 10.4 m GTC telescope. These sources extend our previous study of the oxygen abundance gradient of M31 to galactocentric radii as large as 100 kpc. None of the targets are bona fide members of a classical, metal-poor, and ancient halo. Two of the outermost PNe have solar oxygen abundances, as well as radial velocities consistent with the kinematics of the extended disk of M31. The other PNe have a slightly lower oxygen content ([O/H] ~ -0.4) and in some cases large deviations from the disk kinematics. These PNe support the current view that the external regions of M31 are the result of a complex interaction and merger process, with evidence for a widespread population of solar-metallicity stars produced in a starburst that occurred ~2 Gyr ago.

Co-Spatial Long-Slit UV/Optical Spectra of Ten Galactic Planetary Nebulae with HST/STIS II. Nebular Models, Central Star Properties and He+CNO Synthesis

R.B.C. Henry, B. Balick, R.J., Dufour, K.B. Kwitter, R.A. Shaw, T.R. Miller, J.F. Buell, & R.L.M. Corradi

*The Astrophysical Journal***, 813, 121**, 2015

The goal of the present study is twofold. First, we employ new HST/STIS spectra and photoionization modeling techniques to determine the progenitor masses of eight planetary nebulae (IC 2165, IC 3568, NGC 2440, NGC 3242, NGC 5315, NGC 5882, NGC 7662, and PB 6). Second, for the first time we are able to compare each object's observed nebular abundances of helium, carbon, and nitrogen with abundance predictions of these same elements by a stellar model that is consistent with each object's progenitor mass. Important results include the following: (1) the mass range of our objects' central stars matches well with the mass distribution of other central stars of planetary nebulae and white dwarfs; (2) He/H is above solar in all of our objects, in most cases likely due to the predicted effects of first dredge-up; (3) most of our objects show negligible C enrichment, probably because their low masses preclude third dredge-up; (4) C/O versus O/H for our objects

appears to be inversely correlated, which is perhaps consistent with the conclusion of theorists that the extent of atmospheric carbon enrichment from first dredge-up is sensitive to a parameter whose value increases as metallicity declines; (5) stellar model predictions of nebular C and N enrichment are consistent with observed abundances for progenitor star masses ≤1.5 M⊙. Finally, we present the first published photoionization models of NGC 5315 and NGC 5882.

Hour-Scale Variability in NGC 663 and NGC 1960

S. P. Souza, A. Garcia Soto, and H. Wong

BAAS. **48**, 319.03, 2016

Since 2010 we have been monitoring massive emission-line (mainly Be) stars in young open clusters using narrowband imaging at Hα (656nm) and the nearby continuum (645nm) (Souza, Davis, and Teich 2013, BAAS. 45, PM354.22; Souza, Beltz-Mohrmann, and Sami 2014. JAAVSO, 42, 154). To supplement longer-timescale data taken at Williams College we obtained high-cadence observations, in both filters, of NGC 663 on the night of 12/10/15, and of NGC 1960 on the nights of 12/10/14, 1/23/15, 1/25/15, 11/11/15, and 12/13/15 at the 0.5m ARCSAT at Apache Point Observatory. After raw magnitude extraction using Aperture Photometry Tool (Laher et al. 2012, PASP, 124, 737), we used inhomogeneous ensemble photometry (Bhatti et al., 2010, ApJ Supp., 186, 233) to correct for transparency and seeing variations. The NGC 663 field is crowded; of 29 known Be stars in the observed field, 10 have nearby interferers. None of the remaining 19 Be stars showed significant variation during ~5.5 hours of observation. 1σ uncertainty estimates range from 0.02mag at R~10 to 0.15mag at R~14. To verify the observing and reduction procedure, we recovered hour-scale variability in known variables BY Cas (δ Cephei type, ~0.05mag decline) and V1155 Cas (β Cephei type, ~0.04mag amplitude). In NGC 1960, of 5 known and suspect Be stars observed, two not previously reported as variable (BD+34 1110 and USNOB1.0 1241-0103450) showed irregular variation on timescales of hours. In NGC 1960 we also report the incidental discovery of two non-Be suspect variables: a likely eclipsing binary (0.07mag), and a possible δ Scuti star (maximum amplitude ~0.02mag). We gratefully acknowledge support for student research from NSF grant AST-1005024 to the Keck Northeast Astronomy Consortium, and the Office of the Dean of Faculty and the DIII Research Funding Committee of Williams College. Based on observations obtained with Apache Point Observatory's 0.5-m Astrophysical Research Consortium Small Aperture Telescope.

Biology

Long-term time-lapse video provides near complete records of floral visitation.

J. Edwards, G.P. Smith '13 and M.H.F. McEntee '14

Journal of Pollination Ecology: 16(13): 91-100, 2015

Accurate records of floral visitors are critical for understanding plant pollinator interactions. However, to date, sampling methods are constrained to short sampling periods and may be subject to observer interference. Thus, complete records without sampling bias are rare. We use a portable time-lapse digital video camera to capture near-complete records of visitors to flowers over their entire blooming period. We show the broad applicability of this method by filming a wide variety of flowers of different shapes and inflorescence types. We test the importance of long-term records by studying visitors to Cornus canadensis (bunchberry dogwood). Visitors to C. canadensis filmed simultaneously at four different sites show variation (both in rates and taxa) between inflorescences, between sites, throughout the day, and throughout the season. For C. canadensis our films also provide a record of pollen placement (an indirect measure of male fitness) and fruit set (female fitness). This technique provides near complete records of floral visitors, is likely to capture rare events, and allows simultaneous long-term filming. These results emphasize the importance of both long-term data collection and simultaneous recording at multiple sites for pollination studies.

Rising atmospheric CO_2 is reducing the protein concentration of a floral pollen source essential for North American bees

L. Ziska, J. Pettis, J. Edwards, J. Hancock '11, M. Tomecek, A. Clark, J. Dukes, I. Loladze, and H. Polley

Proceedings of the Royale Society B: DOI: 10.1098/rspb.2016.0414

At present, there is substantive evidence that the nutritional content of agriculturally important food crops will decrease in response to rising levels of atmospheric carbon dioxide, Ca. However, whether Ca-induced declines in nutritional quality are also occurring for pollinator food sources is unknown. Flowering late in the season, goldenrod (Solidago spp.) pollen is a widely available autumnal food source commonly acknowledged by apiarists to be essential to native bee (e.g. Bombus spp.) and honeybee (Apis mellifera) health and winter survival. Using floral collections obtained from the Smithsonian Natural History Museum, we quantified Ca-induced temporal changes in pollen protein concentration of Canada goldenrod (Solidago canadensis), the most widespread Solidago taxon, from hundreds of samples collected throughout the USA and southern Canada over the period 1842–2014 (i.e. a Ca from approx. 280 to 398 ppm). In addition, we conducted a 2 year in situ trial of S. canadensis populations grown along a continuous Ca gradient from approximately 280 to 500 ppm. The historical data indicated a strong significant correlation between recent increases in Ca and reductions in pollen protein concentration (r 2 1⁄4 0.81). Experimental data confirmed this decrease in pollen protein concentration, and indicated that it would be ongoing as Ca continues to rise in the near term, i.e. to 500 ppm (r 2 1⁄4 0.88). While additional data are needed to quantify the subsequent effects of reduced protein concentration for Canada goldenrod on bee health and population stability, these results are the first to indicate that increasing Ca can reduce protein content of a floral pollen source widely used by North American bees.

The gene cortex controls mimicry and crypsis in butterflies and moths

Nadeau N.j., Pardo-Diaz C., Whibley A., Supple M.a., Saenko S.v., Wallbank R.w.r., Wu G.c., **Maroja L.s.** Ferguson L., Hanlyj.j., Hines H., Salazar C., Merrill R.m., Dowling A.j., Ffrench-Constant R.h., Llaurens V., Joronm, Mcmillan W.o. and Jiggins C.D.

Nature 534: 106-110. doi:10.1038/nature17961, 2016

The wing patterns of butterflies and moths (Lepidoptera) are diverse and striking examples of evolutionary diversification by natural selection. Lepidopteran wing colour patterns are a key innovation, consisting of arrays of coloured scales. We still lack a general understanding of how these patterns are controlled and whether this control shows any commonality across the 160,000 moth and 17,000 butterfly species. Here, we use fine-scale mapping with population genomics and gene expression analyses to identify a gene, cortex, that regulates pattern switches in multiple species across the mimetic radiation in Heliconius butterflies. cortex belongs to a fast-evolving subfamily of the otherwise highly conserved fizzy family of cell-cycle regulators, suggesting that it probably regulates pigmentation patterning by regulating scale cell development. In parallel with findings in the peppered moth (Biston betularia), our results suggest that this mechanism is common within Lepidoptera and that cortex has become a major target for natural selection acting on colour and pattern variation in this group of insects.

Major improvements to the *Heliconius melpomene* genome assembly used to confirm 10 chromosome fusion events in 6 million years of butterfly evolution

J. Davey, M. Chouteau, S. Barker, L. Maroja, S. Baxter, F. Simpson, M. Joron, J. Mallet, K. Dasmahapatra and C. Jiggins

G3: Genes, Genomes,Genetics, doi:10.1534/g3.115.023655

The Heliconius butterflies are a widely studied adaptive radiation of 46 species spread across Central and South America, several of which are known to hybridise in the wild. Here, we present a substantially improved assembly of the Heliconius Melpomene genome, developed using novel methods that should be applicable to improving other genome assemblies produced using short read sequencing. Firstly, we whole genome sequenced a pedigree to produce a linkage map incorporating 99% of the genome. Secondly, we incorporated haplotype

scaffolds extensively to produce a more complete haploid version of the draft genome. Thirdly, we incorporated ~20x coverage of Pacific Biosciences sequencing and scaffolded the haploid genome using an assembly of this long read sequence. These improvements result in a genome of 795 scaffolds, 275 Mb in length, with an N50 length of 2.1 Mb, an N50 number of 34 and with 99% of the genome placed and 84% anchored on chromosomes. We use the new genome assembly to confirm that the Heliconius genome underwent 10 chromosome fusions since the split with its sister genus Eueides, over a period of about 6 million years.

The wavy Mutation Maps to the Inositol 1,4,5-trisphosphate 3-kinase 2 (IP3K2) Gene of Drosophila and Interacts with IP3R to Affect Wing Development

D. Dean, L. Maroja, S. Cottrill, B. Bomkamp, K. Westervelt, and D. Deitcher

Genes, Genomes, Genetics, doi: 10.1534/g3.115.024307, 2015

Inositol 1,4,5-trisphosphate (IP3) regulates a host of biological processes from egg activation to cell death. When IP3-specific receptors (IP3Rs) bind to IP3, they release calcium from the ER into the cytoplasm, triggering a variety of cell type- and developmental stage-specific responses. Alternatively, inositol polyphosphate kinases can phosphorylate IP3; this limits IP3R activation by reducing IP3 levels, and also generates new signaling molecules altogether. These divergent pathways draw from the same IP3 pool yet cause very different cellular responses. Therefore, controlling the relative rates of IP3R activation vs. phosphorylation of IP3 is essential for proper cell functioning. Establishing a model system that sensitively reports the net output of IP3 signaling is crucial for identifying the controlling genes. Here we report that mutant alleles of wavy (wy), a classic locus of the fruit fly Drosophila melanogaster, map to IP3 3-kinase 2 (IP3K2), a member of the inositol polyphosphate kinase gene family. Mutations in wy disrupt wing structure in a highly specific pattern. RNAi experiments using GAL4 and GAL80ts indicated that IP3K2 function is required in the wing discs of early pupae for normal wing development. Gradations in the severity of the wy phenotype provide high-resolution readouts of IP3K2 function and of overall IP3 signaling, giving this system strong potential as a model for further study of the IP3 signaling network. In proof of concept, a dominant modifier screen revealed that mutations in IP3R strongly suppress the wy phenotype, suggesting that the wy phenotype results from reduced IP4 levels, and/or excessive IP3R signaling.

The D1 family dopamine receptor, DopR, potentiates hind leg grooming behavior in Drosophila

E. Pitmon, G. Stephens, S. J. Parkhurst, F. W. Wolf, G. Kehne, M. Taylor and T. Lebestky

Genes, Brain and Behavior, DOI: 10.1111/gbb.12264, 2016

Drosophila groom away debris and pathogens from the body using their legs in a stereotyped sequence of innate motor behaviors. Here, we investigated one aspect of the grooming repertoire by characterizing the D1 family dopamine receptor, DopR. Removal of DopR results in decreased hind leg grooming, as substantiated by quantitation of dye remaining on mutant and RNAi animals vs. controls and direct scoring of behavioral events. These data are also supported by pharmacological results that D1 receptor agonists fail to potentiate grooming behaviors in headless DopR flies. DopR protein is broadly expressed in the neuropil of the thoracic ganglion and overlaps with TH-positive dopaminergic neurons. Broad neuronal expression of dopamine receptor in mutant animals restored normal grooming behaviors. These data provide evidence for the role of DopR in potentiating hind leg grooming behaviors in the thoracic ganglion of adult Drosophila. This is a remarkable juxtaposition to the considerable role of D1 family dopamine receptors in rodent grooming, and future investigations of evolutionary relationships of circuitry may be warranted.

Chemistry

Printmaking: An Atomic View of the Materials and Processes

Patrick S. Barber

Reframed: Perspectives on the Madeleine P. and Harvey R. Plonsker Collection, 2016.

This essay explores the Madeleine P. and Harvey R. Plonskser art collection, through the lens of chemistry and atomically examines the art from a materials perspective. Exploration of the attractive and repulsive forces governed by the materials' molecular makeup provides a view of how these interactions create works of art. By examining these works from the perspective of the object's material structure, properties, and reactivity, one gains a more in-depth understanding of this collection.

Exploring Perspectives and Identifying Potential Challenges Encountered with Crime Scene Investigations when Developing Chemistry Curricula

A. Bakarr Kanu, Megan Pajski, Machelle Hartman, Irene Kimaru, Susan Marine, and *Lawrence J. Kaplan*

Journal of Chemical Education, 92(8), 1353-1358, 2015.

In today's complex world, there is a continued demand for recently graduated forensic chemists (criminalists) who have some background in forensic experimental techniques. This article describes modern forensic experimental approaches designed and implemented from a unique instructional perspective to present certain facets of crime scene investigation. Physical evidence collection, handling, and evaluation are reviewed, as are challenges associated with carrying out these tasks. The interrelation of the responsibilities of the crime scene investigator and criminalist also is addressed, as this can be highlighted in an instructional setting. If the investigator does not collect sufficient evidence or collects the evidence improperly, the criminalist will be unable to effectively interpret the data. In this report, the authors describe their experiences at a mock crime scene designed for investigation by undergraduate forensic science students. Key points that must be considered include evidence collection, analysis of the evidence, interpretation of the results, and drawing conclusions from those interpretations. We have presented the information in a way that may be beneficial to instructors looking to create or update existing forensic science courses, or scholars interested in the drawbacks of certain aspects of evidence collection.

Coupled Oscillations and Circadian Rhythms in Molecular Replication Networks

Nathaniel Wagner, Samaa Alasibi, *Enrique Peacock-Lopez*, and Gonen Ashkenazy

The Journal of Physical Chemistry Letters, 6, 60-65, 2015.

Living organisms often display rhythmic and oscillatory behavior. We investigate here a challenge in contemporary System Chemistry, that is, to construct "bottom-up" molecular networks that display such complex behavior. We first describe oscillations during self-replication by applying kinetic parameter relevant to peptide replication in an open environment. Small networks of coupled oscillators are then constructed in silico, producing various functions such as logic gates, integrators, counters, triggers, and detectors. These networks are finally utilized to simulate the connectivity and network topology of the Kai proteins biochemical circadian clocks from the *S. elongtus* cyanobacteria, thus producing rhythms whose chose constant frequency is independent of the input intake rate and robust toward concentration fluctuations. We suggest that this study helps further reveal the underlying principles of biological clocks and may provide clues into their emergence in early molecular evolution.

A Convenient and Practical Method for the Selective Preparation of Deuterofluorocarbons

David P. Richardson, Gordon S. Bauer '14, Andrew A. Bravo '15, Michael Drzyzga '10, Tina Motazedi '10, Emma M. Pelegri-O'Day '12, Shirish Poudyal '10, Daniel L. M. Suess '07, John W. Thoman, Jr.

Journal of Fluorine Chemistry, 180, 208-215, 2015.

A detailed study of the development of efficient and practical conditions for the selective synthesis of 1-deuterononafluorobutane from 1-iodononafluorobutane is reported. The optimal conditions involve treatment of the iodo-precursor in D_2O at ~170 °C in the presence of metallic zinc in a sealed Schlenk tube to give a 59% yield of 1-deutero-1,1,2,2,3,3,4,4,4-nonafluorobutane. The same method was applied successfully

to two higher homologues to produce 1-deutero-1,1,2,2,3,3,4,4,5,5,5-undecafluoropentane and 1-deutero-1,1,2,2,3,3,4,4,5,5,6,6,6-tridecafluorohexane in yields of 64% and 56%, respectively. Surprisingly, even the non-perfluorinated product 6-deutero-1,1,1,2,2,3,3,4,4-nonafluorohexane could be synthesized in 69% yield with this method.

Cova del Rinoceront (Castelldefels, Barcelona): A Terrestrial Record for the Last Interglacial Period (MIS 5) in the Mediterranean Coast of the Iberian Peninsula

J. Daura, M. Sanz, R. Julià, D. Garcia-Fernández, J. Fornós, M. Vaquero, E. Allué, J. López-García, H. Blain, J. Ortiz, T. Torres, R. Albert, À. Rodríguez-Cintas, A. Sánchez-Marco, E. Cerdeño, *Anne R. Skinner,* Y. Asmeron, V. Polyak, M. Garcés, L. Arnold, M. Demuro, A. Pike, I. Euba, R. Rodríguez, A. Yagüe, L. Villaescusa, S. Gómez, À. Rubio, M. Pedro, J. Fullola, J. Zilhâo

Quaternary Science Reviews, 114, 203-227, 2015.

The Cova del Rinoceront, a site in NE Iberia, contains a thick sedimentary fill preserving a faunal archive from the penultimate glacial and the last interglacial periods. Layers I to III have been dated to between 74 and 135 ka, coinciding with MIS 5a to 5e, a period poorly represented in the Mediterranean terrestrial record. The results from Cova del Rinoceront are of broader interest for the reconstruction of ecological dynamics during warm stages and the understanding of the evolution and geographical variation of several taxa. The palaeoecological evidence suggests a landscape dominated by mixed wooded vegetation with mild climatic conditions, slightly more humid than today. Several vertebrate taxa, including *Haploidoceros mediterraneus, Stephanorhinus hundsheimensis* and *Glis glis*, are documented for the first time in the early Upper Pleistocene of Europe, showing that these species persisted across the region for longer than previously thought. In addition, the recovery of a small lithic assemblage indicates human presence in the surroundings of the site. The 11 m-thick stratigraphic section also provides an ideal setting in which to compare several geochronological methods. U-Th dating of the flowstones that cap the deposit of speleothems formed along the cave walls, and of speleothems buried by the deposit at different elevations provides minimum and maximum ages of 74 and 175 ka, respectively, for the accumulation. The ages obtained by luminescence, electron spin resonance (ESR), amino acid racemisation (AAR), palaeomagnetism and Useries dating of bone are in good agreement with each other and are stratigraphically consistent. This well-dated faunal succession presents a unique opportunity to assess changes in the Pleistocene fauna of the Mediterranean coast over an interval of more than 100 ka.

Findings, Context, and Significance of Combustion at the Late Early Pleistocene Palaeolithic Site of Cueva Negra del Estrecho del Río Quípar (Caravaca de la Cruz, Murcia, Spain)

M.J. Walker, D. Anesin, D.E. Angelucci, A. Avilés-Fernández, F. Berna, A.T. Buitrago-López, Y. Fernández-Jalvo, M. Haber-Uriarte, I. Martín-Lerma, A. López-Jiménez, M. López-Martínez, J. Ortega-Rodrigáñez, J.L. Polo-Camacho, S.E. Rhodes, D. Richter, T. Rodríguez-Estrella, J-L. Schwenninger, *Anne R. Skinner*

Antiquity, 90 (351), 571-589, 2016.

Evidence of combustion inside a large rock-shelter in southeastern Spain is afforded by Palaeolithic finds excavated in a deep 0.8Ma (million years ago) closed sedimentary deposit. The principal findings are of abundant charred and calcined fragments of bone and numerous fragments of thermally altered chert; in both cases some fragments were excavated in conjoinable apposition, strongly suggesting in situ combustion and minimal post-depositional disturbance. Palaeotemperature estimates indicate heating in antiquity at 400-600ºC, determined on samples subjected to analyses by thermoluminescence (TL), Fourier Transform infrarred spectroscopy (FTIR), and electron spin resonance (ESR). Taphonomical investigations of bone discolouration, together with scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) of samples, indicate findings that are not typical of post-depositional mineral staining but are compatible with combustion. Macroscopical inspection of the sediment is suggestive of combustion and the demonstration in samples of hydroxyapatite is compatible with the degradation of bone, although micromorphological studies of thin-sections of sediment have not provided conclusive evidence of combustion. The findings are discussed in the context of Early Palaeolithic fire and its likely significance for human evolution.

Studying Chert with Electron Spin Resonance (ESR)

Anne R. Skinner

Quaternary International, 377, 148-156, 2015.

Electron-spin resonance (ESR) is potentially a tool for dating chert using radiation-induced signals analogous to those used for thermoluminescence (TL) dating. The technique is presently applicable only to heated chert. Work on samples from numerous sources has confirmed that heating chert is a complex process, and both the duration and temperature of heating must fall within certain ranges in order to obtain datable samples. Both Old World and New World material has been dated. Looking at these samples has also shown that variability among sources may permit proveniencing.

Computer Science

Preventing Occupancy Detection from Smart Meters.

Dong Chen, Sandeep Kalra, David Irwin, Prashant Shenoy, and *Jeannie Albrecht*.

IEEE Transactions on Smart Grid (ToSG), September 2015.

Utilities are rapidly deploying smart meters that measure electricity usage in real-time. Unfortunately, smart meters indirectly leak sensitive information about a home's occupancy, which is easy to detect because it highly correlates with simple statistical metrics, such as power's mean, variance, and range. To prevent occupancy detection, we propose using the thermal energy storage of electric water heaters already present in many homes. In essence, our approach, which we call Combined Heat and Privacy (CHPr), modulates a water heater's power usage to make it look like someone is always home. We design a CHPr-enabled water heater that regulates its energy usage to thwart a variety of occupancy detection attacks without violating its objective—to provide hot water on demand—and evaluate it in simulation using real data. Our results show that a standard 50-gallon CHPr-enabled water heater prevents a wide range of state-of-the-art occupancy detection attacks.

Cooperative Types For Controlling Thread Interference in Java

Jaeheon Yi, Tim Disney, *Stephen N. Freund*, and Cormac Flanagan

Science of Computer Programming 112, 227-260, 2015.

Multithreaded programs are notoriously prone to unintended interference between concurrent threads. To address this problem, we argue that yield annotations in the source code should document all thread interference, and we present a type system for verifying the absence of undocumented interference in Java programs. Under this type system, well-typed programs behave as if context switches occur only at yield annotations. Thus, well-typed programs can be understood using intuitive sequential reasoning, except where yield annotations remind the programmer to account for thread interference. Experimental results show that yield annotations describe thread interference more precisely than prior techniques based on method-level atomicity specifications. In particular, yield annotations reduce the number of interference points one must reason about by an order of magnitude. The type system is also more precise than prior methods targeting race freedom, and yield annotations highlight all known concurrency defects in our benchmarks. The type system reasons about program behavior modularly via method-level specifications. To alleviate the programmer burden of writing these specifications, we extend our system to support method specification inference, which makes our technique more practical for large code bases.

Array Shadow State Compression for Precise Dynamic Race Detection

James R. Wilcox '13, Parker Finch '14, Cormac Flanagan, and *Stephen N. Freund*

Automated Software Engineering, 155-165, 2015.

Precise dynamic race detectors incur significant time and space overheads, particularly for array-intensive programs, due to the need to store and manipulate analysis (or shadow) state for every element of every array. This paper presents SlimState, a precise dynamic race detector that uses an adaptive, online algorithm

to optimize array shadow state representations. SlimState is based on the insight that common array access patterns lead to analogous patterns in array shadow state, enabling optimized, space efficient representations of array shadow state with no loss in precision. We have implemented SlimState for Java. Experiments on a variety of benchmarks show that array shadow compression reduces the space and time overhead of race detection by 27% and 9%, respectively. It is particularly effective for array-intensive programs, reducing space and time overheads by 35% and 17%, respectively, on these programs.

Deep G-Buffers for Stable Global Illumination Approximation

Michael Mara '12, *Morgan McGuire,* Derek Nowrouzezahrai, David Luebke

Proceedings of ACM SIGGRAPH/Eurographics High-Performance Graphics 2016

We introduce a new hardware-accelerated method for constructing Deep G-buffers that is 2x-8x faster than the previous depth peeling method and produces more stable results. We then build several high-performance shading algorithms atop our representation, including dynamic diffuse interreflection, ambient occlusion (AO), and mirror reflection effects.

Our construction method s order-independent, guarantees a minimum separation between layers, operates in a (small) bounded memory footprint, and does not require per-pixel sorting. Moreover, addressing the increasingly expensive cost of pre-rasterization, our approach requires only a single pass over the scene geometry. Our global illumination algorithms approach the speed of the fastest screen-space AO-only techniques while significantly exceeding their quality: we capture small-scale details and complex radiometric effects more robustly than screen-space techniques, and we implicitly handle dynamic illumination conditions. We include the pseudocode for our Deep G-buffer construction in the paper and the full source code of our technique in our supplemental document.

A Phenomenological Scattering Model for Order-Independent Transparency

Morgan McGuire, Michael Mara '12

Proceedings of ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games 2016

Translucent objects such as fog, smoke, glass, ice, and liquids are pervasive in cinematic environments because they frame scenes in depth and create visually compelling shots. Unfortunately, they are hard to simulate in real-time and have thus previously been rendered poorly compared to opaque surfaces in games.

This paper introduces the first model for a real-time rasterization algorithm that can simultaneously approximate the following transparency phenomena: wavelength-varying ("colored") transmission, translucent colored shadows, caustics, partial coverage, diffusion, and refraction. All render efficiently on modern GPUs by using order-independent draw calls and low bandwidth. We include source code for the transparency and resolve shaders.

CloudLight: A System for Amortizing Indirect Lighting in Real-Time Rendering

Cyril Crassin, David Luebke, Michael Mara '12, *Morgan McGuire,* Brent Oster, Peter Shirley, Peter-Pike Sloan, Chris Wyman

Journal of Computer Graphics Techniques

This paper describes the CloudLight system for computing indirect lighting asynchronously on an abstracted, computational "cloud," in support of real-time rendering for interactive 3D applications on a local client device.

We develop and evaluate remote-rendering systems for three different indirect illumi- nation strategies: path-traced irradiance ("light") maps, photon mapping, and cone-traced voxels. We report results for robustness and scalability under realistic workloads by using assets from existing commercial games, scaling up to 50 simultaneous clients, and deployed on commercial hardware (NVIDIA GeForce GRID) and software (OptiX) infrastructure.

Remote illumination scales well enough for deployment under each of the three methods; however, they have unique characteristics. Streaming irradiance maps appear practical today for a laptop client with a distant, rack-

mounted server or for a head-mounted virtual reality client with a nearby PC server. Voxels are well-suited to amortizing illumination within a server farm for mobile clients. Photons offer the best quality for more powerful clients.

Experimental Validation of Computer Graphics Microfacet Theory

Jamie Lesser ’17, *Morgan McGuire, Ward Lopes*

Poster, Grace Hopper Conference, October 2015

We created slices of a real-world object and scanned them with a very high magnification microscope. From the result, we reconstructed a microfacet-scale 3D model of the surface and used this to evaluate the microfacet models used in computer graphics.

Geosciences

Abundance and Morphological Variation of Vase Shaped Microfossils from the Late Tonian Callison Lake Formation, Yukon

Spencer Irvine ’16, Justin Strauss, and *Phoebe Cohen*

Geological Society of America Abstracts with Programs 47 (7), 334, 2015

Vase-shaped microfossils (VSMs), interpreted as the remains of testate amoebae, are found in Late Tonian sedimentary rocks around the world. A new assemblage of VSMs has recently been described from the Callison Lake Formation in Yukon, Canada. Found in silicified black shale horizons, sedimentological data suggests these VSMs inhabited a lagoonal or shelf interior environment. Dated with Re-Os geochronology at 752.7 +/- 5.5 – 739.9 +/- 6.1 Ma, these microfossils are indicative of the early diversification of eukaryotic life prior to the Sturtian-age Snowball Earth event, and are roughly coeval with the diverse VSM assemblage from the Chuar Group of Grand Canyon, Arizona. Here we investigate the distribution and morphological variation of the Callison Lake VSMs. Fossil abundance, morphospecies identification, and other characteristics were determined by utilizing point counting techniques on petrographic thin sections. Photographs of each “count,” coupled with high-magnification images of well-preserved and distinctive forms, were analyzed using ImageJ software to examine the morphological variation. In order to distinguish morphotypes we measured features such as test length, width, aperture diameter, and concavity. We found that fossil abundances are as high as ~8% of counts per thin section, but vary dramatically across sections and horizons, declining to <1%, even between samples only 0.2 m apart. Among imaged, distinctive forms, vase-shaped and curved morphotypes were found to be more abundant than hexagonal and ovular forms, which is consistent with assemblages from the Chuar Group. Additionally, analyses of well-preserved specimens reveal taxa comparable to those from the Chuar Group, as well as some previously undescribed morphotypes of VSMs. Overlapping species with Chuar Group VSMs include *Melanocyrillium hexodiadema*, *Cycliocyrillium torquata*, *Bonniea dacruchares*, and *Bonniea pytinai*. VSMs observed in one horizon indicate that scaled forms may be present. Further taxonomic classification of the Callison Lake VSMs will serve to help reconstruct Late Tonian ecosystems before the Snowball Earth events, expand our understanding of the early diversification of eukaryotic life in the Neoproterozoic, and help assess the viability of VSMs as index fossils for the Late Tonian.

Determining the Abundance of Microfossils Across the Lower Kellwasser Event in Upstate New York

Abigail Kelly ’16 and *Phoebe Cohen*

Geological Society of America Abstracts with Programs 47 (7), 135, 2015

The Kellwasser events are two globally expressed black shale beds that are associated with the Late Devonian Extinction Interval and include the Frasnian/Famennian transition. The Kellwasser beds have been interpreted as a signal of widespread marine anoxia correlated with the extinction interval. We sampled the lower Kellwasser event at several localities across Upstate New York, representing deeper marine paleoenvironments to the west and shallower marine paleoenvironments to the east. While larger body fossils are mainly absent within the

Kellwasser beds, organic-walled microfossils are abundant and provide a continuous record throughout the event. These fossils are classified as acritarchs and are often inferred to be phycoma, reproductive structures made by members of the green algal group Prasinophycea. However, additional valid interpretations of their taxonomic affinity include the resting stages of metazoan eggs or other algal cysts. In the modern, some algal and metazoan groups are known to produce recalcitrant acritarch-like structures in response to environmental stressors such as anoxia, adding complexity to understanding the environmental and preservational context of the microfossils.

Uncertainties including those discussed above make interpreting the acritarch record across the Late Devonian challenging. To move towards overcoming these challenges, we analyzed microfossil assemblage and abundance variation through the lower Kellwasser event and spatially across the paleo-depth gradient provided by our sampled localities. Here, we present methods for determining relative abundance of microfossils per sample with the use of polyethylene microspheres and total organic carbon (TOC) data in addition to established acid maceration techniques. These methods enable us to quantify abundance changes through the Kellwasser beds and better understand the assemblage and preservational changes throughout the extinction interval. This data will compliment work using trace fossils and geochemical proxies to contribute to our understanding of changing marine environments through the Kellwasser events.

A Reexamination of the Diversity and Stratigraphic Distribution of the Early Tonian Apatite Scale Microfossils, Fifteenmile Group, Yukon

Phoebe Cohen and *Henry Barker '18*

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Binding together biotic and abiotic systems, the evolution of biomineralization is one of the most pivotal events in the history of life on earth. The origins of primary, controlled eukaryotic biomineralization are not entirely clear, but Apatitic Scale Microfossils (ASMs) from the early Neoproterozoic (Tonian Period, 1000 – 717 Ma) Fifteenmile Group of Yukon, Canada, may represent the oldest evidence of eukaryotic biomineralization in the fossil record. These microfossils are constructed of nanoscale crystallite networks comprised of calcium phosphate minerals and organic carbon, and are interpreted as cell coverings similar to those found in modern coccolithophores. Cohen and Knoll (2012) documented the diversity of ASMs macerated from carbonates at the single known ASM locality at Mount Slipper. Here, we examine new specimens collected in 2014 from Mount Slipper. We document new species, reveal new detail of existing taxa, and provide a higher-resolution look at the stratigraphic distribution of ASMs at Mount Slipper.

Cohen and Knoll described fossils from 5 horizons; here we expand that to 23 horizons, spread out over 38 meters of section. In addition to several new taxa, we found well-preserved specimens with intricate, fragile structures still left intact—likely examples of previously described taxa, which lacked these structures due to poor preservation. We found several previously described taxa, such as Characodictyon skolopium, in new horizons, extending the range of those taxa. In addition, we examine the relationship between a local dolomitization front at Mount Slipper and the preservation of ASMs, revealing more information about why these unique fossils appear to be so rare. A clearer understanding of the preservation, stratigraphic distribution, and morphology of ASMs may help us make inferences about Neoproterozoic ocean chemistry and marine ecological dynamics.

Environmental Conditions Amidst the Frasnian-Fammenian Biotic Crisis: Clues from Nitrogen Isotopes and Chlorophyll Derivatives

Benjamin Uveges, Christopher Junium, *Phoebe Cohen*, and Diana Boyer

Geological Society of America Abstracts with Programs 47 (7), 633, 2015

The Frasnian-Fammenian (FF) biotic crisis is ranked among the top six mass extinctions in ecological severity, and was particularly devastating to shallow water tropical faunas and reef systems. The FF biotic crisis interval is expressed in Western New Yorks Java formation as two black shale beds known as the Upper and Lower Kellwasser intervals, and the FF boundary is preserved in Southern Indiana at the base of the Morgan Trail

member of the New Albany shale. The organic matter preserved within these shales is in need of a broader characterization in order to investigate the climatic conditions present during its production/preservation. This will be achieved through nitrogen and carbon isotope analyses of the bulk rock, organic matter, and chlorophyll derived porphyrin fractions of the shales, as well as through porphyrin biomarker characterization.

Nitrogen isotope analyses were performed on bulk, powdered rocks and solvent extracted organic fractions. Extract and porphyrin nitrogen isotope data are produced using a cryo-trapping/capillary focusing procedure capable of analyzing nanomolar quantities of nitrogen. Porphyrin separation and characterization was performed using HPLC/LC-MSn and diode array UV-Vis spectroscopy. Preliminary nitrogen isotope data show low to negative bulk sediment δ15N values (ranging from -2.3 to 0.5‰), which is consistent with many instances of black shale intervals during the Phanerozoic as well as during Ocean Anoxic Events. Also, the εpor (δ15Nbiomass - δ15Nchloropigments) values obtained from the organic extracts are consistent with the balance of sedimentary/extractable organic matter deriving from marine cyanobacteria (clustered around 0-1‰). The εpor values were calculated using bulk organic extract δ15N measurements as there were insufficient porphyrin concentrations in these samples to run compound specific analyses. However, on the basis of 15N NMR characterization, this method is a potential proxy for δ15N of chloropigments in εpor studies, as the majority of the nitrogen contained in the samples is likely pyrrolic and originating from chlorophylls.

Tracing Subarctic Pacific Water Masses with Benthic Foraminiferal Stable Isotopes During the LGM and Late Pleistocene

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Deep Sea Research Part II: Topical Studies in Oceanography 125, 84-95, 2016

As the largest ocean basin, the Pacific helps to set the global climate state, since its circulation affects mean ocean properties, air-sea partitioning of carbon dioxide, and the distribution of global oceanic poleward heat transport. There is evidence that during the Last Glacial Maximum (LGM) the subarctic Pacific contained a better-ventilated, relatively fresh intermediate water mass above ~2000 m that may have formed locally. The source and spatial extent of this water mass is not known, nor do we know how formation of this water mass varied during Pleistocene glaciations with different orbital and ice sheet boundary conditions. Here we present a 0.5 My multi-species benthic stable isotope record from Site U1345 (1008 m) on the northern Bering slope and a 1.0 My record from U1339 (1868 m) from the Umnak Plateau in the southeastern basin. We find that the relatively well-ventilated low-σ^{18}O intermediate water reaches 1000 m in the Bering Sea during MIS2, but that the hydrographic divide between this water mass and poorly-ventilated deep water was shallower than 1000 m for earlier glaciations. We also compare Bering Sea piston core and IODP Expedition 323 *Uvigerina* data from the Holocene and LGM with the modern hydrography, and to previously published profiles from the Okhotsk Sea and Emperor Seamounts. We find that the carbon and oxygen stable isotope signatures of well-ventilated water in the Bering and Okhotsk Seas are distinct, suggesting that there may have been intermediate water formation in both basins during the LGM.

Tephrochronology as a Tool to Constrain Radiocarbon Reservoir Age in the Deglacial Bering Sea

Alice Chapman '15, Caroline White-Nockleby '17, Paul de Konkoly Thege '15, Jeffrey Rubel '17, Mea Cook, Alan Mix, and Jason Addison

American Geophysical Union Fall Meeting

In order to accurately calendar date marine carbon, it is necessary to constrain surface reservoir age, the apparent ^{14}C age difference between the atmosphere and surface ocean that results from incomplete equilibration of ^{14}C across the air-sea interface. Surface reservoir age is generally assumed to be constant at the preindustrial value, but evidence suggests it has varied through time by up to 1000 years. In this study we use tephrochronology, a method of correlating tephras across different environments, to identify equivalent strata, as a tool to quantify reservoir age in the Bering Sea during the transition between the Oldest Dryas and Bolling-Allerod (14.7 kcal BP). With frequent volcanic eruptions that allow for possibility of high-resolution reservoir age reconstructions, the Bering Sea/Aleutian Islands region is uniquely positioned to provide insight into the hypothesis that dense

water formed in the North Pacific during the last deglaciation. We compare a massive tephra found in three deep-sea sediment cores from Umnak Plateau in the southeast Bering Sea (HLY02-02-55JPC, HLY-02-02-51JPC, and IODP Site U1339) to a tephra dated to 14.8 kcal BP from Deep Lake, Sanak Island in the Eastern Aleutians. For both the Umnak and Sanak tephras, volcanic glass shards are geochemically matched using major and trace elements from electron microprobe and laser-ablation inductively-coupled-plasma mass spectrometry. We compare ^{14}C ages of foraminiferal species *Uvigerina peregrina* and *Neogloboquadrina pachyderma* (sinistral) from just above the tephra in HLY-02-02-51JPC (1467 m) to ^{14}C age of the corresponding tephra at Sanak Island from terrestrial plant macrofossils. The surface reservoir age found (930 ± 160 14C y) is similar to the average preindustrial value in the region (790 ± 130 14C y). Benthic-atmosphere age difference (1860 ± 200 14C y) is also comparable to the preindustrial value (2030 ± 60 ^{14}C y). These results and future work on additional tephras from these cores could have implications for evaluating the accuracy of radiocarbon reconstructions of Pacific circulation that assume a constant preindustrial surface reservoir age.

Impact Breaching of Europa's Ice: Constraints from Numerical Modeling

Rónadh Cox and *Aaron Bauer '11*

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Simulations show that impactors can penetrate Europa's ice, creating conduits to the underlying ocean. Breaching becomes inevitable when transient cavity depth exceeds 90% of ice thickness. Results indicate that a 0.5 km comet would penetrate 5 km ice, and a 5 km comet could breach 40 km ice. If actual ice thickness is 8-13 km (indicated by comparing Europan and simulated crater geometries), the ocean could be exposed by impactors in the range 0.7-1.5 km, which have return times ≈3 to 7 m.y. Thus it seems that Europa's ice has been penetrated often in the past, and possibly in geologically recent time. The largest known impact sites, Callanish and Tyre, probably represent transition from craters to penetrating impacts. Full penetration would therefore be represented by as-yet-unrecognized features. Astrobiological materials could be transported to the ocean via these impact-created conduits.

Europa's Ice Can Be Breached by Impact: Hydrocode Modeling Constrains the Conditions

Rónadh Cox and *Aaron Bauer '11*

Geological Society of America Abstracts with Programs 47 (7), 281, 2015

How thick is Europa's ice? How and how often is there communication between Europa's surface and its sealed-in ocean? Can mass and energy be transmitted from the exterior into the liquid beneath? These questions persist in discussions about Europa as a mission target and exobiological prospect. Analysis of impact dynamics provides some answers.

Numerical simulations using iSALE show that impactors in the Jupiter Family Comet size distribution can penetrate through the full range of likely Europan ice thicknesses. The breaching criterion is met when transient cavity depth H_t exceeds 90% of ice thickness T_{ice}. Results indicate that the limiting penetrator size for 5 km ice is 0.4-0.6 km diameter (depending on density and impact velocity), and that a 5-7 km comet could breach 40 km ice.

Comparing simulated crater geometry with that of Europan impact features suggests that Callanish and Tyre, the largest known impact sites, represent boundary cases ($H_t \approx 0.9\ T_{ice}$) preserving the transition from craters to penetrating impacts, and suggesting that larger, full penetrations ($H_t > T_{ice}$) must be represented by some other category of features.

The relationship between Europan crater geometry and simulation data also points to actual ice thickness in the range 8-13 km. This means that the ocean could be exposed by impactors with diameters 0.7-1.5 km, which have recurrence intervals ≈3-7 m.y. Thus it seems that Europa's ice has been penetrated often in the past, and possibly in geologically recent time. Astrobiological materials could be transported to the ocean via these impact-created openings in the ice, which would serve as conduits for mass and energy exchange with the underlying ocean.

Storm-Wave Movement of Megagravel in Western Ireland: Implications for Understanding Storms and Tsunami

Rónadh Cox and *Oona Watkins '15*

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Coastal boulder deposits (CBD) accumulate above the high water mark along high-energy seaboards at locations worldwide. CBD include isolated clasts on coastal platforms as well as sorted, imbricated boulder ridges at the inland extent of marine influence. The extent to which these deposits represent the effects of tsunami versus storm wave activity has been extensively debated in the literature. Ireland's western coasts — where tsunami have not occurred in historical times — are the ideal place to study storm-dominated CBD.

Severe winter storms in 2013-2014 provided an opportunity to quantify the effects of high-energy marine bombardment on CBD in western Ireland. The pre-storm baseline was an extensive archive of precisely-located field photographs taken in the previous few years. Repeat photography and field measurement in summer 2014 documented movement of 1152 clasts on supratidal shore platforms and in boulder ridges. Of these, 13 had masses >50 t, and 67 were in the range 20-50 t. The largest block moved was >400 t.

The large-block movements inform the ongoing discussion of how to distinguish storm deposits from those of tsunami. Not only did these storm waves move a block with mass ≈400 t, they also transported several clasts (masses 36-49 t) horizontal distances of 75-100 m. These measurements mean that without other contextual evidence, the horizontal transport of megagravel cannot uniquely fingerprint paleotsunami events and cannot be used to inform tsunami chronologies. Transported clasts (as well as newly excavated boulders with masses up to 73 t) were added to imbricated boulder ridges, demonstrating that storm waves do contribute to imbricated CBD, and that boulder imbrication is also not diagnostic of tsunami deposition.

It's important to note that although these were significant storms (central pressures in the range 962-940 mb, i.e. equivalent to hurricane Categories 3 and 4), they were not extreme meteorological events: bigger storms with bigger waves are likely to transport larger blocks and move them farther. Work is therefore needed to more finely calibrate the process sedimentology of storm-activated CBD, both to distinguish them from tsunami deposits and to understand high-energy coastal dynamics.

Changes in Supratidal Coastal Boulder Deposits (Aran Islands, Ireland) Measured Using Structure-From-Motion Photogrammetry

Joshua Harrington '17 and *Rónadh Cox*

Geological Society of America Abstracts with Programs 47 (7), 358, 2015

Supratidal coastal boulder deposits (CBD) incorporate clasts with masses 10s to 100s of tonnes. It takes very large waves to activate these deposits, which makes them archives of high-energy events; but their dynamics are difficult to study, as many years can pass without major changes. A series of very strong storms in the winter of 2013-2014 brought an unusual opportunity to examine the before-and-after states of CBD in western Ireland. In the aftermath, we have been documenting the effects of the storm waves, which moved existing boulders, created new clasts from bedrock, and caused inland migration of some CBD.

To measure the changes, we flew an unmanned aerial vehicle (UAV) survey of coastal boulder deposits on Inishmore, one of the Aran Islands off Ireland's west coast. We used the structure-from-motion (SfM) software package Agisoft PhotoScan Pro to construct high-resolution 3D models of the coastal topography and boulder deposits. We compared the SfM models—which characterise post-storm disposition of the CBD—with pre-existing orthoimagery and with the Geological Survey of Ireland's 2003 coastal oblique aerial survey images. The comparisons reveal changes in the morphology of boulder ridges, reorganisation of boulder clusters, and relocation of individual large clasts.

The energy distribution on the coastal platform, as recorded by which boulders moved and which did not, was highly variable. In some cases very large clasts were moved considerable distances, while smaller clasts nearby moved not at all. Seaward faces of some boulder ridges were completely rearranged, but in others only a few

of the constituent clasts changed location. At some sites there was extensive landward migration of clasts (from the platform onto the boulder ridge face, from the ridge base to the crest, and from the ridge crest into the back-ridge area), whereas at other nearby ridge sections there was far less change.

Initial comparisons of pre-and-post storm boulder dispositions used terrestrial rephotography of field sites, and we used those before-and-after images to ground-truth the SfM-orthoimagery comparisons for specific locations. However, the UAV survey provided far more comprehensive image coverage of the entire CBD system, permitting us to construct generalised, regional assessments of the recent changes.

Soil Stratigraphy of Charcoal Kiln Remains (CKR) in the Litchfield Hills, CT, USA

Thomas Raab, Florian Hirsch, *William Ouimet '01*, and *David Dethier*

Geophysical Research Abstracts, 18, 2016

Charcoal kiln relicts (CKRs) are small anthropogenic landforms that are often found in historic mining areas. CKRs have not been a big research topic yet but mainly were studied as by-products of archaeological excavations. In the last years newly available and very accurate Digital Elevation Models (DEMs) based on high-resolution Airborne Laser Scanning (ALS) data have been used to identify these archaeological remains. In addition, findings of several thousands CKRs in the North German Lowland have increased the awareness that historical charcoal production may significantly contribute to Late Holocene landscape change. Besides the archaeological aspect of CKRs, potential impacts of charcoal burning on the ecology of modern soil landscapes and ecosystem processes must be considered.

A relatively high density of CKRs is found in the Litchfield Hills nearby the town of West Cornwall, Litchfield County, CT, USA. The CKRs are especially well preserved on slopes of the tributary valleys of the Housatonic River and form little, circular ramparts with diameters normally less than ten meters. First, rough field surveys in Litchfield County in spring 2015 have suggested differences between soils inside and outside the CKR. Soils on the CKR seem to have relatively deep humus-rich and charcoal containing topsoils whereas the topsoils outside the CKR appear typically thinner and less rich in humus. More thorough investigations have been started in autumn 2015 to prove the hypothesis that properties, distribution and development of soils are controlled by archaeological remains of historical charcoal burning.

We present preliminary results from our field studies conducted in October 2015. The stratigraphy and the extent of the 26 CKRs were studied using a sedimentological-pedological approach by coring and trenching. Our results indicate that in Litchfield County the CKRs were used twice and in quick succession. Before the second reuse, the rim of the platform was stabilized with boulders. The black topsoils on the CKRs contain residual charcoal and the topsoils are thicker compared to the soil sequences outside of the CKRs.

Investigating Holocene and Anthropocene Landscape Change and the Legacy of 19th and 20th Century Mining Using Geomorphic and Stratigraphic Evidence in Fourmile Canyon, Colorado

William Ouimet '01 and *David Dethier*

Association of American Geographers 2016 Annual Meeting 2016

In this study, we investigate mid-19th to mid-20th century mining impacts within Fourmile Canyon, Colorado Front Range. Fourmile Canyon was unglaciated during the last glacial interval, exhibits moderate to steep hillslopes, experiences frequent forest fires, and is susceptible to severe flooding. LiDAR based mapping and field studies highlight the extensive nature of mining impact within the 65 km^2 Fourmile watershed - we found ~18,460 mine waste dumps and prospect pits bigger than 10 m^2, ~495 km of roads, paths and trails near mine sites, ~29 km of historic railroad grades, 15 placer claims totaling 0.7 km^2, and 3 sites adjacent to Fourmile River preserving tailings pond sediment. In total, we estimate 6.23x10^6 m^3 of disturbed and redistributed hillslope sediment (mine dumps, pits, roads, and railroad) and 2.85x10^6 m^3 of modified valley bottom sediments (placer and tailings). Severe flooding along Fourmile Canyon in September 2013 caused direct erosion and mobilization of historic mining deposits and exposed older Holocene deposits. Overall, the exposed stratigraphy reveals that repeated flooding along Fourmile channels and erosion and deposition broadly related to mining activity has

removed and/or covered youngest Holocene deposits and constructed a mainly 20th century Anthropocene floodplain. In contrast, Front Range hillslope areas exposed by gold prospecting and mining are rich in legacy sediment that accumulated between about 1860 and 1940. Some of this sediment is stable, but many deposits are in gullies or on slopes steeper than 20%, areas that have potential for erosion over time, particularly if changing climate produces more intense rainstorms.

Charcoal Remains in Litchfield County Connecticut Record Widespread Hillslope Disturbance in the Iron Corridor from Mid-18th to Early 20th Centuries and Present Day Carbon Storage

Mary Ignatiadis '16, William Ouimet '01, Katharine Johnson, and *David Dethier*

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Landscape evolution in post-industrial southern New England reflects an industrial past revealed on LiDAR imagery and by field studies in the now-wooded landscape. Construction of >20,000 earthen platforms for charcoal production (mounds) in an area of 2450 km^2 affected hillslope processes and altered soil development in Litchfield County (northwestern Connecticut) from mid-18th to early 20th century. Charcoal mounds varied from 7 to 13 m in diameter and were similar to earthen charcoaling mounds built elsewhere in the northeastern USA and Europe at the time. However, colliers supporting northwestern Connecticut's iron industry built their mounds on platforms carved from the region's steep to moderate slopes. We estimate that mound construction moved approximately 10,000 m^3 of sediment downslope and charcoal production operations likely disturbed large hillslope areas. Field measurements show that the steep sides of the platforms have eroded in the past ~120 years, suggesting that platforms enhance movement of adjacent slopes.

The forests of southern New England convert a significant amount of atmospheric CO_2 to organic matter, a portion of which is stored in soils. Understanding changes to this regional C sink is therefore important for understanding CO_2 cycling at a global level. Mound construction mixed the upper meter of local sediment such that texture and moisture retention of the mounds differs from those of background sediments. The upper 10 to 40 cm of relict mounds are rich in charcoal and have high C/N ratios compared to soils on adjacent hillslopes. The concentration of charcoal in the upper meter of the mounds is about 5%, or about 2.5% C. By weight, this suggests that up to 31,800 kg of C is stored in forest soils over the entire study area due to historic charcoal production. C concentration in soils outside the mounds likely contain an average concentration of C in the upper meter that is <2%, and this C would be concentrated in the uppermost layers of the soil profile (<15-20 cm).

From Rock to Dust: Density Changes During the Transformation of Front Range Granite to Saprolite and Soil

David Dethier, William Ouimet '01, and Neil Shea

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The bulk density of granitic regolith (saprolite, grus and soil) records long-term physical and chemical transformation of Colorado Front Range bedrock and mixing with organic material to form mobile regolith. To help quantify geochemical budgets, we measured the density of granitic bedrock and regolith from soil pits or outcrops at stable sites and on slopes in Colorado and adjacent Wyoming. For granular samples from stable sites we measured density in the field using a 4-cm diameter coring tube or the excavation method; in the laboratory we used paraffin coating and displacement techniques. At >75 slope locations we used coring tubes in soil pits or a bulb planter for the upper 10 to 15 cm of the soil. The density of oxidized, fractured bedrock at stable sites ranged from 2.7 to about 2.2 Tm^{-3}, saprolite and grus gave densities between ~2.1 and 1.6 Tm^{-3} and soil B and BC horizons generally ranged between 1.8 and 1.4 Tm^{-3}. Soil horizons from slopes averaged ~1.6 Tm^{-3} and composite soil O + A horizons gave values of 1.1 ± 0.2 Tm^{-3} (n =146). Thin section and geochemical analyses show that chemical weathering rates and clay generation is slow and that strain in Front Range saprolite is driven by formation of fractures and microfractures, enhanced by expansion of weathering biotite. In contrast, saprolites described by M. Pavich from the Appalachian piedmont are rich in neoformed minerals typical of warm, moist climates. On Front Range slopes, where density is less than ~1.7

Tm^{-3}, bioturbation and incorporation of organic matter produces regolith that creeps downslope and can be eroded by overland flow. Organic-rich horizons on slopes incorporate an average of 36% > 2 mm material, much of it pebble gravel derived from upward-mixed saprolite. Catchments have average ^{10}Be erosion rates of 2.2 cm ky^{-1} and the depth to saprolite on slopes is about 40 cm, implying steady-state residence times of a few tens of thousands of years on most slopes. Areas of thick, low-density saprolite may record a relict landscape that formed in pre-late Pleistocene time.

Quantifying 18th to Early 20th Century Human Impacts on Hillslopes and Sediment Mobilization in Southern New England and Colorado Front Range

William Ouimet '01, David Dethier, Katharine Johnson, Maneh Kotikian, and *Will Wicherski '15*

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In this study, we examine 17th to early 20th century human impacts on hillslopes and sediment mobilization in southern New England and the Colorado Front Range. Southern New England exhibits widespread evidence of historic land clearing for agriculture and pasture (stonewalls) and timber harvesting for charcoal production (relict kilns). The Colorado Front Range, meanwhile, displays widespread evidence of historic mining with large mine shafts, exploration pits and waste piles on hillslopes and tailings pond sediment at mill sites along valley bottoms. LiDAR based mapping and field studies in both regions highlight the extensive nature of these periods of human impact. In forested terrain throughout northwestern and eastern Connecticut, we find that towns 100-150 km^2 in area have an average of 408 km of abandoned stonewalls per town representing 300,000 to 400,000 m^3 of moved stone. A regional analysis of a 1,170 km^2 study area in northwestern Connecticut reveals at least 20,434 relict kiln sites 10 to 16 m in diameter, an intensity of about 17 platforms per km^2. In Colorado, analysis within our 65 km^2 Fourmile watershed study area revealed 18,600 prospect pits and small mines (all bigger than ~10 m^2), 455 km of smaller roads and trails near mine sites, 33 km of historic railroad grades, and ~60,000 m^3 of tailings pond sediment. Severe flooding along Fourmile Canyon in September 2013 caused direct erosion and mobilization of mine waste piles, placer deposits, historic railroad and modern road fill, and tailings pond sediment, highlighting the ongoing legacy of historic soil and sediment mobilization. Overall, we find that the human impacts outlined above characterize the Anthropocene for these regions and quantifying them serves as a benchmark for understanding human activities in the context of Holocene landscape evolution. Furthermore, these case studies highlight the utility of LiDAR for fine scale mapping of human induced hillslope sediment transport and historic land modification preserved under sparse and dense forest canopy.

Investigating the Use of Polycyclic Aromatic Hydrocarbons (PAHs) as a Proxy for Holocene Forest Fires on the Colorado Front Range

Gregory Harris, M. Hren, *William Ouimet '01,* and *David Dethier*

Geological Society of America Abstracts with Programs 47 (7), 547, 2015

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous environmental contaminants generated during the incomplete combustion of organic carbon material. PAHs are hydrophobic in nature and can adsorb to clays and organic materials in the soil. These compounds are highly resistant to biodegradation, which allows PAHs to persist in the soil at potentially measurable quantities after a forest fire event. This study examined the distribution of PAHs in modern and ancient soils within the Boulder Creek Critical Zone Observatory (BcCZO) and Fourmile Canyon in the Colorado Front Range to assess whether the spatial and temporal pattern of PAH accumulation preserves a record of Holocene fire frequency. The semi-arid climate of the Colorado Front Range produces conditions conducive to regular forest fires, and there are numerous documented fires throughout the Holocene. We analyzed PAH distributions in soil and sediments from the BcCZO from Gordon Gulch and Betasso Gulch, as well as from Fourmile Canyon, which in 2010 experienced an intense, 16.5 km^2 forest fire as well as severe flooding in 2013. Depth profiles of PAHs show a strong correlation between PAH concentration and incidence of fire, with an observed increase in concentration corresponding to each burned and/or ashy buried layer relative to samples gathered above or directly below each layer. Depth profiles from recent (2010) fires show maximum total PAH concentrations occur at a depth of 5 cm, suggesting influence of volatilization

at the surface PAHs, as well as translocation of PAHs downward through the soil column. Lighter PAHs (less than four rings) were preserved in greatest quantities and display a clearer trend among recently burned areas. Over longer timescales, it appears that total PAH concentrations as well as heavier molecular weight PAHs (four rings or more) offer a more accurate proxy for reconstructing fire occurrence.

Fire and Flood in Fourmile Canyon, Colorado —Analyzing the Geomorphic Effects of Catastrophic Events Using Lidar and Field Studies

Will Wicherski '15, David Dethier, William Ouimet '01, and James Kaste

Geological Society of America Abstracts with Programs 47 (7), 836, 2015

Episodic events inform our understanding of landscape evolution by providing quantifiable geologic change on short timescales. We use results from field measurements and repeat airborne LiDAR difference analysis to reconstruct sediment transport, channel changes, and sediment budgets along a 20 km reach of Fourmile Canyon, Colorado, an area devastated by fire in 2010 and by the September 2013 flood. The 2010 Fourmile Canyon fire burned 23% of the Fourmile Creek watershed, mainly in the lower reaches of the catchment. Over 350 mm of rain fell in the Front Range foothills west of Boulder, Colorado from September 9 to 15, 2013, causing extensive flooding and local mass movements. Steep-slope debris flows and road failures occurred in the most intensely burned areas and locally catastrophic reworking of the channel area. Our measurements focused on flood height and width indicators, and sedimentologic analyses of gravel-rich deposits thicker than 0.5 m. Flood channel and slackwater deposits were analyzed for concentrations of ^{210}Pb and ^{137}Cs to help identify sediment source areas. One-meter resolution DEMs from LiDAR flown before the fire (Aug. 2010) and after the flooding (Oct. 2013) allowed us to measure the geomorphic effects of the flood and fire in the same areas as our detailed field surveys. We used field-checked LiDAR-based cross-sectional profiles to estimate peak discharge using the slope-area and critical-depth methods. LiDAR difference analysis shows 34,000-55,000 m^3 of local deposition despite net erosion of 44,500-96,000 m^3 from the floodplain. 19 debris flows were triggered in burned areas and none in unburned zones. The mass balance of sediment on the valley floor and field observations indicate that the 2013 flood event produced net erosion, mainly by channel widening, despite significant (>100 m long, >1 m thick) depositional zones throughout the canyon. Debris flows mobilized 42,000-60,000 m^3 of sediment from the hillslopes, which influenced local deposition in the floodplain. Radionuclide concentrations suggest deep sediment sources for downstream deposits, showing that sheetwash was not a significant sediment delivery mechanism in 2013. Our erosion estimates from Fourmile Canyon suggest that rare events can account for a large fraction of total sediment transport from Front Range hillslopes.

How Concentration of Porosity, Crack Shape, and Crack Wall Asperity Control the Seismic Structure of the Upper Oceanic Crust

Emanuele Fontana, *Lisa Gilbert*, Nicolleta Marinoni, and Paola Tartarotti

American Geophysical Union Fall Meeting V21A-3023, 2015

Surprisingly little is known about several important aspects of the architecture of oceanic crust, including controls on lithology, heterogeneity of hydrothermal alteration, and thickness of the lava section and sheeted dike complex and their influences on the seismic structure. Ophiolites provide useful analogs of ancient oceanic crust, with more exposure and access than deep-sea drill holes or submarine fracture zones. We examine the brittle structure of the lava, sheeted dikes, and lava-dike transition zone of the Troodos ophiolite (Cyprus) in the Lythrodontas area. The lava zone consists of pillow basalts; the transition zone consists of sheeted basaltic dikes cutting pillow lava through a large interval, and of hyaloclastitic breccia; the sheeted dikes are composed of 1–2 m thick basaltic or dacitic dikes. Detailed sample measurements of P- and S-wave velocity, permeability, porosity, and structures, show that porosity decreases drastically, as does permeability from lava to sheeted dikes. Variation of P-wave velocity mainly depends on the porosity, as well as the shapes of the cracks or pores. To better understand the relationships among P-wave velocity, porosity, and crack shape and aspect ratio, we made laboratory measurements using synchroton X-ray computed microtomography (micro-CT). Micro-CT images enhance the phase-contrast between primary (igneous) minerals and alteration minerals now filling the

pores. Overall, quantitative data of the volume and shape of the pores (at the sample scale) allow us to evaluate the "empty" (effective) porosity as well as the paleo-porosity (pores now partially or completely filled with secondary minerals). We also quantify the asperity of crack walls. These measurements allow us to construct 3D structural patterns in the investigated ophiolite, which we use to examine the influence of cracks in the upper oceanic crust on seismic structure.

Characteristics of a Resilient New England Salt Marsh

Molly Weiner and *Lisa Gilbert*

Geological Society of America Annual Meeting 47 (7)*,* 326, *2015*

The goal of this project is to determine the stability of a New England salt marsh by integrating biotic factors and erosional features. In 2014 and 2015 mosquito-ditched and un-ditched areas in Barn Island Wildlife Management Area, Connecticut were compared by repeat surveys. We studied both marsh edge stabilizing grasses and the mussel species *Geukensia demissa*. Although there were no major tropical storms this year, the marsh suffers from increased tidal inundation due to a local sea level rise of 2.58 ± 0.23 mm/y. Our measurements indicate the edge of un-ditched marsh is relatively stable and dominated by a normal profile. The un-ditched edge has exclusively the low marsh grass *Spartina alterniflora* and 100-200 mussels/m^2. In contrast, the ditched marsh edge is less stable and dominated by overhanging profiles. One area of ditched marsh lost 2 m on its seaward edge and showed significant increase in high marsh grasses on its edge between 2014 and 2015. The ditched marsh headlands bordered on one side by a natural channel have high densities of mussels (3,000 mussels/m^2). The areas of the ditched marsh with no adjacent natural channel had the most change in erosional state in the study year, with a surprising number of overhangs dislodging into islands. Quantifying the changes in a year with no major tropical storm event will aid prediction of marsh resiliency against sea level rise and storms. Mosquito-ditched marshes without the sediment supply of a natural channel and the edge-stabilizing *S. alterniflora* and *G. demissa* will likely show increased deterioration as sea-level rise increases.

Charles Darwin in the Cape Verde and Galápagos Archipelagos: The Role of Serendipity in Development of Theories on the Ups and Downs of Oceanic Islands

Markes Johnson and *Gudveig Baarli*

Earth Sciences History 34, 220-242, 2015

The 1831–1836 voyage of H.M.S. *Beagle* under Captain Robert FitzRoy launched Charles Darwin's entry into the world of geology with two pioneering publications on oceanic islands to his credit. Best known is Darwin's 1842 contribution on the theory of atoll development from the subsidence of volcanic islands and coeval upward growth of coral reefs. This work can be linked, in part, to the ten days during which the *Beagle* visited the Keeling (Cocos) Islands. The subsequent and lesser known of Darwin's parallel contributions is his 1844 summary on all the volcanic islands visited during the expedition, including Santiago (Cape Verde Islands), Terceira (Azores), St. Paul's Rocks, Fernando Noronha, Ascension, St. Helena, the Galápagos Islands, Tahiti, and Mauritius. Ostensibly, the centerpiece of the 1844 volume is Darwin's extensive coverage of Ascension based on the five days spent there in 1836. However, Darwin had many more days at his disposal in the Galápagos and 'St. Jago' (Santiago), where the *Beagle* stopped in the Cape Verde Islands at the outset and again near the end of the voyage. The volcanic islands where Darwin spent the most time were in the Galápagos (thirty-five days) and the Cape Verdes (twenty-nine days). In particular, those island groups make an interesting comparison with respect to the development of Darwin's ideas on tectonic uplift based on basalt flows with inter-bedded limestone formations. Chance played a huge role in what Darwin saw and did not see during his island travels. The initial visit to the Cape Verde islands was instrumental in shaping Darwin's earliest vision of a book on volcanic islands, but his time there was entirely fortuitous due to a forced change in FitzRoy's plan for a stay in the Canary Islands. Although Darwin was on the look out for limestone formations in the Galápagos islands comparable to those on Santiago in the Cape Verdes, he missed finding them due only to the vagaries of FitzRoy's charting schedule in the Galápagos. This overview looks at limestone distribution in the Cape Verde and Galápagos archipelagos as now understood and speculates on how a wider knowledge of both

regions may have influenced Darwin's thinking on global patterns of island uplift and subsidence.

Recent Rhodolith Deposits Stranded on the Windward Shores of Maio (Cape Verde Islands): Historical Resource for the Local Economy

Markes Johnson, Gudeig Baarli, C. Silva, M. Cachão, R. Ramalho, A. Santos, and E. Mayoral

Journal of Coastal Research 32 (4), 735-743, 2016

Maio is a volcanic island with an area of 269 km^2 in the Cape Verde archipelago off the west coast of Africa. Although considered a leeward island, it absorbs northeast trade winds that typically register 5 to 6 on the Beaufort Scale (moderate to fresh breeze). The trade winds produce ocean swells commonly 3.5 m in height that scour the island's north coast but also generate eastern long-shore currents. Outcrops with Pleistocene rhodoliths occur on the southeast and south shores and include lithified dunes mainly composed of crushed rhodolith debris. In contrast, the modern beaches and Pleistocene dunes on the more sheltered west coast are practically devoid of rhodoliths. Present-day rhodolith banks off the north coast would seem to be precluded by intense wave action. This study examines rhodoliths from over-wash and beach-rock deposits around Ponta Cais in the far north. Lumpy rhodoliths (likely *Lithothamnion* sp.) are concentrated in a sheltered corner on the bay south of Ponta Branca. A more extensive over-wash deposit covers an area 27,000 m^2 one meter above mean sea level with a surface exposure of 450 rhodoliths/m^2. A unique specimen nucleated around a ceramic fragment indicates that the deposit is historical in context. Rhodolith beach rock extends all along Praia Real east of Ponta Cais. A northern bank clearly exists, but at a water depth normally adequate to protect larger rhodoliths from all but major storms. Abandoned limekilns behind Praia Real demonstrate that the local economy on a volcanic island utilized rhodoliths as a source of mortar and whitewash.

Tectonic Decapitation of a Pliocene Mega-Delta on Isla Del Carmen in the Gulf of California (Mexico): And a River Ran Through It

Markes Johnson, Jorge Ledesma-Vazquez, and David Backus

Journal of Geology 124, 55-74, 2016

The Tiombó conglomerate on Isla del Carmen in Baja California Sur represents a mega-delta deposited mainly during the Middle Pliocene (early Piacenzian Age). A cross-section with the characteristically arched profile of a fan delta is exposed in sea cliffs 60 m high that extend for 2 km along the east side of the fourth largest island in Mexico's Gulf of California. A tide-water aspect to the delta is proven by the inclusion of fossil-rich lenses dominated by the pecten *Patinopecten bakeri*, which also occurs abundantly together with many other Middle Pliocene fossils in the Arroyo Blanco limestone juxtaposed against the south flank of the delta construction. Inland, the conglomerate fills a broad, cross-island channel approximately 3 km^2 in area that ends with cliff exposures of a lesser thickness overlooking the Carmen Passage between Isla del Carmen and the peninsular mainland of Baja California. Based on exposures that fail to reveal the full basal contact, the combined fluvial and deltaic parts of the system are conservatively estimated to exceed 200 million cubic meters. This study finds that the Pliocene Tiombó Delta is massively too large for the island it now occupies and that the related distributary channels in the delta's original watershed extended to the peninsular mainland and the Sierra de la Giganta in the Loreto area. The direct implication is that the Pliocene delta suffered tectonic decapitation when a reactivated half graben subsided and the Carmen Passage flooded only in later Pliocene time. A useful comparison in scale is provided through examination of the modern delta at Loreto, together with its associated watershed on the peninsular mainland. Long term changes in El Niño Southern Oscillation cycles are appraised as an influence on regional Pliocene delta construction at several other localities along the peninsular gulf coast of Baja California.

Vertically-oriented Trace Fossil *Maronichnus segregatis* from Neogene of Santa Maria Island (Azores; NE Atlantic) Records Vertical Fluctuations of the Coastal Groundwater Mixing Zone on a Small Oceanic Island

Uchman, A.,*Markes Johnson*, Rebelo, A.C., Melo, C., Cordeiro, R., Ramalho, R.S., and Ávila, S.P.

Geobios 49, 229-241, 2016

The trace fossil Macaronichnus segregatis is produced by opheliid polychaetes that feed on epigranular microbes and organic matter commonly abundant in shallow marine foreshore sands. Resulting traces are horizontal and typically random in orientation, but sometimes perpendicular to the shoreline. However, M. segregtis in Neogene sandy sediments from Santa Maria Island in the Azores shows a vertical or sub-vertical orientation. This is explained by vertical habitat migration, i.e within the mixing zone between interstitial marine and fresh water aquifers –where epigranular microbes and organic matter are most enriched. On reefless oceanic islands like the Azores, insular shelves are invariably steep, narrow, and exposed to strong swell. Aquifers in this setting respond rapidly to small changes on account of limited shelf space and a high potential differential that stimulates a vertical shift in habitats. Freshwater aquifers on small, low-relief oceanic islands form a thin lens, the edges of which are wedged against marine interstitial waters and migrate up and down in response to changes caused by tides, storms and precipitation. During the Late Miocene/Early Pliocene, Santa Maria was an island fitting this description. Due to waning volcanisms, intense marine erosion and gradual submersion, the island developed a wide shallow platform covered by sandy shoals, as exemplified by the Malbusca section with vertical Macaronichnus. The process, however, is more acute on small beaches perched on rocky island coasts. Here, sand blankets cover small ramps cut in the basaltic bedrock, resulting in very limited freshwater aquifers subject to strong changes due to the low permeability of basalts. The mixing zone is therefore forced to migrate chiefly up and down. The same response is dramatic in sandy fillings trapped in basalt fissures. As a consequence, the producer of Macaronichus was tightly constrained in movement. Both situations occur in the "Pedre-que-pica" section on Santa Marina.

Gulf of California Coastal Ecology: Insights from the Present and Patterns from the Past

Markes Johnson and Jorge Ledesma-Vazquez

Sunbelt Publications, 134 p. (2016)

Geographically and culturally, the gulf region that surrounds the Gulf of California on the western frontier of Mexico is unique. Compared to the rest of Mexico and most other parts of the world, population centers remain relatively small and the Baja California peninsula continues to be home to a hardy people accustomed to enjoying the fruits of an inland sea bordering on a desert land. The missions of this booklet are 1) to describe the riches with which nature has endowed the region, 2) to instruct how we can better understand its ecological complexities in the context of its geological heritage, and 3) to promote the ways we must be proactive to care for such a great treasure. The gulf region shares with other attractive regions all around the world the challenge of controlling progress in such a way that the natural environment is protected from growing human pressure. While the Mexican federal government has put into place measures to provide for marine bioreserves and marine parks, the public must be informed and vigilant in order to maintain and even expand protections for one of the world's most precious and instructive windows on ecology. This booklet is thus dedicated to the children and young adults in whose care the future of the Gulf of California rests.

The Enduring Impact of E-An Zen on Taconic Geology

Paul Karabinos, Francis MacDonald, and J. Crowley

Geological Society of America Abstracts with Programs 47 (7), 496, 2015

The complex geology of the Taconic Mountains in the northern Appalachians has fueled controversies since 1840. One of these, the existence of thrust faults, was hotly debated until E-an Zen's commanding synthesis of Taconic stratigraphy and detailed structural mapping in the 1960s convinced most geologists that Taconic rocks were allochthonous. Zen was also an influential advocate of submarine gravity sliding, and he argued

that the Taconic allochthons slid from the tops of the Green Mountain and Berkshire massifs. Gravity sliding was consistent with geosynclinal theory, and it circumvented the perceived mechanical paradox of thrusting. Soon after Zen's seminal publications, plate tectonics was used to explain the Ordovician Taconic orogeny as a collision between Laurentia and an island arc. However, Zen's influence echoed for decades as geologists investigated problems he identified, including: hard-rock vs. soft-rock thrusting, the relative timing of thrusting and metamorphism, and the root-zone of the allochthons.

The complex geology of the Taconic region reflects the evolution of a continental margin that was continuously active from Early Ordovician to Carboniferous. By 475 Ma, a major suture formed when the Gondwanan Moretown terrane and the superjacent Shelburne Falls arc collided with Laurentia above an east-dipping subduction zone, outboard of rocks now located in the Taconics. Subduction polarity reversed by 466 Ma when ashes, derived from volcanoes above the newly established west-dipping subduction zone, were deposited in the Indian River Fm. in the Taconics. West of the Taconics, the weakly deformed Utica Shale received 453 to 450 Ma ashes coeval with westward thrusting of the Taconic allochthons. Both the Utica ashes and the critical taper that drove thrusting resulted from collision of the east-facing arc along the Laurentian margin and a second Gondwanan terrain with a west-facing arc in the Late Ordovician. The Devonian collision of Avalon with Laurentia reestablished critical taper, and the Green Mountain and Berkshire massifs were thrust westward up crustal-scale ramps. Taconic thrust sheets were folded and eroded above the basement-cored antiforms, thus isolating the Taconic klippen. The resulting map pattern was the inspiration for Zen's gravity sliding model for the allochthons.

Combining Rectified High-Resolution Gigapan Images and an Interactive Strain Program to Test the Rf-Phi Method for Analysis of Conglomerates

Paul Karabinos and *Lisa Merkhofer '11*

Geological Society of America Abstracts with Programs 47 (7), 49, 2015

Deformed pebbles are commonly used by researchers to estimate strain in rocks, and by instructors to teach fundamental principles of strain. The Rf-Phi method is widely used to measure strain in deformed pebbles. It relies on the assumption that pebbles were deposited with no initial preferred orientation of long axes. We tested this fundamental assumption in the undeformed polymictic Mount Toby Conglomerate from Sunderland, MA. We created high-resolution Gigapans, and used precisely embedded markers to rectify the stitched photos. The rectified images were then imported into Geoshear, an interactive Java program that allows users to explore visually how deformation of a set of elliptical objects appears on Cartesian and polar Rf-Phi plots. We digitized the pebbles based on lithology to measure the clast aspect ratios and orientations. In faces perpendicular to bedding, Rf-Phi plots showed a significant initial preferred orientation of long axes parallel to bedding when all clast lithologies were used. Clasts with higher aspect ratios showed a stronger preferred orientation in accord with the so-called delta configuration of Elliott (1970). On surfaces parallel to bedding, Rf-Phi plots showed no initial preferred orientation of long axes. Results from the Rf-Phi analysis of three joint faces were combined (Mookerjee and Nickleach, 2011) to determine an apparent 'strain ellipsoid'. When all clast lithologies were used in the analysis, the apparent 'strain ellipsoid' for two locations was oblate with normalized axial ratios of 1.2:1:0.55 and 1.3:1:0.56, with a maximum initial axial ratio of 2.1 and 2.3 in the X-Z plane, and apparent octahedral shear strain of 0.57 ± 0.09 and 0.58 ± 0.10, respectively. When we restricted the Rf-Phi analysis to only quartz pebbles, however, faces perpendicular to bedding revealed only a weakly preferred orientation of long axes. When only quartz pebbles were used to compute apparent 'strain ellipsoids' the normalized axial ratios were 1:1:0.87 and 1.2:1:0.92, with a maximum initial axial ratio of only 1.1 and 1.3 in the X-Z plane, and apparent octahedral shear strain of 0.12 ± 0.06 and 0.18 ± 0.06, respectively. Thus, the assumption of no initial preferred orientation of pebble long axes is approximately valid for the quartz-pebble population.

Evidence for the Evolving Plate Geometry in the Taconic Hinterland of the Northern Appalachians and Implications for Foreland Basin Deposits

Paul Karabinos, James Crowley, and Francis MacDonald

Geological Society of America Abstracts with Programs 48 (2), 2015

The Ordovician to Silurian clastic wedge in NY records protracted tectonic activity in the hinterland in western New England, which is collectively thought of as the Taconic orogeny. Evidence in western New England reveals major changes in plate geometry during this interval. By Early Ordovician, the Laurentian margin entered an east dipping subduction zone under the Gondwanan Moretown terrane (MT). This suture is located between the Rowe Schist and the Moretown Fm, and contains numerous lenses of mafic and ultramafic rocks. The Shelburne Falls arc (SFA) formed above the subduction zone on the MT, and the high volume of 475 Ma magmas in the arc may reflect subduction of Laurentian crust and/or slab-breakoff following collision. Detrital zircon grains from five samples in the Hawley Fm in the SFA contain (1) early Ordovician grains derived from arc volcanism, (2) numerous grains between 550 and 650 Ma consistent with a Gondwanan source, and (3) a major component of 960 to 1200 Ma Laurentian derived detritus indicating that by 475 Ma, the MT and SFA were proximal to Laurentia. Ordovician magmatism in the hinterland and foreland are linked by the 466 Ma Barnard Volcanic Member in VT and coeval ashes in the Indian River Fm in the Giddings Brook thrust sheet (GBTS) in NY. A west-dipping subduction zone under the Laurentian margin may have been established by 466 Ma, but was certainly active by 456 Ma when arc-related magmas intruded rocks already deformed during the earliest phase of the Taconic orogeny in western CT. If the Moretown, Cobble Mountain, and Albee Fms are all part of one Gondwanan terrane, as suggested by detrital zircon populations, the younger 454 to 442 Ma magmatic rocks in the Bronson Hill arc (BHA) formed above the same west-dipping subduction zone after accretion of the MT. Thus, magmatic rocks in the SFA and BHA probably formed on the same Gondwanan terrane, but above two oppositely dipping subduction zones, resulting in spatial overlap of older and younger arc rocks. The Taconic clastic wedge began as a pro-arc foreland basin, which is preserved in the Poultney through Pawlet Fms of the GBTS. By ca. 465-460 Ma, a superimposed retro-arc foreland basin developed in which the classic Late Ordovician Taconic clastic wedge was deposited. Late Ordovician to Silurian accretion of Ganderia further modified the plate geometry.

Detrital Zircon Constraints on the Age of the Granville Dome Mantling Sequence

Laura Stamp '16, Francis MacDonald, *Paul Karabinos*, and James Crowley

Geological Society of America Abstracts with Programs 48 (2), 2015

The Granville dome straddles the CT-MA border, occurs within the Connecticut Valley trough, and is considered part of the Ordovician Shelburne Falls arc. As mapped, it is cored by the Ordovician Collinsville Fm, with an inner mantle of Devonian Goshen Fm and an outer mantle of Ordovician Cobble Mountain Fm. Mapping of Devonian schist between the Ordovician core and outer mantle of the Granville dome led to complex structural models of dome formation. Assignment of the inner mantle rocks to the Devonian is critical to the mechanism of dome formation, yet outcrops of highly deformed, coarsely recrystallized, kyanite-grade schist mantling the dome are difficult to assign to specific units. Here we test the assignment of the inner mantle rocks to the Goshen Fm using detrital zircon from schist on the east flank of the dome. Preliminary U-Pb data from 81 analyses show (1) a dominant Grenville component, including a distinctive peak at 980 Ma that links the sediment to western MA and southern VT, (2) a significant population at 600 to 700 Ma consistent with a Gondwanan source, (3) a sharp Ordovician peak derived from arc-related rocks, and (4) a sharp Early Devonian peak. These results are consistent with assigning the inner mantle rocks to the Goshen Fm, which has been dated in western MA at ca. 405 Ma by U-Pb zircon analysis of an interbedded volcanic tuff. The zircon population is similar to those from the Silurian-Devonian Waits River and Gile Mountain Fms from the Connecticut Valley trough in VT (McWilliams et al., 2010). To the north, the Ordovician cored Goshen and Shelburne Falls domes are mantled only by the Devonian Goshen Fm, lacking an outer mantle of Cambrian to Ordovician Cobble Mountain Fm. Therefore, the formation of the Granville dome appears to require an episode of Devonian back-thrusting of the Cobble Mountain Fm over the structurally underlying Devonian units to the west.

Taconic Basin Formation and Magmatism in New England and Newfoundland

Francis MacDonald, James Crowley, Eben Hodgin, and *Paul Karabinos*

Geological Society of America Abstracts with Programs 48 (2), 2015

Previous models have suggested the Taconic orogeny was diachronous along the Appalachian margin. Here we present new CA-TIMS ages on Middle Ordovician ashes in foreland deposits of the Table Head Group of Newfoundland. These ages are indistinguishable from ages on ashes in the Indian River Formation of New York and biostratigraphic constraints on the Saint Daniel mélange in Quebec. Thus, we suggest that this Middle Orodvician Taconic foreland is a feature that is ubiquitous along the margin of the northern Appalachians. In Newfoundland, Middle Ordovician foreland deposition is due to the emplacement of Dashwoods onto the Humber margin. In New York and Quebec, loading may be due to the thrusting of Moretown onto the platform margin. We also present new detrital zircon data to test if Dashwoods is North American or Gondwanan and represents a continuation of the Moretown Terrane. A later, Katian, successor retro-arc foreland basin is preserved in the Long Point Group of Newfoundland, which is superimposed on the underlying Middle Ordovician foreland deposits of the Table Head and Goose Tickle groups. Similarly, the Katian Utica Shale represents a second, distinct, basin-forming event in New York. These two, distinct subsidence events are borne out in subsidence analyses in both New England and Newfoundland.

Integrating Foreland and Hinterland Data: Toward a Greater Synthesis of Appalachian Tectonics and Orogenesis

Charles Ver Straeten and *Paul Karabinos*

Geological Society of America Abstracts with Programs 48 (2), 2015

Integrating data from the foreland basin and hinterland of an orogen has tremendous potential for tectonic reconstructions. The foreland basin contains a detailed, time-integrated record of sediment transfer from the hinterland, mediated by elevation differences, climate, and drainage patterns. The hinterland provides direct evidence for subduction, terrane accretion, crustal thickening, rifting, and tectonic exhumation. Advances in the precise U-Pb dating of zircon, and the recognition of widespread K-bentonites in the foreland, has made it possible to integrate more fully foreland and hinterland histories in the northern Appalachians, and to identify some specific tectonic events that were coeval with the formation of air-fall tephras in the foreland basin. The foreland basin's strengths lie in the patterns and trends of sedimentation, controlled at least in part by orogenesis. Key data include rock type/composition, stratal geometry, altered airfall volcanic tephras or byproducts thereof (e.g., terrestrial vertisols), and more. Changes in data over time often provide a detailed record of long- to short term changes in the orogenic belt often not available from the hinterland, especially from older deeply eroded orogens like the Appalachians.

Despite potential biases in the sedimentary record and possible non-orogenic factors, high quality data can provide insight into hinterland events. Over 100 altered airfall volcanic tephras are now reported from the Devonian Appalachian Basin, providing a coarse proxy of the timing of Acadian/Neoacadian paleovolcanism (terrestrial vertisols may provide a more detailed record). Vertical changes in sandstone and conglomerate grain composition reflect changes over time in rock type exposed in the orogen. Shifts in foreland basin geometry, seen as changes of foreland basin topography (e.g., foredeep, forebulge); sediment package geometries (e.g., tabular- to wedge-shaped); sediment condensation; and some unconformities may reflect changes in foreland basin kinematics, related to changes in the orogen (e.g., uplift and crustal loading, in-plane stresses, etc.).

Studies of the foreland basin and hinterland have complementary strengths and weaknesses. Integration of their unique insights can create a new, broader synthesis of Appalachian orogenesis.

The Fold Analysis Challenge, a Virtual Globe-Based Education Resource

Declan De Paor, Mladen Dordevic, *Paul Karabinos*, Barbara Tewksbury, and Steven Whitmeyer

Journal of Structural Geology 85, 85-94, 2016

We present an undergraduate structural geology laboratory exercise using the Google Earth virtual globe with COLLADA models, optionally including an interactive stereographic projection and JavaScript controls. The learning resource challenges students to identify bedding traces and estimate bedding orientation at several locations on a fold, to fit the fold axis and axial plane to stereographic projection data, and to fit a doubly-plunging fold model to the large-scale structure. The chosen fold is the Sheep Mountain Anticline, a Laramide uplift in the Big Horn Basin of Wyoming. We take an education research-based approach, guiding students through three levels of difficulty. The exercise aims to counter common student misconceptions and stumbling blocks regarding penetrative structures. It can be used in preparation for an in-person field trip, for post-trip reinforcement, or as a virtual field experience in an online-only course. Our KML scripts can be easily transferred to other fold structures around the globe.

Spatial Distribution of Basaltic Rootless Cones as a Function of Water Availability: Icelandic and Experimental Studies

Nell Davis '15, R. A. Wobus, Richard Hazlett, and Jeffrey Karson

Geological Society of America Abstracts with Programs 48 (6), 2016

Rootless cones can form from the interaction of lava with wet ground and are often clustered in topographic lows. On the Laki flow in Southern Iceland, Hamilton et al. (2010) found that spatial distribution within clusters of cones may indicate competition for water resources during cone formation. Cones forming with less available water are more likely to be uniformly distributed than cones with more water, which may have random or clustered spatial distributions. It is important to better understand how lava-water interactions form rootless cones in order to identify areas vulnerable to phreatic eruptions, as well to identify lava-water features on Mars or other planets.

Six rootless cone clusters on the post-glacial Younger Laxárhraun flow in Northeastern Iceland were analyzed. Two of these were plotted with reconnaissance mapping, while the others were mapped in Google Earth. Cone centroids were calculated in ArcMap, and Geologic Image Analysis Software was used to determine spatial distributions of the cones. Based on the geologic history of the area, it was assumed that the location and elevation of water bodies has not changed since 2,000 years ago.

The site farthest from bodies of water had uniformly distributed cones. Regardless of water proximity, three of the other sites had randomly distributed cones, while two exhibited clustered distributions. These results suggest the influence of factors other than water proximity, although uniform distributions and less water were found to correlate in two experimental flows created for this study at the Syracuse University Lava Project (http://lavaproject.syr.edu), where molten basalt from a gas-fired tilt furnace was poured over saturated sand.

In Iceland, elevation above the water table may impact rootless cone spatial distribution more than lateral distance to bodies of water. Rootless cones located on distal lava lobes can appear clustered due to flow morphology. Clearly, future work encompassing more sites is necessary to better characterize factors involved in rootless cone development.

Mathematics and Statistics

A Pi Day Carol

Colin Adams

Mathematical Intelligencer, Vol. 37, No. 3, 22-25, 2015.

Aftermath

Colin Adams

Mathematical Intelligencer, Vol. 37, No. 4, 2015.

What is…A Laminated Deck Transformation?

Colin Adams

Mathematical Intelligencer, Vol. 38, No. 1, 32-33, 2016.

The Galactic Math Repository

Colin Adams

Mathematical Intelligencer, Vol. 38, No. 2, 1-3, 2016.

Bipyramids and Bounds on Volumes of Hyperbolic Links

Colin Adams

ArXiv, 1511.02372, 2015.

Volume and Determinant Density of Hyperbolic Rational Links

Colin Adams, Aaron Calderon, Xinyi Jiang, *Alexander Kastner '17, Gregory Kehne '16, Nathaniel Mayer '16, Mia Smith '16*

ArXiv, 1510.06050, 2015.

The volume density of a hyperbolic link is defined as the ratio of hyperbolic volume to crossing number. We study its properties and a closely-related invariant called the determinant density. It is known that the sets of volume densities and determinant densities of links are dense in the interval [0,v_{oct}]. We construct sequences of alternating knots whose volume and determinant densities both converge to any x in [0,v_{oct}]. We also investigate the distributions of volume and determinant densities for hyperbolic rational links, and establish upper bounds and density results for these invariants.

Generalized Bipyramids and Hyperbolic Volumes of Tiling Links

Colin Adams, Aaron Calderon, Xinyi Jiang, *Alexander Kastner '17, Gregory Kehne '16, Nathaniel Mayer '16, Mia Smith '16*

ArXiv, 1603.03715, 2016.

We present explicit geometric decompositions of the complement of tiling links, which are alternating links whose projection graphs are uniform tilings of the 2-sphere, the Euclidean plane or the hyperbolic plane. This requires generalizing the angle structures program of Casson and Rivin for triangulations with a mixture of finite, ideal, and truncated (i.e. ultra-ideal) vertices. A consequence of this decomposition is that the volumes of spherical tiling links are precisely twice the maximal volumes of the ideal Archimedean solids of the same combinatorial description. In the case of hyperbolic tiling links, we are led to consider links embedded in thickened surfaces S_g x I with genus g at least 2. We generalize the bipyramid construction of Adams to truncated bipyramids and use them to prove that the set of possible volume densities for links in S_g x I, ranging over all g at least 2, is a dense subset of the interval [0, 2v_{oct}], where v_{oct}, approximately 3.66386, is the volume of the regular ideal octahedron.

Using Age-Stratified Incidence Data to Examine the Transmission Consequences of Pertussis Vaccination

Julie Blackwood with DAT Cummings, S. Iamsirithaworn, and P. Rohani

Epidemics 16, pp. 1–7, 2016.

Pertussis is a highly infectious respiratory disease that has been on the rise in many countries worldwide over the past several years. The drivers of this increase in pertussis incidence remain hotly debated, with a central and long-standing hypothesis that questions the ability of vaccines to eliminate pertussis transmission rather than simply modulate the severity of disease. In this paper, we present age-structured case notification data from all provinces of Thailand between 1981 and 2014, a period during which vaccine uptake rose substantially, permitting an evaluation of the transmission impacts of vaccination. Our analyses demonstrate decreases in incidence across all ages with increased vaccine uptake – an observation that is at odds with pertussis case notification data in a number of other countries. To explore whether these observations are consistent with a rise in herd immunity and a reduction in bacterial transmission, we analyze an age-structured model that incorporates contrasting hypotheses concerning the immunological and transmission consequences of vaccines. Our results lead us to conclude that the most parsimonious explanation for the combined reduction in incidence and the shift to older age groups in the Thailand data is vaccine-induced herd immunity.

Business Statistics A First Course, 3rd Edition

Richard De Veaux with Norean Sharpe and Paul Velleman

Pearson, January 2016.

Teaching Statistics Algorithmically or Stochastically Misses the Point: Why Not Teach Holistically?

*Richard De Veaux (*with Paul F. Velleman, in response to George Cobb's *Mere Renovation is too Little Too Late: We Need to Rethink Our Undergraduate Curriculum from the Ground Up*).

American Statistician, 69, **4**, 262–282, 2015.

Review of Steven Weintraub's Differential Forms: Theory and Practice

Thomas Garrity

American Mathematical Monthly, Vol. 121, No. 4, 407-412, 2016.

A review of Weintraub's text and a discussion of how to teach differential forms.

Statistics: The Art and Science of Learning From Data

Bernhard Klingenberg with Agresti, A., Franklin, C.

Pearson, 2017.

Treating Small Bowell Obstruction With a Manual Physical Therapy: A Prospective Efficacy Study

Bernhard Klingenberg with Rice, Patterson, Reed, Wurn, King, Wurn

BioMed Research International, Article ID 7610387, dio:10.1155/2016/7610387, 2016.

Formal Fibers With Countably Many Maximal Elements

Susan Loepp (with *D. Aiello '09* and *P. Vu '11*)

Rocky Mountain Journal of Mathematics, 45, no. 2, 371-388, 2015.

Let T be a complete local ring and G a set of prime ideals of T with countably many maximal elements. We find necessary and sufficient conditions for T to be the completion of a local integral domain whose generic formal fiber is exactly G. In addition, if n is a positive integer, we construct integral domains with a prime ideal of height n whose formal fiber has countably many maximal elements.

Controlling the Generic Formal Fibers of Local Domains and Their Polynomial Rings

Susan Loepp (with P. Jiang, A. Kirkpatrick, S. Mack-Crane, *S. Tripp '14*)

Commutative Algebra, 7, no. 2, 241-264, 2015.

Let T be a complete local ring, C a countable set of incomparable prime ideals of T, and B and D sets of prime ideals of the power series ring over T in n variables such that the cardinality of B and D is less than that of T. We find necessary and sufficient conditions for T to be the completion of an integral domain A such that the generic formal fiber of A has maximal elements equal to C and the generic formal fiber of the polynomial ring over A in n variables contains every element of B and no elements of D. If T has characteristic 0, we find necessary and sufficient conditions for the A above to be excellent.

Completions of Reduced Local Reduced With Prescribed Minimal Prime Ideals

Susan Loepp (with *B. Perpetua '14*)

Involve, 9, no. 1, 101-118, 2016.

Let T be a complete local ring of dimension at least one, and let $C_1,C_2,...,C_m$ each be countable sets of prime ideals of T. We find necessary and sufficient conditions for T to be the completion of a reduced local ring A such that A has exactly m minimal prime ideals $Q_1,Q_2,\ldots,Q_m$, and such that, for every i = 1,2,…,m, the set of maximal elements of the formal fiber of Q_i is the set C_i.

Limiting Spectral Measures for Random Matrix Ensembles With a Polynomial Link Function

Steven Miller (with Kirk Swanson, Kimsy Tor and Karl Winsor)

Random Matrices: Theory and Applications 4, no. 2, 1550004 (28 pages).

Consider the ensembles of real symmetric Toeplitz matrices and real symmetric Hankel matrices whose entries are i.i.d. random variables chosen from a fixed probability distribution p of mean 0, variance 1, and finite higher moments. Previous work on real symmetric Toeplitz matrices shows that the spectral measures, or densities of normalized eigenvalues, converge almost surely to a universal near-Gaussian distribution, while previous work on real symmetric Hankel matrices shows that the spectral measures converge almost surely to a universal non-unimodal distribution. Real symmetric Toeplitz matrices are constant along the diagonals, while real symmetric Hankel matrices are constant along the skew diagonals. We generalize the Toeplitz and Hankel matrices to study matrices that are constant along some curve described by a real-valued bivariate polynomial. Using the Method of Moments and an analysis of the resulting Diophantine equations, we show that the spectral measures associated with linear bivariate polynomials converge in probability and almost surely to universal non-semicircular distributions. We prove that these limiting distributions approach the semicircle in the limit of large values of the polynomial coefficients. We then prove that the spectral measures associated with the sum or difference of any two real-valued polynomials with different degrees converge in probability and almost surely to a universal semicircular distribution.

Relieving and Readjusting Pythagoras

Steven Miller with Victor Luo '15

By the Numbers – The Newsletter of the SABR Statistical Analysis Committee, 25, no. 1, 5-14, 2015.

Bill James invented the Pythagorean expectation in the late 70's to predict a baseball team's winning percentage knowing just their runs scored and allowed. His original formula estimates a winning percentage of RS^2 / (RS^2+RA^2), where RS stands for runs scored and RA for runs allowed; later versions found better agreement with data by replacing the exponent 2 with numbers near 1.83. Miller and his colleagues provided a theoretical justification by modeling runs scored and allowed by independent Weibull distributions. They showed that a single Weibull distribution did a very good job of describing runs scored and allowed, and led to a predicted won-loss percentage of (RSobs−1/2)^γ / ((RSobs−1/2)^γ + (RAobs−1/2)^γ), where RSobs and RAobs are the observed runs scored and allowed and γ is the shape parameter of the Weibull (typically close to 1.8). We show a linear combination of Weibulls more accurately determines a team's run production and increases the

prediction accuracy of a team's winning percentage by an average of about 25% (thus while the currently used variants of the original predictor are accurate to about four games a season, the new combination is accurate to about three). The new formula is more involved computationally; however, it can be easily computed on a laptop in a matter of minutes from publicly available season data. It performs as well (or slightly better) than the related Pythagorean formulas in use, and has the additional advantage of having a theoretical justification for its parameter values (and not just an optimization of parameters to minimize prediction error).

Equipartitions and a Distribution for Numbers: A Statistical Model for Benford's Law

Steven Miller (with *Joe Iafrate '14* and Frederick Strauch)

Physical Review E91, no. 6, 062138 (6 pages), 2015.

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.

Sets Characterized by Missing Sums and Differences in Dilating Polytopes

Steven Miller (with Thao Do, Archit Kulkarni, *David Moon '16*, Jake Wellens and *James Wilcox '14*)

Journal of Number Theory, 157, 123–153, 2015.

A sum-dominant set is a finite set A of integers such that |A+A| > |A-A|. As a typical pair of elements contributes one sum and two differences, we expect sum-dominant sets to be rare in some sense. In 2006, however, Martin and O'Bryant showed that the proportion of sum-dominant subsets of {0,...,n} is bounded below by a positive constant as ntoinfty. Hegarty then extended their work and showed that for any prescribed s,d in N_0, the proportion rho^{s,d}_n of subsets of {0,...,n} that are missing exactly s sums in {0,...,2n} and exactly 2d differences in {-n,...,n} also remains positive in the limit. We consider the following question: are such sets, characterized by their sums and differences, similarly ubiquitous in higher dimensional spaces? We generalize the integers in a growing interval to the lattice points in a dilating polytope. Specifically, let P be a polytope in R^D with vertices in Z^D, and let rho_n^{s,d} now denote the proportion of subsets of L(nP) that are missing exactly s sums in L(nP)+L(nP) and exactly 2d differences in L(nP)-L(nP). As it turns out, the geometry of P has a significant effect on the limiting behavior of rho_n^{s,d}. We define a geometric characteristic of polytopes called local point symmetry, and show that rho_n^{s,d} is bounded below by a positive constant as n -> infinity if and only if P is locally point symmetric. We further show that the proportion of subsets in L(nP) that are missing exactly s sums and at least 2d differences remains positive in the limit, independent of the geometry of P. A direct corollary of these results is that if P is additionally point symmetric, the proportion of sum-dominant subsets of L(nP) also remains positive in the limit.

Newman's Conjecture in Function Fields

Steven Miller (with Alan Chang, David Mehrle, Tomer Reiter, Joseph Stahl ad Dylan Yott)

Journal of Number Theory, 157, pages 154–169, 2015.

De Bruijn and Newman introduced a deformation of the completed Riemann zeta function zeta, and proved there is a real constant Lambda which encodes the movement of the nontrivial zeros of zeta under the deformation. The Riemann hypothesis is equivalent to the assertion that Lambda <= 0. Newman, however, conjectured that Lambda >= 0, remarking, "the new conjecture is a quantitative version of the dictum that the Riemann hypothesis, if true, is only barely so." Andrade, Chang and Miller extended the machinery developed by Newman and Polya to L-functions for function fields. In this setting we must consider a modified Newman's conjecture: sup_{f in F} Lambda_f >= 0, for F a family of L-functions. We extend their results by proving this modified Newman's conjecture for several families of L-functions. In contrast with previous work, we are able to exhibit specific L-functions for which Lambda_D = 0, and thereby prove a stronger statement: max_{L in F} Lambda_L = 0. Using geometric techniques, we show a certain deformed L-function must have a double root, which implies Lambda = 0. For a different family, we construct particular elliptic curves with p + 1 points

over {F}_p. By the Weil conjectures, this has either the maximum or minimum possible number of points over F_{p^{2n}}. The fact that #E(F_{p^{2n}}) attains the bound tells us that the associated L-function satisfies Lambda = 0.

Distribution of Eigenvalues of Weighted, Structured Matrix Ensembles

Steven Miller (with Olivia Beckwith, *Victor Luo '15*, Karen Shen and Nicholas Triantafillou)

Integers: Electronic Journal of Combinatorial Number Theory 15, paper A21, 28 pages, 2015.

The study of the limiting distribution of eigenvalues of N × N random matrices as N → ∞ has many applications, including nuclear physics, number theory and network theory. One of the most studied ensembles is that of real symmetric matrices with independent entries drawn from identically distributed nice random variables, where the limiting rescaled spectral measure is the semi-circle. Studies have also determined the limiting rescaled spectral measures for many structured ensembles, such as Toeplitz and circulant matrices. These systems have very different behavior; the limiting rescaled spectral measures for both have unbounded support. Given a structured ensemble such that (i) each random variable occurs o(N) times in each row of matrices in the ensemble and (ii) the limiting rescaled spectral measure μe exists, we introduce a parameter to continuously interpolate between these two behaviors. We fix a p ∈ [1/2, 1] and study the ensemble of signed structured matrices by multiplying the (i, j)-th and (j, i)-th entries of a matrix by a randomly chosen epsilon_ij ∈ {1, −1}, with Prob(epsilon_ij = 1) = p (i.e., the Hadamard product). For p = 1/2 we prove that the limiting signed rescaled spectral measure is the semi-circle. For all other p, we prove the limiting measure has bounded (resp., unbounded) support if μ has bounded (resp., unbounded) support, and converges to μ as p → 1. Notably, these results hold for Toeplitz and circulant matrix ensembles. The proofs are by Markov's Method of Moments. The analysis of the 2k-th moment for such distributions involves the pairings of 2k vertices on a circle. The contribution of each pairing in the signed case is weighted by a factor depending on p and the number of vertices involved in at least one crossing. These numbers are of interest in their own right, appearing in problems in combinatorics and knot theory. The number of configurations with no vertices involved in a crossing is well-studied, and are the Catalan numbers. We discover and prove similar formulas for configurations with 4, 6, 8 and 10 vertices in at least one crossing. We derive a closed-form expression for the expected value and determine the asymptotics for the variance for the number of vertices in at least one crossing. As the variance converges to 4, these results allow us to deduce properties of the limiting measure.

The Weibull Distribution of Benford's Law

Steven Miller (with Victoria Cuff and Allie Lewis)

Involve, A Journal of Mathematics 38 – 5, pages 859–874, DOI 10.2140/involve.2015.8.859.

Benford's law states that many data sets have a bias towardslower leading digits (about 30% are 1s). There are numerous applications, from designing efficient computers to detecting tax, voter and image fraud. It's important to know which common probability distributions are almost Benford. We show the Weibull distribution, for many values of its parameters, is close to Benford's law, quantifying the deviations. As the Weibull distribution arises in many problems, especially survival analysis, our results provide additional arguments for the prevalence of Benford behavior. The proof is by Poisson summation, a powerful technique to attack such problems.

Leading Digit Laws on Linear Lie Groups

Steven Miller (with Corey Manack)

Research in Number Theory 1:22, DOI 10.1007/s40993-015-0024-4, 2015.

We study the leading digit laws for the matrix entries of a linear Lie group G. For non-compact G, these laws generalize the following observations: (1) the normalized Haar measure of the Lie group R + is dx/x and (2) the scale invariance of dx/x implies the distribution of the digits follow Benford's law. Viewing this scale invariance as left invariance of Haar measure, we see either Benford or power law behavior in the significands from one matrix entry of various such G. When G is compact, the leading digit laws we obtain come as a

consequence of digit laws for a fixed number of components of a unit sphere. The sequence of digit laws for the unit sphere exhibits periodic behavior as the dimension tends to infinity.

Maass Waveforms and Low-Lying Zeros

Steven Miller with Levent Alpoge, Nadime Amersi, Geoffrey Iyer, Oleg Lazarev and *Liyang Zhang '15*

Analytic Number Theory: In Honor of Helmut Maier's 60th Birthday, Springer-Verlag, 2015.

The Katz-Sarnak Density Conjecture states that the behavior of zeros of a family of L-functions near the central point (as the conductors tend to zero) agrees with the behavior of eigenvalues near 1 of a classical compact group (as the matrix size tends to infinity). Using the Petersson formula, Iwaniec, Luo and Sarnak proved that the behavior of zeros near the central point of holomorphic cusp forms agrees with the behavior of eigenvalues of orthogonal matrices for suitably restricted test functions φ. We prove similar results for families of cuspidal Maass forms, the other natural family of GL2/Q L-functions. For suitable weight functions on the space of Maass forms, the limiting behavior agrees with the expected orthogonal group. We prove this for supp(φ^) ⊆ (−3/2,3/2) when the level N tends to infinity through the square-free numbers; if the level is fixed the support decreases to being contained in (−1,1), though we still uniquely specify the symmetry type by computing the 2-level density.

Determining Optimal Test Functions for Bounding Average Rank in Families of L-Functions

Steven Miller with Jesse Freeman '15

Proceedings for Ram Murty's 60th Birthday, Contemporary Math. Series of AMS (jointly with CRM) 2015.

Given an L-function, one of the most important questions concerns its vanishing at the central point; for example, the Birch and Swinnerton-Dyer conjecture states that the order of vanishing there of an elliptic curve L-function equals the rank of the Mordell-Weil group. The Katz and Sarnak Density Conjecture states that this and other behavior is well-modeled by random matrix ensembles. This correspondence is known for many families when the test functions are suitably restricted. For appropriate choices, we obtain bounds on the average order of vanishing at the central point in families. In this note we report on progress in determining the optimal test functions for the various classical compact groups for different support restrictions, and discuss how this relates to improved rank bounds.

Senior Editor for Theory and Applications of Benford's Law

Steven Miller

Princeton University Press, 2015.

One of the greatest beauties in mathematics is how the same equations can describe phenomena in widely different fields. Benfords Law of digit bias is an outstanding example of this. Briefly, it asserts that for many natural data sets we are more likely to see numbers with small leading digits than large ones. Our purposes here are to show students and researchers useful techniques from a variety of subjects, highlight the connections between the different areas and encourage research and cross-departmental collaboration on these problems. To do this, we develop much of the general theory in the first few chapters (concentrating on the methods which are applicable to a variety of problems), and then conclude with numerous chapters on applications written by world-experts in that field.

Gaussian Distribution of the Number of Summands in Generalized Zeckendorf Decompositions in Small Intervals

Steven Miller with *Andrew Best '15*, Patrick Dynes, *Xixi Edelsbrunner '16, Brian McDonald '15*, Kimsy Tor, Caroline Turnage-Butterbaugh and Madeleine Weinstein

Integers 16, #A6, 2015.

Zeckendorf's theorem states that every positive integer can be written uniquely as a sum of non-consecutive Fibonacci numbers {F_n}, with initial terms F_1 = 1, F_2 = 2. Previous work proved that as n \to \infty the distribution of the number of summands in the Zeckendorf decompositions of m in [F_n, F_{n+1}),

appropriately normalized, converges to the standard normal. The proofs crucially used the fact that all integers in [F_n, F_{n+1}) share the same potential summands, and hold for more general positive linear recurrence sequences {G_n}. We generalize these results to subintervals of [G_n, G_{n+1}) as n \to \infty for certain sequences. The analysis is significantly more involved here as different integers have different sets of potential summands. Explicitly, fix an integer sequence alpha(n) to infinity. As n to infinity, for almost all m in [G_n, G_{n+1}) the distribution of the number of summands in the generalized Zeckendorf decompositions of integers in the subintervals [m, m + G_{alpha(n)}), appropriately normalized, converges to the standard normal. The proof follows by showing that, with probability tending to 1, m has at least one appropriately located large gap between indices in its decomposition. We then use a correspondence between this interval and [0, G_{alpha(n)}) to obtain the result, since the summands are known to have Gaussian behavior in the latter interval.

Are Circles Isoperimetric in the Plane With Density e^r?

Frank Morgan with Ping Ngai Chung, Miguel A. Fernandez, *Niralee Shah '14*, and Luis Sordo Vieira

Rose-Hulman Und. Math. J., 16, No. 1, 2015.

Morgan's 2011 NSF SMALL undergraduate research Geometry Group gives evidence that circles about the origin are isoperimetric in the plane with density e^r.

Isoperimetric Problem on the Plane with Density $e^{-1/r}$

Frank Morgan with Paul Gallagher, David Hu, *Zane Martin '13*, Maggie Miller and *Byron Perpetua '15*

Rose-Hulman Und. Math. J., 15, No. 2, 2015.

Morgan's 2012/13 NSF SMALL undergraduate research Geometry Groups provide numerical and theoretical evidence that isoperimetric curves the plane with density $e^{-1/r}$ have an angle at the origin approaching 1 radian from above as area approaches zero and provide further estimates.

Perimeter-Minimizing Tilings by Convex and Nonconvex Pentagons

Frank Morgan with Whan Ghang, *Zane Martin '13* and Steven Warahui

Rose-Hulman Und. Math. J., 16, No. 1, 2015.

Morgan's 2012 NSF SMALL undergraduate research Geometry Group studies the presumably unnecessary convexity hypothesis in the theorem of Chung *et al.* on perimeter-minimizing planar tilings by convex pentagons.

Geometric Measure Theory: A Beginner's Guide, 5th Edition

Frank Morgan

Academic Press, 2016.

An easy-going, illustrated introduction for the newcomer to this somewhat technical field. The fifth edition provides comprehensive updates and a new chapter on the Log Convex Density Theorem, a major new result in an area of mathematics—manifolds with density—that has exploded since its appearance in Perelman's proof of the Poincaré conjecture.

Six Milestones in Geometry

Frank Morgan, Stephen F. Kennedy, Editor

A Century of Advancing Mathematics, Math. Assn. Amer., 51–64, 2015.

My choices for the six biggest advances in geometry during the 100-year lifetime of the MAA.

Unsolved Mathematical Mysteries

Frank Morgan

Virginia Math. Teacher, 42, Vol. 1, 1–20, Fall 2015.

Write-up of talk on "Soap Bubbles and Mathematics" at the Connecting Mathematical Practices Conference at Radford University, May 8, 2015, including some open questions about soap bubble clusters.

Soap Bubbles and Mathematics

Frank Morgan

Eur. Math. Soc. Newsletter, 32–36, September 2015.

Write-up of Abel Science Lecture, May 20, 2015, Oslo.

The Inferiorities of MacMail

Frank Morgan

Huffington Post Blog, September 2015.

Problems with the Mac mail application.

Sphere Packing in Dimension 8

Frank Morgan

Huffington Post Blog, March 2016.

A brief account of this breakthrough in sphere packing by a woman Ukranian mathematician.

On v-Positive Type Transformations in Infinite Measure

Cesar E. Silva with Tudor Padurariu and Evangelie Zachoes

Mathematics Colloquium, 140, 149-170, 2015.

For each vector v we define the notion of a v-positive type for infinite measure-preserving transformations, a refinement of positive type as introduced by Hajian and Kakutani. We prove that a positive type transformation need not be (1,2)-positive type. We study this notion in the context of Markov shifts and multiple recurrence and give several examples.

On Infinite Transformations With Maximal Control of Ergodic Two-Fold Product Powers

Cesar E. Silva with T.A. Adams

Israel Journal of Mathematics, 209, 929-948, 2015.

We study the rich behavior of ergodicity and conservativity of Cartesian products of infinite measure preserving transformations. A class of transformations is constructed such that for any subset R of rationals in (0,1) there exists T in this class such that T^p x T^q is ergodic if and only if p/q is in R. This contrasts with the finite measure preserving case where T^p x T^q is ergodic for all nonzero p and q if and only if T x T is ergodic. We also show that our class is rich in the behavior of conservative products.

For each positive integer k, a family of rank-one infinite measure preserving transformations is constructed which have ergodic index k, but infinite conservative index.

Ergodicity and Conservativity of Products of Infinite Transformations and Their Inverses

Cesar E. Silva with Julien Clancy, Rina Friedberg, *Isaac Loh '15*, Indraneel Kalsmarka, Sahana Vasudevan

Colloq. Math., 143, 271-291, 2016.

We construct a class of rank-one infinite measure-preserving transformations such that for each transformation T in the class, the cartesian product T x T of the transformation with itself is ergodic, but the product T x T^{-1} of the transformation with its inverse is not ergodic. We also prove that the product of any rank-one transformation with its inverse is conservative, while there are infinite measure-preserving conservative ergodic Markov shifts whose product with their inverse is not conservative.

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

Mihai Stoiciu with *Feixue Gong '16, Olivia Meyerson '16, Jeremy Meza, and Abigail Ward*

Involve, A Journal of Mathematics, 9, no. 3, 517-540, 2016.

We study the $\in$-pseudospectra $\sigma_{\in}(A)$ of square matrices $A \in \mathbf{C}^{NxN}$. We give a complete characterization of the $\in$-pseudospectra of 2 x 2 matrices and describe the asymptotic behavior (as $\in \to 0$) of $\sigma_{\in}(A)$ for every square matrix A. We also present explicit upper and lower bounds for the $\in$-pseudospectra of bidiagonal matrices, as well as for finite rank operators.

Physics

"Codon influence on protein expression correlates with E. coli mRNA levels"

Grégory Boël, Reka Letso, Helen Neeley, W. Nicholson Pierce, Kam-Ho Wong, Min Su, Jon D. Luff, Mayank Valecha, John K. Everett, Thomas B. Acton, Rong Xiao, Gaetano T. Montelione, Daniel P. Aalberts† and John Hunt† (†=corresponding author)

Nature **529**, 358-363 (2016)

"Visualizing RNA secondary structure base pair probabilities"

William K. Jannen and Daniel P. Aalberts

http://biovis.net/year/2015/design/update.html

"Automatic quantum experiment control: from circuit compiler to ion routing"

Stevens, K. E., Amini, Jason M., Doret, S. Charles, Volin, Curtis, and Harter, Alexa

*Special Issue on Trapped Ion Quantum Information Processing (*2016*)*

The field of quantum information processing is rapidly advancing. As the control of quantum systems approaches the level needed for useful computation, the physical hardware underlying the quantum system are becoming increasingly com-plex. It is already becoming impractical to manually code control for the larger hard-ware implementations. In this chapter, we will employ an approach to the problem of system control that parallels compiler design for a classical computer. We will start with a candidate quantum computing technology, the surface electrode ion trap, and build a system instruction language, which can be generated from a simple machine-independent programming language via compilation. We incorporate compile time generation of ion routing that separates the algorithm description from the physical geometry of the hardware. Extending this approach to automatic routing at run time allows for automated initialization of qubit number and placement; and additionally allows for automated recovery after catastrophic events such as qubit loss. To show that these systems can handle real hardware, we present a simple demonstration sys-tem that routes two ions around a multizone ion trap and handles ion loss and ion placement. While we will mainly use examples from transport-based ion trap quan-tum computing, many of the issues and solutions are applicable to other architectures.

"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.

"Quantum state synthesis of superconducting resonators"

Roshan Sharma and Frederick W. Strauch

Phys. Rev. **A 93**, 012342 (2016)

We present a theoretical analysis of different methods to synthesize entangled states of two quantum mechanical resonators. These methods are inspired by experimentally demonstrated interactions of superconducting resonators with artificial atoms, and offer efficient routes to generate nonclassical states. Using a two-mode Jaynes-Cummings model, we analyze the theoretical structure of these algorithms and their average performance for arbitrary states and for deterministically preparing NOON and maximally entangled states. Using a new state synthesis algorithm, we show that NOON and maximally entangled states can be prepared in a time linear in the desired photon number and without any state-selective interactions.

"Higher-dimensional Bell inequalities with noisy qudits"

Elena Polozova and Frederick W. Strauch

Phys. Rev. **A 93**, 032130 (2016)

Generalizations of the classic Bell inequality to higher-dimensional quantum systems known as qudits are reputed to exhibit a higher degree of robustness to noise but such claims are based on one particular noise model. We analyze the violation of the Collins-Gisin-Linden-Massar-Popescu inequality subject to more realistic noise sources and their scaling with dimension. This analysis is inspired by potential Bell inequality experiments with superconducting resonator-based qudits. We find that the robustness of the inequality to noise generally decreases with increasing qudit dimension.

"Exotic decays of heavy B quarks"

Patrick Fox and David Tucker-Smith

JHEP **038,** 1601(2016)

Heavy vector-like quarks of charge -1/3, B, have been searched for at the LHC through the decays B → bZ, bh, tW. In models where the B quark also carries charge under a new gauge group, new decay channels may dominate. We focus on the case where the B is charged under a U(1)' and describe simple models where the dominant decay mode is B to bZ' to 3b. With the inclusion of dark matter such models can explain the excess of gamma rays from the Galactic center. We develop a search strategy for this decay chain and estimate that with integrated luminosity of 300 inverse fb the LHC will have the potential to discover both the B and the Z' for B quarks with mass below ~1.6 TeV, for a broad range of Z' masses. A high-luminosity run can extend this reach to 2 TeV.

"Optimal Information Transfer and Real-Vector-Space Quantum Theory"

William K. Wootters

In Quantum Theory: Informational Foundations and Foils, edited by G. Chiribella and R. W. Spekkens (Springer, 2015)

Consider a photon that has just emerged from a linear polarizing filter. If the photon is then subjected to an orthogonal polarization measurement—e.g., horizontal vs vertical—the photon's preparation cannot be fully expressed in the outcome: a binary outcome cannot reveal the value of a continuous variable. However, a stream of identically prepared photons can do much better. To quantify this effect, one can compute the mutual information between the angle of polarization and the observed frequencies of occurrence of "horizontal" and "vertical." Remarkably, one finds that the quantum-mechanical rule for computing probabilities—Born's rule—maximizes this mutual information relative to other conceivable probability rules. However, the maximization is achieved only because linear polarization can be modeled with a real state space; the argument fails when one

considers the full set of complex states. This result generalizes to higher dimensional Hilbert spaces: in every case, one finds that information is transferred optimally from preparation to measurement in the real-vector-space theory but not in the complex theory. Attempts to modify the statement of the problem so as to see a similar optimization in the standard complex theory are not successful (with one limited exception). So it seems that this optimization should be regarded as a special feature of real-vector-space quantum theory.

Psychology

IQ and Defense Mechanisms Assessed with the TAT

Phebe Cramer

Rorschachiana 36, 40-57, 2015.

This paper focuses on the relation between the use of defense mechanisms and intelligence. These two ego functions are not correlated in childhood and adolescence, but are correlated in adulthood. IQ serves as a moderator for the effect of defense use on variables such as psychiatric symptom change, level of ego development, and personality traits.

Adolescent Parenting, Identification, and Maladaptive Narcissism

Phebe Cramer

Psychoanalytic Psychology 32, 559-579, 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 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.

Understanding Defense Mechanisms

Phebe Cramer

Psychodynamic Psychiatry 43, 523-552, 2015.

This article traces the history of the concept of defense, from its origin with Freud to current views. The issue of defense as an unconscious mechanism is examined. The question of whether defenses are pathological, as well as their relation to pathology, is discussed. A series of empirical research studies that demonstrate the functioning of defense mechanisms is presented.

Defense Mechanisms

Phebe Cramer

In S.K. Whitbourne (Ed.), *The Encyclopedia of Adulthood and Aging (V*ol. 1). New York: Wiley-Blackwell (2015)

This paper focuses on how defense mechanisms change with age, and presents several theories to explain why change occurs. Both cross-sectional and longitudinal findings are discussed.

Defense Mechanisms

Phebe Cramer and John Porcerelli

In H.S. Friedman (Ed.), *Encyclopedia of Mental Health, 2nd edition,* vol. 2 (pp. 13-17). Waltham, MA: Academic Press (2016)

This article discusses motives for defense, varieties of defense mechanisms, measures of defense mechanisms, defense and psychopathology, and defense and development.

Working with Sidney Blatt: Developing interactions

Phebe Cramer

Journal of Personality Assessment 98, 26-29, 2016.

This paper describes my collaboration with Sidney Blatt for the study of therapy change among hospitalized patients. In particular, the use of defense mechanisms by the patients, and the relation of defenses to change in personality after treatment, were examined.

Growing Up with an Anxious Sibling: Psychosocial Correlates and Predictors of Sibling Relationship Quality

Ryan J. Jacoby '09 & Laurie Heatherington

Current Psychology 35(1), 57-68, 2015.

Relationships between young people with anxiety and their non-affected siblings are important for both individuals in the dyad, and for family dynamics throughout the lifespan; however, these relationships are not well understood. This study examined the experience of growing up with an anxious sibling from the sibling without anxiety's point of view. We measured psychosocial factors associated with sibling relationship quality in 64 young adults with an anxious sibling. Overall, participants with anxious siblings were resilient, reporting comparable sibling relationship quality, anxiety symptoms, and psychological functioning relative to peers without anxious siblings. The contributions of caregiver burden and attributions about the causes of the sibling's anxiety-related behavior accounted for significant variance in both sibling relationship warmth/closeness and conflict, with responsibility attributions emerging as an individual predictor of conflict. Clinical and research implications for understanding sibling relationships in the context of anxiety, and for the role of attributions in family relationships are considered.

Research on Change Mechanisms: Advances in Process Research

M.L. Friedlander, *Laurie Heatherington* & V. Escudero

In T. L. Sexton & J. Lebow (Eds.), *Handbook of Family Therapy* 4th ed. (pp. 454-467). New York: Routledge (2016)

If it is Stored in my Memory I Will Surely Retrieve it: Anatomy of a Metacognitive Belief

Nate Kornell

Metacognition and Learning 10, 279-292, 2015.

Retrieval failures—moments when a memory will not come to mind—are a universal human experience. Yet many laypeople believe human memory is a reliable storage system in which a stored memory should be accessible. I predicted that people would see retrieval failures as aberrations and predict that fewer retrieval failures would happen in the future. After responding to a set of trivia questions, participants were asked whether they would do better, about the same, or worse if they were given a different, but equally difficult, set of questions to answer. The majority of participants said they would do about the same, but more participants said they would do better next time than said they would do worse, although these participants did not actually do better. This finding was especially pronounced when participants were given feedback, suggesting that hindsight bias—the feeling, which emerges when an answer is presented, that one knew it all along—contributed to participants' belief that they had underperformed on the first set of questions. The finding that metacognitive judgments were influenced by beliefs stands out in a literature full of studies in which beliefs fail to influence judgments.

Self-Regulated Learning: An Overview of Theory and Data

Nate Kornell & B. Finn

In J. Dunlosky & S. Tauber (Eds.), *The Oxford Handbook of Metamemory (pp 1-29),* New York: Oxford University Press (2016)

Effective self-regulated studying can influence students' learning in school and beyond. This chapter reviews research on two key types of decisions: when to study and how to study. We first review the decisions people make about when to start and stop studying—that is, when to study—and the metacognitive judgments that

underlie those decisions. We distinguish between small-scale and large-scale decisions, such as which problem to work on next and whether to study today at all, respectively. We then discuss decisions about how to study, for example, whether or not to take notes, underline, test oneself, or reread. The chapter turns next to a discussion of key areas for future research, with an emphasis on student-centric research and research in digital learning environments. We end with practical recommendations for studiers about how to avoid overconfidence and procrastination and how to choose study strategies that increase difficulty in the short-term but lead to success in the long term.

Do the Best Teachers get the Best Ratings?

Nate Kornell & Hannah Hausman '12

Frontiers in Psychology, 7(570), doi:10.3389/fpsyg.2016.00570, 2016.

We review recent studies that asked: do college students learn relatively more from teachers whom they rate highly on student evaluation forms? Recent studies measured learning at two-time points. When learning was measured with a test at the end of the course, the teachers who got the highest ratings were the ones who contributed the most to learning. But when learning was measured as performance in subsequent related courses, the teachers who had received relatively low ratings appeared to have been most effective. We speculate about why these effects occurred: making a course difficult in productive ways may decrease ratings but enhance learning. Despite their limitations, we do not suggest abandoning student ratings, but do recommend that student evaluation scores should not be the sole basis for evaluating college teaching and they should be recognized for what they are.

Dissociable effects of salience on attention and goal-directed action

Jeff Moher, B.A. Anderson & J-H. Song

Current Biology 25*,* 2040–2046, 2015.

Everyday behavior frequently involves encounters with multiple objects that compete for selection. For example, driving a car requires constant shifts of attention between oncoming traffic, rearview mirrors, and traffic signs and signals, among other objects. Behavioral goals often drive this selection process; however, they are not the sole determinant of selection. Physically salient objects, such as flashing, brightly colored hazard signs, or objects that are salient by virtue of learned associations with reward, such as pictures of food on a billboard, often capture attention regardless of the individual's goals. It is typically thought that strongly salient distractor objects capture more attention and are more disruptive than weakly salient distractors. Counterintuitively, though, we found that this is true for perception, but not for goal-directed action. In a visually guided reaching task, we required participants to reach to a shape-defined target while trying to ignore salient distractors. We observed that strongly salient distractors produced less disruption in goal-directed action than weakly salient distractors. Thus, a strongly salient distractor triggers suppression during goal-directed action, resulting in enhanced efficiency and accuracy of target selection relative to when weakly salient distractors are pre- sent. In contrast, in a task requiring no goal-directed action, we found greater attentional interference from strongly salient distractors. Thus, while highly salient stimuli interfere strongly with perceptual processing, increased physical salience or associated value attenuates action-related interference.

Target Selection Biases from Recent Experience Transfer Across Effectors

Jeff Moher & J-H. Song

Attention, Perception, & Psychophysics 78, 415–426, 2016.

Target selection is often biased by an observer's recent experiences. However, not much is known about whether these selection biases influence behavior across different effectors. For example, does looking at a red object make it easier to subsequently reach towards another red object? In the current study, we asked observers to find the uniquely colored target object on each trial. Randomly intermixed pre-trial cues indicated the mode of action: either an eye movement or a visually guided reach movement to the target. In Experiment 1, we found that priming of popout, reflected in faster responses following repetition of the target color on consecutive

trials, occurred regardless of whether the effector was repeated from the previous trial or not. In Experiment 2, we examined whether an inhibitory selection bias away from a feature could transfer across effectors. While priming of popout reflects both enhancement of the repeated target features and suppression of the repeated distractor features, the distractor previewing effect isolates a purely inhibitory component of target selection in which a previewed color is presented in a homogenous display and subsequently inhibited. Much like priming of popout, intertrial suppression biases in the distractor previewing effect transferred across effectors. Together, these results suggest that biases for target selection driven by recent trial history transfer across effectors.

Reach Tracking Reveals Dissociable Processes of Cognitive Control

C.D. Erb, *Jeff Moher*, D. Sobel & J-H Song

Cognition (in press).

The current study uses reach tracking to investigate how cognitive control is implemented during online performance of the Stroop task (Experiment 1) and the Eriksen flanker task (Experiment 2). We demon- strate that two of the measures afforded by reach tracking, initiation time and reach curvature, capture distinct patterns of effects that have been linked to dissociable processes underlying cognitive control in electrophysiology and functional neuroimaging research. Our results suggest that initiation time reflects a response threshold adjustment process involving the inhibition of motor output, while reach curvature reflects the degree of co-activation between response alternatives registered by a monitoring process over the course of a trial. In addition to shedding new light on fundamental questions concerning how these processes contribute to the cognitive control of behavior, these results present a framework for future research to investigate how these processes function across different tasks, develop across the lifespan, and differ among individuals.

An Instructor's Guide to (some of) the Most Amazing Papers in Neuroscience

Ian A. Harrington, William Grisham, D.J. Brasier, Shawn P. Gallagher, Samantha S. Gizerian, Rupa G. Gordon, Megan H. Hagenauer, Monica L. Linden, Barbara Lom, Richard Olivo, *Noah J. Sandstrom*, Shara Stough, Ilya Vilinsky & Michael C. Wiest

Journal of Undergraduate Neuroscience Education 14(1): R3-R14.

Although textbooks are still assigned in many undergraduate science courses, it is now not uncommon, even in some of the earliest courses in the curriculum, to supplement texts with primary source readings from the scientific literature. Not only does reading these articles help students develop an understanding of specific course content, it also helps foster an ability to engage with the discipline the way its practitioners do. One challenge with this approach, however, is that it can be difficult for instructors to select appropriate readings on topics outside of their areas of expertise as would be required in a survey course, for example. Here we present a subset of the papers that were offered in response to a request for the "most amazing papers in neuroscience" that appeared on the listserv of the Faculty for Undergraduate Neuroscience (FUN). Each contributor was subsequently asked to describe briefly the content of their recommended papers, their pedagogical value, and the audiences for which these papers are best suited. Our goal is to provide readers with sufficient information to decide whether such articles might be useful in their own classes. It is not our intention that any article within this collection will provide the final word on an area of investigation, nor that this collection will provide the final word for the discipline as a whole. Rather, this article is a collection of papers that have proven themselves valuable in the hands of these particular educators. Indeed, it is our hope that this collection represents the inaugural offering of what will become a regular feature in this journal, so that we can continue to benefit from the diverse expertise of the FUN community.

Division III Collision Sports are not Associated with Neurobehavioral Quality of Life

Williams P. Meehan, Alex M. Taylor, Paul Berkner, *Noah J. Sandstrom*, Mark W. Peluso, Matthew M. Kurtz, Alvaro Pascual-Leone, & Rebekah Mannix

Journal of Neurotrauma 33, 254-259.

We sought to determine whether the exposure to the sub-concussive blows that occur during division III collegiate collision sports affect later life neurobehavioral quality-of-life measures. We conducted a cross-sectional study of alumni from four division III colleges, targeting those between the ages of 40–70 years, using several well-validated quality-of- life measures for executive function, general concerns, anxiety, depression, emotional and behavior dyscontrol, fatigue, positive affect, sleep disturbance, and negative consequences of alcohol use. We used multivariable linear regression to assess for associations between collision sport participation and quality-of-life measures while adjusting for covariates including age, gender, race, annual income, highest educational degree, college grades, exercise frequency, and common medical conditions. We obtained data from 3702 alumni, more than half of whom (2132) had participated in collegiate sports, 23% in collision sports, 23% in non-contact sports. Respondents with a history of concussion had worse self- reported health on several measures. When subjects with a history of concussion were removed from the analyses in order to assess for any potential effect of sub-concussive blows alone, negative consequences of alcohol use remained higher among collision sport athletes (b-coefficient 1.957, 95% CI 0.827-3.086). There were, however, no other significant associations between exposure to collision sports during college and any other quality-of-life measures. Our results suggest that, in the absence of a history of concussions, participation in collision sports at the Division III collegiate level is not a risk factor for worse long-term neurobehavioral outcomes, despite exposure to repeated sub-concussive blows.

Psychological Science on Eyewitness Identification and the U.S. Supreme Court: Reconsiderations in Light of DNA exonerations and the Science of Eyewitness Identification.

Laura Smalarz, Sarah Greathouse, Gary Wells, & Karen Newirth

In C. Willis-Esqueda, R. Wiener, & B. Bornstein (Eds.), *The Witness Stand and Lawrence S. Wrightsman, Jr.* New York: Springer

The U.S. Supreme Court has not reexamined the test for admission of eyewitness identifications that are the product of suggestive procedures in over 35 years (*Manson v. Brathwaite*, 1977). Since then, there have been over 220 DNA-based exonerations of individuals who were wrongfully convicted on the basis of mistaken eyewitness identification (www.innocenceproject.org), and an extensive and rich scientific literature on eyewitness identification has emerged. We discuss the Court's 1977 ruling, which was meant to be a safeguard against wrongful conviction, and we note how the DNA-based exonerations can only be a small fraction of the total cases of wrongful convictions based on mistaken identification. We then use the science of the last 30 years to show the ways in which the *Manson* ruling is flawed. We explain how the three objectives considered by the Court in the *Manson* ruling, namely presenting reliable evidence to the jury, ensuring the administration of justice, and deterring police use of suggestive procedures, cannot be met with the basic approach inherent in *Manson*. We then consider possible alternatives to *Manson* and describe two recent court cases that have rejected *Manson* in favor of other approaches to determining admissibility.

ROC Analysis of Lineups Obscures Information that is Critical for Both Theoretical Understanding and Applied Purposes

Gary Wells, Andrew Smith & *Laura Smalarz*

Journal of Applied Research in Memory and Cognition 4, 313-317.

Our previous article (Wells, Smalarz, & Smith, 2015, *Journal of Applied Research in Memory and Cognition*) showed how ROC analysis of lineups does not measure underlying discriminability or control for response bias. Wixted and Mickes (2015, *Journal of Applied Research in Memory and Cognition*) concede these points. Hence, in this article we focus more on how forcing the 3 × 2 lineup into the 2 × 2 structure required for

ROC analysis obscures important underlying phenomena of theoretical value. Moreover, ROC analysis fails to account for the unique diagnostic properties of exonerating eyewitness behaviors (filler identifications and rejections). We describe how an examination of the full 3 × 2 structure helps reveal the critical underlying phenomena that ROC analysis hides. We also show how a Bayesian approach yields a family of diagnosticity functions that exposes the unique diagnosticity of all three eyewitness behaviors (suspect identifications, filler identifications, and rejections). Moreover, we show how Bayesian methods can examine diagnosticity as a function of witness confidence for all three eyewitness behaviors, which gives it a significant applied advantage over ROC analysis.

ROC Analysis of Lineups does not Measure Underlying Discriminability and has Limited Value

Gary Wells, *Laura Smalarz* & Andrew Smith

Journal of Applied Research in Memory and Cognition 4, 324-328.

Some researchers have been arguing that eyewitness identification data from lineups should be analyzed using Receiver Operating Characteristic (ROC) analysis because it purportedly measures underlying discriminability. But ROC analysis, which was designed for 2 × 2 tasks, does not fit the 3 × 2 structure of lineups. Accordingly, ROC proponents force lineup data into a 2 × 2 structure by treating false-positive identifications of lineup fillers as though they were rejections. Using data from lineups versus showups, we illustrate how this approach misfires as a measure of underlying discriminability. Moreover, treating false-positive identifications of fillers as if they were rejections hides one of the most important phenomena in eyewitness lineups, namely filler siphoning. Filler siphoning reduces the risk of mistaken identification by drawing false-positive identifications away from the innocent suspect and onto lineup fillers. We show that ROC analysis confuses filler siphoning with an improvement in underlying discriminability, thereby fostering misleading theoretical conclusions about how lineups work.

Individual Differences in Early Adolescents' Latent Trait Cortisol (LTC): Relation to Recent Acute and Chronic Stress

C.B. Stroud, F.R. Chen, L.D. Doane & D.A. Granger

Psychoneuroendocrinology (in press).

Research suggests that environmental stress contributes to health by altering the regulation of the hypothalamic pituitary adrenal (HPA) axis. Recent evidence indicates that early life stress alters trait indicators of HPA axis activity, but whether recent stress alters such indicators is unknown. Using objective contextual stress interviews with adolescent girls and their mothers, we examined the impact of recent acute and chronic stress occurring during the past year on early adolescent girls' latent trait cortisol (LTC) level. We also examined whether associations between recent stress and LTC level: a) varied according to the interpersonal nature and controllability of the stress; and b) remained after accounting for the effect of early life stress. Adolescents (n=117;M age=12.39years) provided salivary cortisol samples three times a day (waking, 30 min post-waking and bedtime) over 3 days. Results indicated that greater recent interpersonal acute stress and greater recent independent (i.e., uncontrollable) acute stress were each associated with a higher LTC level, over and above the effect of early adversity. In contrast, greater recent chronic stress was associated with a lower LTC level. Findings were similar in the overall sample and a subsample of participants who strictly adhered to the timed schedule of saliva sample collection. Implications for understanding the impact of recent stress on trait-like individual differences in HPA axis activity are discussed.

Individual Differences in Early Adolescents' Latent Trait Cortisol (LTC): Relation to Early Adversity

C.B. Stroud, F.R. Chen, L.D. Doane & D.A. Granger

Developmental Psychobiology (in press).

Substantial evidence suggests that youth who experience early adversity exhibit alterations in hypothalamic pituitary adrenal (HPA) axis functioning, thereby increasing risk for negative health outcomes. However, few studies have explored whether early adversity alters enduring trait indicators of HPA axis activity. Using

objective contextual stress interviews with adolescents and their mothers to assess early adversity, we examined the cumulative impact of nine types of early adversity on early adolescents girls' latent trait cortisol (LTC). Adolescents (n 1⁄4 122; M age 1⁄4 12.39 years) provided salivary cortisol samples three times a day (waking, 30min post-waking, and bedtime) over 3 days. Latent state-trait modeling indicated that the waking and 30 min post- waking samples contributed to a LTC factor. Moreover, greater early adversity was associated with a lower LTC level. Implications of LTC for future research examining the impact of early adversity on HPA axis functioning are discussed.

Predicting the Transition from Anxiety to Depressive Symptoms in Early Adolescence: Negative Anxiety Response Style as a Moderator of Sequential Comorbidity

L.R. Starr, *C.B. Stroud* & I. Li

Journal of Affective Disorders 190*,* 757-763, 2016.

Background: Anxiety often precedes depression. The anxiety response styles theory of comorbidity suggests anxious individuals with a tendency to ruminate or make hopeless attributions about anxiety symptoms (negative anxiety response styles [NARS]) are more vulnerable to subsequent depressive symptoms. However, this theory has never been tested in adolescence, when the anxiety-depression transition may frequently occur, or using an extended (one-year) follow-up period. Method: 128 early adolescent girls (M1⁄412.39 years) participated with caregivers in a one-year longitudinal study. At baseline and follow-up, participants completed diagnostic interviews and self-report measures assessing child NARS and brooding rumination. Results: T1 NARS predicted longitudinal elevations in depressive symptoms and increased associations between T1 anxiety and T2 depressive symptoms. Limitations: This study examines anxiety and depression comorbidity using a community sample. The sample is relatively low on sociodemographic diversity. Conclusions: Results support the anxiety response styles theory, with potential implications for early identification of anxious youth at risk for later development of comorbid depression.

Rumination in Early Adolescents: Interactive Contributions of Parent-Child Relationship Quality and Maternal Coping Suggestions

C.B. Stroud & J. Fitts '13

Journal of Clinical Child & Adolescent Psychology (in press).

Research suggests that rumination places adolescents at risk for psychopathology. However, little is known about the association between parenting and rumination. Moreover, relevant theoretical models suggest that parents contribute to the development of rumination both explicitly through their suggestions about how to cope and implicitly through the context of the mother–adolescent relationship. However, prior work has not examined implicit and explicit factors within the same investigation, precluding exploration of their unique and interactive effects. To address these gaps, the present study examined links between mother– adolescent relationship quality, maternal coping suggestions, and adolescent rumination. Participants were early adolescent girls (M age = 12.41 years) and their primary female caregivers. Findings suggested that maternal disengagement suggestions and mother–adolescent relationship quality were each uniquely associated with adolescent rumination. Moreover, the effect of maternal disengagement suggestions depended on the level of maternal engagement suggestions and mother–adolescent relationship quality. Follow-up analyses revealed that these findings were specific to the maladaptive ruminative brooding component of rumination. Future directions for research were elaborated.

Additive Genetic Risk from Five Serotonin System Polymorphisms Interacts with Interpersonal Stress to Predict Depressive Episodes

S. Vrshek-Schallhorn, *C.B. Stroud*, S. Mineka, R. Zinbarg, E.K. Adam, E.E. Redei, C. Hammen & M.G. Craske

Journal of Abnormal Psychology 124*,* 776-790, 2015.

Behavioral genetic research supports polygenic models of depression in which many genetic variations each

contribute a small amount of risk, and prevailing diathesis-stress models suggest gene–environment interactions (G X E). Multilocus profile scores of additive risk offer an approach that is consistent with polygenic models of depression risk. In a first demonstration of this approach in a G X E predicting depression, we created an additive multilocus profile score from 5 serotonin system polymorphisms (1 each in the genes HTR1A, HTR2A, HTR2C, and 2 in TPH2). Analyses focused on 2 forms of interpersonal stress as environmental risk factors. Using 5 years of longitudinal diagnostic and life stress interviews from 387 emerging young adults in the Youth Emotion Project, survival analyses show that this multilocus profile score interacts with major interpersonal stressful life events to predict major depressive episode onsets (hazard ratio [HR] = 1.815, $p < .007$). Simultaneously, there was a significant protective effect of the profile score without a recent event (HR = 0.83, $p < .030$). The G X E effect with interpersonal chronic stress was not significant (HR = 1.15, $p < .165$). Finally, effect sizes for genetic factors examined ignoring stress suggested such an approach could lead to overlooking or misinterpreting genetic effects. Both the G X E effect and the protective simple main effect were replicated in a sample of early adolescent girls (N = 105). We discuss potential benefits of the multilocus genetic profile score approach and caveats for future research.

U.S. College Students' Sexual Activity: The Unique and Interactive Effects of Emotion Regulation Difficulties and Attachment Style

C.B. Stroud, R. Hershenberg, *S. Cardenas '14*, E. Greiter '12 & M. Richmond '12

International Journal of Sexual Health (in press).

Emotion regulation has implications for interpersonal relationships and behavior, but little is known about its relation to sexual activity, a critical component of close relationships. This study explored the association between emotion regulation difficulties and sexual activity, and whether emotion regulation difficulties moderated the link between attachment and sexual activity. College student participants from two institutions in the United States reported on emotion regulation difficulties, attachment, and the frequency of exclusive and non-exclusive sexual activity. Findings indicated that greater emotion regulation difficulties were associated with less frequent exclusive sexual activity. Moreover, emotion regulation difficulties moderated links between attachment avoidance and sexual activity, and associations varied according to relational context and gender. Implications for promoting emerging adults' sexual health and relationship intimacy are discussed.