Report of Science
at
Williams College

2016-2017

A record of the professional and academic activites of faculty and students in the natural sciences

Williamstown, Massachusetts

Front Cover Image:

Luminescent molecules (background) and terbium and europium complexes (foreground) prepared in the lab of Patrick Barber of the chemistry department.

My research interests lie in the design, development, and application of functional materials made from lanthanide ion complexes for imaging in environmental and biological systems. The lanthanides have long been studied for their interesting luminescent and magnetic properties. Through the use of these well-known properties, lanthanide ion complexes are excellent choices for use as probes to monitor living and non-living systems.

The Science Executive Committee wishes to express its gratitude to the extensive efforts of all the science departmental administrative assistants in preparing contributions for this publication.

Editor: Norman Bell, Science Coordinator

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The Sciences at Williams College

Students learn science best by doing science; that is by formulating and testing 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 2017 had 525 graduates, with 255 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 67 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 91 completing theses and 171 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 39 NSF grants totaling $5,786,152 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 30th 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 2017 Offerings

ASTR 25 The Great American Eclipse of 2017

For the first time in 99 years, the path of totality of a solar eclipse will sweep across the United States from coast to coast. We will study the science and social science of total solar eclipses, including both the astronomy aspects and the aspects of introducing hundreds of millions of Americans to eclipse observing. The whole United States will have a partial eclipse, with the 70-mile-wide path of totality going from Oregon to South Carolina.

We will begin the month of January 2017 with the American Astronomical Society's meeting in Texas and then work with solar scientists (including an alumni) at U. Colorado/Boulder and National Oceanic and Atmospheric Administration and then proceed to our chosen eclipse site on the campus of Willamette University in Salem, Oregon. (See a map animation at GreatAmericanEclipse.com.) After overseeing the eventual expedition arrangements, we will visit major astronomical observatories in California, including the Palomar Observatory with its 200" telescope with which Williams College is joining a consortium for educational aspects of its Zwicky Transient Facility, with lodging in Pomona or Pasadena.

CHEM 10 Zymurgy

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

CHEM 11 Science for Kids

Are you interested in teaching? Do you enjoy working with kids? Do you like to experiment with new things? Here is a chance for you to do all three! The aim of this Winter Study Project is to design a series of hands-on science workshops for elementary school children and their parents. Working in teams of 2-4, students spend the first two and a half weeks of Winter Study planning the workshops. This involves deciding on a focus for each workshop (based on the interests of the students involved) followed by choosing and designing experiments and presentations that will be suitable for fourth-grade children. On the third weekend of Winter Study (January 21, 22) we bring elementary school kids with their parents to Williams to participate in the workshops.

You get a chance to see what goes into planning classroom demonstrations as well as a sense of what it's like to actually give a presentation. You find that kids at this age are great fun to work with because they are interested in just about everything and their enthusiasm is infectious. You also give the kids and their parents a chance to actually do some fun hands-on science experiments that they may not have seen before, and you are able to explain simple scientific concepts to them in a manner that won't be intimidating. It is a rewarding experience for all involved.

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.

CSCI 11 Developing Your Developer Toolbox

Becoming an effective developer takes knowledge, dedication, and the right set of tools. In this course, you will take control of your development environment and add some important tools to your development toolbox.

Students will learn to customize and interact with their Linux environments; compile, install, and use common open source and command-line tools; and perhaps most importantly, learn how to navigate and produce useful documentation. From low-level systems researchers to aspiring App developers, these skills will help you be more efficient and more independent.

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 The Mathematics of Lego Bricks

This course is a modification of three previous winter studies I have done on the Mathematics of LEGO bricks. Similar to those, 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 build a large suspension bridge in Paresky for MLK Day, and partner with Williamstown Elementary and the Williamstown Youth Center on projects (probably Lego Mindstorm).

STAT 25 The History, Geography and Economics of the Wines of France

The history of wine making in France is long, dating back to the Greeks and later the Romans. Not surprisingly, the first areas to be planted were the areas around present day Marseille, (Massalia in Ancient Greece) in Provence, and the areas just north farther up the Rhône river valley. We will briefly survey the history of wine in France from the Romans through the middle ages, the influence of monasteries on wine production, the impact of the French revolution and the evolution of the modern classification system in the 19th century which is still in place today. The late 19th century saw a series of catastrophes that had devastating effects on both the quantity and quality of wine produced. The solutions to these problems are varied and fascinating and resulted in the hybridization of American and French vines which exist to this day. Recent history includes the spread of quality wines to the Languedoc area, an area which now rivals some of the more prestigious traditional areas of Bordeaux and Burgundy. During the first week in Williamstown, before traveling to France, we will study the basics of the French wine industry of today. During our first week we will also study the impact of global warming on the future of wine production in France and the potential economic impact. We will look at temperature data and study the relationship between temperature change and quality using statistical regression analysis. Finally, we will discuss the role of wine in French cuisine and the importance of wine to French culture.

Geography and climate play an essential and important role in grape growing. Due to its temperate and incredibly varied climates, France, while not holding a monopoly on fine wine production, is blessed with being able to grow a wide range of different styles of grapes whose sugar and acidity lend themselves to the production of quality wines. During our 10 days in France, we will visit four different areas of French wine production: Bordeaux, Languedoc, the Rhône and Burgundy. Chateau visits will include lectures by the wine growers on various methods of production particularly to the region and the varietals used. One of the sites we plan to visit is the Agricultural Research Center (INRA) in Montpellier, which has helped modernize the Languedoc wine growing region and contributed to its current standing as a major high quality wine producing region.

Structure of the course: During the first week in Williamstown, we will read about the history of wine production, study the geography of France and perform various statistical analyses relating to quality, temperature and production. In particular, we will study the relationship between price and quality as judged by experts for the 2000 Bordeaux vintage. In the second part of the course we will visit and talk with wine producers from a range of vineyards including the largest and most prestigious in Bordeaux to family operations in the Languedoc and Provence.

PHYS 13 Electronics

Electronic circuits and instruments are indispensable parts of modern laboratory work throughout the sciences. This course will cover the basics of analog circuits, including transistors and operational amplifiers, and will briefly introduce digital circuits and the Arduino, a microcontroller. Class will meet four afternoons a week for a mixture of lab and lecture, 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 14 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 16 The Science of Star Trek

Comprising twelve motion pictures and five major television series, totaling over 500 hours of film, Star Trek has had a profound impact on pop culture and the scientific imagination. In this Winter Study course, we will board Star Trek as vehicle towards a critical discussion of science, technology, and their consequences to society. We will boldly question topics such as the nature of reality, the (uni/multi)verse according to quantum theory and general relativity, the origins of consciousness and the possibility and consequences of extraterrestrial and artificial intelligence. We will view select episodes and films from the franchise, discussing their basis in actual science and using them as a prism to understand issues facing us on Earth. For more details, see http://web.williams.edu/Mathematics/sjmiller/public_html/1701/

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 topics related to woodworking such as sharpness and sharpening, metallurgy, moisture and wood movement, and forestry. We will meet for approximately 12 hours weekly for demonstrations and individual work on projects.

No previous experience is required; however, students with patience, good fine-motor skills, and some imagination will find the course most rewarding. This course is open to both artistically and scientifically minded students.

PSYC 15 Ephquilts: an Intro to Traditional Quiltmaking

This studio course will lead the student through various piecing, appliqụe and quilting styles and techniques, with some non-traditional methods included. Samples will be made of techniques learned, culminating in the completion of a sizeable project of the student's choosing (wall quilt or lap-size quilt). There will be an exhibit of all work (ephquilts), at the end of winter study. "Woven" into the classes will be discussions of the history of quilting, the controversy of "art" quilts vs. "traditional" quilts, machine vs. hand-quilting and the growing quilting market. Reading list: Pieces of the Past by Nancy J. Martin; Stitching Memories: African-American Story Quilts by Eva Ungar Grudin; Sunshine and Shadow: The Amish and Their Quilts by Phyllis Haders; A People and Their Quilts by John Rice Irwin; Treasury of American Quilts by Cyril Nelson and Carter Houck; The Quilt: New Directions for an American Tradition, Nancy Roe, Editor. Requirements: attendance of all classes (including field trip), a love of fabric, design and color, an enthusiasm for handwork, participation in exhibit. Extensive time will be spent outside of class working on assigned projects.

PSYC 16 Psychology of Eating

Research suggests that we make an average of over 200 food-related choices each day — including what, when, where, with whom, and, importantly, how much to eat and drink. In this course, we will consider how behavioral science can inform our understanding of why we eat the things we do and how our food-related decisions can be powerfully influenced by an overwhelming number of factors — only one of which is hunger. Among the questions we'll consider: How does everything from the utensils you use and the plate a meal is served on influence what and how much you consume? Can we make changes to our eating environments in ways that will encourage us to make healthier choices? What factors influence our perception of our gustatory experience, shaping our expectations and ultimate enjoyment of the foods we eat? Classes will be structured around discussing and critiquing behavioral science that speaks to each of these core questions. Along the way, we'll: (a) watch the latest Blockbuster movie (over popcorn, of course), (b) make our own ice cream sundaes, and (c) take a trip to the supermarket, the dining hall, and a high-quality restaurant to explore these eating environments firsthand and the ways in which behavioral science has informed the way they structure food-related decisions.

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 disciplines. 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 colloquia 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 2016-2017, there were 23 individual Williams College science faculty members with active NSF grants totaling more than $4.6 million for the purchase of equipment and support of research projects.

2016-17 Science Lunch Colloquia

Tiku Majumder, Physics	Welcome and Introductions
Laura Muller	Avenues for Peer Support in Div3 courses
Ralph Morrison, Math/Stats	Triangles and tropical curves
Luana Maroja, Biology	The aesthetics of evolution: Natural and sexual selection in the era of Abbott Thayer
Nate Cook, Chemistry	Light, Camera, Action: Pushing the limits of imaging
Jeannie Albrecht and Bill Wootters	CPC and Division III
José Constantine, Geosciences	Unraveling the origin of meandering rivers
Diana Davis, Math/Stats	Negative refraction and tiling billiards
Jon Park, Computer Science	Assisting Argument Construction through Automated Feedback
Bill Jannen, Computer Science	Organizing Data, Logically and Physically
Matt Carter, Biology	The Neural Basis of Appetite and Appetite Suppression
Mihai Stoiciu, Chris Goh, Laura Muller	LACOL Hack-a-thon report and ideas for moving forward
Phoebe Cohen, Geosciences	Tiny fossils making hard parts: biomineralization and the radiation of life before animals
Kate Stroud, Psychology	Understanding Individual Differences in HPA axis Regulation: Implications for the Development of Anxiety and Depression
Catherine Kealhofer, Physics	Ultrafast electron sources: illuminating the small and fast
Ed Larson '73	Science and Religion
Tiku Majumder, Physics	Clocks, Navigation, and Cold Atoms
Don Beaver, History of Science	Sarah Bowdich, 1791-1856, naturalist, author, and illustrator, and her honeymoon in Wales
Swati Singh, Physics	Using simple quantum systems as detectors
Steve Swoap, Biology	Hibernating Humans and Mouse Diving

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 171 individuals at Williams during the summer of 2017. 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 third 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 $4400 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.

[We received extensions in 2017 on both the Sherman-Fairchild and CBL grants. We hired 7 students on Sherman-Fairchild and 6 on CBL so that we could run down the remaining balances of both grants. Neither grant will be available for 2018.]

[Are you trying to list all of the department specific grants? New this year was the Prof. William C. Grant, Jr. Science Research Fellowship, which prefers bio or chem (not restrictive). There’s also Freeman Foote and Sperry Family for Geos, Finnerty for applied math, the Louis 1950 Summer Science Research Fellowship (not restrictive, one stipend). Also the Lowe 1940 Summer Science Research Fellows (physics preferred, not restrictive).]

2017 Summer Science Research Funding Sources

Contributors	Number of Stipends Supported
Arnold Bernhard Foundation Summer Fellows Program	26
Clare Boothe Luce Scholarships for Women in Science	5
Class of 1951	8
Computer Science Department	1
Prof. William C. Grant, Jr. Science Research Fellowship	2
John & Louise Finnerty Fund for Applied Mathematical Research	1
Louis 1950 Summer Science Research Fellowship	1
Lowe 1940 Summer Science Research Fellows	5
Lowe 1973 Chemistry Fellowships	6
Markgraf JH 1952 Fellowships	7
McDonnell Foundation	1
MIT NASA	2
NSF/NIH grants to individual faculty	15
Sherman Fairchild Foundation	6
Somers B&L 1948 Physics Internships	4
Summer Science Program Alumni	5
Tyng S&S Scholarship	1
Wege-Markgraf Chemistry Fellowships	7
Whitehead Scholars Program - Biology	2
Williams Bicentennial Psychology Scholarship	2
Williams Science Center Funding	28
Total 10-week Student Stipends	**135**

Summer Science Students and their Faculty Advisors 2017

Astronomy	
Declan Daly	Jay Pasachoff
Charles Ide	Jay Pasachoff
Christian Lockwood	Jay Pasachoff
Connor Marti	Jay Pasachoff
Erin Meadors	Jay Pasachoff
Cielo Perez	Jay Pasachoff
Brendan Rosseau	Jay Pasachoff
Ross Yu	Jay Pasachoff
Biology	
Rebecca Gorelov	Lois Banta
Louisa Goss	Pei-Wen Chen
Calvin Ludwig	Pei-Wen Chen
Jeffrey Sload	Pei-Wen Chen
Seema Amin	Derek Dean
Hannah Weinstein	Derek Dean
Alexandra Griffin	Joan Edwards
Natalia Miller	Joan Edwards
Emma Rogowski	Tim Lebestky
Jesse Ames	David Loehlin
Ye Rem Kim	David Loehlin
Jeromy DiGiacomo	Dan Lynch
William Doyle	Dan Lynch
Se Rin Kim	Dan Lynch
Jack Page	Dan Lynch
Zachary Brand	Luana Maroja
Haley Lescinsky	Luana Maroja
Tyma Nimri	Luana Maroja
Danielle Sim	Luana Maroja
Metlik Tesfaye	Luana Maroja
Andrea Alvarez	Martha Marvin
Rodsy Modhurima	
Jenks Hehmeyer	Manuel Morales
Sonya Jampel	Manuel Morales
Daniel Kirsch	Manuel Morales
Sehwheat Manna	Manuel Morales
Jeffrey Pullano	Manuel Morales
Tucker Lemos	David Smith
Mark Bingaman	Steve Swoap
Cordelia Chan	Steve Swoap
Aaron Goldstein	Steve Swoap
Maia Hare	Steve Swoap
Yang Lee	Claire Ting
Matthew Lennon	Damian Turner
Nicole Tanna	Damian Turner
Omar Kawam	Damian Turner
Jonah Levy	Heather Williams
Rebecca Smith	Heather Williams
Edwards Kyrien	Henry Art
Environmental Studies	
Angelica Saldaña	D. Dethier & J. Racela
Chemistry	
Nicholas Bernier	Amy Gehring
David Gorestki	Amy Gehring
Grace Kromm	Amy Gehring
Kenny Liu	Amy Gehring
Anastasia Tishena	Amy Gehring
Kevin Zhou	Amy Gehring
Natalie Albright	Charles Lovett
David Azzara	Charles Lovett
Michael Green	Charles Lovett
Emily Harris	Charles Lovett
Si Hou Lon	Charles Lovett
Nicholas Madamidola	Charles Lovett
Dylan Millson	Charles Lovett
Larissa Silva	Charles Lovett
John Velez	Charles Lovett
Brandon Vuong	Charles Lovett
Emily Elder	Enrique Peacock-Lopez
Selin Gumustop	Enrique Peacock-Lopez
Walker Knauss	Enrique Peacock-Lopez
Julia Vargas	Enrique Peacock-Lopez
Neena Patel	D. Richardson & J. Thoman
Andres Villasmil Ocando	D. Richardson & J. Thoman
Alan Zhang	D. Richardson & J. Thoman

Computer Science

John Ferguson	Jeannie Albrecht
Lylia Li	Jeannie Albrecht
Landon Marchant	Duane Bailey
Daniel Yu	Duane Bailey
Wei Luo	Andrea Danyluk
Linda Zeng	Andrea Danyluk
Timothy Randolph	William Lenhart
Quan Do	Tom Murtagh
Louisa Nyhus	Tom Murtagh
Qianwen Zheng	Tom Murtagh

Geosciences

Emmett Blau	Jose Constantine
Andrew Bloniarz	Jose Constantine
Daniel Donahue	Jose Constantine
Anna Black	Mea Cook
William Downs	Mea Cook
Wendy Hernandez	Mea Cook
Roberta Miller	Mea Cook
Jacob Cytrynbaum	Ronadh Cox
Jordan Fields	David Dethier
Henry Barker	Paul Karabinos

Mathematics and Statistics

Carlos Albors-Riera	Colin Adams
Beatrix Haddock	Colin Adams
Zhiqi Li	Colin Adams
Daishiro Nishida	Colin Adams
Braeden Reinoso	Colin Adams
Luya Wang	Colin Adams
Jackson Barber	Julie Blackwood
Molly Knoedler	Julie Blackwood
Kiran Kumar	Brianna Heggeseth
Chloe Avery	Susan Loepp
Caitlyn Booms	Susan Loepp
Timothy Kostolansky	Susan Loepp
Nina Pande	Susan Loepp
Alex Semendinger	Susan Loepp
Granger Carty	Steven Miller
Ryan Chen	Steven Miller
Alexandre Gueganic	Steven Miller
Yujin Kim	Steven Miller
Jared Lichtman	Steven Miller
Benjamin Logsdon	Steven Miller
James Millstone	Steven Miller
Alina Shubina	Steven Miller
Shannon Sweitzer	Steven Miller
Eric Winsor	Steven Miller
Jianing Yang	Steven Miller
Eliot Bongiovanni	Frank Morgan
Alejandro Diaz	Frank Morgan
Arjun Kakkar	Frank Morgan
Nat Sothanaphan	Frank Morgan
Desmond Coles	Ralph Morrison
Neelav Dutta	Ralph Morrison
Sifan Jiang	Ralph Morrison
Andrew Scharf	Ralph Morrison
Sarah Fleming	Allison Pacelli
Isaac Loh	Cesar Silva

Williams Mystic

Chen-Yi Hung	Lisa Gilbert
Emma McCauley	Lisa Gilbert
Meghan Suslovic	Lisa Gilbert
Jason Swartz	Lisa Gilbert

Physics

Ian Banta	Daniel Aalberts
Eliza Matt	
Kirby Gordon	Charlie Doret
Ashay Patel	Charlie Doret
Felix Knollman	Kevin Jones
Iona Binnie	Catherine Kealhofer
Ian Shen	Catherine Kealhofer
Emily Stump	Catherine Kealhofer
Abdullah Nasir	Tiku Majumder
Jeremy Thaller	Tiku Majumder
Nathaniel Vilas	Tiku Majumder
Bingyi Wang	Tiku Majumder
Derek Galvin	Swati Singh
Qiyuan Hu	Swati Singh
Samuel Alterman	Frederick Strauch
Skylar Chaney	Frederick Strauch
Mariam Ughrelidze	Frederick Strauch
Noah Cowit	David Tucker-Smith
Nyein Chan Soe	David Tucker-Smith

Psychology

Shaheen Currimjee	Jeremy Cone
Kathryn Flaharty	Jeremy Cone
Charles Levin	J. Cone & S. Fein
Anna DeLoi	Susan Engel
Alexandra Medeiros	Steven Fein
Abigail Soloway	Amie Hane
Gabrielle Ilagan	Laurie Heatherington
Griffin Colaizzi	Nate Kornell
Emily McDonald	Nate Kornell
Erin Cohn	Noah Sandstrom
Anna Leonard	Noah Sandstrom
Kendall Bazinet	Ken Savitsky
Chloe Kaplan	Kate Stroud
Morgan Richman	Kate Stroud
Masen Boucher	Lauren Williamson
Syed Hussain Fareed Bukhari	Lauren Williamson
Rachel Oren	Lauren Williamson
Lauren Brown	Safa Zaki
Dawn Penso	Safa Zaki
Isabella Salmi	Safa Zaki
Lauren Steele	Betty Zimmerberg

Summer Science Research Poster Session: August 11, 2017

Student Names	Advisor Names	Poster Title
Carlos Albors-Riera, Beatrix Haddock, Zhiqi Li, Daishiro Nishida, Braeden Reinoso, Luya Wang	Colin Adams	Hyperbolicity of Links in Thickened Surfaces
Lylia Li, Jack Ferguson	Jeannie Albrecht	Visualizing Power and Energy Usage
Daniel Yu '20	Duane Bailey	An Investigation of Rush Hour Puzzles
Landon Marchant	Duane Bailey	Building Data Structures in Swift
Rebecca Gorelov	Lois Banta, Janis Bravo	Dissection of pathways used by *Agrobacterium tumefaciens* to dampen host plant defenses
Alexandra Griffin, Molly Knoedler	Julie Blackwood, Joan Edwards	Insect Partitioning Based on Functional Traits in Isle Royale Flower Visitation Networks
Kathryn Flaharty, Alex Medeiros, Shaheen Currimjee	Jeremy Cone	I see a different you: The role of behavioral information in visual representation
Anna Black	Mea Cook	Testing the Fidelity of Laminations as a Proxy for Oxygen Concentration in the Bering Sea Over Millennial to Orbital Timescales
William Down	Mea Cook	Statistical Methods in Tephrochronology
Wei Luo, Linda Zeng	Andrea Danyluk	Identifying Individual Salamanders Using Deep Learning and Nearest-Neighbor Algorithms
Lucy Saldaña, Morgan Harris	David Dethier, Jay Racela	Characteristics of Cold Water Fisheries: Surveying Tributaries to the Hoosic River
Ashay Patel, Kirby Gordon	Charlie Doret	Towards Quantum Simulation with Trapped Calcium Ions
Grace H. Kromm, Kenny Liu	Amy Gehring	Isolation and Activity of SCO5883 (RedU), a Phosphopantetheinyl Transferase (PPTase) for Carrier Protein Activation in *Streptomyces coelicolor* A3(2)
Nicholas Bernier, Kevin Zhou	Amy Gehring	Purification and Activation of Carrier Proteins within *Streptomyces coelicolor*

Anastasia Tishena, David Goretsky	Amy Gehring	Investigating the Role of Sigma Factors of *Streptomyces coelicolor* A3(2): SCO1723 and SCO4409
Iona Binnie, Ian Shen, Emily Stump	Catherine Kealhofer	Production and Characterization of Ultrafast Light Pulses
Emma Rogowski	Tim Lebestky	Modeling Autism and Assessing Optomotor Response in *Drosophila*
Tim Randolph	Bill Lenhart	Using Ports to Better Represent Clustered Graphs
Jeremiah Kim	David Loehlin	Understanding Tandem Gene Duplication Expression Using CRISPR/Cas9
Chloé Avery, Caitlyn Booms, Timothy Kostolansky, Alex Semendinger	Susan Loepp	Completions of Noncatenary Local Domains and UFDs
Michael Green, David Azzara, Emily Harris, Si Hou Lon, Larissa Silva, Brandon Vuong, Natalie Albright, Nicholas Madamidola, Dylan Millson, and John Vélez	Charles Lovett	Fighting Antibiotic Resistance: Identification and Characterization of Bacterial SOS Response Inhibitors
Bingyi Wang	Tiku Majumder	Precise Measurements of the 7P Excited-States Indium Polarizabilities Using Atomic Beam
Jeremy Thaller, Abdullah Nasir, Bingyi Wang	Tiku Majumder	A Precise Measurement of the Electric Quadrupole Amplitude Within the 6s^2p^2 ^{3}P_0 -> ^{3}P_2 Transition in Pb
Manna Sehwheat	Luana Maroja, Manuel Morales	Mapping the Landscape Genetics of Subpopulations of *Publilia concava*
Andrea Alvarez	Martha Marvin	Targeting Methylation of Exon 1 of hspb7 in Zebrafish
Granger Carty, Alexandre Gueganic, Yujin Kim, Alina Shubina, Shannon Sweitzer, Eric Winsor, Jianing Yang,	Steven Miller	Limiting Distributions in Generalized b-bin Zeckendorf Decompositions
Granger Carty, Ryan Chen, Yujin Kim, Jared Lichtman, Alina Shubina, Shannon Sweitzer, Eric Winsor, Jianing Yang	Steven Miller	Variance of Gaussian Primes Across Sectors and the Hecke L-Function Ratios Conjecture
Eric Winsor	Steven Miller	Slow Decay and Missing Term Distributions in Generalized Sum and Difference Sets
Ryan Chen, Yujin Kim, Jared Lichtman, Alina Shubina, Shannon Sweitzer, Eric Winsor	Steven Miller	Spectral Statistics of Non-Hermitian Random Matrix Ensembles
Ryan Chen, Yujin Kim, Jared Lichtman, Eric Winsor, Jianing Yang	Steven Miller	Biases in Fourier Coefficients of Elliptic Curve and Cuspidal New-form Families
Sonya Jampel, Daniel Kirsch, Jenks Hehmeyer, Jeffrey Pullano	Manuel Morales	Spatial Dynamics of *Publilia concava* and Ant Mutualism

Arjun Kakkar, Eliot Bongiovanni, Nat Sothanaphan, Alejandro Diaz	Frank Morgan	It's all about the Isoperimetric Problem
Quan Do, Qianwen (Tiffany) Zheng	Tom Murtagh	Implementing a Log-Structured File System for NAND Memory
Declan Daly, Charles Ide, Christian Lockwood, Connor Marti, Erin Meadors, Cielo Perez, Brendan Rosseau, Ross Yu	Jay Pasachoff	Williams College 2017 Great American Eclipse Expedition
Emily Elder	Enrique Peacock-Lopez	Minimal model of seasonal melatonin regulation
Walker Knauss	Enrique Peacock-Lopez	Turing patterns in a cross-catalytic self-replicating system
Selin Gumustop	Enrique Peacock-Lopez	Beyond the Repressilator and Other Complex Artificial Genetic Networks
Julia Vargas	Enrique Peacock-Lopez	Complex Dynamics in Coupled Systems
Erin Madison Cohn, Anna Keen Leonard	Noah Sandstrom	Anxiety- and Depression-Related Behaviors in Mice after Repeated Mild-Traumatic Brain Injury
Qiyuan Hu	Swati Singh	Detecting Gravitational Waves with Superfliud Helium
Derek M Galvin	Swati Singh	Monte Carlo Wave Functions To Model Doppler Laser Cooling
Mariam Ughrelidze	Frederick Strauch	Errors in Quantum Channels: A Tale of Two Metrics
Skylar Chaney	Frederick Strauch	Quantum Computing Simulation with LIQUi|>
Sam Alterman	Frederick Strauch	Efficient Environment-Assisted Quantum Transport
Noah Cowit '20, Nyein Soe '19	David Tucker-Smith	Bubble Nucleation During the Electroweak Phase Transition
Omar Kawam, Matthew Lennon, Nicole Tanna	Damian Turner	Generation of Lung Resident Memory Cells with Lipopolysaccharide and Ovalbumin

Summer Science Research Colloquia 2017

Norman Bell	Lab Safety
Luana Maroja, Biology	It is just not cricket - adventures at species boundaries
Jose Constantine, Geosciences	Meandering Rivers: the role of sand grains in their evolution and demise
Kate Stroud, Psychology	Just stop thinking about it! Understanding the causes and consequences of rumination in early adolescent girls
Ralph Morrison, Mathematics	Tropicalize ALL The Things!
Daniel Aalberts, Physics	RNA's strange folding landscape
Jay Pasachoff, Astronomy	The Upcoming Solar Eclipse
Duane Bailey, Computer Science	The Story of One Pink Multiplication

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 thirtieth summer in 2017, twenty-eight 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.

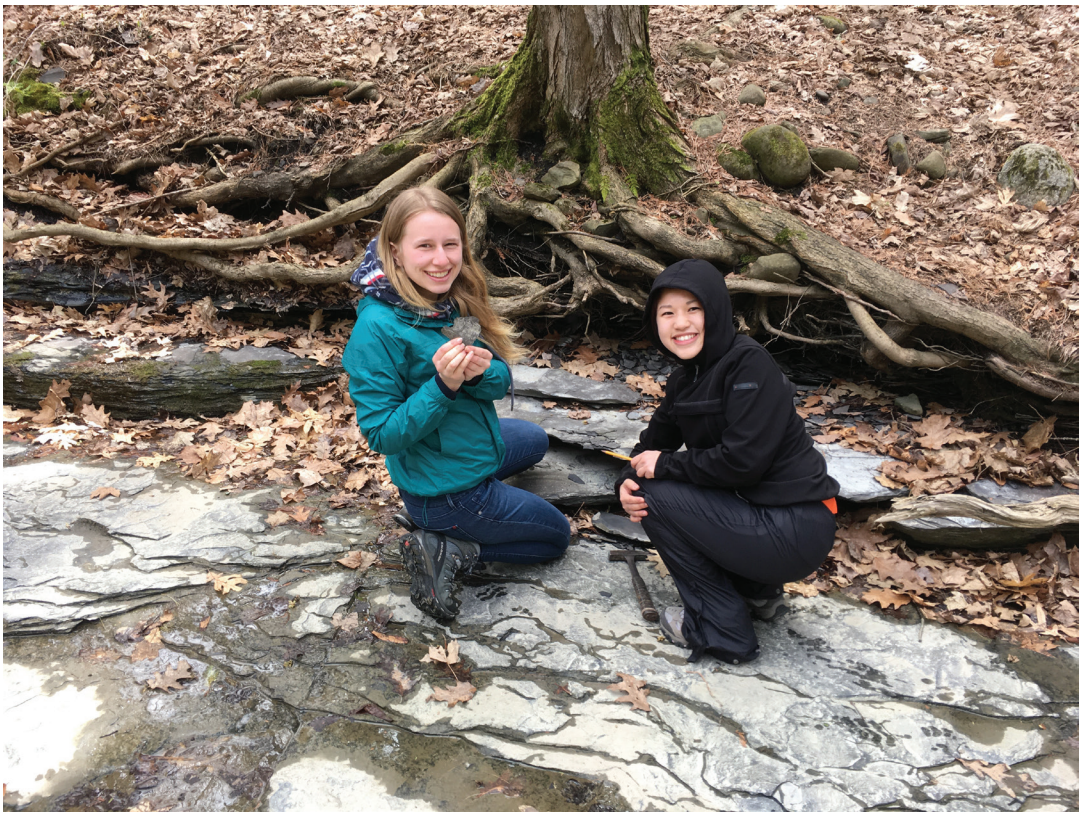
Faculty involved in the teaching for the Summer Science Program included Professors Charles Lovett, Chris Goh, and David Richardson (Chemistry), Professors Lori Pedersen and Cesar Silva (Mathematics), Professor Dan Lynch (Biology), Professor Cassandra Cleghorn (English), and Professor Ronadh Cox conducted the geology field laboratory.

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

Professor Chip Lovett has been involved with the Summer Science Program since its inception in 1987 and has been its director for the past 20 years. 2017 will be Chip's final year with the program as he moves into retirement. Professor Chris Goh will be taking over the program next year. We wish Chip all the best and express our deep gratitude for his work over the years in helping hundreds of young people excel in the sciences.

Pre-First Year Summer Science Program Participants 2017

Students		Faculty
Mazie Alexander	Shadae McClean	Cassandra Cleghorn
Jonathan Deng	Steve Menjivar	Ronadh Cox
Cassie Deshong	Nevyn Neal	Chris Goh
Julius Dodson	Jamie Nichols	Charles Lovett, Director
Abe Eafa	Maria Noya	Dan Lynch
Uriel Garcia	Sonia Nyarko	Lori Pedersen
Kimberly Hadaway	Andrea Orozco	David Richardson
Joey Headley	Nicholas Patino	Cesar Silva
Angel Ibarra	Juan Peticco	
Bariki Innis	Vanessa Quevedo	**Student Tutors**
Ali Ladha	Brian Valladares	Alexia Barandiaran
Elida Lopez	Fernando Villegas	Jeromy Di Giacomo
Dayana Manrique	Isaki Wada-Law	Jennyfer Galvez
Gabrielle Martin	George Yacoub	Dylan Millson



Erikka Olson ’19 and Caroline Hung ’19 hunting for fossil trilobites on the spring Paleobiology (GEOS 212) field trip

Summer Science Lab Program

For the last nineteen 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 2017, eleven Williams College students and one MCLA student taught elementary students through hands-on experiments, which explore scientific processes. Hailing from eighteen different towns, fifty 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, the 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 2017

Students	Williams Faculty
Natalie Albright '20	Dave Richardson
Andrea Alvarez '20	Chip Lovett
David Azzara '19	
Emily Harris '19	**Local Teachers**
Si Hou Lon '19	Stephen Bechtel - Director
Nicholas Madamidola '20	Tim Hermann - Lead Teacher
Rodsy Modhurima '19	
Larissa Silva '19	**And 50 elementary students!**
Anastasia Tishena '20	
John Velez '20	
Brandon Vuong '19	
Naseema Amin (MCLA)	

Williams College Sigma Xi Chapter and 2017 Inductees

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 2016-2017 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 November, Charlie Doret, Assistant Professor of Physics, presented two talks entitled "Atoms at Work: Quantum mechanics, qubits, and quool tools for research and technology," and “Quantum Simulation with Trapped Calcium Ions.” In April, Jay Pasachoff, Field Memorial Professor of Astronomy, presented two talks entitled "Our Sun - From the Ground and From Space," and "The Great American Eclipse of August 21." 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 Josephine Gollin.

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 67 newly elected associate members from the Class of 2017 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.

Astrophysics	**Chemistry**	**Mathematics**	**Physics**
Anneliese M. Rilinger	Varun L. Bhadkamkar	Megumi A. Asada	Jaeho Choi
	Laura D. Elmendorf	Paul P. Baird-Smith	Eli V. Hoenig
Biology	Matthew B. Goss	David R. Burt	Sierra E. Jubin
Robert N. Bates	Emily A. Hoyt	Yuanchu Dang	William M. Kirby
Osama F. Brosh	Luis D. Jaramillo	Rebecca F. Durst	Michael Q. May III
Ivy A. Ciaburri	Hanson D. Koota	Elizabeth S. Frank	Maria V. Prado
Lane A. Davis	Lia Y. Lee	Elijah M. Fromm	Sarah A. Stevenson
Cesar F. Dominguez	Jose M. Lopez	Anand S. Hemmady	Nathaniel B. Vilas
Ruby M. Froom	Erica N. Myers	Nikolaus H.R. Howe	Daniel P. Wong
Daniel P. Gainey	Hanna L. Shebert	Alexander S. Kastner	
Yanira Guerra	Computer Science	Nina G. Pande	**Psychology**
Intekhab Hossain	Alexander S. Majercik	Matthew J. Quinn	Claire A. Bergey
Roya E. Huang	Melanie S. Subbiah	Yu Zhu Yao	Jose E. Rivera-Aparicio
Sara L. Lehman			Isabella L. Salmi
Jonathan N. MacDougall	**Geosciences**	**Statistics**	Stephanie E. Stacy
Rachel O. O'Sullivan	Kyrien R. Edwards	Kathryn N. Grice	Gabriela L. Suarez
Ian R. Outhwaite	Jordan F. Fields	Hae-Min Jung	
Jeffrey A. Sload	Krystina M. Lincoln	John Robert D. Shuck	
Kelly Téllez	Matthew S. Marcarelli		
Maria A. Vicent Allende	Maoli N. Vizcaíno	**Neuroscience**	
	Noah N. Williams	Terrance S. Mensah	

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 project which 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.

Teaching to Learn Student Participants

Bushra Ali ‘17
Fatima Anaza ‘18
Eduardo Avalos ‘17
Daisy Banta ‘18
Derrick Bonafilia ‘17
Leslie Chae ‘16
Christina Chen ‘16
Ivy Ciaburri ‘17
Olivia Daniels ‘16
Hadley DesMeules ‘16
Greg Ferland ‘16
Claudia Forrester ‘18
Andrea Garundo ‘15
Diego Gonzalez ‘18
Sola Haye ‘15
David Hourin ‘18
Matthew Jang ‘17
Mpaza Kapembwa ‘15
Jeremiah Kim ‘18
Elizaveta Lavrova ‘18
Gabrielle Llagan ‘18
Aaron Maruzzo ‘17
Maryanne Masibo ‘19
Lauren Moseley ‘16
Tobias Muellers ‘18
Austin Nguyen ‘15
Daishiro Nishida ‘18
Cynthia Okoye ‘18
Ashay Patel ‘18
Apshara Ravichandran ‘18
Moiz Rehan ‘19
Alia Richardson ‘19
Jose Rivas-Garcia ‘17
Ryan Roels ‘18
Megan Rogers ‘15
Abigail Sanchez ‘16
Jaqueline Serrano ‘17
Adrienne Strait ‘15
Grace Sullivan ‘17
Valeria Sosa Garnica’19
Darla Torres ‘18
Rachel Waldman ‘17
Bingyi Wang ‘18
Joyce Wang ‘18
Chanae Williams ‘16
Zachary Wood ‘18
Dawn Wu ‘18
Greg Zaffino ‘17

Teaching to Learn Advisors

Jean Bacon
Chris Himes
Lindsay Osterhoudt
Molly Polk
Leslie Rule
Nick Stroud
Jennifer Swoap
Lindley Wells

In Memoriam

Over the part year we have lost some important and beloved members of our community. They will be missed:

Raymond Chang, the Halford R. Clark Professor of Natural Sciences, emeritus died at the age of 77 in Washington State. Professor Chang was a much loved presence in the Chemistry Department for nearly 4 decades.

Robert Kozelka who taught in the Mathematics department from 1957 until 1988, including as chair for 5 years, died at the age of 90 in Chapel Hill, NC.

Richard Rouse, the Mary A and William Wirt Warren Professor of Psychology, emeritus died at the age of 95 in Pittsfield, MA. Richard taught in the Psychology Department from 1948 until 1983 and served as chair from 1961 to 1973 during a period of great expansion of the department. Richard remained active in Science Center activities until quite late in life and could often be seen at the science lunch colloquia.

Astronomy Department

Faculty of the Astronomy Department included Karen B. Kwitter, Ebenezer Fitch Professor of Astronomy and Chair; Jay M. Pasachoff, Field Memorial Professor of Astronomy and Director of the Hopkins Observatory; and Steven P. Souza, Senior Lecturer in Astronomy. Bryce A. Babcock, who retired as Staff Physicist and Coordinator of Science Facilities, has continued at Williams as Associate of the Hopkins Observatory. Two students were named as Class of 1960 Scholars in Astrophysics this year.

Class of 1960 Scholars
Anneliese Rilinger
Sarah A. Stevenson

Professor **Jay Pasachoff** and his team studies the solar corona, which is now entering the minimum of the solar-activity cycle. Their research this year focused on studying data from the most recent total solar eclipses (Gabon, 2013, Norway 2015, and Indonesia 2016) as well as preparing for the solar eclipse of August 21, 2017. The 2017 eclipse's path of totality crossed the continental United States in a 60- to 71-mile wide swath. With the most favorable cloudiness statistics in the northwest part of the path, Pasachoff arranged an expedition to the campus of Willamette University in Salem Oregon. The trip was supported with funding from the NSF and the National Geographic Society's Committee for Research and Exploration. Among the observers were eight current undergraduates (*Declan Daly '20, Charles Ide '20, Christian Lockwood '20, Connor Marti '20, Erin Meadors '20, Cielo Perez '19, Brendan Rosseau '19,* and *Ross Yu '19*), as well as over a dozen alumni of the Williams College astronomy and astrophysics program, and over 200 other collaborators and participants from around the world.

Pasachoff is participating in the Megamovie project to crowd-source images of the 2017 total solar eclipse in a project based at the Space Sciences Laboratory of the University of California, Berkeley. He was coauthor of a paper about the project given at the American Geophysical Union meeting in December.

Pasachoff continued his solar-system work studying the atmosphere of Pluto and other aspects of the outer solar solar system through the method of stellar occultations. A paper is in press in the journal Icarus working with the data from the 2015 Pluto occultation of a 12th magnitude star.

Two annular solar eclipses were viewed this year, one on September 1, 2016 at Réunion Island in the Indian Ocean; and another on February 26, 2017 in Patagonia, Argentina.

He continued as chair of the International Astronomical Union Working Group on Solar Eclipses which maintains a website at http://eclipses.info. This provides links to maps, safe-observing information, and other information about past, current, and future eclipses. He is also a member of the Eclipse 2017 Task Force of the American Astronomical Society, and participated in its April meeting in Columbia, SC.

Pasachoff worked with Windfall Films (London) for a PBS NOVA television show which aired the night of the eclipse on public television stations nationwide. His additional outreach included webcasts for *365daysofastronomy.org* and *academicminute.org*. He gave a webinar on the eclipse for AccessScience in May.

Continuing his work on the overlap of art and astronomy with Roberta Olson, curator of drawings at the New York Historical Society, they worked with the Williamson Gallery in Pasadena, CA to plan an exhibition of eclipse-related art and artifacts for the summer of 2017 to overlap with the eclipse. Pasachoff and Olson are preparing a book on several hundred astronomy related art works. This is based on their long research collaboration dating back to the Halley's Comet passage of 1985-86.

Pasachoff assisted Williams College art/architecture professor E. J. Johnson with aspects of the history of the Hopkins Observatory. Profs. Johnson and Michael Lewis are working on a book that will include an architectural history and walking tour of Williams College.

Pasachoff continued as chair of the Working Group on Solar Eclipses of the International Astronomical Union, and is a member of 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. Following his correction of an 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 of the IAU: Star Names.

Pasachoff was chair of the prize committee of the Historical Astronomy Division of the American Astronomical Society, arranging for the award of the Osterbrock Prize at the January 2017 meeting of the American As-

tronomical Society in Grapevine, Texas. Following the meeting, Pasachoff took three students as their Winter Study course for a week in Boulder, Colorado, and a week at CalTech where he remains a visitor in the Planetary Science Department. While there, students visited the 200" Hale Telescope at the Palomar Observatory, the Jet Propulsion Laboratory, the Griffith Observatory, and the Carnegie Observatories headquarters.

Pasachoff continues as representative of the American Astronomical Society to the American Association for the Advancement of Science: Astronomy Division. He attended the AAS: Planetary Sciences Division meeting in November 2016 in Pasadena and the meeting of the Solar Physics Division in Boulder, Colorado. He gave two eclipse-related papers at the 230th meeting of the AAS in Austin in June 2017, and participated in a press conference on the eclipse.

In January, Pasachoff gave a paper about the eclipse, and participated in a press conference, at the April Meeting of the American Physical Society.

Pasachoff received the Richtmyer Memorial Lecture Award from the American Association of Physics Teachers. He gave his prize lecture at the AAPT meeting in Atlanta, Georgia, in March. Immediately prior to that, he arranged a special session about the eclipse at the annual meeting of the American Association for the Advancement of Science, held in Boston.

Pasachoff continued as President of Williams College's Sigma Xi chapter. *Allen Davis '14*, now a graduate student, received a Sigma Xi research grant to participate in the Oregon eclipse expedition. Pasachoff continued as the Williams College representative to the NASA-sponsored Massachusetts Space Grant Consortium. The Consortium provided partial support for three students to participate in the Oregon eclipse expedition.

Pasachoff continues as astronomy consultant for the McGraw-Hill Encyclopedia of Science and Technology and its yearbooks. He remained on the Physical Science Board of World Book through the end of 2016. 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 the January 2017 special issue of the children's magazine *Dig into History* about solar eclipses and their history, providing some of the articles and soliciting the others.

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

Pasachoff continued to supervise the activities at the Old Hopkins Observatory. The observatory received its biennial repair/maintenance in September, and a 10-year extension of the service contract on the planetarium projector was negotiated. Students operating the planetarium during the 2016-17 academic year included *Rebecca Durst '17, Sarah Stevenson '17, Diego Gonzalez '18, Brett Bidstrup '18,* and *Glenn Gallik '18*.

Especially suitable in this eclipse year, Pasachoff gave a tutorial on Solar Physics (ASTR 412) in the spring semester.

Pasachoff worked with Alex Filippenko of the University of California, Berkeley, on the fifth edition of their text The Cosmos: Astronomy in the New Millennium (http://thecosmos4.com).

Along with *Allison Carter '16*, he and former Fulbright visitor Marcos Peñaloza-Murillo of the Universidad de los Andes in Mérida, Venezuela, published a paper in the Philosophical Transactions of the Royal Society (the oldest scientific journal in the world) based on measurements taken during the March 2015 eclipse at Svalbard, Norway.

Pasachoff and Leon Golub of the Harvard-Smithsonian Center for Astrophysics completed a popular book, The Sun, the first in a new series for the Science Museum, London, published by Reaktion Press in London and distributed in the U.S. by the University of Chicago Press.

With colleagues, Pasachoff published a paper in *The Physics Teacher* about using the 2016 transit of Mercury to find the distance to the sun, elucidating an historical method.

For more information about Williams College's eclipse and transit expeditions check out *http://www.eclipses.info, http://www.transitofvenus.info,* and *http://totalsolareclipse.org*

Professor **Karen Kwitter** continues her research on the chemical compositions of planetary nebulae (PNe) and their role in enriching the interstellar medium in galaxies. PNe are the ejected shells of dying sun-like stars, and contain products of nuclear processing – helium, nitrogen, carbon – that occurred inside their parent stars, so are valuable probes into the chemical enrichment history of the Milky Way and other galaxies. She and her national and international colleagues have most recently been working on spectra of eight PNe in M31 observed with the 10.4-meter Gran Telescopio Canarias (GTC), currently the world's largest optical telescope, and spectra of four PNe in the Large Magellanic Cloud, obtained with one of the 8.2-m Very Large Telescopes in Chile. In the summer of 2016, *Anneliese Rilinger '17*, Kwitter's honors student, began working on the spectral analysis.

Joining her and Kwitter for several weeks was Rebeca Galera-Rosillo, a graduate student of colleague Romano Corradi's at the Instituto de Astrofísica de Canarias.

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 PNe parent stars. The latest paper from this collaboration was published in the Astrophysical Journal in October 2016; another is in press.

Williams is part of a consortium of small colleges that has contracted to purchase time on the 3.5-meter and 20-inch telescopes at Apache Point Observatory. Kwitter and Souza will continue to observe remotely from campus this fall with students in the course *Astronomical Data Acquisition and Analysis* (ASTR 211T), and next spring in *Between the Stars–The Interstellar Medium* (ASTR 402T).

In October 2016, Kwitter and Anneliese Rilinger attended the KNAC annual student research symposium at Wesleyan University, where Rilinger presented her thesis work. In January 2017, Kwitter and Rilinger attended the AAS meeting in Grapevine, TX, where Rilinger presented a poster on her thesis research. In July 2017 Kwitter and Souza attended the KNAC faculty meeting at Colgate University.

Kwitter served on the Hubble Space Telescope TAC (Telescope Allocation Committee) for the upcoming Cycle 25. She is is a member of 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 is a member of the newly-convened scientific organizing committee for a focus meeting entitled "Radial Metallicity Gradients in Star-Forming Galaxies," to be held at the IAU General Assembly's next meeting in Vienna, Austria in August 2018. She also continued as the coordinator for the summer intern program of the Keck Northeast Astronomy Consortium (KNAC).

Senior Lecturer **Steven Souza** conducts and supervises the astronomy observing program, indoor labs, and daytime observing. He hosted observatory visitors and school groups, including planetarium groups, Summer Science Program participants, Science Blast 2017 participants (MGHS students), Family Days attendees, Stearns Elementary School 4th graders, Girl Scouts, Cub Scouts, Sigma Xi talk attendees, and numerous student previews and prospective students.

Souza continues to maintain and improve the observatory, this year undertaking a major modernization of the 0.6m DFM telescope facility. Upgrade items include new telescope control electronics, dome power delivery and automation, all new software, recoating of the 24" telescope mirrors, a new main camera and filter wheel, and installation of a weather station. The goals of the project include long-term maintainability and the option of remote operation. During this year of upgrades, his research on variations in H-alpha emission in massive stars has been on hiatus, but is resuming during the summer of 2017. Upgrade work had impacted our ability to accommodate visitors, but it is now back to normal.

Souza acts as department liaison with OIT and Facilities, and continued to work with the administration on reducing the impact of campus lighting on observing, specifically from new science building and new path lighting. He served on the Information Technology committee, and continues to advise first-year students. He attended the Keck Northeast Astronomy Consortium (KNAC) faculty meeting in June 2016 at Wellesley College, and the KNAC Student Symposium in October 2016 at Wesleyan University.

Post-Graduate Plans of Astronomy Majors

Shubhanga Pandey	Working as a journalist, writing as well as editing
Anneliese M. Rilinger	PhD program at Boston University Department of Astronomy
Sarah A. Stevenson	Working at NIST in Boulder, CO, then grad school

Astronomy Colloquia

Jay Pasachoff

Sigma Xi Lectures
Spring 2017

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

Off-Campus Astronomy Colloquia

Jay M. Pasachoff

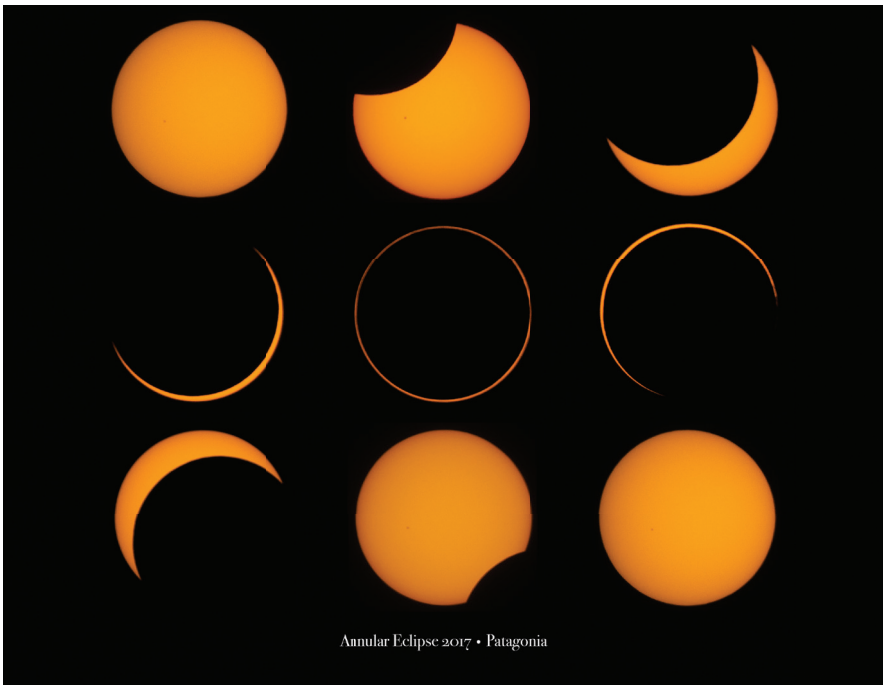
"Observing the Great American Eclipse of August 21, 2017"
Richtmyer Memorial Lecture Award, Atlanta, March 2017

“This August 21st Solar Eclipse”
North Carolina Museum of Natural Sciences, Raleigh, NC, January 2017

"Nature's Super Spectacular: The August 21 Total Solar Eclipse"
Southern Star Astronomical Convention: Charlotte, NC, Amateur Astronomers Club, Blue Ridge Mountains, NC, April 2017

“This Summer’s Solar Eclipse”
Williamstown Elementary, Williamstown, MA, April 2017
Monte Viste School, May 2017
Pine Cobble School, Williamstown, MA, May 2017
Watkins School, May 2017
Peabody School, May 2017
Mt. Greylock Regional High School, Williamstown, MA, June 2017

“Science at Solar Eclipses”
American Astronomical Society Eclipse 2017 Task Force, Columbia, SC, April 2017



Biology Department

Working closely with many interdisciplinary programs on campus (BiMo, Neuroscience, Environmental Studies, BiGP, and Public Health), the Biology Department provides opportunities for students to conduct hands on, individual research with professors in addition to offering state of the art academic courses. The department had 29 honors students working in faculty labs this past year and 17 of them were inducted into the Sigma Xi Honors Society. In the upcoming 2017-18 academic year the department will have 26 students conducting honors work. The Biology department is committed to providing a positive research and learning experience for all students. This commitment has helped several of our students achieve grants and fellowships to pursue post graduate studies. Notably, *Roya Huang* received a Stratton Fellowship to further her studies. The department also has 37 students doing summer research, either here at Williams or off campus. *William Doyle '19* and *Julie Kim '19* will be working at the Whitehead Institute. Funding for summer research comes from 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 presenting their research at Williams.

Each year at graduation, the Biology Department awards prizes to several outstanding majors. *Daniel Patrick Gainey* and *Jeffrey Sload* each received the Benedict Prize in Biology. *Cesar Dominguez* and *Ruby Froom* each received the Dwight Botanical Prize. *Maria Vicent Allende* received the Conant-Harrington Prize for exemplary performance in the biology major, and *Lane Davis, Ian Outhwaite* and *Intekhab Hossain* each received the William C. Grant, Jr. Prize for demonstrating excellence in a broad range of areas in biology.

Arriving in the Summer of 2017, the Biology department welcomed two new Assistant Professors, Ron Bassar and David Loehlin. Ron is an evolutionary ecologist and comes to us following post-doctoral research at the University of Oxford with Tim Coulson studying the ecological and evolutionary consequences of competitive interactions. Previously he conducted post-doctoral research at the University of Massachusetts with Ben Letcher studying the population dynamic consequences of climate change on stream fishes. His graduate work was at the University of California, Riverside in the lab of David Reznick focusing on the ecological effects of evolutionary change in natural populations of Trinidadian guppies. At Williams his research will focus on how evolutionary change influences species coexistence.

David did his post-doctoral research at the University of Wisconsin-Madison in the laboratory of Sean Carroll. His work focuses on the genetic changes behind adaptive evolution, in particular how the alcohol metabolisms of Drosophila fruit flies have changed in species with high- or low-alcohol diets. One notable finding was that duplication of a gene (such as the Alcohol Dehydrogenase enzyme) does not necessarily result in a doubling of gene expression, a finding with potential relevance to understanding certain human genetic disorders. David did his graduate work at the University of Rochester in the laboratory of Jack Werren. His graduate work evaluated the genetic basis of size and shape changes that differentiate species of *Nasonia*, a parasitoid wasp. At Williams, his research will focus on evolutionary and molecular mechanisms that influence duplicate gene expression and that determine how a gene's expression level is shaped by adaptation.

The Biology Department continued to participate in the Class of 1960 Scholars program. In the fall, Dr. Joshua Obar from Dartmouth Medical School spoke on *Aspergillus fumigatus strain-specific virulence and inflammation in the respiratory tract*.

In the spring, we invited five biology alumni to give poster presentations on their research and to take part in a panel discussion covering topics ranging from graduate schools to life after Williams. The following research presentations covered diverse topics as follows:

- *Daniela Zarate '15*, a second year graduate student at the University of San Diego, presented the poster Mapping ancestral admixture across the genomes of hybrid Africanized honeybees.
- *Gregory McElroy '12*, an MD-PhD candidate at Northwestern University, presented the poster The role of mitochondrial electron transport chain complex 1 function in neurodegeneration, diabetes, and cancer.
- *Kimberley Davis '08*, Postdoctoral Scholar at the University of Montana, presented the poster Patterns, impacts, and feedbacks of global Pinus contorta (lodgepole pine) invasions.

- *Galen Holt '04*, a Postdoctoral Scholar at the University of Arizona, presented his research Branching patterns, environmental variation, and diversity in river networks.
- *Jason Fan '08*, an MD-PhD candidate at Columbia University, presented his research Progenitor Cell Marker Aldehyde Dehydrogenase 1a3 Defines a Subset of Failing Pancreatic β Cells in Diabetic Mice.

Class of 1960 Scholars in Biology

Erin Cohn	Haley Lescinski
Marianna Frey	Rebecca Smith
Heidi Halvorsen	Nicole Tanna
Omar Kawam	Alonso Villasmil Ocando
Juchan Kim	Hannah Weinstein

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 *Michelle Buncke '17, Ruby Froom '17,* and *Adam Resnick '17,* along with *Abby Brustad '19, Jovana Calvillo '19, Nicole Tanna '18,* and *Alonso Villasmil '18* pursued this line of investigation. Post-doctoral fellow Janis Bravo was a key member of the group. This research is funded by a four-year individual research grant to Professor Banta totaling $462,000 from the National Science Foundation. At the annual Crown Gall Conference in Bloomington, IN, Professor Banta presented a talk on this research. She was joined by *Ruby Froom* and Janis Bravo who presented their research as a poster. Professor Banta also gave an invited talk at the International Molecular Plant-Microbe Interactions XVII Congress in Portland, OR.

During the fall semester, Professor Banta taught the lab-intensive *Genomics, Proteomics, and Bioinformatics* capstone course (BIOL 319). The course focuses on one model system, the Ras/MAPK signal transduction pathway, and its role in the development of colon cancer. Highlights of the course include a substantial programming project, as well as quantitative real-time PCR and proteomic analyses to probe the contributions of inflammation to human colon cancer. New aspects this year included a hands-on workshop using the Rosetta computational tools for protein structure prediction and protein design which was led by two guest scientists from the Rosetta Design group. In the spring, Professor Banta taught the sophomore-level tutorial *Dangerous Exposure: Environment, Immunity, and Infectious Disease* (BIOL 219). 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 worldwide 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. Under Professor Banta's leadership, the Gaudino Fund organized or co-sponsored a wide variety of public events on topics including the refugee crisis, the visible and invisible wounds of war, and stewardship of place and stories through oral history and documentary film, as well as a day-long retreat for students to reflect on "Living Just One Life." During this academic year, Professor Banta was a reviewer for the National Science Foundation, *Molecular Plant Pathology, Applied and Environmental Microbiology, Computational Biology and Chemistry,* and *Frontiers in Plant Science*. 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 five-year CAREER award from the National Science Foundation for $586,000 for his project, *Bidirectional Control of Sleep and Wakefulness by the Hypothalamic Arcuate Nucleus.* He also continues to be funded by an R15 grant from the National Institutes of Health. His lab studies neurons that regulate food intake and sleep/wake architecture. This year he worked with four thesis students: *Will Duke '17*, *Sara Lehman '17*, *Rachel O'Sullivan '17*, and *Maria Vicent Allende '17*. *Adam Jamnik '17*

and *Heidi Halvorsen '18* also worked in the lab conducting independent study and *Theresa Legan '14* worked as a lab technician. Using mice as a model organism, all students completed projects related to regulation of food intake, sleep/wake dynamics, and regulation of torpor. Matt gave invited talks at the Wadsworth Institute, University of California at San Francisco, University of MA Amherst, the 50th Annual Winter Conference on Brain Research, the National Institute of Diabetes and Digestive and Kidney Disorders, and Emory University. He attended the Annual Meeting of the Society for Neuroscience with students during which which *Rachel Essner '16* presented a poster based on her thesis research. Matt was on leave during the 2016-17 academic year and did not teach any courses.

This year, Assistant Professor **Pei-Wen Chen** worked with two thesis students. *Christine Reed '17* studied the roles of ASAP1 and non-muscle myosin2 in ovarian cancer progression. *Jeffrey Sload '17* studied the mechanism by which ASAP1 controls non-muscle myosin2 filament formation via phospholipid PIP2. They published a review entitled "Arf GAPs and molecular motors" in the journal *Small GTPases*. Pei-Wen was co-author on two other papers: "Direct functional interaction of the Kinesin-13 family member Kinesin-like protein 2A (Kif2A) and Arf GAP with GTP-binding protein like, ankyrin repeats and PH domains 1 (AGAP1)" in the *Journal of Biological Chemistry*; "Arf GAPs: a family of proteins with disparate functions that converge on a common structure, the integrin adhesion complex" in *Small GTPases*. Pei-Wen taught *Cellular Assembly and Movement* (BIOL 326) in the fall and *Nanomachines in Living Systems* (BIOL 410) in the spring.

Over the past year Lecturer **Derek Dean** has continued to teach labs for *Genetics* (BIOL 202) and *The Organism* (BIOL 102). He has also continued efforts to bring primary research into these classrooms, both to engage students in the modern research approaches and to excite them about pursuing research during their academic careers. For example, in Genetics, the infamous "Fly Lab" has been mapping unknown mutations to genes for the past 6 years. During the Fall semester 2016, we began to map *sable*, a mutation causing a darkened body in adult flies. This mutation is historically interesting in that it was first described by Thomas Hunt Morgan's lab 100 years ago but no one knows the responsible gene. Students narrowed down the possible *sable* genes to just 6 from hundreds of possibilities. Next fall, we hope to identify the gene from this group and publish our findings with a smaller group of students.

Dean's research lab continues to use *Drosophila* genetics as a model to study wing development and seizure disorders. Dean, along with *Emma MacAvoy '17*, *Breelyn Karno '20*, and colleagues David Deitcher and Ron Hoy from Cornell University have a manuscript under review with the journal *Fly* describing a seizure-sensitive *Drosophila* mutant. The mutation *julius seizure* (named for Emperor Julius Caesar who reportedly had a seizure disorder) appears to be involved in the development as opposed to the manifestation of seizures. This will hopefully be useful as a model to study the development of epilepsy.

Professor Joan Edwards completed her second year as Chair of the Biology Department. She taught *Field Botany and Plant Systematics* (BIOL 220) in spring 2017. In the summer of 2016, Professor Edwards studied pollinators at Isle Royale Wilderness National Park with *Nico MacDougall '17, Jonah Levy '18* and *Christopher Carley '18*. She also worked with *Lane Davis '17* at Hopkins Memorial Forest (HMF) to study goldenrods and their pollinators. The Isle Royale study focused on filming 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 19th year of data collection). The focus of the HMF study was to continue the on-going study of the impact of different mowing patterns on fall blooming members of the Asteraceae. During the academic year, Professor Edwards advised *Natalia Miller '18* and *Andrea Alvarez '20* in her lab. Together they worked on two projects: maintaining the greenhouse populations of different species of *Oxalis* for study of their explosive seed dispersal and scoring videos taken during the previous summers.

Nico McDougall (co-advised with Luana Maroja) and *Lane Davis* (co-advised with David Smith) continued working on their senior theses in the Edwards lab. Nico's work on pollinators visiting *Primula mistassinica* (bird's-eye primrose) showed that insect taxa visiting this flower vary among sites, supporting the neighborhood model of pollinator visitors. Using local pollinators may benefit flowers by allowing them to hedge their bets and draw on whichever insects are local. The genetic structure of the primroses may also be defined by this pattern of visitation as gene flow between patches may be less common than gene flow within patches. Lane continued her work on the experimental field plots in Hopkins Memorial Forest where she tested different mowing treatments (early *vs*. late and annual *vs.* every other year) on floral production. Her thesis shows that

late (October) mowing significantly increases the number of flowering stems of goldenrods and asters when compared to early mown (July) plots. By delaying mowing until fall, landowners can increase floral resources for pollinators and help to counter the global decline in pollinators.

Professor Edwards was invited to give the keynote address for the opening of the Spring Bulb Show at the Botanic Garden of Smith College. The talk entitled *Botanical Explosions: The Evolutionary Impact of Ultra-fast Plants* was attended by an enthusiastic audience of over 200 at the Smith College Student Center Auditorium. She also gave a Log Lunch talk on *Protecting Pollinators in the Midst of the 6th Extinction.* and three additional presentations on pollinator conservation hosted by Wild Oats Food Co-op, the Williamstown Agriculture Commission, and "Green Drinks", a local environmental group. These talks were given in conjunction with the proposal to make Williamstown a Pollinator Friendly Community, which was voted in at the town meeting in May.

This year, Associate Professor **Tim Lebestky** taught *Neural Development and Plasticity* (BIOL 310) in the fall semester and *Neurobiology of Emotion* (BIOL 407) in the spring. In March, his thesis student, *Kelly Tellez '17*, and former thesis student, *Ellie Pitmon '16*, presented the lab's research at the Genetics Society of America Annual Drosophila Meeting in lovely San Diego, CA.

A grant was submitted to the NIH and two papers were published from the lab featuring undergraduate authors.

Research this year in the Lebestky lab was carried out by two thesis students, *Kelly Tellez and Graham Buchan '17*, with contributions from research assistants, *Mikhayla Armstrong '19, Emma Rogowski '19, Francesca Barradale '19,* and *Nebiyou Metaferia 19*. Projects focused on the characterization of the Dopamine Receptor mutants in visuolocomotor arousal and optomotor responses.

Associate Professor **Luana Maroja** taught *Genetics* (BIOL 202) in the Fall and *Evolution* (BIOL 305) in the Spring. This year she was awarded two NSF proposals to start new projects on the genetics of speciation in the crickets *Gryllus firmus* and *G. pennsylvanicus* and in the North American fruit fly *Drosophila Athabasca.* She advised the honor students *Nico McDougall '17* (with Joan Edwards) and *Osama Brosh '17* (with David Smith). Maroja co-authored a paper describing a new species of day-flashing firefly from Panama. During the summer 2017 Prof. Maroja worked with *Zach Brand '19, Haley Lescinsky '18, Tyma Nimri '19, Danielle Sim '18* and *Meklit Tesfaye '20*. Danielle and Haley will be continuing as honor students in the upcoming academic year. In June Maroja, Nico McDougall and Joan Edwards presented results from the arctic plant population genetics project in the Evolution meeting in Portland, Oregon. she will also present results from the new firefly species description.

Associate Professor **Claire Ting** taught a capstone course in the fall semester on *Life at Extremes: Molecular Mechanisms* (BIOL 414), which explored the physiological and molecular survival kits organisms have evolved that permit them to acclimate to environmental stresses and to thrive in extreme environments, such as the deep sea. In the spring semester she taught the Biology core course, *The Organism* (BIOL 102). Through lectures, discussions of original research papers, and laboratories, this large, introductory 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*. 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 *Ian Outhwaite '17*, who joined her laboratory as an honors thesis research student. With the goal of understanding the evolution of niche differentiation within the *Prochlorococcus* lineage, Ian developed a range of computational methods to identify proteomic signatures of closely and more distantly related *Prochlorococcus* isolates. His research established that ecotypes associated with the large clade of recently differentiated lineages have less genomic variability, as defined by relative core genome size, compared to deeply branched ecotypes. He also characterized the representation and prevalence of *Prochlorococcus* within the microbiomes of open ocean samples collected by the Ting lab from the Sargasso Sea. His results indicate that the distribution of *Prochlorococcus*

genes within these samples is consistent with ecotype niche partitioning within the open ocean water column.

In addition, *Roya Huang '17* joined the Ting Lab for the first time in the fall 2016 semester to conduct her senior honors thesis research. Building upon previous research in the Ting Lab, Roya investigated the physiological responses of *Prochlorococcus* to light stress. While maintaining the same magnitude of light stress as previous studies in the lab, but by altering initial growth irradiance levels and the actual irradiance level of the light stress, Roya established that light-sensitive *Prochlorococcus* strains can recover rapidly from photoinhibition. Although cells exhibit extensive loss of chlorophyll and an inhibition of cell division upon exposure to excess irradiance levels, chlorophyll synthesis resumes rapidly upon return to normal growth irradiance levels. These results suggest *Prochlorococcus* ecotypes adapted to thrive at low irradiance levels have the capacity to acclimate to short-term changes in light levels associated with mixing events present within the open ocean water column. Roya was assisted in her research by *Yang Lee '20*, who joined the lab as a research assistant during the fall 2017 semester. Yang will be continuing this research project during the summer and next academic year.

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.

Professor **Heather Williams** taught *Neuroscience* (NSCI 201) in the fall. In the spring, she taught *Animal Behavior* (BIOL 204), which continued the long-term investigation of red-winged blackbird behavior at Eph's Pond. Research on cultural evolution of bird song continued, both at the Kent Island Field Station in the Bay of Fundy and in Williamstown, with *Andrew Scharf '18* and *Amanda Lugo '18*. *Ivy Ciaburri '17* did her honors thesis in Prof. Williams' lab, on quantifying syntax in house finch song and how it changes with social context. In the spring semester, *Jonah Levy '18* began an honors thesis on directional change of song traits, and *Rebecca Smith '18* began her honors work on the relationship between coloration and song in house finches.

Post-Graduate Plans of Biology Majors

Funmilayo D. Adejobi	Undecided
Robert N. Bates	Undecided
Natalie G. Bernstein	Research Technician at the Feinberg School of Medicine, Northwestern University
Brett A. Bidstrup	Undecided
Osama F. Brosh	MPhil in Biological Sciences (Genetics), University of Cambridge
Graham B.J. Buchan	Research Technician, Dana-Farber Cancer Institute, Boston, MA
Michelle J. Buncke	Scribe, Platte Valley Medical Center, Boulder, CO, then Medical School.
Minwei Cao	Undecided
Ivy A. Ciaburri	Undecided
Sarah E. Cooperman	Florence Chandler Memorial Fellowship to study perceptions of bats around the globe
Jane Dai	Undecided
Ronak M. Dave	Undecided
Lane A. Davis	Ecology research Fulbright in Tungurahua, Ecuador
Cesar F. Dominguez	Research Technician at Umass Medical, Worcester, MA then Graduate School
Margaret C. Draper	Undecided
William L. Duke	Undecided
Candice S. Dyce	Undecided

Elijah M. Fromm	Ph.D. program in Mathematics, Yale University
Ruby M. Froom	Research assistant at Rockefeller University in NYC
Daniel P. Gainey	Undecided
Hanane Goelzer	Undecided
Ronald Govin	Undecided
Garrick H. Gu	MD program, Umass Worcester
Yanira Guerra	Associate Science Teacher, Success Academy Charter Schools, New York, NY then to Graduate School to pursue a PhD in Biology
Jacques P.G. Guyot	Undecided
Maria G. Guzman	Undecided
Amelia N. Hidalgo	Undecided
Intekhab Hossain	Analyst, Analysis Group Inc., Boston, MA
Roya E. Huang	PhD program at Harvard University in cell biology and biophysics
Tracey H. Kim	Undecided
Joyce Lee	Clinical Research Assistant, Mt. Sinai Neurosurgery, New York, NY
Kendall O. Leet-Otley	Undecided
Sara L. Lehman	Undecided
Christopher K. Lyons	Attending the Master's of Medical Sciences program at Boston University School of Graduate Medical Sciences for two years before pursuing a medical degree
Borah P. Kim	Undecided
Jonathan MacDougall	Undecided
Tsaina V. Mahlen	Undecided
Aaron J. Maruzzo	Undecided
Emma P. McAvoy	Undecided
Lauren M. McCall	Undecided
Terrance S. Mensah	Undecided
Velia A. Moran Olivas	Admission Counselor, Williams College, Williamstown, MA
Rachel O. O'Sullivan	Research Associate, Kallyope, New York City
Ian R. Outhwaite	Research Technician, The Stephen Long Lab at the Memorial Sloan Kettering Cancer Center, New York, NY
Christine E. Reed	Associate Consultant, Trinity Partners, Waltham, MA. Then medical school.
Adam J. Resnick	M.D. at the University of Massachusetts Medical School
Abigail E. Robinson	Strategy Consultant at Oliver Wyman, in Boston, MA
Roxana Rodriguez	Undecided
Chloe M. Rogers	Undecided
Diana S. Sanchez	Jesuit Volunteer with the Jesuit Volunteer Corps, working as a Reentry Coordinator for the Kolbe Society of Catholic Community Services in Tucson, AZ.
Sophia E. Schmidt	Undecided
Maeve A. Serino	Research Associate, Close Concerns, San Francisco, CA
Varun S. Sharma	Attending ETH Zürich for the Masters program in Systems Biology.
Jeffrey A. Sload	MPhil in Comparative Social Policy at Oxford University (on the Martin-Wilson Fellowship), then Associate Consultant at Bain & Co., New York City
Cameron B. Speyer	Clinical Research Assistant (*Karen Costenbader's '89* lab), Brigham and Women's Hospital, Boston, MA
Kathleen G. Swoap	Associate, Parthenon-EY, Boston MA

Stacey M. Tamura	Teaching English in Japan through the JET Program
Kelly Tellez	Undecided
Jacob G. Verter	Immunology Research Technician, The Rudensky Lab, Memorial Sloan Kettering Cancer Center, New York, NY
Maria A. Vicent Allende	Awarded Hubbard Hutchinson Fellowship in dance. Will pursue dance technique and composition classes in Chicago, IL.

Biology Colloquia

Bruce Beehler ’74, Senior Director for Biodiversity Assessment at Conservation International
“North with the Songbirds: The Future of Neotropical Migration in North America”

Jeremy Fox, University of Calgary
“The spatial hydra effect: that which does not kill metapopulations makes them stronger”

Elinor Karlsson, UMass Medical, Broad, MIT
“Natural selection, disease, and genome function in humans and dogs”

Luana Maroja, Associate Professor of Biology and Tim Lebestky, Assistant Professor of Biology
“Strategies for designing and delivering a scientific presentation”

Josh Obar, Dartmouth Medical School
“Aspergillus fumigatus strain-specific virulence and inflammation in the respiratory tract”

Elena Vazey, UMass Amherst
“Focus on the locus: Noradrenergic roles in attention and inattention”

Paul Yancey, Whitman College
“Life in the Trenches: How do Animals Cope with Pressure in the Ocean’s Greatest Depths?”

Alumni Retreat featuring:

Kimberley Davis ‘08
“Patterns, impacts, and feedbacks of global *Pinus contorta* (lodgepole pine) invasions”

Jason Fan ‘08
“Progenitor Cell Marker Aldehyde Dehydrogenase 1a3 Defines a Subset of Failing Pancreatic β Cells in Diabetic Mice”

Galen Holt ‘04
“Branching patterns, environmental variation, and diversity in river networks”

Gregory McElroy ‘12
“The role of mitochondrial electron transport chain complex 1 function in neurodegeneration, diabetes, and cancer”

Daniela Zarate ‘15
“Mapping ancestral admixture across the genomes of hybrid Africanized honeybees”

Off-Campus Biology Colloquia

Janis Bravo, *Aubrey Kenefick, Breanna Nguyen, Jacob Kim, Adam Resnick, Ruby Froom* and Lois Banta.
"Impact of Type VI Secretion System (T6SS) Effectors on Arabidopsis thalianaTransformation in *A. tumefaciens*"
International Molecular Plant-Microbe Interactions Congress, Portland, OR, July, 2016.
Poster presentation by post-doctoral fellow; also presented by Ruby Froom '17 and Janis Bravo at the 37th Annual Crown Gall Conference, Bloomington, IN, Nov, 2016.

Matt Carter
"Strategies for designing and delivering a scientific presentation"
Wadsworth Center, New York State Department of Health, Albany, NY, July, 2016.

"Dissecting the neural basis of appetite and appetite suppression"
Graduate Program in Neuroscience and Behavior, University of Massachusetts, Amherst, Nov, 2016.
Program in Neuroscience, University of California, San Francisco, CA, Oct, 2016.
Wadsworth Center, New York State Department of Health, Albany, NY, July, 2016.

"The promise of sleep"
University of Washington Department of Educational Outreach, Seattle, WA, Dec, 2016.

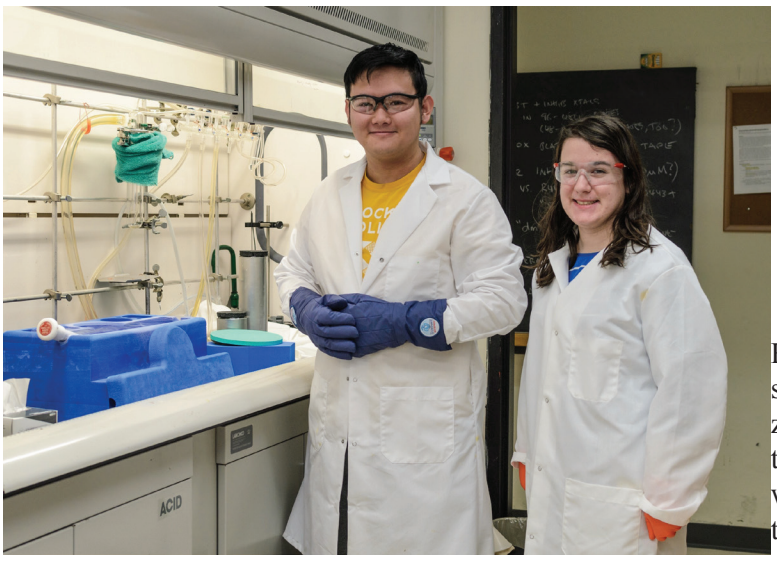
"WCBR Public Outreach Lecture: The neuroscience behind a good night's sleep"
50th Annual Winter Conference on Brain Research, Big Sky, MT, Jan, 2017.

"AgRP neurons can increase food intake during conditions of appetite suppression by inhibiting the parabrachial nucleus"
50th Annual Winter Conference on Brain Research, Big Sky, MT, Jan, 2017.
Department of Human Genetics, Emory University,Atlanta, GA, Feb, 2017
National Institute of Diabetes and Digestive and Kidney Disorders, Bethesda, MD, Feb, 2017.

"Interplay between appetite-stimulating and appetite-suppressing neuronal populations"
1st Annual Meeting of the Western Massachusetts Chapter of the Society for Neuroscience, Amherst, MA, March, 2017

"Designing effective science presentations"
Experimental Biology Annual Meeting, Chicago, IL., April 2017

Tim Lebestky
Invited lecture at the conference on the dopaminergic regulation of optomotor arousal.



Hanna Shebert '17 and Garrick Gu '17, thesis students with Professor Jimmy Blair, prepare frozen samples of protein crystals for shipment to the Stanford Synchrotron Radiation Lightsource, where they collected X-ray diffraction data on these crystals.

Chemistry Department

The Chemistry Department was deeply saddened in April with the passing of Professor Raymond Chang, the Halford R. Clark Professor of Natural Sciences, Emeritus. Professor Chang mentored countless students and faculty in the classroom, the laboratory, and at his home. A prolific author, he wrote books on general, physical, and industrial chemistry; his book *Chemistry* is currently in its 12th edition. With his wife Margaret, he wrote children's books based on stories from his childhood in China. We will always cherish the countless memories we had with Raymond as a researcher, colleague, and friend. We will genuinely miss him.

Professor Lee Park has been appointed Dean of Faculty for a one year appointment to begin this summer and Professor Sarah Goh was promoted to full professor. We congratulate both Lee and Sarah on their accomplishments. We also welcome two new faculty members, Assistant Professors Anthony Carrasquillo and Katie Hart. Dr. Carrasquillo, a physical/environmental chemist, will teach *Principles of Modern Chemistry* (CHEM 155) in the fall and will co-teach *Introduction to Environmental Science* (ENVI 102) in the spring. Dr. Hart, a biochemist, will teach *Biochemistry I: Structure and Function of Biological Molecules* (CHEM 321) in the fall, and *Biophysical Chemistry* (CHEM 367) in the spring.

Unfortunately, we bid farewell to Visiting Professor Patrick Barber and Chemistry Lab Instructor Asvelt Nduwumwami. Dr. Barber will be molding minds in the chemistry department at Earlham College, while Asvelt will be starting graduate school at Penn State. We wish them both the very best of luck.

As the Chemistry Department ended the 2016-17 academic year, we adorned graduation caps to 42 chemistry majors, with 16 of these students completing senior thesis research projects. As they depart from their four years in the Science Quad, the remaining students will continue to watch the new construction of the Morley Science Labs "South Building", which is slated to open in 2018.

We are particularly proud of our seniors and their accomplishments. Each year, individual students are recognized with departmental awards. In the Class of 2017, the John Sabin Adriance prize went to *Matthew Goss* for outstanding work throughout his chemistry career. The James F. Skinner prize was awarded to *Emily Hoyt* for her distinguished achievement in chemistry and future promise as a researcher. The Leverett Mears prize went to *Paige Chardavoyne* in recognition of both her abilities in chemistry and her future in medicine. *Hanna Shebert* was awarded the American Chemical Society Connecticut Valley Section Award for her sustained scholastic excellence. *Garrick Gu* was awarded the American Institute of Chemists Student Award for outstanding scholastic achievement, *Laura Elmendorf* received the ACS Undergraduate Award in Inorganic Chemistry, *Hanson Koota* was presented with the ACS Division of Organic Chemistry Award, and *Erica Myers* was awarded the newly established ACS Undergraduate Award in Physical Chemistry.

Over the course of the academic year, a number of additional awards were presented to undergraduate chemistry students for outstanding scholarship. *Anna Harleen '18* and *Michael Curran '20* received the CRC Awards as the outstanding students in CHEM 151 and CHEM 155, respectively. *Katherine Mahoney '20* was presented with the Raymond Chang First-Year Chemistry Award for her exceptional work in CHEM 153. Allison Wong '18 was the recipient of the ACS Analytical Chemistry Award for her aptitude for a career in analytical chemistry. Recognized for their achievement in organic chemistry, *Walker Knauss '19* received the Polymer Chemistry Award and *Luke Cai '19* was the recipient of the Harold H. Warren Prize.

During the summer of 2017, approximately 25 Williams College chemistry students were awarded research assistantships to work in the laboratories of departmental faculty. We gratefully acknowledge support from 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.

We continued to participate in the Class of 1960 Scholars Program, with Professor Luis Campus from Columbia University as our distinguished scientist visiting campus to present a seminar and meet with our students during the 2016-17 academic year. 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.

Class of 1960 Scholars in Chemistry

Raisha Ismail	Tobias Muellers
Esther Kim	Caroline Ryan
Elizaveta Lavrova	Carl Sangree
Alexi McAdams	Miranda Villanueva
Jonathan Meng	

Visiting Professor **Patrick Barber** spent the summer of 2016 hosting five students in his laboratory: *Laura Elmendorf '17* (Thesis student), S*uyee Win '17* (Thesis student), *Alexi McAdams '18*, *James Rasmussen '19*, *Emily Harris '19*, and *Walker Knauss '19*. Together they furthered two projects focused on the development of lanthanide ion complexes for mercury and arsenic sensing and biological imaging. In the fall Laura and *L. David Jaramillo '17*, an Allison Davis Fellow, worked on the synthesis and characterization of two types of Gemini surfactants for biological imaging as thesis projects with Suyee pursuing the synthesis of lanthanide ion complexes for arsenic sensing for her thesis. Also in the fall, Professor Barber presented a talk at Williams Mystic on the use of waste shrimp shells to extract uranium from seawater.

During Winter Study, two additional students, *Caroline Weinberg '19* and *Ulises Molina-Vega '18,* joined the lab to work on a new project developing materials from waste lobster shells from a collaborator in Booth Bay Harbor, Maine. They were joined by *Dylan Millson '20* in the Spring semester who started working on modifying the lobster shells to absorb arsenic from the environment. Over the course of the year, all projects made substantial progress and are on the way to becoming publications. Professor Barber kicked off the Science on Screen® grant with Images Cinema by discussing The Chemistry of Chocolate before a viewing of Willy Wonka and the Chocolate Factory. In addition, all three students, Laura, David, and Suyee defended their theses with talks to the department and writing up their efforts in the lab. Teaching efforts were focused on two new courses for Professor Barber, *Materials Chemistry* (CHEM 366) and two lab sections of *Organic Chemistry: Intermediate Level* (CHEM 251), along with another round of *Instrumental Methods of Analysis* (CHEM 364) this academic year. He also received a grant from the NSF-sponsored Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS) program to attend a workshop on Forensic Science taught by our very own Professor Larry Kaplan. This year ends Professor Barber's three-year visiting position at Williams and he has accepted a tenure-track position at Earlham College starting in the Fall 2017.

Assistant Professor **Jimmy Blair** had another productive year at Williams. In the fall, Professor Blair taught *Biophysical Chemistry* (CHEM 367) for the second time. Professor Blair and his students experimented with a new laboratory unit focused on the structural biology of lysozyme. Students grew lysozyme crystals, and they learned how to process X-ray diffraction data and build crystallography models of lysozyme. In the spring, Professor Blair taught *Organic Chemistry: Introductory Level* (CHEM 156) for the first time along with one section of the CHEM 156 lab. One important change for CHEM 156 this year involved our reorganization of the lab program. We ended lab a month early to allow construction crews to begin merging the Morley Science Lab building with the new building to the south, which is nearing completion.

The year was productive for Professor Blair's research lab. He endeavors to develop new antibacterial agents targeting histidine kinases using the α-proteobacterium *Caulobacter crescentus* as a development platform. Histidine kinase-mediated signaling pathways are well conserved across bacterial species and are essential for virulence in many pathogenic bacterial strains, suggesting that discoveries in *Caulobacter* will open the door to potential new antibacterial strategies effective against a broad-spectrum of bacteria. *Caulobacter* contains essential histidine kinase signaling pathways that his lab targets to assess whether pharmacological inhibition of these essential signaling pathways provides a new mechanism for antibacterial action. Over the summer *Hanna Shebert '17* joined him to work on biochemical and antimicrobial testing of small molecules against CckA, an essential histidine kinase to *Caulobacter*, and three bacterial strains. *Tony Huang '16* returned for one month after his graduation to complete the synthesis of a series of drug-like molecules he developed for his thesis. Thesis students Hanna Shebert and *Garrick Gu '17* spent the school year in the Blair Lab following up on these results. Thanks to generous support from the Hellman Fellows Fund, Blair and his students began structural biology work to determine the binding orientation of histidine kinase inhibitors for the histidine kinase active site. Together, they have solved the first X-ray crystal structures of their inhibitors for a histidine kinase. Professor Blair presented much of the work these students have accomplished to the Department of Biochemistry and Molecular Pharmacology at the UMass Medical School in December.

Professor Blair served as a member of the Honor and Discipline Committee throughout the academic year. Finally, Professor Blair collaborated with the Shapiro Lab

at Stanford University on one manuscript, which was published in *Nature Communications* and was based, in part, on work he performed in his postdoctoral studies.

Professor **Amy Gehring** had the opportunity to interact with many students this year, both in her capacity as Chair of the Chemistry Department and through teaching in both the introductory chemistry and biochemistry curriculum. In the fall, Gehring taught *Concepts of Chemistry* (CHEM 153); she particularly enjoyed getting to know many students beginning their studies in chemistry. In the spring, Gehring taught the capstone course for the Biochemistry and Molecular Biology (BIMO) concentration, *Topics in Biochemistry and Molecular Biology* (BIMO 401). This literature and discussion-based course is always an exciting and invigorating teaching experience.

Gehring also enjoyed mentoring a number of students pursuing biochemistry research in her laboratory. The 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 representative of a large bacterial genus that is well known for its biosynthesis of molecules with important applications in medicine. Over the summer of 2016, she was joined in this research by *John Ahn '18* and *Alexia Barandiaran '19*, who worked as an effective team on a variety of projects related to understanding the control of antibiotic production in *S. coelicolor*. John and Alexia continued on during the 2016-17 academic year and were joined by thesis, work-study and Winter Study students. Thesis student *Lia Lee '17* studied the substrate specificity of a phosphodiesterase enzyme likely involved in the regulation of antibiotic production. Thesis student *Varun Bhadkamkar '17* made progress towards the isolation and purification of a phosphopantetheinyl transferase, another type of enzyme with an important function in antibiotic biosynthesis. Varun also began work on a new collaborative project with the lab of Daniel Aalberts in the Physics department to optimize expression of *Streptomyces* genes in *E. coli*. Thesis student *Zihan Su '17* studied the role of sigma factor and anti-sigma factor genes, which encode important regulators of gene expression in bacterial organisms, in the developmental events of the *S. coelicolor* life cycle. During January 2017, the thesis students were ably assisted by students taking the *Introduction to Research in Biochemistry* (CHEM 18) Winter Study course: *Selin Gumustop '20*, *David Gorestki '20*, *Kenny Liu '19* and *Kevin Zhou '20*. In the fall semester *Esther Kim '18* contributed to the phosphodiesterase substrate specificity project and *Adam Calogeras '18* worked on getting a CRISPR mutagenesis system up and running in the lab. In the spring semester, *Liza Lavrova '18* continued the group's collaboration with Enrique Peacock-Lopez on a project to visualize oscillations in bacterial gene expression via fluorescence microscopy. It was a productive and busy year of research!

Gehring also participated in the broader scientific community by serving on a career panel at the Microbial Stress Response Gordon Research Seminar and attending the associated conference during July 2016. She served as a reviewer for the journals *Scientific Reports*, *Microbiology* and *BBA Proteins and Proteomics*.

Professor **Christopher Goh** taught *Inorganic/Organometallic Chemistry* (CHEM 335) in the fall semester, and *Bioinorganic Chemistry: Metals in Living Systems* (CHEM 338) in the spring. The latter was a largely literature-based course. Research in the field of transition-metal mediated homogeneous catalysis continued with *Uygar Sozer '17*, *Anna Ringuette '19*, *Larissa Silva '19* and *Josemaria Silvestrini '19* working on iron-catalyzed epoxidations of alkenes. The designs of these catalysts are based on iron-containing enzymes. Another senior thesis student *Jose Lopez '17* focused on a renewable polymer project, forming a team with *Janet Rodriguez '20*. The students had fun synthesizing molecules, coming up with lab rules and thoughts on "Things that make us feel like real chemists" and polling each other about all manner of things ("pancakes or waffles anyone?"). They definitely made the lab an active place. Professor Goh also worked with the chemistry student group CSAC to organize events including an end-of-year BBQ and welcoming new majors with chemistry-themed swag (designed by *James Rasmussen '19*). In addition to his role in the chemistry department, Professor Goh held a position as Faculty Fellow in the Office of Institutional Diversity and the Davis Center. In that capacity, he worked with student groups on issues of diversity in STEM fields.

Professor **Sarah Goh** spent the summer of 2016 working with rising seniors *Matt Davies '17* and *Hanson Koota '17*. The lab's research continues to be focused on polymers for drug delivery applications. The lab seemed to be quite athletically and musically inclined this year, with thesis students *Hannah Cole '17* (cross country, Nordic, track and field), *Emily Hoyt '17* (ultimate), and *Hanson Koota '17* (football) joined by independent study students *Matt Davies '17* (cycling) and *Nora Lee '17* (swimming), as well as *Lauren Gunasti '19* (Ephoria). Despite all of their co-curricular activities, the students produced an amazing amount of work that Professor Goh

will be writing up this summer. Professor Goh taught a variety of laboratory sections in the fall for Intermediate *Organic Chemistry* (CHEM 251 and CHEM 255) and the introductory *Concepts in Chemistry* (CHEM 153). She offered her tutorial in *Physical Organic Chemistry* (CHEM 344T) in the spring. The students engaged in kinetics, isotope effects, linear free energy relationships, and molecular orbital theory before venturing into their self-directed laboratory experiments. This year's theme seemed to be pericyclic reactions, with students exploring Diels-Alder, Fries, sigmatropic, and dipolar cycloaddition reactions, as well as oxidation reactions. The end of this year will also see Professor Goh advancing to Full Professor at the College.

Professor **Lawrence J. Kaplan** taught *Biochemistry I: Structure and Function of Biological Molecules* (CHEM 321) in the fall semester and was on a sabbatical for the spring semester.

He continues to administer the Center for Workshops in the Chemical Sciences with 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 sixteen years ago, the CWCS has received major grants from the National Science Foundation totaling approximately $10,000,000 and continues with the current collaborative grants to Williams, Georgia Tech, and Georgia State. As a result of the current NSF grant the CWCS was rebranded the Chemistry Collaborations, Workshops and Communities of Scholars (cCWCS). The cCWCS sponsors workshops related to the chemical disciplines including Food Chemistry, Chemistry and Art, Environmental Chemistry, Material Science and Nanotechnology, Fundamentals of Proteomics, Biomolecular Crystallography, and Forensic Science. In addition to offering workshops, the CWCS continues to develop a series of Communities of Scholars. With the workshops and their alumni serving as the nucleus, the Communities will continue to develop high-quality course content and pedagogy; propagate the use of successful teaching strategies; and provide discussion venues such as online discussion boards and video conferencing. The website for the Forensic Science Scholars Community, launched in 2010 continues to be expanded and updated with many more members and more educational resources.

Kaplan taught a weeklong CWCS workshop in forensic science during the summer of 2016 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. Deb Morandi and Penny Sage, both assistants in the Chemistry Department, assisted Kaplan in the organization and instruction of the workshop.

Kaplan attended the 24th Biennial Conference on Chemical Education at the University of Northern Colorado, Greeley, in August 2016 where he chaired a symposium entitled "cCWCS as a Catalyst for Curriculum and Pedagogical Reform: Faculty Development and Communities of Scholars—New Contexts for Chemistry." He also presented a paper, *An Integrated Biochemistry Laboratory Program in which Students Take Ownership of the Experimental Investigation of β-Galactosidase* which was a compilation of experiments proposed and conducted by students in Chemistry 321 over the past half-dozen years. In the presentation, Kaplan highlighted experiments involving the crystallization of β-galactosidase (β-gal), the analysis of the *E. coli* proteome and the effect of growing conditions on β-gal production, comparison of various methods of purification of β-gal, determination of the properties of the β-gal in Lactaid pills, and the thermodynamic analysis of the binding of various substrate analogues to β-gal.

Last year, with a number of colleagues, alumni of the forensic science workshop, he published a paper detailing the scope and perspectives as well as the challenges encountered with teaching this type of workshop in the *Journal of Chemical Education*. This year, he published a companion paper dealing with the quest for confirmatory data during the workshop in the *Chemical Educator*.

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

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

Professor Lovett continued his research on the *Bacillus subtilis* SOS response to DNA damage, which comprises a set of DNA damage-inducible genes (SOS genes) that code for DNA repair and cellular survival functions. During the past 3+ decades Lovett and students working in his lab have discovered more than 30 SOS genes and characterized their genetic regulation in response to DNA damage. Based on recent evidence implicating the SOS response in the development of antibiotic resistance in bacteria, research in the Lovett lab has focused on finding SOS response inhibitors. Lovett and his research students developed a high throughput assay to search a library of 14,400 bioactive compounds for

SOS response inhibitors and last year they developed an in vivo assay to test the inhibitors' ability to block the SOS response in bacteria. During the past year Lovett's students completed the screening of nearly 13,000 compounds and have now found a total of 20 compounds that inhibit the SOS response. Summer research students who worked on this project included *Richard (Alex) Ruberto '17*, *Cindy Liao '17*, *Michael Green '18*, *Chinonso Anokwute '19*, *Oscar Merino '19*, and *Brandon Vuong '19*. Alex Ruberto and Cindy Liao continued as senior thesis students for the academic year. John (Jack) Roberts worked on an independent research project in the spring of 2017. Professor Lovett also supervised work study research students *Kelly Chen '17*, *Joseph Flores '20*, *Michael Gao '19*, *Cecilia Hurtado '17*, *Charles Laurore '18*, *Mei Liang '19*, *Nicholas Madamidola '20*, *Oscar Merino '19*, *Brandon Vuong '19*, *Katie Spence '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 16th year of science camp for elementary school students and teachers.

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

Professor **Lee Park** spent 2016-17 on sabbatical at Ewha Womens University in Seoul, South Korea where she worked on the synthesis of novel thiol ligands for use in driving self-assembly of gold nanoparticles. Upon her return to Williamstown in the summer of 2017, she'll begin a year as interim Dean of Faculty before returning to the department.

While on sabbatical, she spoke at an alumni gathering in Hong Kong on "From Lotus Leaves to Solar Cells, Architecture at the Nanoscale". She also gave an invited talk at Lingnan University in Hong Kong on "Thinking Small: The Role of Self-Assembly Strategies in Designing Nanoarchitectures".

During the 2016-17 academic year Professor **Enrique Peacock-López** taught *Quantum Chemistry and Chemical Dynamics* (CHEM 361), a lab section of *Principles of Modern Chemistry* (CHEM 155), and *Thermodynamics and Statistical Mechanics* (CHEM 366). In these courses, Peacock-López extended the use of MATHEMATICA to solve problems and data analysis. In particular, he covered the basics of probability theory, chemical modeling, and Monte Carlo simulations. As a result of the inclusion of MATHEMATICA in the curriculum, Peacock-López was able to submit one of the CHEM 361 final projects to *Physica D* for publication. *Eliza Matt '18* and *Diego Guimarães-Blandón '18* developed the project *Parrondo's paradox or chaos control in discrete two-dimensional dynamic systems*.

During the summer Peacock-López continued his 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. The proposal has been funded for the 2015-2018 period for an amount of $244,117, and it supported *Benjamin Bui '19* and *Si Hou Lon '19* summer research 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 *Erica Myers '17* initiated her work on perturbation theory applied to a quantum particle in a corrugated box, *Bobby Rowledge '18* worked on models of melatonin regulation associated with seasonal depression.

The academic year was a busy time with one thesis student (*Erica Myers '17*) and three Winter Study students. During the academic year, Erica use perturbation theory and the WKB approximation to analyze a quantum particle in a corrugated box. Erica considered several perturbative potential to explain the behavior of the experimental data. During the winter, *Michael Curran '20* considered a cellular automata approach to simulate chemical reactions; *Ching-Hsien (Justin) Ho '20* studied pattern formation in 2D for cross-catalytic self-replicating systems; *Nebiyou Metaferia '19* studied a discrete model of Cicada oscillations.

During spring semester Peacock-López dedicated some time to study non-fickian diffusion and self-replicating peptide networks. Artificial peptide networks have been synthesize 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.

While continuing with his research, Professor Peacock-López, Gisela Demant, and instructor Cheryl Ryan (Hoosac Valley High School: 12 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-López has served as reviewer for the

journals*, Chaos, International Journal of Bifurcation and Chaos, European Journal of Physics, Nonlinear Dynamics, Chemical Physics Letters,* and *Journal of Nonlinear Functional Analysis.*

During the 2016-2017 academic year, Professor **David Richardson** returned from a mini-sabbatical to the reality of another full year at Williams. In the fall semester, he taught *Introductory Chemistry (*CHEM 151) with 45 students, and 16-student lab section of the same course, for the first time, while in the spring semester he taught *Toxicology and* Cancer (CHEM 341) with 30 students, plus a 16-student lab section of *Organic Chemistry, Introductory* Level (CHEM 156). During the Winter Study Period, he taught *Introduction to Research in Organic Chemistry* (CHEM 23).

Professor Richardson's research lab returned to full activity during the fall and throughout the year. Together with Professor Jay Thoman he supervised the senior honors thesis research of *Matthew Goss '17* which extended the development of a zinc-based method for the deuteration of iodine-containing organic substrates, with a particular focus on the stereochemical outcome of the process. He also supervised the research efforts of several work-study students on an assortment of research projects: during the fall semester, *Jonathan Hall '18* and *Astia Innis '20* worked on conducting PCB measurements in a newly-acquired crayfish sample set as part of our on-going study of PCB contamination in the Hoosic River; also during the fall semester, *Tobias Muellers '18* and *Malcolm Singleton '18* worked on our initial efforts to develop methods for the measurement trace-levels of PFOA in aqueous and soil samples using our department's newly installed LC-MS system; Tobias continued this work throughout WSP 2017, and was joined in the project then, and throughout the spring semester, by *Neena Patel '18*.

After 28 years of supervision and maintenance of the Department's nuclear magnetic resonance instruments, Professor Richardson handed off these duties to the Department's new Instrumentation Specialist, Dr. Nate Cook. He also served the Department by supervising the process of preparing 11 lab spaces in the Morley labs for renovations during the summer of 2017 that will be part of the upcoming science building project.

Professor Richardson served as a grant reviewer for the American Chemical Society's Petroleum Research Foundation. 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*, continues her research studies on the ages of fossils related to human evolution. This year she also looked at light-sensitive quartz samples to test these as a potential new material for dating sand deposits. She has been awarded a Fulbright Fellowship to spend four months in Brazil in 2018, involving both field work and lectures at three different Brazilian universities.

Professor **Tom Smith** spent his nineteenth year at Williams pursuing his research in organic synthesis and methods development, *Asymmetric Methods for the Synthesis of Pyran-Based Anticancer Natural Products*, under an NIH Academic Research Enhancement Award (AREA) grant and a Henry Dreyfus Teacher-Scholar Award. Senior honors research student *Paige Chardavoyne '17* investigated new synthetic approaches toward the cytotoxic marine natural product, enigmazole-A. Professor Smith taught *Intermediate Organic Chemistry* (CHEM 251) and *Synthetic Organic Chemistry* (CHEM 342) and completed his second year as a member of the Committee on Appointments and Promotions.

In the fall semester, Professor **Jay Thoman** taught *Principles of Modern Chemistry* (CHEM 155) and its associated lab. During January 2017, he once again taught *Glass and Glassblowing* (CHEM /ARTS 16). In the spring semester, he attended the meeting of the American Society of Scientific Glassblowers held at UMASS Amherst. While on sabbatical in spring 2017, he remained on campus continuing research projects with Professor Richardson (described above). As College Marshal, Thoman also spent time planning for Commencements 2017-2020 in the new Library Quad (where the brick-box Sawyer Library once stood). In service to the larger chemistry community, he continued work with Educational Testing Services and served as an external reviewer.

Post-Graduate Plans of Chemistry Majors

Ava Atri	Undecided
Varun Bhadkamkar	Ph.D. in Biology/Biosciences, University of California, San Francisco
William Cao	Undecided
Melissa Caplen	Undecided
Selena Castro	Chemistry Teacher, Camden Charter School Network, Teach for America
Paige Chardavoyne	M.D., Penn State University College of Medicine
Kelly Chen	Clinical Researcher, Boston Children's Hospital, Harvard Medical School
Julia Cheng	Clinical Research for Kaiser Permanente, then to medical school
Hannah Cole	Bridger Ski Foundation, Bozeman, MT
Alyssa Crain	Research Assistant, MD Anderson Cancer Center, Houston, TX
Matthew Davies	Research Associate, Center for Regenerative Medicine, Boston University
Laura Elmendorf	Ph.D. in Chemistry, University of Wisconsin-Madison
Matthew Goss	Undecided
Garrick Gu	M.D., University of Massachusetts Medical School
Justin Harris	Undecided
Aglaia Ho	Undecided
Emily Hoyt	M.Phil. in Chemistry, Cambridge University, UK, Herchel Smith Fellowship
Roya Huang	Ph.D. in Cell Biology and Biophysics, Harvard University
Cecilia Hurtado	Research Associate, Beckman Research Institute of City of Hope, CA
Luis (David) Jaramillo	Research Technician, Tufts Univ. School of Medicine, Integrative Physiology and Pathobiology
Olivier Joseph	Fulbright English Teaching Assistant Program, Spain
Sophie Kitchen	M.Sc. in Epidemiology and Public Health, University of British Columbia
Hanson Koota	Consultant, Trinity Partners, Boston, MA
Lia Lee	Research Associate, Broad Institute of MIT and Harvard, Cambridge, MA
Nora Lee	Chemistry Teacher, Phillips Academy, Andover Teaching Fellowship
Cindy Che-Hsuan Liao	Undecided
Jose Lopez	Undecided
Erica Myers	Ph.D. in Chemistry, University of Utah
Taylor Patterson	Undecided
Michael Polson	Work for Bates White, Washington, DC
Richard (Alex) Ruberto	Research Associate, Broad Institute of MIT and Harvard, Cambridge, MA
Jaqueline Serrano	Undecided
Hanna Shebert	Ph.D. in Chemistry, Cornell University
Linda Shin	Undecided
Uygar Sozer	Research Specialist, University of Pittsburgh, then to graduate school
Zihan Su	Teach for America, then to medical school
Heidi Tan	AmeriCorps, New York
Kaleb (Yitong) Tseo	Work at Facebook, Menlo Park, CA
Juliana Veira	Lab Technician, CA, then to medical school
Rachel Waldman	Undecided
Suyee Win	Work at Los Angeles County Department of Public Health Substance Abuse Control & Prevention, then to medical school
Sabrina Zaldana	French Teacher, Milton Academy, Milton, MA

Chemistry Colloquia

Luis Campos, Columbia University, Class of 1960 Scholars
"Thiophene Rust in Organic Electronics"

Andre Martinez '09, University of Maryland
"Polymeric Nanoparticles in Drug Delivery"

Janet Morrow, SUNY Buffalo, Charles Compton Lectureship
"Transition Metal MRI Contrast Agents that Respond to Biological Environment"

Rajarshi Roy, University of Maryland
"Seeing the Light: Visual Illusions and Reference Frames"

Off-Campus Chemistry Colloquia

Jimmy A. Blair
"Repurposing Cancer Drugs as Antibiotics: Development of Hsp90 Inhibitors as Inhibitors of Bacterial Histidine Kinases"
Department of Biochemistry and Molecular Pharmacology, UMass Medical School, Worcester, MA, December, 2016.

Lawrence J. Kaplan
"cCWCS as a Catalyst for Curriculum and Pedagogical Reform: Faculty Development and Communities of Scholars—New Contexts for Chemistry"
Department of Chemistry, Bowdoin College, Brunswick, ME, November 2016.
Symposium at the 24th Biennial Conference on Chemical Education, University of Northern Colorado, Greeley, CO, August 2016.

"An Integrated Biochemistry Laboratory Program in which Students Take Ownership of the Experimental Investigation of ß-Galactosidase"
Paper presented at the 24th Biennial Conference on Chemical Education, University of Northern Colorado, Greeley, CO, August 2016.

Lee Park
"From Lotus Leaves to Solar Cells, Architecture at the Nanoscale"
Williams Alumni Gathering, Hong Kong, March 2017.

"Thinking Small: The Role of Self-Assembly Strategies in Designing Nanoarchitectures"
Lingnan University, Hong Kong, April 2017.

Enrique Peacock-López
"Temporal and Spatial Patterns in Chemical Self-replication"
Department of Chemistry, Bowdoin College, Brunswick, ME, November 2016.

"The Dynamics of Chemical Self-replication"
Dynamic Days Latin America and the Caribbean, Puebla, Mexico, October 2016.

"First and second order chemical self-replication in open systems"
Gordon Conference: Oscillations and Dynaic Instabilities in Chemical Systems, Stowe, VT, July 2016.

Computer Science Department

The 2016-2017 academic year was marked by extensive growth in both enrollments and faculty. Student interest in computer science soared with over 50 sophomore students declaring a major. Thankfully, the department will also increase in size with the addition of three new full-time professors. We are excited to welcome Dan Barowy (PhD UMass), Iris Howley (PhD CMU), and Bill Jannen '09 (PhD SUNY Stoneybrook) as new tenure-track faculty members of the computer science department!

In the spring, the department hosted Hany Farid as its Class of 60s speaker. Dr. Farid spoke about his work in reigning in online abuse including cyberbullying, and his research into digital forensics. The department also sponsored and hosted events from Google and Facebook that featured alumni Josh Ain, Paul Bethe, Joshua Geller, and Hillary Hutchinson.

For the first time ever, members of the department attended the ACM Richard Tapia Celebration of Diversity in Computing. Joining faculty member Brent Heeringa were students *Jose Rivas-Garcia '18 and Matheus Cruz Correia de Carvalho Souza'18.* In October, *Melanie Subbiah, '17, Jamie Lesser '17, Emily Hoyt '17, Julia Goldman '18, Stephanie Liu '18, Miranda Chaiken '19* and *Anjali Pai '19* attended the Grace Hopper Celebration of Women in Computing. Also attending the conference in Houston, TX were faculty members Jeannie Albrecht and Andrea Danyluk.

The department sponsored its first-ever hackathon, which was ambitiously organized and led by a group of majors. The Computer Science Student Advisory Council (CoSSAC) continued its successful Monday night snacks and the two-year old Under-Represented Identities in Computer Science (UnICS) group continued to expanded its programming by organizing popular dinners with faculty.

Class of 1960's Scholars in Computer Science

Derrick Bonafilia '17

Alexander Majercik '17

Melanie Subbiah '17

Jose Rivas-Garcia '17

Russell Jones '17

Matheus Cruz Correia de Carvalho Souza '18

Nicholas Post '18

Time Randolph '18

Brianna Rettig '18

This year Professor **Jeannie Albrecht** continued to investigate techniques for using computing to decrease the energy impact of society. She primarily focused on challenges related to the Class of 1966 Environmental Center on campus. The 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. In May 2017, Albrecht attended the Living Future un-Conference in Seattle, where the building officially received Petal certification by the Living Future Institute, indicating that 6 out of 7 requirements had been met. The remaining unmet requirement is net zero energy usage. 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. 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 continued working with several students, including *Dawn Wu '18, Anjali Pai '19, Katherine Blake '19,* and *Jack Ferguson '18*, on a system for monitoring and visualizing energy usage in the Environmental Center, focusing specifically on the kitchen. They developed several prototype visualizations that display both power and energy usage for kitchen appliances in an intuitive and aesthetically pleasing way. They conducted preliminary 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 *Jack Ferguson '18* and *Lylia Li '18*, and hopefully publish the results.

In addition, Albrecht supervised nine students who were awarded a grant from Google as part of their igniteCS initiative. The program "provides funding and resources for groups of college and university students to make a difference in their local communities through CS mentorship." The students designed a 6-week programming course for students at Mt. Greylock Regional High School. The program was very well received, and the students plan to expand the program next year.

Professor **Duane Bailey** continued a number of collaborations this year. During July of 2016 he began de-

sign, with prominent local stained glass artist, Debora Coombs, of a series of a half dozen paper sculptures of aperiodic tilings. Each colors the same structure in a way that celebrates theoretical work of different honors students he has collaborated with over two decades. The project, called a.periodic, is due to be completed in the next year.

Bailey also developed, with the aid of several students of his introductory class, an application that allows visitors to WCMA's Accession Number exhibit to design and arrange their own gallery space. The software gives viewers the chance to explore and display hundreds of objects from the museum's collection based on metadata queries. The exhibit is on display into the fall. This spring students of his Python-based course developed algorithms that scour images of 9,500 works to find those colored pink. The results of a half dozen approaches will appear in an exhibit opening this fall. That effort is an inaugural collaboration exploring open digital collections sponsored by a grant from the Mellon Foundation.

Professor **Andrea Danyluk** was back in the classroom this year after a productive sabbatical. She was excited to teach courses at both the introductory and advanced levels. Danyluk continued her research in machine learning. She supervised the honors thesis work of *Melanie Subbiah '17*, who worked to develop a model for open narrative generation. The goal of this research area, which is at the intersection of natural language processing and machine learning, is to develop algorithms by which computers can generate original, interesting, and coherent stories. Also at the intersection of machine learning and art was the thesis of *Lauren Yu '16*, in which she applied machine learning to induce models of expressivity for violin and viola. This year Danyluk and Yu wrote a paper based on the research, which was published in April. Yu presented it at the International Conference on Computational Intelligence in Music, Sound, Art, and Design, where the work was recognized as a "Best Paper" nominee. Danyluk also supervised an independent study. In their research-focused project, *Derrick Bonafilia '17* and *Russell (Kenny) Jones '17* developed Generative Adversarial Networks, a deep learning technique, to create visual art of a desired genre. This summer Danyluk continues her work in applied machine learning, this time with a focus on ecology.

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 run undergraduate research mentoring programs at various events. She also speaks at mentoring programs for graduate students, early- and mid-career researchers.

Professor **Stephen Freund** continues to explore ways to help programmers write more reliable and efficient multithreaded software designed to run, for example, on multicore processors. This work involves not only developing defect detection tools but also exploring scalability-oriented optimizations that enable programmers to more easily design safe and efficient code for computers with many processing cores.

Last summer, Freund worked with two students, *Miranda Chaiken '19* and *Matheus Cruz Correia de Carvalho Souza '18*. Miranda implemented an adaptive lock mechanism for protecting share resources in a concurrent program that would tailor its underlying implementation to the particular workload observed as a program runs. Matheus developed a new way to compress the information a dynamic data race detector gathers as a program runs. He also served on the External Program Committee for the 2017 ACM Conference on Programming Language Design and Implementation. Freund also chaired the Committee on Priorities and Resources this past year. This advisory committee, which includes faculty, students, and staff, works with the administration to ensure the College makes informed, principled, and effective financial decisions.

In the fall, Freund taught *Introduction to Computer Science* (CSCI 134) with Andrea Danyluk, followed by a course on programming languages in the spring. He is now beginning a year of sabbatical during which he will continue his research in collaboration with his colleagues at UC Santa Cruz and University of Massachusetts, Amherst.

Professor **Brent Heeringa** chaired the Department of Computer Science for his third and final year. In the fall, he taught *Diving into the Deluge of Data* (CSCI 135) with *Bill Jannen '09* and in the spring he taught *Algorithm Design and Analysis* (CSCI 256). Algorithm Design had an enrollment of 46 students, a record number for the course!

Heeringa continued his collaboration with Nate Kornell (Psychology) on recognition codes, which transform arbitrary pieces of information into representations that are human-friendly. The pair are hoping to publish this work soon.

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 defined as one

that is never more than one-third smaller than optimal.

In September, Heeringa attended the Tapia Celebration in Computing Conference in Austin, TX. He was accompanied by students *Jose Rivas-Garcia '17* and *Matheus Cruz Correia de Carvalho Souza '18*. In January, Heeringa filmed a segment highlighting computer science in the liberal arts for the South Korean national television network. 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.

Assistant Professor **Bill Jannen** uses modern data structures, in particular write-optimized dictionaries, to improve storage software. He is a member of the team developing BetrFS, an in-kernel Linux file system that performs random writes, metadata operations, and directory scans orders-of-magnitude faster than conventional file systems. In addition to contributing new techniques that improve the performance of write-optimized file systems, his team has studied file system aging, the degeneration of file system performance over time.

Taking advantage of a Spring semester sabbatical, Professor **Bill Lenhart** continued pursuing his interests in graph drawing and computational geometry, focusing mainly on problems involving the drawing of graphs and geometric objects in two and three dimensions, subject to various constraints. Bill spent his sabbatical as a Visiting Scholar with the Department of Computer Science at the University of New Brunswick, Saint John, NB. During this time, he was also an invited participant at the 2017 McGill-Univerity of Victoria-INRIA Workshop on Geometry and its Applications at the Bellaires Research Institute of McGill University in Barbados. He also spent time working with colleagues at the Università degli Studi di Perugia.

The paper *On Partitioning the Edges of 1-Planar Graphs,* with co-authors Giuseppe Liotta and Fabrizio Montecchiani (Università degli Studi di Perugia) submitted last year, appeared in the Feburary 2017 issue of the journal *Theoretical Computer Science.* In this paper we demonstrate 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.

Other projects begun last year continue to move forward. In work with co-authors Sylvain Lazard of *INRIA* (France) and Giuseppe Liotta, we establish tight bounds on the planar edge-length ratio of outerplanar graphs. This work is summarized in the paper *On the Edge-length Ratio of Outerplanar Graphs,* which we plan to submit to the conference *Graph Drawing 2017*.

Another ongoing project considers the question of simultaneous embeddings of multiple graphs. In the paper *Mixed Simultaneous Geometric Embeddings of Planar Graphs and ULPs,* joint work with David Bremner (University of New Brunswick, Canada), Giuseppe Liotta, Vera Sacristán (Universitat Politècnica de Catalunya, Spain), and Steve Wismath (University of Lethbridge, Canada), we show that a planar graph can be embedded as a bar visibility graph in such a way that any unlabeled level planar (ULP) graph can be simultaneously embedded using the same vertex locations.

Associate Professor **Morgan McGuire** advised the theses of *Jamie Lesser '17* on Monte Carlo methods for computer graphics and *Zander Majercik '17* on version control systems for software engineering. He attended SIGGRAPH '16, High Performance Graphics '16 (HPG), Interactive 3D Graphics and Games '17 (I3D), the Game Developers Conference '17, and the GPU Technology Conference '17, receiving the best presentation award at I3D for his research with *Michael Mara '12* on light field probes for photorealistic lighting in real-time computer graphics. On campus, he co-taught the new interdisciplinary course *Film and Media Studies: An Introduction* (COMP 258). He will be spending his sabbatical next year at the University of Waterloo, McGill University, and NVIDIA Research working on virtual and augmented reality, and serving as the co-chair of HPG'17, I3D'18, and I3D'19 conferences.

Professor **Tom Murtagh** continues to investigate file system designs that are more compatible with the performance characteristics of NAND memory devices. Manufacturers have packaged NAND memory with interfaces that imitate disk drives so that NAND memory devices can be used in place of disks without any change in system software. This approach works, but it cannot work well. Because the software is fooled into viewing the NAND memory as a disk, it makes data placement decisions optimized for disk device rather than NAND memory. Tom has developed an approach that extends techniques used in log structured file systems to organize the data and metadata of a file system more efficiently on a NAND memory. By having the system maintain multiple logs simultaneously. Such an organization promises to reduce both the overhead associated with space reclamation and metadata updates within the file system. This summer, Tom will be working with *Quan Do '19* and Qianwen Zheng '20 to complete an experimental implementation of such a file system and evaluate its performance.

Visiting Assistant Professor **Jon Park** is currently focusing on automated extraction of arguments from on-

line user comments leveraging machine learning/natural language processing techniques. Identifying claims and respective support in unstructured text has many applications including automated evaluation of argumentative structures and generating summaries. For this task, Jon has incorporated deep learning and graph theory to identify global argumentative structures in online user comments, as opposed to a pair-wise classification of propositions in claim-premise relation. Jon has worked with *Dietrich Hartman '20* to prepare for a user study on the automated evaluation by the system.

Post-Graduate Plans of Computer Science Majors

Amelia Archer	Engineering resident, Google, Mountain View, CA
Paul Baird-Smith	Masters in Computer Science, UT Austin
Derrick Bonafilia	Undecided
Yuanchu Dang	Quantitative strategist, Goldman Sachs Securities, New York, NY
Scott Daniel	Freelance Violinist
Ross Flieger-Allison	Undecided
John Freenam	Undecided
Nola Gordon	Amazon, Boston, MA
Victoria Jasuta	Undecided
Russell K. Jones	Software Engineer, Facebook, Menlo Park, CA
Erik Kessler	Undecided
Hiroshi Kirby	Consultant, Galatea Associates, Raleigh, NC
Paul Lindseth	Undecided
Alexander Majercik	Research Intern, NVIDIA, Santa Clara, CA
Riley Peek	Undecided
Jose Rivas-Garcia	Software Engineer, Capital One, Plano, TX
Benjamin Solis-Cohen	Software Engineer, Google, Mountain View, CA
Melanie Subbiah	Software Engineer, Apple, Cupertino, CA
Mairead Toms	Undecided
Yitong Tseo	Software Engineer, Facebook, Menlo Park, Ca
Anthoney Tsou	Asset Management Analyst, J.P. Morgan, New York, NY
Jacob Watt-Morse	Program Associate, Start:ME Accelerator Program, Atlanta, GA
Miller (Zijie) Zhu	Equities Analyst, Goldman Sachs, New York, NY

2017 Computer Science thesis students and their faculty advisors.

Computer Science Colloquia

Sara Mathieson, Smith College
"Deep Learning for Population Genetic Inference", October 2016

Stephanie Taylor, Colby College
"Computational Models Are Critical to Understanding Circadian Clock Networks", November 2016

Kevin Walsh, College of the Holy Cross
"Web Security: Fundamentally Broken, or Merely Outdated?", November 2016

Martin Farach-Colton, Rutgers
"Ubiquitous Write Optimization", December 2016

Jelani Nelson, Harvard
"Heavy Hitters via Cluster-Preserving Clustering", February 2017

Kevin Webb, Swarthmore College
"Outsourcing Complexity to the Cloud", March 2017

Nick Webb, Union College
"Social Robotics: How to approach people to ask for help (if my wheels worked)", April 2017

Sam Blackshear '10, Facebook
"Moving Fast With Static Program Analysis", April 2017

Joel Sommers, Colgate University
"Internet Research Needs Better Simulation Tools", April 2017

Hany Farid, Dartmouth
"Photo Forensics", May 2017

Off-Campus Computer Science Colloquia

Jeannie Albrecht
"Creating Information and Action for Building Data"
Living Future unConference, Seattle, WA, May 2017

"Sensor Driven Energy Management for Smart Buildings"
Smith College, Northampton, MA, January 2017

"Living Building Challenge"
Teach It Forward Campaign Launch Event, Washington, D.C., April 2016

"Scientific Leadership for the Century Ahead: Launching Division III Majors onto Post-Graduate Career Paths"
Teach It Forward Campaign Launch Event, San Francisco, CA, February 2016

Andrea Danyluk
"Machine Learning in the Arts, Sciences, and Social Sciences"
MinneWIC 2017, Minneapolis, MN, February 2017

"Research/Funding Strategies for Faculty"
Grace Hopper Celebration of Women in Computing Conference, Houston, TX, October 2016

Morgan McGuire
"The Virtual Frontier: Computer Graphics Challenges in Virtual Reality"
GPU Technology Conference, May 9, 2017
Real-time Global Illumination using Precomputed Light Field Probes
I3D'17, San Francisco, Feb 25, 2017

"Peering Through a Glass, Darkly at the Future of Real-Time Transparency"
Invited talk at SIGGRAPH 2016, Los Angeles, July 26, 2016

"CS + X: Cross-campus Collaborations"
Invited panel at SIGGRAPH 2016, Los Angeles, July 24

"Deep G-Buffers for Stable Global Illumination Approximation"
HPG'16, Dublin Ireland, June 24, 2016

"Irradiance & Light Field Probes with Visibility"
Game Developers Conference, March 2, 2017

"Virtual Reality"
WAMC / Albany National Public Radio member, December 29, 2016

"Phenomenological Transparency"
Dartmouth College, October 5, 2016
University of Pennsylvania, November 30, 2016

Steve Freund

"Data Race Detection: FastTrack and Beyond"
University of Massachusetts, Amherst, MA, April, 2017

Bill Lenhart

"Colorful Point-Set Embeddings of Trees"
Computer Science Seminar, University of New Brunswick, March 2017

Melanie Subbiah, '17, Jamie Lesser '17, Emily Hoyt '17, Julia Goldman '18, Stephanie Liu '18, Miranda Chaiken '19 and *Anjali Pai '19* along with Professors Andrea Danyluk and Jeannie Albrecht at the Grace Hopper Celebration of Women in Computing conference in Houston, TX

Geosciences Department

2017 marks the 200th year of teaching geoscience at Williams. In 1817, Amos Eaton (himself a Williams alum) began teaching mineralogy and geology, and thus began our long history. To mark the Bicentennial, Bud Wobus and David Dethier have organised a two-day event that will bring about fifty alumni back to campus in June. The schedule includes talks, discussions, meals, and—of course—field trips.

We added a new department member this year: José Constantine, formerly on the faculty at Cardiff University in Wales (but originally from the U.S., with a PhD from U.C. Santa Barbara) moved with his family to Williamstown last summer and began teaching in Fall of 2016. José is a fluvial geomorphologist. David Dethier, into whose position José is moving, has transitioned to half-time, and will retire in June 2018. The two-year overlap allows José to learn the ropes from David, who has decades of local geomorphological knowledge to pass on.

We had a number of students attending national conferences this year. In September the Geological Survey of America held its annual meeting in Denver, Colorado, and *Kyrien Edwards '17, Abigail Kelly '16*, *Martin Keenan '17, Ezekiel King Phillips '18, Krystina Lincoln '17, Matthew Marcarelli '17, Timothy Nagle-McNaughton '18, Christina Seeger '16, Maoli Vizcaino '17,* and *Noah Williams '17* all attended. Poster presentations were given at the meeting by Martin, Matt, Tim, Maoli, and Noah. Krystina and Abigail gave talks at the conference. Christina also attended the 48th Annual Lunar and Planetary Science Conference In Houston, Texas, March 20-24. Maoli also attended the Northeastern Geobiology meeting in March where she presented on her thesis research. *Joshua Harrington '16* gave a poster presentation at the AGU meeting in San Francisco in December.

Timothy Nagle-McNaughton '18 was awarded the Lauren Interess Fellowship and spent Winter Study 2017 conducting a study in Death Valley on "Dust to Dust: Exploring Geologic Changes in America's Hottest and Driest National Park."

This year we had six senior thesis students who gave presentations of their work on Monday, May 15, at the annual Senior Thesis Day (see section on Geosciences Student Colloquia for titles of their presentations). *Jordan Fields '17* was awarded the Freeman Foote Prize for best presentation of a senior honors thesis and *Miaoru Guan '17* and *Krystina Lincoln '17* were both given the David Major Prize for outstanding Geosciences senior for their invaluable contribution to the Geosciences Department. *Matthew Marcarell '17* 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. *Caroline White-Nockleby '17* was named the first Ellen Toll Intern, from the Ellen Toll (Geos '77) Memorial Fund at Williams, established to support projects in the "general area of environmental studies with preference related to land use." Caroline studied urban planning at Berlin Technical University. We ended this academic year with *Jeffrey Rubel '17* being named Class Speaker for graduation and *Caroline White-Nockleby '17* named Valedictorian, as well as receiving a Fulbright award.

We continue to have a spirited and enthusiastic student community. The Geosciences Student Advisory Committee (GSAC), established this year, organised a number of events including screenings of geos-themed movies, periodic "teacher features" showcasing individual faculty members, and departmental gatherings of various sorts. We will miss the fifteen seniors who graduate this year, who were a fun and accomplished bunch. They leave a legacy of energy and good ideas to the twelve rising seniors and thirteen new junior majors coming up behind them.

Class of 1960 Scholars in Geosciences

Henry Barker	Anna Leonard
Ellen Coombe	Krystina Lincoln
William Downs	Erikka Olson
Miaoru Guan	Gemma Porras Nielsen
Chen-Yi Hung	Jordan Sadowsky
Martin Keenan	Ang Sherpa
Ezekiel King Phillips	Maoli Vizcaino
Sasha Langesfeld	Caroline White-Nockleby

Alex Apotsos continued to lecture part-time in the Geoscience Department at Williams College as well as serve as a part-time Climate Change Advisor at the U.S. Agency for International Development. During the Spring Term at Williams, Alex took his GEOS 258 *Coastal Processes and Geomorphology* class down to the U.S. Army Corps of Engineers Field Research Facility in Duck, North Carolina for a week over Spring Break. This trip, sponsored by the Freeman Foote Field

Trip Fund, allowed the students in Coastal Processes to take part in actual coastal oceanographic research. The students collected data using more than 8 different field collection methods, and then prepared short presentations on the results of their data collection. Next year, Alex will travel to Cape Town, South Africa where he will complete an 11 month Fulbright Research grant. During his time in Cape Town, Alex will work with scientists at the University of Cape Town and local decision-makers to create a better understanding of the vulnerability of coastal urban areas to climate change, especially sea level rise. As part of his work for USAID, Alex continued to work to ensure that USAID's development investments in Sub-Saharan Africa address the impacts of climate change, especially related to rain-fed agriculture.

Assistant Professor **Phoebe Cohen** spent the summer of 2016 doing lab work with Williams students. Thesis student and Allison Davis Fellow *Maoli Vizcaino '17* spent the summer working on her project on organic walled fossils from the Cryogenian of Mongolia, examining fossils under the Williams scanning electron microscope and trying to better understand these enigmatic fossil forms. *Brian Coakley '18* spent the summer working on a new project to try to find evidence of biomineralized fossils from ~800 million year old rocks collected by collaborator David Jones (Amherst College) from Victoria Island, Canada. *Ezekiel King-Phillips '18* spent his summer as a Mellon Mayes Fellow in Cohen's lab working on evidence of the late Devonian mass extinction event. In the fall, Phoebe took Maoli to the Geological Society of America meeting in Denver, CO, where she presented a poster on her thesis research; *Abby Kelly '16* also returned to the meeting to give a talk on her thesis research on the late Devonian mass extinction.

In the fall, Phoebe taught *Co-evolution of Earth and Life* (GEOS 101) and one of the two departmental senior seminars, *Geobiology* (GEOS 411). A highlight of the fall was the *Geobiology* field trip, where students braved freezing rain to row out into Green Lake in Upstate New York and sample low-oxygen water that contains unique bacteria and a chemical composition similar to oceans from hundreds of millions of years ago. In the spring, Phoebe taught *Paleobiology* (GEOS 212 / BIOL 211), where students also had a fun but wet field trip learning about and collecting fossils in Upstate New York.

Phoebe's lab was busy during the school year as well with *Maoli Vizcaino '17* working on her thesis project, *Ezekiel King-Phillips '18* working on his Mellon Mayes research, and new students *Sara Shamenek '20* and *Jared Bathen '20* joining the lab this spring. Phoebe and Maoli attended the Northeastern Geobiology meeting in March, where Maoli presented on her thesis research.

This year, Phoebe served as a manuscript reviewer for *Precambrian Research*, *Geobiology*, and *Geosciences*. She also reviewed educational grants for the Paleontological Society, and was elected to a three-year term to the Paleobiology Database executive committee.

Assistant Professor **José Constantine** finished his first year at Williams, having arrived during the summer of 2016. Prior to his arrival, he was a Lecturer at Cardiff University in the UK and an Invited Professor at the École Normale Supérieure de Lyon in France. With *Daniel Donahue '19* and *Samuel Gowen '18*, José spent part of his first year developing a new study that is unravelling the environmental history of the local Hoosic River, research that will inform restoration efforts being planned for the river. The research stems from his interest in anthropogenic impacts on river systems, which resulted in a publication in the journal *Geology* during his first year. Entitled "Modification of river meandering by tropical deforestation," the work was highlighted by the journal *Nature Geoscience*. José was invited to present the findings of this work at the University of Pennsylvania and Indiana University. José also presented his research on the evolution of floodplain lakes at the annual meeting of the Geological Society of America (September 2016) and on the effects of climate change on soil erosion at the annual meeting of the American Geophysical Union (December 2016). With Geosciences colleague and collaborator, Rónadh Cox, he organized an international keynote symposium to be held at the upcoming annual meeting of the Geological Society of America (October 2017) entitled "Landscapes in the Anthropocene." The symposium will highlight environmental research challenges we face in preparation of intensifying climate and land-use change.

During the summer, José will continue his work on the Hoosic River with *Daniel Donahue '19*, developing the first geographic database of environmental change for the river system. Working with *Emmett Blau '18*, José will be undertaking a sediment coring expedition along the nearby Housatonic River, assessing the importance of floodplain lakes in sequestering harmful pollutants. Thesis student *Andrew Bloniarz '18* will be developing a new study to understand the environmental impacts of historical land-cover clearance on the Mississippi River. Both Emmett and Andrew will be accompanying José to the International Conference on Fluvial Sedimentology in Calgary (July 2017), where José was invited to discuss his work on anthropogenic impacts on river systems. The conference will also involve a field trip to

assess the consequences of extreme floods on the Saskatchewan River. José was invited to participate in an NSF Early Careers Geoscience workshop (July 2017), where he will begin planning the submission on an NSF grant to study the controls on the evolution of meandering rivers in the Amazon Basin.

Three research assistants worked on projects in Associate Professor **Mea Cook's** lab studying the influence of Pacific Ocean circulation on climate changes during ice age cycles. *Anna Black '19* studied how changes in ocean oxygen concentrations are recorded in the texture of deep-sea sediments. She developed a protocol for categorizing sediment texture using digital images of sediment cores, and applied it to a site in the northern Bering Sea in sediments that span the last glacial maximum to the present, around 20,000 years. *Wendy Hernandez '20* and *Will Downs '19* collected microfossils from a sediment core from the southeast Bering Sea which they will analyze for oxygen and carbon stable isotopes. These data will show how the density and nutrient structure of the water column evolved through rapid climate changes that occurred during the last 20,000 years. This project is funded by the National Science Foundation. Cook reviewed a proposal for the Marine Geology and Geophysics Program of the National Science Foundation and a manuscript for the journal *Science of the Total Environment*. She is a member of the American Geophysical Union, the National Association of Geoscience Teachers, and the Earth Science Women's Network.

Professor **Rónadh Cox** continues as department chair, and serves on the Editorial Board for the Geological Society of America's journal *Geology*, and is also a member of the society's Publications and Ethics Advisory Committee. Her research continues to focus on coastal boulder deposits. As PI of an international collaborative research program, Rónadh co-ordinates with researchers in Ireland and Northern Ireland to model the mechanisms by which storm waves move large boulders in steep nearshore environments. *Tim Nagle-McNaughton '17* and *Jacob Cytrynbaum '17* will carry out thesis research as part of this project. Tim will use UAV photogrammetry to quantify changes in coastal boulder deposits over time, and Jacob will conduct wave-tank experiments in which he will model wave amplification over steep bathymetry. In a new collaboration with Prof. Kasuhisa Goto at Tohouku University. *Kyrien Edwards '17* also did wave-tank experiments for the thesis that he completed this spring, but his project involved tsunami rather than storm waves. Tim presented initial results at last fall's GSA annual meeting, and both Kyrien and Jacob will present at this year's meeting in October in Seattle. Rónadh also works on planetary science questions, and at the Lunar and Planetary Science conference this Spring, she and student *Christina Seeger'16* presented the results of Christina's thesis work, investigating the geomorphology of mountains on Io. In addition, Rónadh presented new work, in collaboration with Marty Gilmore from Wesleyan, looking at similarities between gullies on Mars and in Madagascar.

Professor **David Dethier** continued his research with students from Williams College, focusing mainly on the measurement of hydrologic and geochemical processes on Niwot Ridge in the Colorado Front Range. Dethier worked there in May and July, 2016 with *Jordan Fields '17* and in July with *Noah Williams '17* on projects that focused on the chemistry of springs and on infiltration and groundwater flow. In cooperation with *Will Ouimet '01* (University of Connecticut) and colleagues from Germany, Dethier worked on a project that emphasizes the long-term geomorphic and geochemical impacts of charcoal production in northwestern Connecticut. Dethier, Ouimet and Jim Kaste (College of William and Mary) continued their investigations of Front Range erosion rates and the effects of wildfire on 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 other nearby areas and their analysis in the Environmental Science Lab in the Morley Science Center (https://www.wunderground.com/personal-weather-station/dashboard?ID=KMAWILLI14). 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.

Associate Professor **Lisa Gilbert** and *Miranda Bona '13* continued to collaborate on Miranda's thesis work and published an article together on the permeability of rock samples drilled from deep sea. Gilbert has continued working on water flow through rocks with student research assistants *Muriel Leung* and *Nicholas Mitch* (both Williams-Mystic Spring 2017). This summer she is advising four research students working in her marine geosciences laboratory on a range of topics from the deep sea to coastal marshes: *Caroline Hung '19*, *Meghan Suslovic* (Williams-Mystic Fall 2016), *Emma McCauley* (Williams-Mystic Spring 2017), and *Jason Swartz* (Williams-Mystic Spring 2017).

As part of her work with the NSF-funded InTeGrate project, which focuses on improving sustainability education across the nation, she published a module of undergraduate teaching materials entitled "Systems Thinking" with co-authors from Carleton College and the University of Maine. Gilbert also led several professional development programs for geoscience faculty and future faculty. In July 2016, at the Earth Educators' Rendezvous in Madison, WI, she co-convened a 3-day workshop for about 50 graduate students and post-doctoral researchers on Preparing for an Academic Career in Geosciences. She was an invited speaker at the Pushing Boundaries in Marine Science Symposium in Woods Hole, MA. She led several other workshops and webinars on topics ranging from interdisciplinary teaching to fostering systems thinking.

Emeritus Professor **Markes Johnson** attended the "Thirteenth International Workshop on Palaeontology in Atlantic Islands" at Ville de Port on Santa Maria Island in the Azores, July 10-16, 2016, where fieldwork on Pliocene sedimentary strata including hurricane deposits was continued from the previous year. Following the workshop, he traveled to Terceira Island (also in the Azores) to attend the Second International Conference on Island Evolution, Ecology, and Conservation, where he presented a paper on the Neogene history of barnacle dispersal in the North Atlantic Ocean. Due to his research connections, Prof. Johnson was named as one of three advisors in the post-doc program of Dr. Cristina Rebelo through the Portuguese Agency for Science, Research and Technology in co-operation with the Institute of Hydrography under the Portuguese Navy's Division of Marine Geology. He will serve a three-year term as advisor, staring in 2017. During the Fall Term 2017, related projects on the Pliocene Warm Period in connection with major storm patterns in Baja California (Mexico) and the Azores were completed with successful submissions to the journals *Facies* and *Marine Geology*. During the 2017 Spring Term, Johnson made two research trips to Baja California that also involved giving several public lectures in Todos Santos and Loreto on themes related to the Gulf of California. In co-operation with researchers at the University of Vienna, field and laboratory results regarding highly diverse microbes from the closed lagoon at Volcan Prieto in Baja California have been summarized and submitted for publication. Together with Research Scientist Gudveig Baarli and Anne Skinner (Chemistry Department), Markes attended the April 22 (Earth Day) March for Science in Boston.

Professor **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 continued a research project investigating the stratigraphy of a Silurian and Devonian basin in Vermont and Massachusetts. This project uses U-Pb dating of single detrital zircon grains to constrain the depositional age and the source of sedimentary rocks in the basin, and precise U-Pb dates of airfall tephras from volcanic eruptions to provide important benchmark ages within the basin. *Laura Stamp '16*, *Didier Jean-Michel '17*, and *Henry Barker '18* are student collaborators on this project.

In August of 2016, Karabinos helped organize and attended the fourth biennial Structural Geology and Tectonics Forum at Sonoma State in Reichert Park, California where he gave a presentation entitled: "3D Models and Animations for Teaching Structural Geology and Tectonics." In september he attended the national meeting of the Geological Society of America in Denver, Colorado where he gave a presentation titled "Tectonic Exhumation of Mid-crustal Rocks Recorded by Textural Unconformities in Garnet from the New England Appalachians."

Karabinos published four articles in the *International Journal of Digital Earth*, *GSA Today, and the American Journal of Science*. He also published a chapter in a Geological Society of America Memoir on "*Linkages in Orogenic Systems*."

At the annual meeting of the Geological Society of America in Denver in September, Professor **Bud Wobus** received the Neil Miner Award from the National Association of Geoscience Teachers. The award, the highest presented to established college teachers by the NAGT, recognizes "exceptional contributions to the stimulation of interest in the earth sciences." Presenting the award was *Cathy Manduca '80*, Executive Director of NAGT and a former student of Bud's. A half dozen Williams geosciences alumni and current students attended the awards luncheon. While at the meeting Bud again orchestrated the reunion of some 35-40 alumni at the department's favorite Denver venue, WynKoop Brewery. (He also was organizer for the alumni reunion at the meeting of the America Geophysical Union in San Francisco in December.)

Both of his current thesis students made presentations at GSA based on their research the previous year in

New Zealand with the Frontiers Abroad program. For his thesis, *Matt Marcarelli '17* studied the geochemistry and tectonic setting of a group of previously unstudied 1.4-billion-year granite plutons in the Colorado Front Range, beginning with field work last August. *Krystina Lincoln '17* was part of a 6-member Keck Geology Consortium research team that studied the erosion of volcanic rootless cones in Iceland for a month last summer. Her thesis work continued at Williams as a GIS-based project to try to establish the discharge of a phenomenal glacial outburst flood in 2015, based on its effect on the cones in its floodplain. She presented her results at the 30th annual Keck Geology Symposium at Wesleyan in April.

In November Krystina and Matt joined Bud in hosting a program about the granite of the Clark Art Institute campus building in conjunction with the re-opening of the Manton Research Center. The half-day program included viewing the granite in thin section through petrographic microscopes as well as "tours" of the building walls.

During Winter Study, *Martin Keenan '17* joined Bud in preparing an exhibition of works from the Williams archives by the 19th Century "Founding Fathers" of geology at Williams in the Schow Special Collections Gallery in Sawyer Library. The exhibition commemorates the bicentennial of the teaching of geology at the college by Amos Eaton in 1817 and will be open through the coming summer. To celebrate that bicentennial, Bud, David Dethier, and Pat Acosta have organized a reunion of Geosciences alumni at the end of Reunion Weekend in June. The 3-day event will include faculty talks about Williams' early geologists and the trajectory of the department since then along with an alumni panel considering future challenges of preparing geoscientists as undergraduates. There will also be field trips, hikes, a barbecue, and a banquet for the 50+ participants expected.

Wobus continues to lead annual trips for Williams alumni, to Switzerland in summer 2016 and back to Colorado (for the 24th time) in July 2017.

Post-Graduate Plans of Geosciences Majors

Kyrien Edwards	GIS work at Williams for summer; undecided after that
Jordan Fields	Undecided
Miaoru Guan	Project Finance Analyst, Safari Energy, NYC
Didier Jean-Michel	Undecided
Martin Keenan	Economic consulting at Matrix Economics, Boston
Sasha Langesfeld	FoodCorps, Oregon for one year
Krystina Lincoln	OET Seafloor Mapping Intern, deckhand educator aboard schooners A.J.Meerwald and Roseway (AmeriCorp volunteer)
Matthew Marcarelli	Associate Consultant, Cross Sector Consulting, Hamden, CT
Gemma Porras Nielsen	Undecided
Sarah Ritzmann	Sustainable Writing Summer Intern at Zilkha Center
Michael Rodriguez	Williams Office of Student Life Intern
Jeffrey Rubel	Associate Consultant at Bain and Company
Maoli Vizcaino	Undecided
Caroline White-Nockleby	Environmental education field; 2018 Fulbright Research Award in northern Chile to study causes and consequences of water scarcity and water-related tensions
Noah Williams	Undecided

Geosciences Student Colloquia

Kyrien Edwards ‘17
“Waves in Japan: An Investigation into Tsunami Boulder Deposits”

Jordan Fields ‘17
“From on High: Geochemistry of Alpine Springs, Niwot Ridge, Colorado Front Range”

Krystina Lincoln ‘17
“Reconstructing Jökulhlaup Discharge Using the Morphology of Eroded Volcanic Rootless Cones”

Matthew Marcarelli ‘17
“A Reconnaissance Study and Interpretation of Enigmatic ca. 1.4 Ga Plutons in the Southern Front Range, Colorado”

Maoli Vizcaino ‘17
“Reinterpretation of Putative Tintinnid Lorica Fossils from the Trsagaan Olom Group, Mongolia”

Noah Williams ‘17
“Infiltration Variability and Shallow Groundwater Response to Snowmelt in Headwater Catchments, Niwot Ridge, Colorado”

Geosciences Colloquia

Lisa Gilbert, Williams Mystic
Elizabeth Kolbert’s The Sixth Extinction: An Unnatural History panelist, September 2016

Peter Huybers, Harvard University
“Climate, Crops, and Consequences”, October 2016

Alex Sessions ’91, California Institute of Technology
“The Role of Sulfur in Organic Carbon Burial”, November 2016

William D. Leavitt, Dartmouth College
“From Single Enzymes to Ancient Oceans: Sulfur Isotopic Fractionation During Microbial Sulfate Reduction”, November 2016

Michèle LaVigne, Bowdoin College
“Investigating Coastal Acidification in Maine’s Intertidal Ecosystem: Connecting Undergraduate Research with Citizen Science”, March 2017

Jacquelyn Gill, University of Maine
“The Past is Not Dead: How the Last 2.5 Million Years of Global Change Can Prepare Us for the Next Century”, April 2017

Kira Lawrence, Lafayette College
“Back to the Future? Insights into Future Climate from Warm Climate Intervals of the Past”, April 2017

Off-Campus Geosciences Colloquia

Phoebe Cohen

"Life in the Neoproterozoic: Hard Parts, Hard Dates, and Hard Questions"
Syracuse University, February 2017
University of Wisconsin-Madison, March 2017
Dartmouth College, April 2017

"Biomineralization, Ocean Chemistry, and the Radiation of Eukaryotes: the View from Mount Slipper"
Agouron Project Workshop, Kingston, Ontario, May 2017

Mea Cook

"The Oceans in a Changing Climate"
Stockbridge Library, Museum and Archives, June 2017

Rónadh Cox

"Gullies, Erosion and Landscape Evolution in Madagascar: Trying to Tease Apart Natural and Anthropogenic Effects"
Yale University, Institute for Biosphereic Studies, September 2016

"Megagravel on the Move: Storm Waves, Boulder Transport, and the Erosion of Rocky Coasts"
Massachusetts Institute of Technology, October 2016
Notre Dame University, January 2017

"Geological Underpinnings of the Kalarama Region, Williamstown"
Williamstown Historical Society, May 2017

Lisa Gilbert

"What is a System?"
Earth Educators Rendezvous, Madison, WI, July 2016

"Interdisciplinary Teaching"
Earth Educators' Rendezvous, Boulder, CO, July 2016

"Teaching About Natural Hazards and Risks"
InTeGrate webinar, August 2016

"Navigating a Career in Marine Science"
Pushing Boundaries in Marine Science Symposium, Woods Hole Oceanographic Institution, September 2016

"Science on the Charles W. Morgan"
Mystic Seaport Museum, October 2016

"Firehoses and Other Recent Geologic Activity of Hawai'I"
Pine Point School, February 2017

"Fostering systems thinking"
InTeGrate webinar, March 2017

Markes Johnson

"Historical Over-wash Deposit of Large Rhodolilths on the North Shore of Maio (Cape Verde Islands)"
Thirteenth International Workshop on Palaeontology in Atlantic Islands, Ville de Port, Santa Maria Island, July 2016

"Transatlantic Dispersal of Coral-dwelling Barnacles Belonging to Ceratochoncha"
Second International Conference on Island Evolution, Ecology, and Conservation, University of the Azores at Angra do Heroismo (Terceira Island), July 2016

"Dynamics of Wind and Water Circulation in the Gulf of California"
Sierra School, Todos Santos, Baja California, Mexico, February 2017

"Imprint of the 1940 E.W. Scripps Expedition on Geology and Regional Tectonics"
Colorado State University (Todos Santos campus), Baja California Sur, Mexico, February 2017

"Reading the Rock Record of Changing Hurricane Activity in the Gulf of California"
Todos Santos Speaker Series, Baja California Sur, Mexico, February 2017

"To the Roof of Isla Monserrat: Climbing for Science in Baja California"
Loreto Explorers Club, Loreto, Baja California Sur, Mexico, March 2017

Paul Karabinos

"3D Models and Animations for Teaching Structural Geology and Tectonics"
Structural Geology and Tectonics Forum, Sonoma state in Reichert Park, California, August 2016

"Tectonic Exhumation of Mid-crustal Rocks Recorded by Textural Unconformities in Garnet from the New England Appalachians"
Geological Society of America National Meeting, Denver, Colorado, September 2016

Bud Wobus

"Geology of the 2.5 Billion Year Milbank Granite, South Dakota"
Clark Art Institute, November 2016

Geobiology (GEOS 411) students (Henry Barker '18, Miaoru Guan '17 and Caroline White-Nockleby '17) braving the freezing rain to collect water samples from Green Lake, NY

Mathematics and Statistics Department

This year 29 seniors graduated with a major in statistics and 71 graduated with a major in mathematics, making it a record-breaking year for both majors. We continue to see a large number of majors in the department with 79 rising seniors who have declared a math major and 17 rising seniors who have declared a statistics major. In summer 2017 we moved into Bascom House where we will be until we move into a newly constructed building in 2020.

We had three outstanding visiting professors who are leaving this year: *Diana Davis '07*, Alejandro Sarria, and Peyam Tabrizian. We hired two new mathematicians who will be joining us this fall: *Haydee Lindo '08*, a commutative algebraist who has been a Bolin Fellow in our department for the last two years, and Chad Topaz, an applied mathematician who has spent the last ten years on the faculty at Macalester College.

Four new assistant professors did a great job in their first year at Williams: Pamela Harris and *Ralph Morrison '10* in Math and Laurie Tupper and Daniel Turek in Stats. Leo Goldmakher was reappointed, Mihai Stoiciu has been promoted to full professor, and Lori Pedersen, who has been a visiting faculty member for several of the past few years, is now a regular faculty member in our department.

Professors Colin Adams, Julie Blackwood, Tom Garrity, Leo Goldmakher (spring), Brianna Heggeseth, and Cesar Silva (spring) were on leave in 2016-2017. Professors Dick De Veaux, Leo Goldmakher (fall), and Allison Pacelli (spring) will be on leave for 2017-2018.

We are very proud of the accomplishments of our majors: Rosenburg prize for outstanding senior: *David Burt '17*; Goldberg award for outstanding colloquium: *Connor Mulhall '17* for stats and *Molly Siebecker '17* for math; Wyskiel award for teaching: *Si Young Mah '17*; Morgan prize in applied math: *Anand Hemmady '17* and *Intekhab Hossain '17*; Kozelka award for outstanding student in statistics: *Hae-Min Jung '17*; Beaver prize for service to the department and math/stat community: *Nina Pande '17* and *Troy Sipprelle '17*; Benedict prize for outstanding sophomore: *Anya Michaelsen '19* (first prize) and *Anthony Simpson '19* (second prize); Witte problem solving prize: *Elijah Fromm '17*; Colloquium attendance prize: *David Burt '17* for math and *Dongheon Lee '17* for stat.

Seven of our seniors won Herchel Smith Fellowships: *Megumi Asada '17, Osama Brosh '17, David Burt '17, Nikolaus Howe '17, Alexander Kastner '17, Aaditya Sharma '17,* and *Vidya Venkatesh '17*. *Sarah Fleming '18* was runner-up for the national Alice T. Schafer award, given by the Association for Women in Mathematics. The Green Chicken contest, a problem-solving exam between Williams and Middlebury students was held at Williams in November. The Williams team successfully defended their title. The top three scorers for Williams were *Ian Banta '19, Elijah Fromm '17*, and *Abe Leite '20*. In December, twenty-seven Williams students took the notoriously difficult national Putnam exam. *Tuan Tran '18* placed in the top 200, *Elijah Fromm '17* and *Hunter Wieman '20* were in the top 500 and *Osama Brosh '17*, *Ian Banta '19, Matthew Davis '20, Canvas Li '19*, and *Alina Shubina '19* were in the top 1000.

Finally, we thank the members of our student advisory board, SMASAB, who did a great job this year: *David Burt '17, Nina Pande '17, Reidar Riveland '17, Troy Sipprelle '17, Stephanie Stacy '17, Sarah Fleming '18, Jay Habib '18, Kiran Kumar '18, Haley Lescinsky '18, Claudia Reyes '18, Zihan Ye '18, Anya Michaelsen '19, Aesha Siddiqui '19*, and *Anthony Simpson '19*.

In summer, 2016, Professor **Colin Adams** led a group of SMALL students who produced a paper on cusp densities of hyperbolic 3-manifolds. He co-organized the Knots in Hellas conference in Ancient Olympia, Greece, where he spoke and put on theater. He also co-organized and obtained funding for the UnKnot Conference at Denison University, where he and his students spoke (and put on theater). And he co-organized a special session on knots at MathFest in Columbus, OH.

Adams was on leave for the academic year 2016-17. He worked on various papers, and wrote a math novel entitled "Lost in the Math Museum: A Survival Story." He gave a variety of talks in various venues, some serious and some silly, but all with mathematical content. At the Joint Meetings in Atlanta in January, he put on theater and presented a mini-course on teaching applied topology. He continued to serve as the humor columnist for the expository math magazine the Mathematical Intelligencer.

Assistant Professor **Julie Blackwood** was on leave during the 2016-17 academic year. She had two papers accepted for publication (one of which included two student co-authors, *Alexander Meyer '16* and *David Stevens '14*) and submitted three manuscripts which are

currently under review (two of which have undergraduate co-authors).

Over the past year, Blackwood continued several ongoing projects in mathematical ecology including her work on spatial synchrony in periodical cicadas as well as disease transmission dynamics in several infectious diseases. Blackwood expanded her research on white-nose syndrome in little brown bats and participated in a related working group sponsored by the US Fish and Wildlife Service.

In addition, Blackwood developed several new projects over the course of this year. For example, Blackwood, along with other collaborators, received funding to be hosted by the National Institute for Mathematical and Biological Synthesis (NIMBioS) in the form of a working group, which will bring together 13 researchers from multiple fields (including mathematics, agricultural and resource economics, ecology, and computer science). The topic of the working group is "ecosystem federalism," in which the multi-disciplinary team will develop new mathematical and economic frameworks to optimally manage ecosystems that are both adaptive and account for multiple levels of government authority. The tools created by this work will be directly useful in her other ecological research.

Professor **Dick De Veaux** continued his work in data mining and writing textbooks and gave a variety of talks and workshops on teaching and data mining throughout the world. He served as Chair of the section on Statistical Learning and Data Science of the American Statistical Association. He also organized the Undergraduate Faculty Workgroup at the 2016 Park City Math Institute (PCMI), the result of which was a paper detailing curriculum guidelines for undergraduate data science programs.

Professor **Thomas Garrity** has continued his research in number theory. He has spent a delightful year in Paris on sabbatical at the Institut de Reserche en Informatique Fondamentale (IRIF) at l'Université Paris-Diderot (Paris 7). He is, though, looking forward to returning to Williams.

His paper: "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, has appeared in the Journal of Integer Sequences. With co-author *Ilya Amburg '14*, he put "Functional Analysis behind a Family of Multi-dimensional Continued Fractions: Triangle Partition Maps" on the math arxiv preprint server, and, with co-author *Peter McDonald '16*, he put "Generalizing the Minkowski Question Mark Function to a Family of Multi-dimensional Continued Fractions" on the math arXiv.

He has spoken at least twice at Paris-Diderot, at l'Université de Liège in Belgium, at the l'Institut Fourier in Grenoble, at a special session on continued fraction at the joint meeting of the AMS-MAA in Atlanta and to alums in London.

Assistant Professor **Leo Goldmakher** continued his research in number theory and additive combinatorics with a number of collaborators, including Williams student *Elijah Fromm '17*. He spent the Spring semester on sabbatical leave in Berkeley, where he participated in research programs on analytic number theory (at MSRI) and pseudorandomness (at the Simons Institute for the Theory of Computing). This was a productive time; in addition to starting a number of new research projects, he submitted one paper, is finishing up two more, and had two other papers accepted to journals. He spent a week at the (invitation-only) analytic number theory workshop at Oberwolfach, and also gave talks at the Williams faculty seminar and at the MSRI analytic number theory seminar. He was invited to give a number of research talks in the coming months, including at the Mathematical Congress of the Americas this July.

Assistant Professor **Pamela Harris** developed two new courses for the Mathematics and Statistics Department: *Representation Theory* (Math 456) and *Undergraduate Research Topics in Representation Theory* (Math 293). Professor Harris continued her work in algebraic combinatorics focusing on problems at the intersection of the representation theory of Lie algebras and combinatorics. Of note is her new article co-authored with Alexander Diaz-Lopez, Erik Insko and Mohammed Omar, which proves in the affirmative the Peak Polynomial Positivity Conjecture of Billey, Burdzy and Sagan posed in 2013. This article appeared in the Journal of Combinatorial Theory Series A, and was accepted as an extended abstract and oral presentation, by Professor Harris, at the Formal Power Series and Algebraic Combinatorics conference in London, England in July 2017.

Professor Harris was awarded six grants this year, two of which supported the research of 7 Williams students, one through the National Science Foundation and the other from the Center for Undergraduate Research in Mathematics. Harris presented 16 lectures, of which three were conference plenary/keynote addresses, one was a Distinguished Women in Math Lecture, and two talks were international invitations to present her research in Buenos Aires, Argentina and Toronto, Canada. In addition, Harris attended eight conferences and was invited to two working workshops one at the American

Institute for Mathematics in San Jose, California and the second at the Banff International Research Station in Banff, Canada.

Professor Harris is committed to fostering the success of underrepresented scientists and to improving diversity and retention rates among women and minorities in the mathematical sciences. To this end she is highly involved with the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) and organizes multiple scientific symposia and professional development sessions at the society's annual national conference. This year, in collaboration with Alexander Diaz-Lopez, Alicia Prieto-Langarica and Gabriel Sosa, Harris founded the website www.lathisms.org whose mission is to provide an accessible platform that features prominently the extent of the research and mentoring contributions of Latinas and Hispanics in different areas of the Mathematical Sciences. The American Mathematical Society used the information contained in their website and created a new poster featuring the 2016 mathematicians which has been distributed to high schools and colleges nationwide.

Assistant Professor **Brianna Heggeseth** transitioned from maternity leave to her research sabbatical to continue her methodology research in the area of longitudinal data analysis and establish new applied collaborations.

During her leave, she met colleagues at the Dartmouth Department of Epidemiology and Biostatistics and was added as a statistical consultant on a grant application. Additionally, she submitted a grant application to NIEHS/NIH to develop statistical methods for chemical mixtures with a set of interdisciplinary collaborators from the west coast.

In her methodology work, she finished a comparison of statistical methods for detecting the relationship between environmental exposures and non-linear childhood growth patterns and she submitted a manuscript for review. She presented this work at the ENAR Biometrics 2017 conference and the Joint Statistical Meetings 2017. Additionally, her work on centered longitudinal data was accepted for publication in the Annals of Applied Statistics. She continued work on developing a new correlation model for centered longitudinal data. She is preparing a new project to utilize tree-based methods to determine important factors that explain variation in growth patterns that she will work on with a summer student and then her thesis student.

With collaborators in Berkeley, CA, she started a new applied project studying the impact of phthalates on childhood growth and applied statistical techniques from the area of functional data analysis. At Williams, she acted as a statistical consultant and then collaborator on a project of implicit and explicit bias with a colleague in the psychology department.

She looks forward to returning to the rewarding work of teaching in the fall and working with her thesis student during the year.

Professor **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.

Professor Johnson appeared in NESN's Kid's Clubhouse, discussing his joint work with Prof. Frank Morgan and *Davide Carozza '09* on the science of base running.

Professor **Bernhard Klingenberg** conducted various consulting projects on and off campus, one of them leading to a paper in the journal Gynecologic Oncology on patient's acceptance of various side effects in treating ovarian cancer. Klingenberg also expanded and improved his website *ArtofStats.com* which now allows public access to over 20 web-apps for all sorts of basic statistical analysis in the cloud. In May, he presented these to a broader audience at the 2017 United States Conference on Teaching Statistics conference at Penn State University. Prof. Klingenberg continued to serve as an associate editor for the journal *Statistical Modelling*.

In July 2016, Professor **Susan Loepp** took over from Frank Morgan as chair of the Math/Stats department. In addition to her chair duties, she enjoyed teaching and her research in commutative algebra. In spring 2017, she taught *Protecting Information* (MATH 316) for the last time with Bill Wootters who is retiring from Williams. Loepp especially enjoyed meeting regularly with Cory Colbert and Haydee Lindo about their research in commutative algebra. Colbert and Lindo are both Gaius Charles Bolin Fellows in mathematics at Williams. Lindo and Loepp co-advised the senior honors thesis of *Nina Pande '17* and Loepp advised the senior honors thesis of *Sarah Fleming '18*.

In summer 2015, Loepp advised the Commutative Algebra research group as part of the department's SMALL program. The group included the three Williams students *Sarah Fleming '18*, *Peter McDonald '16*, and

Nina Pande '17. Two papers that include original results from SMALL 2015 have recently been accepted for publication, and both papers will appear in the *Journal of Commutative Algebra.*

In January, Loepp attended the Joint Mathematics Meetings in Atlanta where she gave a talk on the undergraduate research she has been advising for the last 20 years. She is also serving in her second 5-year term as an associate editor for the Mathematical Monthly, and she continues to serve on committees for the American Mathematical Society, the Mathematical Association of America and the Association for Women in Mathematics.

Professor **Steven Miller** received a three year individual NSF grant to continue his investigations in number theory and probability, and served as co-Director of the Williams SMALL REU (as well as being co-PI on a successful three year renewal grant for the program from NSF). He and his students published more than 10 papers and gave nearly 40 talks, including conferences in Canada, France and India. 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, to giving continuing education lectures to junior high and high school teachers, to writing a textbook/study guide on Probability, and to giving presentations to the public at the Boston Museum of Science. With Ralph Morrison he ran math puzzle night and continued our streak of over 1% campus participation on the Putnam exam. He was the thesis advisor to *David Burt '17* (Information Theory), *Becky Durst '17* (Benford's law), *Aaditya Sharma '17* (Random Matrix Theory), *Anand Hemmady '17* (L-functions), the second reader on four more, 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. Additionally, with colleagues in LACOL he beta tested shared courses across liberal arts colleges, with 3 Swarthmore and 2 Amherst students taking his spring Problem Solving class. In addition to giving many math talks at Williamstown Elementary, he is the faculty advisor to the Rubik's Cube Club at Mt Greylock Regional High School, where he serves as an elected school committee member.

Professor **Frank Morgan** spent his first year of retirement as mathematical traveler and Editor-in-Chief of the *Notices of the American Mathematical Society*, the largest publication in higher mathematics. He gave 35 talks on four continents. Meanwhile he is continuing work on optimal shapes, some with his 30th group of SMALL undergraduate research students this summer.

Assistant Professor **Ralph Morrison** completed his first year at Williams College. He continued his research on tropical geometry and algebraic geometry with a number of collaborators, both in the U.S. and abroad. Morrison taught three sections of *Multivariable Calculus* (MATH 150) in the fall, and introduced a new 300-level post-core class on *Computational Algebraic Geometry* (MATH 378) in the spring. Along with Steven Miller, he ran the department's weekly Math Puzzle Night, led the Williams team to a Green Chicken victory over Middlebury, and continued the streak of at least 1% of campus participating on the Putnam exam.

Professor **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-5 teachers. She continued her teaching and research in algebraic number theory. The Williams College Math Camp, which she founded in 2013, is now in its fifth year.

In summer 2016, Professor **Cesar Silva** was SMALL director and had a research group of six students; they completed two papers, one of which has been accepted for publication. He also taught in the Summer Science Program. In fall 2016, Silva taught *Real Analysis* (Math 350) and a topology tutorial (Math 374). In spring 2017, he was on sabbatical and continued his research in ergodic theory. Silva visited colleagues at the University of Rouen, France, in March-April and at the University of Brest, France, in May-June. In the academic year 16-17, he had two thesis students, *Alex Kastner'17* and *Matt Quinn '17*. Together with his colleague Steve Miller, Silva wrote and were awarded a new National Science Foundation grant to support the SMALL summer research program.

Silva was a member of an AMS committee and participated in an NSF panel. He was also Associate Editor for the *Notices* of the American Mathematical, and was on the Editorial Board of Pro Mathematica, Peru. He completed a volume as editor, jointly with Auslander (Maryland) and Johnson (Swarthmore) published by the American Math Society in 2016.

During the 2016-17 academic year, Professor **Mihai Stoiciu** taught *Foundations in Quantitative Skills* (MATH 102) and *Numerical Problem Solving Tutorial* (MATH 318) during the Fall Semester and *Measure Theory and Probability* (MATH 402) in the Spring. He supervised the undergraduate theses of *Nikolaus Howe '17* and *Andy Yao '17*. Stoiciu continued his research on spectral properties of random and deterministic operators.

His paper "Orthogonal Polynomials on the Unit Circle, CMV Matrices, and the Distribution of Their Eigenvalues" was published in the journal *Memoria - Seminario de Operadores y Fisica-Matematica, IIMAS-UNAM*.

Stoiciu was invited to present his research at the Summer Analysis Workshop, hosted by Oberlin College and at the conference *NEAM - 1st Northeastern Analysis Meeting,* hosted by SUNY Brockport. At Williams College Stoiciu gave a faculty seminar in April 2017 on his recent research in spectral theory. During the academic year, Stoiciu served as a member of the LACOL (Liberal Arts Consortium for Online Learning) Faculty Advisory Council and worked on LACOL projects in Quantitative Skills.

Assistant Professor **Laurie Tupper** finished her first year at Williams College. She has continued her research in spatial, temporal, and high-dimensional data, with particular emphasis on defining distance and similarity between such observations. She taught three sections of Elementary Statistics and Data Analysis, and in the spring developed and taught a new course on Time Series Analysis.

Assistant Professor **Daniel Turek** successfully completed his first year at Williams. In the Fall, he created and taught a course on Bayesian Statistics which covered analytical theory in the first half of the semester, and use of modern statistical software in the second half. This provided students with a mix of theory and practical ability for modern large-scale data analysis.

Turek co-edited a book on reproducible scientific research, titled *The Practice of Reproducible Research: Case Studies and Lessons from the Data-Intensive Sciences*, which was published in 2017. As part of the book launch, he was invited to give a talk at the Berkeley Institute of Data Science, at the University of California, Berkeley.

Turek received a sub-award of an NSF grant to continue development of the NIMBLE statistical software package for R. This package provides an algorithmic platform for advanced computational tools and analysis workflows for graphical statistical models.

Post-Graduate Plans of Mathematics and Statistics Majors

Patrick Anderson	Undecided
Megumi Asada	Undecided
Yoonsang Bae	Undecided
Paul Baird-Smith	Attending a Master's program in Computer Science at the University of Texas, Austin
Kathryn Barnitt	Working for the economic consulting firm, Analysis Group
Bridget Bousa	Undecided
Osama Brosh	Pursuing an MPhil in Biological Sciences (Genetics) at the University of Cambridge
David Burt	Pursuing a MPhil in Machine Learning, Speech and Language Technology at Cambridge University as a recipient of the Herchel Smith Fellowship.
Melissa Caplen	Undecided
Richard Chen	Undecided
Jaeho Choi	Undecided
Jack Cloud	Undecided
Dana Cohen	Working as a Solutions Analyst at Opera Solutions
Marcus Colella	Management Consulting at McKinsey's Pittsburgh office
Alyssa Crain	Undecided
Duncan Cummings	Undecided
Yuanchu Dang	Quantitative Trading Specialist with Goldman Sachs
Catherine Dickinson	Working as part of the Business Association Program at Wellington Management Group in Boston
Tyler Duff	Working in Debt Capital Markets for Credit Suisse in New York
Rebecca Durst	Pursuing a Ph.D. in Applied Mathematics a the Brown University

Jack Ferguson	Undecided
Ross Flieger-Allison	Working as a Software Systems Engineer at Cisco Systems in Boxborough, MA
Naomi Francois	Undecided
Elizabeth Frank	Working as a Data Analyst in Pediatric Oncology at Dana Farber Cancer Institute in Boston
Max Friend	Pursuing a career in criminal advocacy law
Elijah Fromm	Pursuing a Ph.D. in Pure Mathematics at Yale University
Cole Futterman	Working at Analysis Group in Boston
Daniel Gainey	Undecided
Joseph Glass-Katz	Undecided
Alexander Gonye	Undecided
Kathryn Grice	Undecided
Hans Halvorsen	Working at Analysis Group in Boston
Matthew Hayes	Working at a consulting firm in Boston
Anand Hemmady	High school math teacher
Matthew Hennessy	Management Consulting at Parthenon-EY in Boston
Stephanie Horan	Undecided
Intekhab Hossain	Analyst at Analysis Group, in Boston, MA
Nikolaus Howe	Studying Chinese with the Princeton in Beijing Program in Beijing over the summer, then pursuing a second bachelor's degree in Computer Science at Cambridge University on a Herchel-Smith Fellowship.
Christian Hoyas	Undecided
George Hunkele	Teaching math and possibly chemistry and coaching hockey, lacrosse and soccer at Avon Old Farms School in CT.
Grant Johnson	Undecided
Hae-Min Jung	Undecided
Patrick Kane	Investment Banking Analyst at Bank of America Merrill Lynch in Manhattan
Alexander Kastner	Attending Cambridge University on a Dr. Herchel Smith Fellowship to study for Part III of the Mathematical Tripos, then pursuing a Ph.D. in Mathematics
Dongheon Lee	Undecided
Jae Yeon Lee	Undecided
Kathryn Leinbach	Working as an Analyst in the Investment Bank at JP Morgan in New York City
Lia Lee	Working as a Research Assistant for the Broad Institute of MIT & Harvard.
Jamie Lesser	Working as a Software Engineer at Apple
Jilly Lim	Working as a Junior Data Specialist at Twitter in Boston
Olivia Lima	Undecided
Benjamin Lin	Undecided
Paul Lindseth	Undecided
Jieming Liu	Undecided
Si Young Mah	Pursuing a Master of Arts in Teaching at the University of California, Irvine, in the Secondary Education track for Mathematics
Chinmayi Manjunath	Accepted the Fulbright to Bulgaria to teach English for 1-2 years
Samuel Manzi	Undecided
Gabrielle Markel	Skiing in Revelstoke, British Columbia

William McGuire	Undecided
Jonathan McLean	English Teaching Assistant in France
Schuyler Melore	Undecided
Frank Mork	Working at Morgan Stanley
Connor Mulhall	Undecided
Johnson Nei	Undecided
Kimthannh Nguyen	Undecided
Gabriel Ngwe	Undecided
Sein Oh	Undecided
Phillip Oung	Undecided
Nina Pande	Undecided
James Pappas	Working as an Analyst at Cornerstone Research in New York
Rohan Paranjpe	Undecided
Robin Park	Working as a Research Analyst at NERA Economic Consulting
Dylanger Pittman	Undecided
Matthew Quinn	Pursuing a Ph.D. in Biostatistics at Harvard University
Brooks Rao	Undecided
Reider Riveland	Undecided
Ariana Ross	Undecided
Nicole Salani	Undecided
Miguel Samayoa	Undecided
Aaditya Sharma	Undecided
Anne Sher	Undecided
John Shuck	Undecided
Molly Siebecker	Undecided
Sean Spees	Consulting at Accenture Strategy in Boston
Troy Sipprelle	Working as a Software Engineer at Booz Allen Hamilton in DC
Benjamin Solis-Cohen	Working as a Software Engineer at Google in Mountain View, CA.
Sean Spees	Undecided
Stephanie Stacy	Pursuing a Ph.D. in Statistics at UCLA
Madeline Swarr	Working Acumen, LCC/The SPHERE Institute in Washington, DC
Elena Teaford	Undecided
Matthew Thomas	Pursuing a Ph.D. in Economics at Northwestern University
Dvivid Trivedi	Working as an Investment Banking Analyst at KeyBane Capital Markets in New York
Anthoney Tsou	Undecided
Stephen Tyson	Undecided
Vidya Venkatesh	Going to Dublin on a Fulbright, studying for an MA in Philosophy
Eleanor Wachtel	Undecided
Wendy Wiberg	Undecided
Andy Yu Zhu Yao	Working as a Trader in New York
Fan Zhang	Working at JP Morgan in New York
Jenny Zheng	Undecided
Miller Zhu	Working at Goldman Sachs Securities Division

Mathematics and Statistics Student Colloquia

Patrick Anderson ‘17
“Game, Set, Match – On the Mathematics of the Card Game Set”

Yoonsang Bae ‘17
“Voting in Agreeable Societies”

Kathryn Barnitt ‘17
“An Exploration of K-Nearest Neighbors”

Bridget Bousa ‘17
“Julia Sets and the Mandelbrot Set”

Osama Brosh ‘17
“Dimension of Crowns”

Melissa Caplan ‘17
“Three Proofs of the Ballot Theorem”

Richard D. Chen ‘17
“Wave Breaking in the Hunter-Saxton Equation”

Jaeho Choi ‘17
“The Wave Equation”

Dana Cohen ‘17
“The Dynamics of a Multi-Strain Disease with Cross Immunity”

Marcus Colella ‘17
“The Chinese Remainder Theorem”

Alyssa Crain ‘17
“Synchronizing Biological Oscillators”

Duncan Cummings ‘17
“Optimal Strategy for he Best Choice Problem”

Catherine Dickinson ‘17
“The Algebra of Wallpaper”

Tyler Duff ‘17
“A Bayesian Approach to the Multinomial”

Jack Ferguson ‘17
“Life in the Permuting Lane”

Ross Flieger-Allison ‘17
“Pseudorandom Number Generation”

Max Friend ‘17
“Squares, Damned Squares, and The Gaussian Integers”

Stetson Futterman ‘17
“Rejection Sampling and Adaptive Rejection Sampling”

Patrick Gainey ‘17
“Geodesics on the Tetrahedron”

Joseph Glass-Katz ‘17
“A Comparison of Bayesian and Frequentist Statistics”

Alexander Gonye ‘17
“The German Tank Problem”

Hans Halvorson ‘17
“A Winning Strategy in Dots-and-Boxes”

Matthew Hayes ‘17
“Global Solutions to the Camassa-Holm Equation”

Matthew Hennessy ‘17
“The Banach-Tarski Paradox”

Stephanie Horan ‘17
“Cayley Digraphs and Hamiltonian Paths”

Intekhab Hossein ‘17
“Discrete Bidding Games”

Christian Hoyos ‘17
“The ABCs of Approximate Bayesian Computation”

George Hunkele ‘17
“Conway’s Napkin Problem”

Grant Johnson ‘17
“Exploring GARCH Models”

Patrick Kane ‘17
“Gambler’s Ruin”

D.H. Lee ‘17
“Simultaneous Confidence Intervals for Benford’s Law”

Janice Lee ‘17
“Expanding e into a Continued Fraction”

Lia Lee ‘17
“Using Conditional MLE for Logistic Regression Models”

Kathryn Leinbach ‘17
“The Stable Marriage Problem”

Jamie Lesser ‘17
“An Afternoon with Buffon”

Jilly Lim ‘17
“What Do Fluids and Fractional Linear Transformations Have in Common?”

Olivia Lima ‘17
“Clustering Methods”

Benjamin Lin ‘17
“Why Count Von Count Should Study Abstract Algebra”

Paul Lindseth ‘17
“The Stable Marriage Problem and Generalizations”

Jieming Liu ‘17
“Closed Testing Procedures for Multiple Comparisons”

Steven Louis-Dreyfus ‘17
“A Function Without an Anti-Derivative”

Si Young Mah ‘17
“Map Coloring for Mathematicians”

Chinmayi Manjunath ‘17
“Seven Bridges of Königsberg”

Samuel Manzi ‘17
“The Basketball Problem”

Gabrielle Markel ‘17
“A Finite Talk on Infinite Sets”

William McGuire ‘17
“The Geometry of Musical Harmony and Counterpoint”

Jonathan McLean ‘17
“Valid Configurations of the Rubik’s Cube”

Schuyler Melore ‘17
“Using PDE to Model Tumor Growth”

Frank Mork ‘17
“Multiple Comparison Testing Analysis in ANOVA”

Connor Mulhall ‘17
“The NTRU Public Key Cipher”

“Controlling the False Discovery Rate”

Johnson Nei ‘17
“Negative Binomial Regression Modeling”

KimThanh Nguyen ‘17
“VWEIrgvctxmsr”

Gabriel Ngwe ‘17
“Continuous but Nowhere-Differentiable Functions”

Sein Oh ‘17
“Handling Imbalanced Datasets Using SMOTE”

Philip Oung ‘17
“Lagrange Four Square and Waring’s Problem”

James Pappas ‘17
“Game Theory and the Brouwer Fixed-Point Theorem”

Rohan Paranjpe ‘17
“How Abelian Are Non-Abelian Groups: What is the Probability that Two Elements in a Group Commute?”

Robin Park ‘17
“Bézout in the Tropics”

Dylanger Pittman ‘17
“Double Bubbles in Borell Space”

Brooks Rao ‘17
“Exploring Double Lasso Variable Selection”

Reidar Riveland ‘17
“Polynomial Interpolation”

Ariana Ross ‘17
“The Fold-and-Cut Problem”

Nicole Salani ‘17
“Longitudinal Data Analysis Using GLMs”

Michael Samayoa ‘17
“The Power of the Exact Test”

Aaditya Sharma ‘17
“Wigner’s Semicircle Law and Random Matrix Ensembles with Split Limiting Spectral Distributions”

Anne Sher ‘17
“Cauchy’s Corollary to Sylow’s First Theorem”

Molly Siebecker ‘17
“Straightedge and Compass Constructions”

Troy Sipprelle ‘17
“The Art (and Math) of Illumination”

Benjamin Solis-Cohen ‘17
“Ramsey Theory and the Probabilistic Method”

Sean Spees ‘17
“Discrete Fourier Transform Encoding”

Stephanie Stacy ‘17
“Random Graphs: The Erdos-Renyi Model”

Madeline Swarr ‘17
“A Bayesian Approach to A/B Tests”

Elena Teaford ‘17
“Blue-Red Hackenbush and Surreal Numbers”

Matthew Thomas ‘17
“The Isoperimetric Inequality”

Dvivid Trivedi ‘17
“Regression Transformations”

Anthoney Tsou ‘17
“Compression Algorithms”

Stephen Tyson ‘17
“Continued Fractions and the Twelve-Tone Musical Scale”

Vidya Ventkatesh ‘17
“Prime Decomposition in Number Rings”

Eleanor Wachtell ‘17
“A Global Problem: Projecting Spheres onto Flat Surfaces”

Wendy Wiberg ‘17
“The Mathematics of Tetris”

Fan Zhang ‘17
“Nonparametric Regression”

Jenny Zheng ‘17
“Modeling Car Traffic Flow: Burgers Equation”

Miller Zhu ‘17
“HMM Inference with Baum-Welch Algorithm”

Mathematics and Statistics Colloquia

Colin Adams, Williams College
"Hyperbolic Knots and Links"

Ian Adelstein, Trinity College
"Can You Hear the Shape of a Drum?"

Iddo Ben-Ari, University of Connecticut
"The Bak-Sneppen Model of Biological Evolution and Related Models"

Julie Blackwood, Williams College
"From Rabies Transmission in Vampire Bats to Coral Reef Conservation: Insights from Mathematical Models"

Erika Camacho, Arizona State University
"The Role of RdCVF in the Health of Cone Photoreceptors"

Cory Colbert
"Results Concerning the Spectrum of Noetherian Rings"

Diana Davis, Williams College
"Lines on Polygon Surfaces"

"Periodic Paths on the Pentagon"

Richard De Veaux, Williams College
"What is a P-value Anyway?"

Alexander Diaz-Lopez, Swarthmore College
"A Proof of the Peak Polynomial Positivity Conjecture"

"Coxeter Groups, Root Systems, and Hecke Algebras"

Courtney Gibbons, Hamilton College
"Representations of the Kronecker Quiver"

"Free Resolutions"

Leo Goldmakher, Williams College
"Refinements of Lagrange's Four-Squares Theorem"

Pamela Harris, Williams College
"Kostant's Partition Function"

Chad Higdon-Topaz, Macalester College
"Collective Behavior, Models, and the Unreasonable Effectiveness of Mathematics"

Trachette Jackson, University of Michigan
"Mathematical Biology: An Essential Part of 21st Century Science"

Stewart Johnson, Williams College
"Chaos and Emergent Structures in High Dimensional Dynamics"

Matkos Katsoulakis, University of Massachusetts, Amherst
"Can We Make Mathematical Models More Predictive?"

Bernhard Klingenberg, Williams College
"Modeling Longitudinal Binary Data"

Haydee Lindo, Williams College
"Trace Ideals and Endomorphism Rings"

Susan Loepp, Williams College
"Rings with Strange Properties"

Steven Miller, Williams College
"Problems in Number Theory"

"From the Manhattan Project to Elliptic Curves: Introduction to Random Matrix Theory"

"Secrets of the Tax System with Steve Miller: Keep More of your MOOLA"

"Pythagoras at the Bat: An Introduction to Statistics and Modeling"

Stephen Moseley '05 & Charlie Upton '08, AthenaHealth
"Using Data to Unbreak Healthcare"

Frank Morgan, Williams College
"Soap Bubbles in Spaces with Density"

Ralph Morrison, Williams College
"The Moduli Space of Tropical Plane Curves"

Bhramar Mukherjee, University of Michigan
"How Small Data Can Leverage Big Data"

Allison Pacelli, Williams College
"The Beauty of Numbers, Part I"

"The Beauty of Numbers, Part II"

Alicia Prieto Langarica, Youngstown State University
"A Mathematical Model of the Effects of Temperature on Human Sleep Patterns"

Alejandro Sarria, Williams College
"Suppression of Singularities in Fluids"

"On a Proposed Higher-Dimensional Analogue of the Camassa-Holm Equation"

Cesar Silva, Williams College
"What is an Ergodic Transformation?"

"Conditions Implied by Ergodicity of Cartesian Products"

Gabriel Sosa, Amherst College
"Monomial Orders Uniquely Determined by Their Induced Orders"

Mihai Stoiciu, Williams College
"Random Matrices with Poisson Eigenvalue Statistics"

Peyam Tabrizian, Williams College
"Chemical Reactions and Diffusions"

Naomi Tanabe, Dartmouth College
"Central Values of L-Functions"

Scott Taylor, Colby College
"The Bridge Distance of a Knot"

Jesse Thorner, Stanford University
"An Explicit Bound for the Least Prime Ideal in the Chebotarev Density Theorem"

Laurie Tupper, Williams College
"Classification of Multivariate Time Series Data with Applications to ECIS"

Maria Vega, United States Military Academy
"Hopf Algebras and Twisted Extensions"

Off-Campus Mathematics and Statistics Colloquia

Colin Adams

"Multi-Crossing Number for Knots and Links"
Knots in Hellas, Ancient Olympia, Greece, July 16, 2016

"Introduction to Multi-Crossing Number"
UnKnot Conference, Denison University, Granville, OH, August 1, 2016

"Turning Knots into Flowers"
Special Session on Knots, MathFest, Columbus, OH, August 4, 2016

"Bipyramid Decompositions of Multi-Crossing Projections"
AMS Special Session, Bowdoin College, Brunswick, ME, September 25, 2016
Harvard University Gauge Theory Seminar, Cambridge, MA, October 21, 2016

"Blown Away: What Knot to do When Sailing"
Western Kentucky University Symposium, Bowling Green, KY, November 12, 2016
University of Utah, Salt Lake City, April 14, 2017
CURM/MUMS Conference, Simpson College, Indianola, Iowa, March 31, 2017

"Multi-Crossing Number for Knots: Turning Knots into Flowers"
Special Session, Atlanta, Georgia Joint Mathematics Meetings, January 7, 2017
University of Utah, Salt Lake City, April 14, 2017

"Mathematically Bent Theater with 'Skype Interview'"
"The Seven Labors of Hercules"
"A Grader's Dream"
"The Topology of Terrors"
Joint Mathematics Meetings, Atlanta, GA, January 6, 2017

"Applied Topology Minicourse"
With Robert Franzosa, Joint Mathematics Meetings, Atlanta, GA, January 5-7, 2017

"Multi-Crossing Number for Knots"
AMS Special Session, College of Charleston Charleston, SC, March 11, 2017

"Multi-Crossing Number for Knots: Undergraduate Research"
CURM/MUMS Conference, Simpson College, Indianola, Iowa, March 31, 2017

"Cusp Densities for Hyperbolic 3-Manifolds"
AMS Sectional Meeting, Hunter College, New York City, NY, May 6, 2017

Julie Blackwood

"From the Dynamics of Periodical Cicadas to Caribbean Coral Reefs: Insights from Mathematical Models"
Pi Mu Epsilon Induction Ceremony, Marist College
MAA Northeastern Section Meeting, Trinity College

"Rabies Persistence in Vampire Bats: Immunity, Pathogenesis, & Immigration"
SIAM Conference on the Life Sciences, Virginia Tech

"Controlling Rabid Vampires…With Math!"
Mount Greylock Regional High School

Diana Davis

"Interval Exchange Transformations from Tiling Billards"
City University of New York
Centre International de Rencontres Mathématiques

Diana Davis (cont.)

"Periodic Billard Paths on the Pentagon"
Lehigh University Joint Mathematics Meetings, Atlanta, Georgia
Colorado College
University of Rhode Island

"Three Flavors of Billards"
Lunch Talk Series, Smith College
Colorado College
Colby College
Siena College

"Lattice Surfaces and the Modulus Miracle"
Algebra/Geometry/Combinatorics Seminar, Smith College

Richard De Veaux

"The Seven Deadly Sins of Big Data"
International Conference on Applied Statistics for Development in Africa (SADA '16) Cotonou BENIN, November 2016
Park City Mathematics Institute, Midway, UT, July 2016

"Data Mining: Fool's Gold or the Mother Lode?"
Sanofi-Pasteur, Boston, MA, June 2016

"Building Better Models Through Predictive Analytics"
Denver, CO, July 2016
Toronto, Canada, October 2016
Cary, NC, February 2017
New York University, March 2017
Pleasanton, CA, March 2017
Gaithersburg, MD, April 2017
Falls Church, VA, May 2017

"Workshop on Presentation Skills"
Joint Statistical Meetings, Chicago, IL, August 2016

"Short Course: Successful Data Mining in Practice"
Joint Statistical Meetings, Chicago, IL, August, 2016
International Conference on Applied Statistics for Development in Africa (SADA '16) Contonou BENIN, November, 2016

Thomas Garrity

"On Writing Numbers"
Institut de Reserche en Informatique Fondamentale (IRIF) at l'Université Paris-Diderot (Paris 7), September 2017
Université l'Liége Liége, Belgium, October 2017

"On a Family of Multidimensional Continued Fractions: Attempts at a Common Framework"
Project Dyna3S, Institut de Reserche en Informatique Fondamentale (IRIF) at Université Paris-Diderot (Paris 7)

"Minkowski Question Mark Type Functions for a Family of Multidimensional Continued Fractions"
Special Session on Continued Fractions, AMS-MAA Meetings, Atlanta, GA, January 2017
Recontre autour de la function de Minkowski, Institut Fourier, Grenoble France, March 2017

"On the Search for Truth"
Williams Alums in London, UK, April 2017

Leo Goldmakher

"The Long and the Short of Character Sums"
MSRI Analytic Number Theory Seminar, April 13, 2017

Pamela Harris

"A Proof of the Peak Polynomial Positivity Conjecture"
Mathematicians of Color Alliance (MOCA), Research Seminar, Iowa State University, March 2017
Combinatorics Research Seminar, University of Kentucky, March 2017
Applied Algebra Seminar, York University, January 2017
University of Wisconsin Milwaukee 50th Anniversary Celebration, Algebra Session, October 2016
XXI Coloquio Latinoamericano de Algebra, Special Session on Algebraic Combinatorics, Buenos Aires, Argentina, July 2016

"A Hands on Exploration of Zeckendorf's Theorem and its Generalizations"
Student Math Club Talk, University of Kentucky, March 2017

"Coloring Maps: The Story of a Traveling Mathematician"
Sonya Kovsalesky Day Keynote Speaker, University of Wisconsin-Eau Claire, March 2017

"Peaks on Graphs"
Research Symposium, University of Wisconsin-Eau Claire, March 2017

"Research Experiences with Undergraduates"
ASPiRE (Advancing Student Participation in Research Experiences) Conference, Florida Gulf Coast University, February 2017

"The q-analog of Kostant's Partition Function and the Highest Root of the Simple Lie Algebras"
AMS Special Session Lie Groups, Discretization, and Gelfand Pairs, JMM 2017, Atlanta, GA, January 2017

"Peak Sets of Graphs"
AMS Special Session RE(UF)search on Graphs and Matrices, JMM 2017, Atlanta, GA, January 2017

"Permutations, Peaks, Polynomials, and a Positivity Conjecture"
Distinguished Women in Math Lecture, San Francisco State University, November 2016
Plenary Speaker, WiMiN (Women in Math in New England) Conference, Smith College, September 2016
Mathematics Colloquium, Providence College, March 2017

"A Generalization of Zeckendorf's Theorem"
Mathematics Colloquium, Union College, September 2016

Brianna Heggeseth

"Estimating the Relationship Between Baseline Values and Change Over Time How Easy it is to Get It Wrong!"
Department of Epidemiology and Biostatistics, Dartmouth Geisel School of Medicine, July 2016

"Intro Stats for Future Data"
ECOTS, May 2016
Joint Statistics Meetings, August 2016

"Estimating Complex Relationships with Nonlinear Longitudinal Growth Patterns"
ENAR, March 2017

Bernhard Klingenberg

"Intro Stats in the Cloud"
29th International Conference on Technology in Collegiate Mathematics, Chicago, IL, March 2017

"Take a Risk: Talk About the Risk Ratio"
2017 United States Conference on Teaching Statistics, Pen State, May 2017

Susan Loepp

"Understanding the Relationship Between Local Rings and Their Completions: Contributions by Undergraduates"
AMS Special Session on Commutative Algebra: Research for Undergraduate and Early Graduate Students, Joint Mathematics Meetings, Atlanta, Georgia, January, 2017

"The Key to Sending Secret Messages"
Guterman Lecture, Tufts University, March 2017

"Completions of Local Rings"
Mathematics Colloquium, Baylor University, March, 2017

Steven Miller

"Gaps Between Zeros of GL(2) L-Functions"
Southern New England Conference on Quadratic Forms and Modular Forms, June 2, 2016

"Springboards to Mathematics: From Zombies to Zeckendorf"
Math League Summer Program, College of New Jersey, July 25, 2016

"Convergence Rates in Generalized Zeckendorf Decomposition Problems"
(with Zhao Pan and Huanzhong Xu) 17th International Fibonacci Conference, June 28, 2016

"Pythagoras at the Bat: An Introduction to Statistics and Modeling"
University of Vermont, December 2, 2016

"From M&Ms to Mathematics, or, How I Learned to Answer Questions and Help My Kids Love Math"
"Springboards to Mathematics: From Zombies to Zeckendorf"
Math League Summer Program, College of New Jersey, July 25, 2016

"Extending Pythagoras"
Hampshire College Summer Studies in Mathematics, August 3, 2016

"Pythagoras at the Bat: An Introduction to Mathematical Modeling"
Science Days for Prospective Williams Students, August 12, 2016

"From the Manhattan Project to Elliptic Curves"
Duke University, September 7, 2016
SUMS, Brown University, March 18, 2017

"From the Fibonacci Numbers to Roulette"
Boston Museum of Science, September 14, 2016

"Can Math Detect Fraud? CSI: Math? The Natural Behavior of Numbers"
Science Café, Northampton, Mt. Holyoke, September 26, 2016

"Pythagoras on the Ice"
Babson Hockey Analytics Conference, Babson College, October 1, 2016

"Random Matrix Ensembles with Split Limiting Behavior"
AMS Special Session on Graphs and Matrices, Joint Statistical Meetings, January 5, 2017

"One-Level Density for Holomorphic Cusp Forms of Arbitrary Level"
31st Annual Workshop on Automorphic Forms, ETSU, March 6, 2017

"Benford's Law: Why the IRS Cares About Algebra and Number Theory (And Why You Should Too!)"
"Biases in Fourier Coefficients of Elliptic Curve L-Functions"
Washington State University, April 21, 2017

Frank Morgan

"Pentagonal Tilings"
Hong Kong, IMO, July 14, 2016

"Future of Notices AMS"
MathFest, August 6, 2016
Joint Mathematics Meetings, Atlanta, Georgia, January 4 - 7, 2017

"The Log-Convex Density Conjecture"
San Paulo, IME USP Geometry Seminar, August 26, 2016

"Introduction Isoperimetric Problem with Density"
Rio: Univ. Fed., August 30, 2016

"Isoperimetric Problem With Density"
Rio: Brazil-Italy Conference, August 29 - September 2, 2016
Univ. Buenos Aires, Analysis Seminar, September 6, 2016
Trento, April 3, 2017
Padua, April 6, 2017
Pullman, Washington, April 23, 2017

"Pompas Dobles de Jabón" Double Soap Bubbles in Spanish
Univ. Buenos Aires, Colloquium, September 8, 2016

"The Isoperimetric Problem in Spaces With Density"
Swarthmore College, September 13, 2016

"Soap Bubbles and Mathematics"
Alicante, September 29 – 30, 2016
Texas State University, November 4, 2016
U Los Andes, February 9, 2017
Sacred Heart College, March 22, 2017
Providence College, March 24, 2017

"International Mathematics"
Ensworth High School, Nashville, TN, November 1, 2016

"Isoperimetry With Density"
Luminy, November 21 – 25, 2016
Mathematics Conference, Union College, December 3 - 4, 2016

"Soap Bubbles"
IST Austria, November 28 – 30, 2016

"Least Perimeter Tiles of the Hyperbolic Plane"
Joint Mathematics Meetings Atlanta, Georgia, January 4 - 7, 2017

"Learning by Doing"
"Problemas Isoperimétricos con Densidad"
"Geometric Measure Theory y Problemas Isoperimétricos"
"Pompas de Jabón y las Matemáticas"
U Antonio Nariño, Bogotá, February 7 - 18, 2017

"Pompas de Jabón y las Matemáticas"
U Havana, February 28, 2017
U Havana, for High School students, February 2, 2017

"The Isoperimetric Problem"
U Havana, February 28, 2017
Milano Lezioni Leonardesche, May 25, 2017
Dos días de Análisis Geométrico en IEMath-GR, Granada, Spain, June 1, 2017

"If You Want to Bring Math to the World, Start with the Mathematicians"
Math and Culture XX, Venice, March 31, 2017

Frank Morgan (cont.)

"¿Repuestgas antes las preguntas?" ("Answers Before Questions?" remote video)
U Antonio Nariño, Bogota

Ralph Morrison

"Tropical Curves of Genus 2"
BATMOBYLE, Providence, RI, September 2016
Joint Math Meetings, Atlanta, GA January 2017

Allison Pacelli

"Albany Math Content Workshops for K-2 Elementary School Teachers"
Albany, NY, August 5, December 6, 2016; May 22, 2017

"Albany Math Content Workshops for 3-5 Elementary School Teachers"
Albany, NY, August 4, October 13, 2016; February 7, April 4, and May 23, 2017

Cesar Silva

"Nociones de transformaciones mezclantes en medida infinita"
Department of Mathematical Analysis, University of Malaga, Spain, June 21, 2016

"One Proof is Not Enough"
Analysis Workshop, Oberlin, July 10, 2016

"On Conditions Implied by Ergodic Cartesian Square"
AMS Special Session on Dynamical Systems, Atlanta, January 5, 2017

"The Mathematical Work of Dorothy Maharam"
AMS Special Session Measure and Measurable Dynamics (In memory of Dorothy Maharam, 1917–2014), January 7, 2017

"Weak Mixing Notions in Infinite Measure"
University of Rouen, France, April 6, 2017
University of Brest, France, June 1, 2017

Mihai Stoiciu

"Random Unitary Operators and the Microscopic Distribution of Their Eigenvalues"
Summer Analysis Workshop, Oberlin College, July 2016

"Transition in the Eigenvalue Distribution of Random and Deterministic Unitary Operators"
NEAM – 1st Northeastern Analysis Meeting, SUNY Brockport, October 2016

Laurie Tupper

"Classification of Multivariate Time Series Data with Applications to ECIS"
Joint Statistical Meetings, Chicago, IL, August 2016

Daniel Turek

"Features and Trends of the Reproducibility Case Studies"
University of California, Berkeley, January 2017

Neuroscience Program

The Neuroscience Program continues to flourish, with a strong set of concentrators and faculty drawn from the Biology and Psychology Departments teaching courses specific to the program as well as a slate of electives. Heather Williams co-taught the core course *Neuroscience* (NSCI 201) and *Animal Behavior* (NSCI 204); Lauren Williamson co-taught *Neuroscience* and the capstone seminar *Brain, Behavior and the Immune System* (NSCI 312); Tim Lebestky taught *Neural Development and Plasticity* (NSCI 310) and a Biology senior seminar on the *Neurobiology of Emotion* (NSCI 347); Amie Hane taught *Early Experience and the Developing Infant* (PSYC 335) and the senior seminar in Public Health; Betty Zimmerberg was on leave in the fall and taught *The Brain and Visual Arts* (NSCI 318) in the spring; Matt Carter was on leave; Noah Sandstrom taught *Introductory Psychology* (PSYC 101) and *Experimentation and Statistics in Psychology* (PSYC 201); Martha Marvin taught the core labs and supported many other parts of the program.

Our students continue to conduct research with neuroscience faculty including the regulation of torpor by hypothalamic neurons in the Carter lab and the role of the immune system in regulating learning with Lauren Williamson. Sixteen graduating seniors completed the neuroscience concentration in 2017. Terrance Mensah completed a neuroscience thesis with honors, and three concentrators did neuroscience-related research for honors work recognized by the Biology department. Another four completed independent study research projects in neuroscience labs. Rachel O'Sullivan was awarded the Patricia Goldman-Rakic Prize in Neuroscience for 2017.

Fourteen students were named as Neuroscience Class of 1960s Scholars. The Neuroscience Class of 1960s Scholars program co-sponsored four speakers during the year, including two alumni of the program. *Jennifer Hill '97* who visited from her lab at University of Toledo and spoke about her career path and about her research on neuro-endocrine regulation of reproductive and feeding behaviors. *Mark Springel '12*, a current Ph.D. student at Harvard Medical School in the lab of Dr. David Ginty, talked about choosing a research path and about his current work on the development of pain and gentle touch sensory systems. Both talks were well attended.

During National Brain Awareness Week (March 13-17), students and community members participated in activities surrounding neuroscience. Professors Williamson, Marvin and Sandstrom and *Katie Swoap '17* visited Williamstown Elementary School 6th graders to introduce brain anatomy and function, in part by decorating swim caps with the lobes of the cortex. Dr. Williamson also hosted a trivia night at the Log, in which participants displayed their knowledge of neuroscience as they vied for brain-themed prizes.

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.

Class of 1960s Scholars in Neuroscience

Josselyn Barahona '17
Hussein Fareed Bukhari '18
Will Duke '17
Marianna Frey '18
Amelia Hidalgo '17
Tracey Kim '17
Sara Lehman '17
Christopher Lyons '17
Terrance Mensah '17
Rachel O'Sullivan '17
Jacob Sperber '18
Katie Swoap '17
Kelly Tellez '17
Maria Vicent Allende '17

Martha Marvin continued 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 4th graders at the Williamstown, Lanesborough, and Brayton (North Adams) elementary schools. She also taught a workshop on watersheds to 8th graders at Mt Greylock Middle School. She mentored three honors students and four research assistants this year.

Research in the Marvin lab investigates stress responses and the development of the cardiovascular system. This work focuses on signaling pathways that may be modified by environmental conditions. *Jacqueline Harris '16* found that low levels of environmental estrogens potentiate birth defects through interactions with other developmental pathways. *Miriam Semmar '18* is following up on this work. A major topic in the lab has been investigating small heat shock proteins which protect animals

from temperature stress. *Ashley Ngo '16*, *Naomi Currimjee '18* and *Christie Black '15* knocked out hspb7, a member of this gene family, using CRISPR/Cas9 genome editing. Our previous work showed that reducing transcription of hspb7 caused defects in heart valves and left-right asymmetry. *Maeve Serino '17* demonstrated that large deletions in the hspb7 gene do not cause heart defects. We are working to understand the differences between the methods; we suspect that there is a compensatory effect due to up-regulation of a similar gene. Expanding on our new interest in genomic regulation, *Daniel Patrick Gainey '17* investigated the feasibility of targeting epigenetic modification of DNA by methylation to a single gene. This work could prove methylation's long-postulated role in transcriptional regulation. Naomi Currimjee plans to continue this work.

Early life stress in humans can cause long-lasting behavioral and physiological abnormalities associated with disorders such as depression and PTSD. *Tracey Kim '17, Jack Page '18* and *Rodsy Modhurima '19* 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* and *Rodsy Modhurima '19* created mutations in fkbp5, a gene known to modulate the stress response. fkbp5 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-Graduate Plans of Neuroscience Concentrators

Natalie Bernstein	Research Technician at Feinberg School of Medicine, Northwestern University
Olivia Clark	Research assistant, Gerhardt Lab, Nationwide Children's Hospital, Columbus, OH
Will Duke	Research assistant, Mullally Lab, Brigham and Women's Hospital, Boston, MA
Candice Dyce	K-12 teaching and coaching
Devyn Hébert	Columbia Law School
Amelia Hidalgo	Research assistant
Tracey Kim	undecided
Sara Lehman	Research assistant, Kallyope Inc., New York, NY
Christopher Lyons	Master's of Medical Sciences program at Boston University
Ananya Mayukha	undecided
Terrance Mensah	Herchel Smith Fellow, Cambridge University, UK
Liam Mullen	Consulting
Rachel O'Sullivan	Research assistant, Kallyope Inc., New York, NY
Katie Swoap	Associate, Parthenon-EY, Boston MA
Apurva Tandon	Master's program in English at University of Pennsylvania
Sara Vitale	applying to medical school

Neuroscience Colloquia

Susana Martinez-Conde, SUNY Downstate Medical Center
"Splendor, Myth and Vision: Nudes from the Prado", September 30, 2016

Jennifer Hill '97, University of Toledo
"The Neural and Endocrine Regulation of Behavior Related to Reproduction and Food Intake in Rodents" January 5, 2017

Mark Springel '12, Harvard University Ph.D.
"Development of the Senses of Pain and Touch" January 19, 2017

Elena Vazey, University of Massachusetts, Amherst
"Focus on the locus: Noradrenergic roles in attention and inattention" March 10, 2017

Physics Department

The 2016-2017 academic year was a transitional one for the Physics Department, ending with the retirements of Professors Jeff Strait and Bill Wootters. Through their dedication to teaching and scientific research, Professors Strait and Wootters have both impacted the lives of countless Williams students during the past 30-plus years. They are inspirational colleagues, and we are grateful for their contributions to the Physics Department and to the College.

This year we were delighted to welcome Assistant Professors Catherine Kealhofer and Swati Singh into our department. 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, and Singh is a theorist who studies quantum phenomena in atomic, optical, and condensed matter systems. We look forward to welcoming into the department Assistant Professor Kate Jensen, an experimental materials scientist, during the summer of 2017.

Research with students continues to be a central activity of physics department faculty. In the summer of 2016, 18 students did research with physics faculty, and 18 are signed up to do research in the department this coming summer. This year we were proud to learn that the American Physical Society selected Professor Tiku Majumder as the 2017 recipient of its Prize for a Faculty Member for Research in an Undergraduate Institution. The APS cited Majumder "for contributions to the precision measurement of atomic properties, and sustained, inspirational mentorship of undergraduate researchers."

Class of 1960 Scholars in Physics

Jaeho Choi	Michael May, III
Eli V. Hoenig	Maria V. Prado
Sierra E. Jubin	Nathaniel B. Vilas
William M. Kirby	Daniel P.G.H. Wong

Professor **Daniel Aalberts** taught: *Seminar in Modern Physics* (Phys 151) in the Fall, then during a Spring mini-sabbatical, supervised three honors research projects. *Daniel Wong '17* quantified biases in Ribosome Profiling experiment, *Intekhab Hossain '17* studied several species to compare codon and other influences on mRNA and protein levels, and *Niki Howe '17* developed an algorithm for RNA folding and counted the number of microstates. Aalberts' research is supported by the NIH.

Assistant Professor **Charlie Doret** taught at both ends of the curriculum during the 2016-17 academic year. He spent the fall with a large group of junior and senior physics majors in *Classical Mechanics* (Phys 411T); he also gave a pair of public talks on his research in November as part of the annual Sigma Xi lecture series. In the spring he taught *Electromagnetism and the Physics of Matter* (PHYS 132). For the second consecutive year, Doret taught *Wood and Woodturning* (Phys 018) during Winter Study, offering hands-on instruction at benchtop wood lathes set up in the Bronfman Science Center. Professor Doret was also delighted to welcome Rebecca Abigail Doret to the family (born 1/22/2017), making for a hectic conclusion to Winter Study!

During the 2016-17 school year Prof. Doret continued to work towards trapping calcium ions, joined by thesis students *Sierra Jubin '17* and *Sarah Stevenson '17* as well as rising sophomore *Will Fung '19*. These trapped, laser-cooled ions can be exquisitely controlled in the laboratory, making them ideally suited for use in so-called 'quantum simulations' wherein a well-controlled quantum system is used to emulate the behavior of another system of interest that is too challenging to study in its native form. Sierra's work focused on making improvements to all aspects of the group's ion-trapping apparatus, culminating with the trapping of ions for the first time in March 2017. Sarah and Will teamed up to install a new diode laser in the laboratory, working towards its eventual use in coherently manipulating the quantum states of the trapped ions. Sierra and Sarah presented a poster on their work at the APS DAMOP conference in Sacramento in the summer 0f 2017. Sierra will be begin her Ph.D. work in plasma physics at Princeton, while Sarah is headed for work as a researcher at NIST in Boulder, CO.

During summer 2017 Doret will begin a year-long research sabbatical; he will be joined in the lab by incoming thesis student *Ashay Patel '18* and rising sophomore *Kirby Gordon '20*. Supported in part by a new Cottrell Scholar Award from the Research Corporation, Doret plans to study non-equilibrium dynamics in quantum systems. A particular focus will be towards understanding thermal conductivity at the nanoscale, relevant both to quantum information processing with trapped ions and for understanding power dissipation in microelectronic devices.

McElfresh Professor of Physics **Kevin Jones** is spending a sabbatical leave year at the Joint Quantum Insti-

tute (JQI) at the University of Maryland, College Park. The institute, which collaborates between the university and the National Institute of Standards and Technology (NIST), brings together a variety of federal and university researchers working to understand more fully the implications of quantum mechanics and to explore ideas for controlling and exploiting quantum systems. Williams alums *Shelby Kimmel '08* and *Paul Hess '08* are postdoctoral research associates at the JQI. *Allison Carter '16*, a University of Maryland graduate student, and *Adnan Khan '12* are also conducting research at JQI.

Jones has a longstanding research collaboration with the NIST Laser Cooling and Trapping group headed by Nobel Laureate William Phillips whose members are now largely located at JQI. NIST has been very generous in supporting Jones' research and many summer students from Williams. This generous support has continued at JQI. A grant from the National Science Foundation to Jones and NIST researcher Paul Lett has helped support recent work. Jones' current research is in the field of quantum optics. An important tool in many scientific fields is optical interferometry (a recent example being the spectacular observation of gravitational waves from colliding blackholes). The ultimate sensitivity limits of such interferometers, if technical complications are eliminated, are set by the quantum properties of the light beams used. Normally interferometers work with light fields generated by a laser, so called "classical" states of light. Jones and his JQI colleagues are exploring ways in which to use non-linear optics to produce non-classical light fields to improve the sensitivity of interferometers. They have recently completed a scientific demonstration of a (modest) improvement in sensitivity "beyond the standard quantum limit."

During the summer of 2016, *Ashay Patel '18* worked with Jones at JQI. Ashay investigated the optical transparency of heated glass cells containing Rubidium vapor, a key piece of the apparatus that the research group uses to generate non-classical states of light. *Felix Knollmann '19* is working with Jones for the summer of 2017. He is helping initiate a new project exploring the mechanical resonances of an optical nano-fiber, with an eye towards the possibility of exploiting opto-mechanical couplings to generate novel states of light.

Jones and his JQI colleagues published a paper on the *Effect of input phase modulation to a phase-sensitive optical amplifier*" in the journal *Optics Express*. Two more papers have been accepted for publication. *Phase sensing beyond the standard quantum limit with a modified SU(1,1) interferometer* will appear in *Optica*. and *Optimal phase measurements with bright and vacuum-seeded SU(1,1) interferometers* will appear in *Physical Review A*.

Finally, Jones enjoyed the opportunity to speak to a Washington DC alumni gathering in May. His talk started with the historical connection between precise timekeeping and navigation and then moved on to recent advances (some related to his earlier research) in the production of ultra-cold atoms and their use in ultra-precise atomic clocks.

Assistant professor **Catherine Kealhofer** arrived at Williams at the beginning of July 2016 to start setting up her research lab. She taught *Introduction to Electricity and Magnetism* (PHYS 201) in the fall and *Applications of Quantum Mechanics* (PHYS 402T) in the Spring.

Kealhofer's research interests are the development of tools for generating, manipulating, and characterizing ultrafast electron pulses. Ultrafast electron pulses are extraordinarily short pulses of electrons that can extend electron microscopy techniques to study processes that happen very fast—for example, to make a "movie" of how atoms in a crystal rearrange during a phase transition. She was lucky enough to start her experience at Williams working with physics majors *Derek Galvin '18* and *Iona Binnie '19*, who spent the second half of last summer building an apparatus to electrochemically etch tungsten nano-emitters, which the lab will use in its ultrafast electron gun. Derek continued work on this project and others as an independent study during the Winter Study Period.

Over the course of the Spring semester, first-years *Kirby Gordon '20* and *Sam Wischnewsky '20* worked on (re)-constructing a Titanium sapphire laser the group inherited from Professor Sarah Bolton's lab. The upcoming summer should be exciting and filled with ultrafast optics: *Iona Binnie '19* and *Ian Shen '19* are building crucial tools for characterizing ultrafast laser pulses, and Honors Thesis student *Emily Stump '18* is beginning development of a femtosecond Erbium fiber laser. The lasers will ultimately be used to study ultrafast electron emission processes from nano-emitters.

In November, Kealhofer wrote the Viewpoint *An ultrafast switch for electron emission* in *Physics*, which publishes online commentary on recent papers in the journals of the American Physical Society.

During the 2016-17 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, organized the summer student research program, and has focused extensively

this year on planning and design for the exciting new science center project.

Majumder has continued to pursue diode laser and atomic physics experiments in his research lab, teaming up with senior thesis students *Eli Hoenig '17* and *Nathaniel Vilas '17*, as well as postdoctoral researcher Milinda Rupasinghe. The group is supported by a generous grant from the National Science Foundation. Eli is headed to a research assistant position at NIST/Boulder in the Fiber laser source/frequency standards group. Nathaniel will spend one year at Cambridge Univ. on a Herschel Smith fellowship, and then will begin in the Harvard Physics Ph.D. program in the fall of 2018. In the fall, Prof. Majumder was awarded the American Physical Society's Prize to a Faculty Member for Research at an Undergraduate Institution, which he received at the annual Division of Atomic, Molecular, and Optical physics meeting in June in Sacramento, CA.

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 lead (in heated vapor cells) and indium (in a high-vacuum atomic beam apparatus). New results were obtained by both thesis students this year, and their work will be completed and written up in the coming months. Incoming thesis student *Bingyi Wang '18*, who worked in the group last summer, will begin her research this June, and will be joined by *Jeremy Thaller '18*, and *Abdullah Nasir '19* this summer.

A large group of students from the Majumder and Doret groups, along with Professor Singh, attended this year's DAMOP meeting in Sacramento, CA from June 5-9, 2017. At this meeting, in addition to Majumder's APS Prize talk, both thesis students presented posters on their work.

Assistant Professor **Swati Singh** uses theoretical techniques from quantum optics, AMO, and condensed matter to understand and exploit quantum effects in macroscopic systems. Singh is particularly interested in identifying emerging quantum platforms as precise detectors of various physical phenomena, quantifying the effects of decoherence, and developing quantum simulators for many-body effects. Singh uses both analytical and computational methods and works in close collaboration with experimentalists in atomic, optomechanical and solid-state qubit systems.

Derek Galvin '18 takes over Ashay's numerical work in Singh's lab and use it to model the complex behavior of ultracold atoms interacting with lasers. His work will hopefully elucidate some recent experimental results in the field.

Qiyuan Hu '20 will be joining Singh's group for the summer. He will be using his newly acquired math skills to model the interaction of gravitational waves with elastic media.

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 off short pulses of light propagating in fiber, an essential element of high speed fiber optic communications.

In recent years Strait has developed an interest in energy policy and technology. In the fall semester he taught a course for non-science majors called *Energy Science and Technology* (PHS 108) covering electric power generation and distribution, and energy use in transportation, lighting, and buildings. During the winter study period, he taught an electronics class including building and testing electronic circuits. During the spring semester he taught the advanced seminar, *Condensed Matter Physics* (PHYS 451) which included an introduction to solid state physics theory and some applications to semiconductors and semiconductor devices.

Strait served as the college's pre-engineering advisor and as a member of the Campus Environmental Advisory Committee.

Associate Professor **Frederick Strauch** was on sabbatical during the 2015-2016 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 returned from leave to teach, for the first time, *Quantum Physics* (PHYS 301) in the Fall of 2016. He took advantage of the expertise of the laboratory guru, Kevin Forkey, and was grateful to work with the new

semiconductor laser built by students and under the supervision of colleague Charlie Doret. After a brief tour of the universe during his Winter Study course *The Science of Star Trek* (PHYS 15), he returned for a second tour in the Spring of 2017 teaching *Foundations of Modern Physics* (PHYS 142).

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 '17* (now at MIT). During the academic year, he worked with thesis students *Michael May '17* on quantum cellular automata and their applicability to the simulation of the relativistic Dirac Equation, and *Will Kirby '17* on the quantum Schur transform, a method to generate and manipulate highly-symmetric states on a quantum computer to enable enhanced information processing tasks. For summer 2017, Strauch will be working *Sam Alterman '18, Skylar Chaney '19,* and *Mariam Ughrelidze '20.*

In the fall semester, Professor **David Tucker-Smith** taught *Mechanics and Waves* (PHYS 141), and in the spring, he taught *Vibrations, Waves, and Optics* (PHYS 202). Tucker-Smith also taught the winter-study course *Light and Holography* (PHYS 14).

Tucker-Smith continued his research in theoretical particle physics. In June 2016 he participated in a three-week workshop at the Aspen Center of Physics, New Perspectives on Naturalness. There he began a new collaboration developing and studying testable models of baryogenesis, which attempt to explain the matter-antimatter asymmetry in the universe. This work eventually led to a publication in the journal *Phys. Rev. D*. After returning from the workshop, Tucker-Smith worked with summer students *Ian Banta '19* and *Alex Semendinger '18* on aspects of baryogenesis, and he will continue this work with *Noah Cowit '20* and *Nyein Chan Soe '19* during the summer of 2017. During the academic year, Tucker-Smith supervised the research of *Maria Prado '17*, who studied the potential of the Short Baseline Neutrino program at Fermilab to test theoretical explanations of anomalous data recently obtained by various neutrino oscillation experiments. Maria will begin the Physics PhD program at the University of Wisconsin next fall.

Over the past year, Professor **Bill Wootters** has worked with two students, *Sam Alterman '18* and *Jay Choi '17*, in an investigation of an intriguing correspondence between quantum mechanics and statistical mechanics. Initial explorations into this correspondence had already been carried out by *Becky Durst '17* and *Sarah Fleming '17* in a six-week summer project in 2014. In the simplest example, one notices that the position distribution of a single quantum particle in a box, when the particle is in thermal equilibrium with an environment, is remarkably uniform even at modest temperatures. Wootters and his students have been asking to what extent the statistical mechanics of the system can be deduced simply by insisting on this uniformity. Sam undertook a numerical study of the problem in the summer of 2016, and Jay, in his senior thesis, aimed to put Sam's numerical results on a firm mathematical footing. The group hopes to submit a paper on the subject this summer.

In the classroom, Wootters, who is retiring at the end of this academic year, spent his last regular semester teaching two of his favorite courses, each co-taught with a professor from another department. The courses are *Protecting Information: Applications of Abstract Algebra and Quantum Physics* (PHYS 316), co-taught with Prof. Susan Loepp of Math/Stats, and *Philosophical Implications of Modern Physics* (PHYS 312), co-taught with Prof. Keith McPartland of Philosophy. In the latter course, the professors and students were not able to solve all the conceptual problems of quantum mechanics; so the course will have to be taught again in some form in a future year!

In March of 2017, Wootters served as an outside examiner for a doctoral defense at Università della Svizzera italiana (USI) in Lugano, Switzerland.

Post-Graduate Plans of Physics Majors

Jaeho Choi	Seeking employment
David A. Folsom, Jr.	Peace Corps volunteer in Burkina Faso
Jonathan W. Greeno	Finance consultant in Boston
Eli V. Hoenig	Working in Fiber Sources and Applications Group at NIST in Boulder, CO
Sierra E. Jubin	PhD in plasma physics at Princeton University
Owen A. Kay	Research assistant at Federal Reserve Board in Washington, D.C.
William M. Kirby	Working, applying to grad school in physics, traveling and rock climbing
Michael M. May, III	MSc in physics at University of Edinburgh
Dylanger S. Pittman	Seeking employment
Maria V. Prado	Pursuing PhD in physics at University of Wisconsin-Madison
Samuel B. Steakley	Fulbright grant scholar doing smartgrid research at PUC in Santiago
Nathaniel B. Vilas	MPhil in physics at University of Cambridge on Hechel Smith fellowship
Daniel P.G.H. Wong	Masters program in physics at Cambridge University (UK)
Andy Yu Zhu Yao	Trader in New York

Physics Colloquia

[Colloquia are held jointly with the Astronomy Department.]

Amy Banzaert, Wellesley College
"Engineering in the Liberal Arts: Education & Research"

William Bialik, Princeton University
"Physics problems in early embryonic development"

Charles Doret
"Atoms at Work: Quantum mechanics, qubits, and quool tools for research and technology"
Sigma Xi Talk, November 2016

"Quantum Simulations with Trapped Calcium Ions"
Sigma Xi Talk, November 2016

Darine El Haddad, NIST
"Planck's constant, the NIST-4 Watt Balance, and the future of the kilogram"

Leon Golub, Harvard
"Sun and Earth"

Dave Kaiser, MIT
"Testing Quantum Theory with the Cosmos"

Catherine Kealhofer
"Ultrafast electron sources: illuminating the small and fast"
Summer Science Lunch, April 2017

Jeff Linsky, University of Colorado
"UV and X-Ray Emission from exoplanet host stars: Results of the muscles HST Survey"

Scott Olesen '10, MIT
"Discovering hidden ecological relationships between bacteria using modeling and statistics"

Larry Ruzzo, University of Washington
"Bias in RNA sequencing and what to do about it"

Joseph Silk, University of Oxford
"Dark Matters"

Abi Singh, University of Delaware
"Reverse engineering cellular processes and making cells to do fun things"

Swati Singh
"Using simple quantum systems as detectors"
Summer Science Lunch, May 2017

"Testing Reality with Quantum Physics"
Faculty lecture series, March 2017

Duffy Turner, NYU
"Distinguishing line-broadening mechanisms in CdSe nanocrystals using two-dimensional spectroscopy"

Alipasha Vaziri, Rockefeller University
"Direct detection of a single photons by humans"

Lorenza Viola, Dartmouth College
"Perspective On Quantum Information Science and Quantum Noise Control"

Amar Vutha, University of Toronto
"Time in the tides of gravity"

Bill Wootters
"Einstein's spooky action at a distance"
Staff Lunch Lecture, April 2017

Off-Campus Physics Colloquia

Daniel Aalberts

"Optimum Protein Technologies: Harnessing the commercial power of proteins"
MassVentures, August 2016.

"Codon Influence Models for E. coli and B. Subtilis"
(Intekhab Hossain '17 and DPA), RNA Symposium, U. Albany, March 2017

"Calculation of RNA Secondary Structure Multiplicity of Microstates"
Poster presentation (Nikolaus Howe '17 and DPA), RNA Symposium, U. Albany, March 2017

"Optimizing mRNA for high protein expression"
Poster presentation (Daniel Wong '17 and DPA), RNA Symposium, U. Albany, March 2017

"The mRNA sequence features controlling protein expression in E. coli"
Invited Talk. Biophysics Group at the Free University Berlin, April 2017.

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

Kevin Jones

"Where am I? Cold Atoms, Super-accurate Clocks and Navigation"
Washington DC Williams Alumni event, May 2017

Catherine Kealhofer

"Generating and controlling ultrafast electron pulses for time-resolved electron diffraction"
Trinity College, Hartford, CT (Physics Seminar), September 2016

"Generating and controlling ultrafast electron pulses for time-resolved electron diffraction"
Amherst College Physics Colloquium, Amherst, MA, January 2017

Tiku Majumder

"Research and Teaching through high-precision spectroscopy of heavy atoms"
APS Prize talk, Sacramento, CA, June 2017

"Precise measurement of the lead 3P0-3P2 electric quadrupole transition using Faraday rotation spectroscopy"
APS Division of Atomic Molecular and Optical Physics meeting, Sacramento, CA, June 2017

"Precise measurement of indium 7p polarizabilities using two-step excitation in an Atomic Beam"
APS Division of Atomic Molecular and Optical Physics meeting, Sacramento, CA, June 2017

Swati Singh

"Using quantum systems as detectors"
Physics Department Colloquium, Amherst College, April 2017

"Detecting continuous gravitational waves with superfluid helium"
ITAMP Lunch Seminar, Harvard University, Cambridge, MA, November 2016

David Tucker-Smith

"Baryogenesis at the weak scale"
Physics Colloquium at Amherst College, March 2017

Bill Wootters

"A curious quantum-classical correspondence"
Kenyon College, September 2016

"Why does nature like the square root of negative one?"
University of Massachusetts, Amherst, October 2016

Psychology Department

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

Psychology students have multiple opportunities to conduct research collaboratively with professors. Some of these are empirical projects conducted within required 300-level lab courses, and others are in work-study or research assistant positions, or as more formal independent studies. Also, in 2016-17, 11 students completed yearlong senior honors thesis research under the direction of Psychology faculty. Their projects are listed in the Student Thesis Abstracts section of this report. Department events this year included student/faculty/family picnics, evening programs on "Graduate Study in Psychology" and "Careers in Psychology," and a wine and cheese reception to celebrate honors theses presentations. Our student liaison committee met to discuss departmental policies and host "snacks" in our lounge. To encourage students to explore careers in psychology, the Class of 1960 Scholars Program brought accomplished researchers from universities to campus to give colloquia. The junior and senior 1960 Scholars read the speaker's work and then joined the speaker and faculty for a reception and dinner afterward. This year marked the eighth 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 *Julia Cheng '17* 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 that our two newest faculty, Jeremy Cone and Laura Smalarz, are both off to fantastic starts at Williams with both their innovative research and highly successful teaching. 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. 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.

The Psychology department benefited greatly by having three visiting faculty stay on this year: Jeff Moher, teaching in cognitive psychology, Nicole Harrington, teaching in clinical psychology, and Lauren Williamson, 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, 2016-17 marked our last year in the long-time home of the psychology department at Williams, the Bronfman Science Center. The College is in the process of building two new science buildings, one of which will replace Bronfman, and from the summer of 2017 through the summer of 2020, the psychology department offices and labs will be housed in a temporary building on Stetson Court. The move from Bronfman was bittersweet, as we have long and good memories of our years in Bronfman but are also excited at the prospect of a new, modern building in the coming years. As we were preparing to vacate Bronfman, we were hit with the sad news of the death of Richard Rouse, the Mary A. and William Wirt Warren Professor of Psychology, emeritus, who taught at Williams from 1948 until 1983; when the Bronfman Science Center was designed and built in the late 1960s and early 1970s, Richard played a leading role in the planning and outfitting of the building, as well as raising research and equipment funds. Even though Richard retired in 1983, until recently he was a regular presence in the psychology department, working mornings in his small office in Bronfman, attending talks and events, giving tours of Williamstown to new and visiting faculty, and regaling many of us with stories of his many years in the field of psychology.

Class of 1960 Scholars in Psychology

Claire Bergey ‘17	Min Kim ‘17
Mollie Bernstein ‘18	Chris Lyons ‘17
Julia Cheng ‘17	Megan Maher ‘17
Olivia Clark ‘17	Velia Moran Olivas ‘17
Jane Dai ‘17	Arielle Rawlings ‘18
Anna DeLoi ‘18	Jose Rivera-Aparicio ‘17
Gabrielle Gauthier ‘17	Scott Shelton ‘17
Hanane Goelzer ‘17	Abigail Soloway ‘18
Gabrielle Ilagan ‘18	

Assistant Professor **Jeremy Cone** continued to build and develop the Implicit Cognition and Evaluation (ICE) Lab this year. *Katie Flaharty ’18* continued her work in the lab in her junior year, which she began as a sophomore in Spring 2016. A number of new students also joined the lab this year: in the Fall, *Michael Ding ’18*, *Mollie Bernstein ’18*, and *Spencer Lee-Rey ’18* all joined the lab, working on studies assessing the extent to which the believability of new information about someone can influence the extent to which it is incorporated into non-conscious responses towards them, among others. Michael and Mollie moved on to study abroad after their Fall semester, but Spencer continued in the lab into the Spring semester. *Carmen Bango ‘20* joined the lab during Winter Study ’17 in which she and Katie conducted research that continued into the Spring semester exploring how people can sometimes be unaware of reversals in their preferences and how these kinds of situations in which people experience “choice blindness” can influence people’s implicit, non-conscious preferences for different faces. *Grace Murray ’20* joined the lab in the Spring semester and conducted research exploring how people’s levels of empathy and compassion can influence how they visually represent ingroup and outgroup members. *Charley Wyser ’17* also joined the lab for the Spring semester and conducted work exploring how people respond to fairness violations, as well as work exploring how surprising revelations about well-known figures can influence people’s implicit impressions of them.

Cone also supervised three thesis students: *Gabby Gauthier ’17*, *Ananya Mayukha ’17*, and *Benjamin Lin ’17* and served as an unofficial advisor and second reader for *Jose Rivera Aparicio ’17* and *Jane Dai ’17*, respectively. He also supervised two independent studies. *Alexander Huang ’17* completed an independent study assessing how ideas from the social cognition literature can inform our understanding of how to optimize the efficacy of interventions targeting people’s subjective well-being. *Erika Diaz ’17* completed an independent study assessing the role of implicit associations with guilt and innocence in people’s assessments of evidence in criminal cases. She explored, in particular, how Black defendants may suffer from a greater (implicit) presumption of guilt when they fail to disclose information, such as when pleading the fifth or exercising Miranda Rights. She also explored, in collaboration with *Elizabeth Rounds ’17*, the psychology of planting evidence.

Eva Fourakis ’16 attended her first Society for Personality and Social Psychology (SPSP) conference, presenting a poster featuring some of her work conducted while she was at Williams exploring the role of causal attribution processes in implicit attitude change. *Benjamin Lin ’17* and *Jose Rivera-Aparicio ’17* also attended their first conferences, presenting work from their theses, co-authored with Prof. Mariko Moher, at both Object Perception Attention and Memory (OPAM) and Vision Sciences Society (VSS).

Next month, a high-profile invited chapter will appear in *Advances in Experimental Social Psychology*, titled “Changing Your Implicit Mind: How, When, and Why Implicit Evaluations Can Be Rapidly Revised”, summarizing his theoretical approach to implicit evaluative approach and several lines of research conducted to date. His work was also featured in a piece in the *New York Times*, “How Kids Learn and Unlearn Prejudice”, as well as in a piece in Quartz that he co-authored with Prof. Ken Savitsky, *Jeffrey Rubel ’17*, and Richard Eibach “The big mistake most people make when they receive negative feedback”. Finally, his winter study course, *Psychology of Eating*, was featured in Williams Magazine.

He gave a talk at “Boston JDM Day” hosted by Boston University in May 2017 titled “Implicit Intuition: Implicit assessments of the accuracy of intuition and reason are uniquely predictive of judgment and choice” co-authored with a graduate student at Yale University, Matthew Jordan, and Fiery Cushman at Harvard University. He gave a talk in Granada, Spain in summer ’17 as part of a symposium on “Explicit effects on implicit attitudes: New perspectives on mechanisms of attitude formation and change” to the 18th General Meeting of the European Association of Social Psychology (EASP). In late July, he attended a mini-conference hosted by Yale University on the relative contributions of associative and propositional information to implicit evaluative change.

In addition to all of these positive developments, he is very happy to report that, after suffering a devastating 0-8 loss to the Smalarz lab last year (as documented in

last year's Report of Science), the ICE Lab has been on a positive trajectory in its inter-lab competitions, achieving an exact tie in the ICE Lab—ECC Lab (Moher) Chopped! Challenge in the Fall, and edging out a very narrow win in candlepin bowling against the CRUDD Lab (Kornell) in the Spring.

Professor Emeritus **Phebe Cramer** continued her research on defense mechanisms, and carried out two longitudinal studies. One of these traced the childhood precursors of adult borderline personality disorder. The other followed the development of Williams students after graduation, looking at personality change.

In June, she was invited to present a seminar to the staff of the Austen Riggs Center, in Stockbridge, Mass., on the topic "Learning to Assess Defense Mechanisms from the TAT". In January, she was an invited discussant for a research seminar at the American Psychoanalytic Association meetings in New York City.

In February, she gave a seminar to the Valley View Mental Health Center in Washington on the study of defense mechanisms. Also, in February she gave a presentation to the Griffin Seniors Association on the topic of Change in Narcissism with Age.

In March, she attended the annual meeting of the Society for Personality Research, where she presented a workshop on "Using the TAT to Assess Defense Mechanisms". At these meetings, she was also the discussant at a Research Seminar on Defense Mechanisms at which she also presented a paper, "Defense Mechanism Card Pull in TAT stories".

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, Professor **Susan Engel** published a new book, written with her son Samuel Levin, called A School of Our Own: The Story of the First Student-Run High School and a New Vision for American Education (October 2016, The New Press).

She presented a paper on children's curiosity at the Summit for Grit and Imagination at University of Pennsylvania, and a paper on children's pursuit of ideas at an interdisciplinary conference on curiosity, also, coincidentally, at the University of Pennsylvania. In January, she gave at talk at The Harvard Graduate School of Education titled "Do Children Have Ideas?"

She gave talks on K-12 education to educators and families at public schools in New York, Chicago, Los Angeles, Palo Alto, and Baltimore.

In the fall she taught a new upper level seminar with a lab called: *Inquiry, Invention and Ideas* (PSYC 338) Students' research included an experiment comparing several kinds of adult influence on children's innovative use of several every day materials, children's ideas about dreams, stones and thoughts (a replication of a study conducted by Jean Piaget in 1929), an experiment measuring the impact of delayed answers on children's curiosity, and two studies comparing the intellectual curiosity of first and fourth year college students.

She and *Anna DeLoi '18* conducted a study comparing the impact of several kinds of narratives in eliciting philosophical thinking in young children.

She continues to serve on the board of Planet Word, a new museum of language in Washington DC, and Math Talk, an initiative designed by Omo Moses, aimed at encouraging families to talk about math with their toddlers and preschoolers. She participated in a consortium in South County involved in implementing new ways to make sure that low-income children will thrive in school.

Professor **Laurie Heatherington** and her students continued research on change processes in psychotherapy, the role of cognitive factors in individual and relationship difficulties, outcomes of residential treatment for major mental illness, and global mental health.

She published two studies with *Pacifique Irankunda '13*, one of which was co-authored by *Jessie Fitts '13*, in the *Journal of Transcultural Psychiatry,* based on his honors thesis research on mental health in Burundi. She presented a paper based on this research, "Lessons for psychotherapy researchers on treatment research in developing countries" at the June 2016 International Society for Psychotherapy Research Conference in Jerusalem and another talk, "Measuring the "unmeasurable?": Interactional concepts and the process of psychotherapy" at a panel in honor of Varda Shoham, at the same conference. In August 2016, she presented a poster, "From service to science: A 15-year study of outcomes of residential treatment for severe and persistent mental illness" at the 23rd NIMH Conference on Mental Health Services Research, Bethesda, MD, with several co-authors including *Ellen Finch '13*. In May 2017, with *Chanel Zhan '16* and Bernhard Klingenberg (Williams Statistics Dept.), she presented a poster, "Disordered eating- and exercise-related cognitions and behaviors during the first year of college: A three-wave longitudinal study at the Association for Psychological Science (APS) Convention in Boston, based on data. In May 2017, she gave an invited talk at the Austen Riggs Cen-

ter, Stockbridge, MA, "Measuring the milieu: A 15-year study of outcomes of residential treatment for serious mental illness."

Professor Heatherington served on the Editorial Boards of *Psychotherapy Research; Journal of Family Psychology; Psychotherapy: Theory, Research, Practice, and Applications; Journal of Clinical Psychology: In Session;* and *Journal of Marital and Family Therapy* and on the Publications Board of the Society for the Advancement of Psychotherapy. She also served on a Grant Review Panel for the Uniformed Services University – Global Health Engagement Center. For Berkshire NAMI (National Alliance for the Mentally Ill) Chapter, she conducted an evaluation of the Crisis Intervention Training program, which helps police deal with mentally ill individuals. She served on the Directors and Associates Board, and chaired the Program Committee, of the Gould Farm, a treatment center/working farm in Monterey, MA, which serves people with schizophrenia and other serious mental illness.

Assistant Professor **Mariko Moher**'s research focuses 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, her thesis students *Ben Lin '17* (co-advised with Professor Jeremy Cone) and *Jose Rivera-Aparicio '17* presented some of their work at the annual Object Perception, Attention, and Memory meeting in Boston. Jose also traveled to St. Pete Beach, FL, in May to present their thesis work at the annual meeting of the Vision Sciences Society. Throughout the year, Ben and Jose worked with *Mallory Chen '17* and *Maya Bracy '19* to go to local elementary schools including Pine Cobble School and Lanesborough Elementary School to collect data for their work. In addition, *Megan Pierce '17* and *Brian Benitez '18* worked with children at Williamstown Elementary School to continue a project that Megan had begun last year as her empirical project in the Cognitive Development class, examining how children's narrative skills were related to their pretend play and language development.

Professor Moher served as a reviewer for *Infancy*, and is a consulting editor for *Developmental Psychology*.

Professor **Noah Sandstrom** returned from a two-year stint co-directing the Williams-Exeter Programme at Oxford University and has resumed his research exploring factors that influence outcome following repeated mild traumatic brain injuries. In preparation for a new tutorial on neuroethics, he attended the annual meeting of the International Society for Neuroethics in November. He also attended the annual meetings of the Society for Neuroscience and the meeting of the Faculty for Undergraduate Neuroscience where he serves as a past-president. Professor Sandstrom spoke about his research to alumni groups in Toledo, Cleveland, and Charlotte.

Assistant Professor **Laura Smalarz** finished her second year in the Psychology Department at Williams College. She worked with students *Max Friend '17* and *Kenneth Park '17* over the course of the year on two research projects designed to investigate the contaminating effects of social influence on eyewitness identification evidence. She also collaborated with *Angela Chang '17* on two studies that followed up on original research conducted by Chang as part of Smalarz's "Research in Psychology and Law" course the previous spring. This spring, Smalarz worked together with fellow Social Psychology Professor Jeremy Cone to supervise students *Elizabeth Rounds '17* and *Erika Diaz '17* on an independent study project examining the psychology of planting evidence – a research inquiry inspired by the Netflix original series *Making a Murderer*. Also inspired by the series, *Scott Shelton '17* successfully defended his honors thesis, which tested whether having been wrongfully convicted of a crime puts exonerees at risk of subsequent conviction.

Smalarz published three papers in varied areas of the Psychology and Law interface, including two on criminal suspects' decision making and suggestibility during custodial police interrogation (Smalarz, Scherr, & Kassin, 2016; Madon et al., 2016) and one on the effects of criminal stereotypes on evaluations of forensic fingerprint evidence (Smalarz, Madon, & Buck, 2016). Smalarz served as an ad-hoc reviewer for a number of journals including *Law and Human Behavior* and *Journal of Experimental Psychology: Applied* and as a reviewer of grant proposals for the National Science Foundation and the American Psychology-Law Society. Smalarz presented her work at the New York University Journal of Legislation and Public Policy Annual Symposium and at the Annual Meeting of the American Psychology-Law Society Conference.

Associate Professor **Catherine Stroud** received tenure and promotion in January of 2017. She 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 depression. *Julia Cheng '17* completed a senior honor thesis under her mentorship. Julia examined rumination as a mechanism through which serotonergic genetic risk interacts with early adversity to predict stress generation and depressive symptoms. Catherine and her colleagues presented their work examining the contribution of ear-

ly adversity and recent stress to trait-like individual differences in HPA axis activity at the Annual Meeting of the Association for Behavioral and Cognitive Therapies (ABCT). In the *Journal of Adolescence*, Catherine, *Effua Sosoo '12*, and her colleague published a paper demonstrating that adolescents who use higher levels of rumination (a maladaptive coping style) tended to create more stressful interpersonal environments. In addition, Catherine and her colleagues published a meta-analysis in *Psychological Bulletin* examining the role of interpersonal dysfunction in personality disorders. Stroud also co-authored a manuscript examining day-to-day links between diurnal cortisol and coping strategies in the *Journal of Youth and Adolescence*, the findings of which were presented at ABCT. She co-authored a manuscript investigating the link between rumination and diurnal cortisol in the *Cognition & Emotion*. Along with her colleagues, she co-authored a manuscript in *Development & Psychopathology* showing that experiencing early adversity during childhood moderates the impact of proximal acute stress on the cortisol awakening response. Catherine and her colleagues published a chapter on the role of interpersonal relationships in mood and anxiety disorders in the *APA Handbook of Contemporary Family Psychology*, as well as an essay in the *Encyclopedia of Adolescence* on pubertal timing. Catherine continued in her role as Associate Editor of *Family Process*.

Professor **Betty Zimmerberg** continued her research during her fall sabbatical with *Anika Mitchell '18* and *Lauren Steele '18*. They use an epigenetic animal model that explores interactive effects of genetically determined affective temperament and adverse environmental conditions to better understand the deleterious effects of an early negative trauma on brain and behavioral development. The Zimmerberg lab also collaborated on a neuroimmunology project with Visiting Assistant Professor of Psychology Lauren Williamson. 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. In the spring term, Zimmerberg taught her interdisciplinary seminar, *Image, Imaging and Imagining* (PSYC 318) which pairs the scientific literature on visual neuroscience and the psychology of perception with weekly sessions in the Williams College Museum of Art's Rose Gallery, examining works from their collection as they relate to the scientific content.

Psychology Department

Gabrielle M. Amos-Grosser	Working in the marketing department for WME | IMG, a sports and talent agency/management company
Ashley E. Arnold	Working as a Customer Experience Analyst at NYC-based fashion company MM.Lafleur
Nini Arshakuni	Unknown
Johanna M. Beattie	Planning to do something in Marketing either in Boston or NYC
Caitlan B. Benell	Hoping to work towards becoming a comedic television writer
Claire A. Bergey	Attending the University of Chicago in the psychology PhD program, specifically in the developmental and cognitive areas.
Sierra W. Betts	Working for InterVarsity Christian Fellowship on college campuses in the Cambridge/Boston Area
Brett A. Bidstrup	Undecided
Megan K. Bird	Planning to find a research lab to work in, possibly dealing with language or memory
Phillip R. Brockman	Going to Louisville, Kentucky to get a master's degree in teaching in order to be a high school math teacher
Yvonne C. Bungei	Working as a resident assistant at the Fellside House in Boston
Angela Chang	Teaching high school math with Teach For America for two years, then law school
Mallory Y. Chen	Hoping to be a medical scribe or work in clinical research
Julia C. Cheng	Doing clinical research with a gynecologic oncologist at Kaiser Permanente in California and then medical school
Jenna R. Chodos	Working for HawkPartners doing market research and marketing consulting in Boston

Olivia E. Clark	Planning to take a position in a Physiology research lab at Nationwide Children's Hospital in Columbus, OH
Garcelle E. Coldros	Working in School Operations as an Office Manager at Uncommon Schools in NYC
Jane Dai	Pursuing a MPH at Yale University School of Public Health
Erika C. Diaz	Applying to John Jay College of Criminal Justice's Master of Arts in Forensic Psychology program after working to earn a certificate of proficiency in German
Rebecca L. Dunwoody	Working an internship in strategy at the digital agency POSSIBLE in Seattle this summer and possibly pursuing that long term
Justin B. Edwards	Taking a gap year and then applying to grad school in Human-Computer Interaction; during the gap year, he is hoping to spend at some time working in a Psychology lab
Yedidya A. Erque	Currently in the process of applying to research assistant positions; eventually, hoping to go to graduate school for clinical psychology
Gabrielle M. Gauthier	Working as a research assistant at the National Center for PTSD (NCPTSD) in Boston, which operates through the VA
Hanane Goelzer	Planning on going on to PA school
Samuel D. Gray	Working for A.T. Kearney, a management consulting firm in New York City.
Seba Haidar	Planning to go into teaching (hopefully middle school Math)
Sarah R. Hasselman	Doing a teaching apprenticeship
Alexander C. Huang	Working in consulting at OC&C in New York for the next 2 years!
Kristen L. Johnson	Unknown
Min Kim	Unknown
Christopher I. Leflore	Unknown
Jonah M. Levine	Unknown
Jilly Lim	Working as a junior data specialist at Twitter in Boston
Benjamin Lin	Hoping to get a job as an analyst to work in data science or perhaps to move into advertising/marketing type positions
Larry Lopez	Unknown
Christopher K. Lyons	Attending the Masters of Medical Sciences program at Boston University's School of Graduate Medical Sciences for two years, and then applying to medical school
Megan J. Maher	Working At Purdue University with the Coalition for Christian Outreach, an organization that partners with local churches and community service organizations throughout the nation to reach out to college students.
Ananya Mayukha	Unknown
Rose W. Miles	Teaching English and volunteer with refugee/immigrant children in Berlin; then applying to graduate school and hopefully write a lot of poetry along the way
Velia A. Moran Olivas	Working as an Admission Counselor at Williams College
Alyza B. Ngbokoli	Planning to get a temporary teaching, coaching, or administrative assistant job before applying to graduate programs in school psychology and/or urban education policy
Kyung Chan Park	Unknown
Megan L. Pierce	Working as a Kindergarten teaching fellow at Basis Independent charter School in Manhattan
Jose E. Rivera-Aparicio	Working as the lab manager of the Perception and Mind Lab at Johns Hopkins University with Prof. Chaz Firestone
Michael A. Rodriguez	Unknown

Amy M. Rosten	Teaching at Derby Academy in Hingham, MA, as a 3rd grade Assistant Teacher and Spanish teacher
Elizabeth P. Rounds	Heading to grad school to become a neonatal nurse practitioner
Isabella L. Salmi	Working at a data science firm
Scott A. Shelton	Working as an Associate at Parthenon-EY, a Management Consulting firm in Boston
Jada L. Smith	Unknown
Anna M. Spellman	Unknown
Stephanie E. Stacy	Going to UCLA for their doctoral program in statistics
Gabriela L. Suarez	Heading to the University of Maryland to work as a faculty research assistant in the Child Development Lab under the direction of Dr. Nathan Fox
Katherine A. Tardiff	Hoping to pursue a career in either political science research or in library sciences
Aunrika D. Tucker-Shabazz	Ph.D. Program in Sociaology at University of Michigan, Ann Arbor
Katherine A. Wardlaw	Work at the FBI as an Operational Support Technician
Austin B. Wruble	Going to UVA law school
Charley Wyser	Working as a Global Data Operations Associate at the tech startup, Flexport, in NYC

Psychology Colloquia

Susana Martinez-Conde, SUNY Downstate
"Neuroscience lecture on Splendor, Myth, and Vision: Nudes from the Prado at The Clark"

Goren Gordon, Tel Aviv University
"Curiosity in Children and Robots: What Can They Learn From Each Other?"

Eli Finkel, Northwestern University
"Dating, Marriage, and Modern Romance"

Nicola Caldwell '92, Cincinnati V.A. Medical Center
"Research on Trauma"

Off-Campus Psychology Colloquia

Mariko Moher
"Flexible Prioritization of Feature Dimensions in Perception of Objects, Ensembles, and Social Stimuli"
Poster presented with *J. E. Rivera-Aparicio '17, B. Lin'17*, J. D. Cone. At the Annual meeting of the Vision Sciences Society, St. Pete Beach, FL, May 2017

"Effect of Spatial and Conceptual Chunking Cues on Children's Working Memory"
Biennial meeting of the Society for Research in Child Development, Austin, TX, April 2017

"Prioritization of Features in Object and Ensemble Perception"
Poster presented with B. *Lin '17*, J. E. Rivera-Aparicio '17, J. D. Cone
Annual meeting of Object Perception, Attention, and Memory, Boston, MA, November 2016

Noah Sandstrom
"Decoding the Brain: Clinical and Ethical Perspectives"
Toledo, OH, December 2016

"Decoding the Brain: Clinical and Ethical Perspectives"
Cleveland, OH, December 2016

"Head Injury in Sport: A Multidimensional Perspective"
Charlotte, NC, January 2017

Laura Smalarz

"Miranda at 50: A Psychological Analysis"
New York University Journal of Legislation and Public Policy Annual Symposium, New York University School of Law, New York, NY, February 2017 with Coauthors: K. Scherr and S. Kassin

"On the 'Forensic Equivalence' of Filler Identifications and Lineup Rejections: The Case of Multiple Lineups"
American Psychology-Law Society Conference, Seattle, Washington, March 2017 with Coauthors: N. Kornell and K. Vaughn

"Using the Right Tool for the Job: Memory Performance is (still) Superior when Lure-Target Similarity is Low"
American Psychology-Law Society Conference Seattle, Washington, March 2017 with Coauthors: A. Smith, G. Wells, and J. Lampinen

Catherine Stroud

"Daily Physiological Stress Processes Among Early Adolescent Girls: Relation to Day-to-Day and Individual Differences in Coping"
Annual meeting of the Association for Behavioral and Cognitive Therapies, New York, NY, October 2016. Presented with M. Sladek, L. Doane

"Individual Differences in Early Adolescents' Latent Trait Cortisol (LTC): Relation to Early Adversity and Recent Stress"
Co-chair Oral Symposium
Annual meeting of the Association for Behavioral and Cognitive Therapies, New York, NY, October 2016 Presented with F. R. Chen, L. D. Doane, & D. A. Granger

"Depression Risk and Affective Response to a Sad Mood Induction"
Annual meeting of the Society for Research in Psychopathology, Baltimore, MD, September 2016 Presented with V. Sapuram, S. Vrshek-Schallhorn, & L. M. Hilt

Abstracts from Student Theses

Astronomy

Spectroscopy of Planetary Nebulae at the Bright End of the Luminosity Function

Anneliese M. Rilinger

We have obtained spectra of eight luminous planetary nebulae (PNe) in M31 and four in the Large Magellanic Cloud with the goal of understanding their properties and those of their progenitor stars. These PNe are at or near the M* region in their respective galaxies. M31 PNe were observed at the Gran Telescopio Canarias using the OSIRIS spectrograph; LMC PNe were observed with the FORS2 spectrograph at the Very Large Telescope. Line intensities were measured in IRAF. Using our n-level atom program, ELSA (Johnson, et.al, 2006, Planetary Nebulae in our Galaxy and Beyond, 234, 439), we determined temperature, density, and elemental abundances for each nebula. We then modeled the nebulae and central stars with Cloudy (Ferland, et al. 1998, PASP, 110, 761). We use these models of the central stars to estimate the masses and ages of the progenitor stars. We find that the progenitor stars of M* PNe may exhibit some different characteristics from those of other PNe progenitors, namely oxygen abundance, density, and luminosity, but there is no significant difference between the masses and ages of the two groups of nebulae.

Towards Control of Trapped 40Ca+ for Quantum Simulation

Sarah A. Stevenson

We have worked towards control of 40Ca+ ions to be used for analog quantum simulation by preparing the laser which will be used to manipulate the internal state of the ions. We work to stabilize this laser at its frequency of 729 nm, meant to address the narrow 4S1/2 →3D5/2 electric quadrupole transition. Our chosen method is the Pound-Drever-Hall technique, which allows us to lock the laser to an ultra-stable Fabry-Perot cavity. We have assembled the necessary optics, aligned the laser into the cavity with the necessary high precision, and set up the phase modulation with an electro-optic modulator which will allow us to obtain the Pound-Drever-Hall error signal.

Biology

Optogenetic Stimulation of AgRP Neurons Lengthens and Deepens Torpor in Mice

Maria Vicent Allende

In response to food scarcity and low ambient temperatures, mice enter bouts of torpor resulting in energy conservation. During a torpor bout, mice exhibit a substantial decrease in body temperature (Tb), heart rate (HR), and metabolic rate. The neurobiological basis of torpor is relatively unknown. Peripheral administration of ghrelin, a stomach-derived hormone released during energy deprivation, deepens and lengthens torpor bouts. Ghrelin induces physiological effects by activating agouti-related protein (AgRP) expressing neurons in the arcuate nucleus of the hypothalamus. Therefore, we hypothesized that optogenetic and chemogenetic stimulation of AgRP neurons would decrease the minimum Tb of torpid mice and increase the time spent in torpor. We also hypothesized that chemogenetic inhibition of AgRP neurons would have the opposite effects. To test these hypotheses, mice were implanted with electrocardiography and body temperature telemeters and hypothalamic AgRP neurons were selectively targeted with optogenetic or chemogenetic transgenes. Optogenetic stimulation of AgRP neurons significantly lengthened and deepened torpor, while chemogenetic stimulation of AgRP neurons showed a non-significant trend towards deepening and lengthening torpor. There was no effect on torpor physiology by chemogenetic inhibition of AgRP neurons. These data support the hypothesis that AgRP neurons directly regulate torpor physiology and begin to elucidate the neural circuits responsible for torpor regulation.

Quantifying Spatial and Temporal Patterns of Carbon Sequestration in the Beinecke Stand, Williamstown, MA

Nigel Bates

Old-growth forests had long been thought to stop accumulating carbon upon reaching a certain age. However, several studies conducted in the past two decades have begun to challenge that notion. In an attempt to contribute to the yet unresolved question of carbon sequestration in old-growth forests, I completed a full inventory of organic carbon in the Beinecke Stand, a 12.5-acre parcel in the Hopkins Memorial Forest estimated to be over 250 years old. Unlike most of the surrounding land, the Beinecke Stand was never cleared for farming, grazing, or timber production, so it offers a significant opportunity to study the dynamics of an old-growth ecosystem. The stand is dominated by the climax species sugar maple (Acer saccharum) and American beech (Fagus grandifolia), while red oak (Quercus rubra) is gradually dying off. The total estimated carbon in the Beinecke Stand in 2016 was 1,318 mt, or 26,200 g/m^2. Historical comparisons, though limited by the scope of the data, are still instructive. The 2016 survey represented the highest carbon concentration ever measured in the Beinecke Stand. From 2013 to 2016, organic carbon stored aboveground in standing trees increased by 350 g/m^2, an annual increase of 0.71%. Most of the increase could be attributed to growth by A. saccharum. This continued a pattern of increasing carbon that had held for the past 15 years. For the 15 years before that, though, the trend was one of decreasing carbon facilitated mostly by decline of Q. rubra. It is yet unclear whether the Beinecke Stand is an old-growth carbon sink over the long term, or whether 2016 simply represents a local maximum in a fluctuating steady-state equilibrium. More years of data collection, ideally across all strata in which organic carbon are stored, will be needed before a stronger conclusion may be drawn.

Hedging Bets and the Pattern of Sibling Group Membership in Populations of the Chorus Frog Pseudacris maculata.

Osama Brosh

Natural populations often inherit their spatial structure from their ecosystem. It is of great interest how populations adapt to this structure and what strategies they take up in their life histories to maximize their fitness under such conditions. Further, the existence of complex and overlapping spatial gradients presents an interesting problem in habitat selection and maximizing fitness relative to spatial as well as well as ecological variables. We looked at a population of Pseudacris maculata, a species of chorus frog found in many parts of the United States and Canada, that resides on North Government Island in Isle Royale. Females in this population lay their eggs in highly variable freshwater pools that span the length of the island's shore, and, as a result, the fitness of the tadpoles is largely affected by the quality of the pools they are in, creating a fascinating challenge for the frogs in their selection of high quality pool. Using microsatellite data from 2009 and 2012, we reconstructed full sibling and half-sibling groups to determine the population structure across the pools, inferring that females engage in brood partitioning behavior across multiple pools. We also used the genetic data to find estimates of effective population size in our study site noting an increase from 21 in 2009 to 49 in 2012. Although only probabilistic, these results provide clear insight into this frog population. Finally, we used morphological information to find relationships between sibships, pools, and phenotype. We also established a dataset that will be used in future studies to conduct further analyses of the population structure, such as an exploration of the forces that shape the spatial patterns in morphology relative to the spatial structure of the shore, and the underlying reproductive and life history strategies of the frogs. This marks a big step in understanding the way these natural populations are structured relative to their environment, and therefore allows for a better grasp of the interaction between evolution and ecology in this kind of system.

The Role of Dopamine Receptor in Arousal Regulation in Drosophila melanogaster

Graham Buchan

An organism's arousal state is modulated by many factors, both internal and external, which are regulated by various mechanisms including dopamine signaling in the nervous system. Arousal has been found to modulate attention-related processes in a bell- shaped manner, where too low or too high arousal results in decreased performance of a given attention-regulated behavior. To study this relationship, this investigation used the Stampede Assay, an experimental rig that can modulate arousal in Drosophila melanogaster through mechanical startle stimulus in order to asses the flies' visual attention through visual motion stimulus that elicits a phototactic behavior called the opto-

motor response. Previous studies have shown that populations of wildtype flies perform the optomotor response in the assay better at heightened arousal states and that flies with a dopamine receptor mutation perform the behavior poorly, regardless of startle conditions. Thus, using the Drosophila melanogaster model system, this investigation sought to determine how the dopamine receptor mutation may affect arousal and attention, as well as what parameters modulate the optomotor response. The results indicated that 1) behavioral phenotypes in populations are also observable in individual animals 2) the speed of the visual motion stimulus and pattern of the mechanical startle stimulus modulate optomotor performance by wildtype flies, while population size may affect performance by dopamine receptor mutants 3) DopR activity is required in multiple areas of the Drosophila brain, in particular the ellipsoid body and optic lobes, for proper optomotor performance and thus arousal regulation.

The Role of Peptidoglycan Recognition in A. Thaliana Defense Against A. tumefaciens Infection

Michelle Buncke

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 the T6SS presence limits transient transformation (TT) by A. tumefaciens onArabidopsis seedlings. The aim of this project is to determine what T6SS effectors are responsible for eliciting specific host defense responses. We found that the T6SS limits TT even in the absence the defense gene, mlo12, which underscores the role of MLO12 in mediating physical barrier defenses. We found that bacteria lacking the amidase effector were better able to transformArabidopsis seedlings lacking LYM receptors, LYM1 and LYM3, which are responsible for PGN recognition. This may indicate that LYM2 and/or LYM3 recognize general PGN fragments in addition to those specifically degraded by the T6SS amidase effector. Furthermore, we observed that Arabidopsis seedlings with a C-terminus insertion within the lym3 gene had constitutively on defenses, whereas seedlings with an N-terminus insertion within the lym3 gene or an insertion within the lym1 promoter behaved as loss-of-function mutants. Agrobacterium lacking the T6SS DNase effector were unable to dampen defenses in seedlings, which may suggest that the DNase effector may be necessary to dampen plant defenses. In all, these findings contribute nuance to a strong body of literature relating A. tumefaciens T4SS virulence, T6SS activity and plant defense responses. These findings may prove useful in agricultural studies focused on plant-pathogen interactions.

Targeting Lung Tissue Resident Memory T-cells in Allergic Asthma

Minwei Cao

Tissue resident memory T-cells (TRMs) reside in lung parenchyma and contribute to chronicity and recurrent inflammation in allergic asthma. We hypothesized that if lung TRMs could be induced to leave the lung tissue then asthmatic symptoms could be ameliorated upon subsequent re-exposure. The exact mechanism of TRMs' retention in lungs is unknown, but antagonism of the chemotactic receptor S1P1 receptor by the protein CD69 is one suggested possibility. In order to elevate S1P1 receptor expression levels and allow for TRMs to egress, CD69 needs to be downregulated by blocking the IFN-1 cytokine signaling. We treated HDM-sensitized asthmatic mice with a blocking antibody (α-MAR1) to block IFN-1α receptors and concluded that this treatment does not promote TRMs to egress. These results showed that IFN-1α receptor blocking antibody may not be the right treatment or could even enhance TRMs' retention; furthermore, the experiments demonstrated that TRMs could be retained in lungs despite CD69 downregulation and elucidated areas of further research.

Context-dependent Syntactical Variation of House Finch Song

Ivy Ciaburri

In this study, I focus on the syntactical variation of songs of individual House Finches within a single population in order to explore the role of social context and behaviors in maintaining a species-wide syntax. During courtship, males sang longer songs, suggesting that the content of the song is less important than the amount of song for females. In contrast, countersinging bouts involving more than one male are marked by increased diversity in both the content and the syntax of an individual male's song. My results suggest that the driving force behind maintaining a stable species-wide syntactical song structure is female choice, whereas the driving force behind syllable and syntax diversity and thus dialect formation is male competition.

Investigating the Cellular Pathways Leading to Lung Residency in CD4+ TRM Cells in Asthma

Ronak Dave

Asthma is a chronic inflammatory disease of the airways that affects 300 million people worldwide. TH2 tissue resident memory cells in the lungs are believed to initiate recurrent asthmatic symptoms in response to allergen re-exposure. In order to determine what genes and cellular pathways are differentially expressed in TH2 TRM cells as compared to circulating CD4+ T cells, a murine house dust mite model of asthma was used. An initial 14 day sensitization period to house dust mite was insufficient to generate a TH2 TRM population of cells in the lungs. However, a subsequent 10-day immunization period generated a population of lung resident TH2 cells. Treatment with the drug FTY720 sequestered circulating T cells in the lymph nodes, thereby removing contaminating circulating T cells from the lungs. However, a CD4 antibody isolation technique intended to separate a pure population of TH2 TRM cells from a suspension of lung derived cells failed. Further, RNA derived from these isolated cells was too impure and dilute to be analyzed by either RNA-seq or qPCR. The work described by this paper will prepare the way for future attempts at RNA-seq in an effort to elucidate what pathways are differentially regulated in TH2 TRM cells in asthma.

The Influence of Mowing on the Abundance of Fall-Blooming Asteraceae in a New England Field

Lane Davis

Habitat degradation, climate change, and insecticide use globally threaten pollinators, which are critical for agricultural production and preservation of biodiversity. Goldenrods and asters (family Asteraceae, e.g. Solidago spp and Euthamia spp) bloom in New England fields in late summer and early fall, providing a critical food resource for pollinators just before they overwinter. Our weekly phenological censuses show that goldenrod species temporally separate peak blooming, thus providing pollinators a consistent food resource from late July through mid October. We use a complete randomized block design to investigate the influence of timing (July or October) and frequency (annual or biennial) of mowing on the fall abundance of reproductive stems of native Asteraceae in a field in Williamstown, Massachusetts, USA. We confirm Jung's 2015 finding that, compared to July mowing, October mowing greatly increases the fall abundance of reproductive stems of native Asteraceae. We find the same effect for woody invasive species and Circisum arvense. Our results suggest annual compared to biennial mowing leads to more reproductive native Asteraceae stems. By comparing data from 2014 and 2016, we demonstrate that October mowing results in greater between year increases in Solidago rugosa and S. altissima flowering stem number. We encourage New England field owners and managers to promote high quality pollinator habitat and help combat global pollinator decline by delaying mowing until after flowering of late blooming flower species.

Boron Depletion Causes Plasma Membrane-Cell Wall Detachment and Modulation of Sphingolipid Biosynthesis in Physcomitrella patens

Cesar Dominguez

The complex repertoire of sphingolipids are essential for eukaryotic cells to maintain apoptotic pathways, the endomembrane system and signaling responses to environmental changes. Their conserved role in diverse and crucial cellular mechanisms require finely tuned regulation of sphingolipid biosynthesis. Recent advances have uncovered highly conserved proteins involved in stimulating (ssSPTs) and inhibiting (ORMs) the first enzymatic step of the metabolic pathway catalyzed by serine palmotoyl transferase (SPT) (Breslow et al., 2010; Harmon et al., 2013; Kimberlin et al., 2013; Kimberlin, 2016). However, the upstream environmental changes that modulate ssSPTs, ORMs and SPT activity remain elusive and may differ depending on the organism. Herein, boron depletion is shown to be an abiotic stress that causes membrane-cell wall detachment and temporal modulations in expression of genes encoding the isoforms of regulatory proteins (ssSPTa/b, ORM1/2, LCB1/2) in Physcomitrella patens. After one week of boron depletion, long-chain bases (LCBs) in P. patens were halved, accompanied by induction of ORM1, a potent inhibitor of sphingolipid production. We propose a model in which disruption of boron-GIPC cross bridges increase concentration of liberated GIPCs that can then mediate modulations in the sphingolipid metabolism. After prolonged boron depletion, P. patens restores sphingolipid levels and balances expression of genes involved in stimulating and inhibiting sphingolipid biosynthesis. Broader changes in pectin sugar distribution and AGP expression in response to boron depletions are considered. Together, P. patens is established as model system to investigate sphingolipid homeostasis in response to boron depletion.

Food Restriction is Sufficient to Increase Wakefulness and Decrease the Quality of Sleep

Will Duke

Sleeping and eating are critical behaviors for survival, yet represent mutually exclusive states. The neural systems that regulate these behaviors must communicate to balance the drive to eat or sleep depending on an animal's needs. To investigate how activating one of these systems affects the other, we measured sleep using electroencephalographic and electromyographic recordings from mice deprived access to food. We found that food restriction increases the length of wake bouts and decreases time in non-rapid eye movement sleep. This effect is milder yet still evident in food restricted mice that have had food returned 10 minutes prior to recording, suggesting that sleep in mice requires at least four hours to equilibrate to ad libitum conditions. We further found that food restriction decreases the quality of sleep by increasing the frequency of microarousals per minute of sleep without affecting the frequency of sleep stage switches or the power of sleep states. Interestingly, these results differ from previous work showing a decline in power during acute stimulation, which may be indicative of a compensatory mechanism that protects sleep over longer periods. Finally, we validated a pharmacogenetic method for studying prolonged AgRP neuron activity and its effects on sleep quality and quantity. \

Investigating an Abscisic Acid-Linked Defense Pathway in Arabidopsis thaliana: The Influence of Agrobacterium tumefaciens' Type VI Secretion System on IOS1 may mediate Infection Success

Ruby Froom

Agrobacterium tumefaciens is a soil-borne bacterium capable of inducing Crown Gall tumors in a variety of host plant species, by genetically transforming them with bacterially-derived DNA. The Banta lab has found that the A. tumefaciens Type VI Secretion System (T6SS) appears to limit genetic transformation of host Arabidopsis thaliana, suggesting that Arabidopsis may sense A. tumefaciens' T6SS and mount subsequent defenses to limit pathogen efficacy. Here we use a transient transformation assay and RT-qPCR to investigate the role of abscisic acid (ABA) signaling, and a suite of related proteins, in contributing to T6SS-elicited plant defense.

In seedlings, we find that IOS1 and LYK3, two receptor tyrosine kinases involved in PAMP-triggered immunity and ABA signaling, may be necessary to produce T6SS-specific differences in transformation. IOS1 appears to promote transformation, while three different lyk3 alleles produced contradictory results. ABI1, a phosphatase that propagates and inhibits certain aspects of ABA signaling, is not required to mediate T6SS-specific transformation differences; however, in the absence of ABI1, the plant is sensitized to A. tumefaciens, and the T6SS may trigger local apoptosis. RNS1, a secreted ribonuclease under ABA regulation, limits seedling transformation in a T6SS-independent manner, but exhibits T6SS-specific expression patterns in stems. We tested an additional strain of WT and T6SS- A. tumefaciens to validate our results: however, we found that TT induced by these strains differed dramatically from TT induced by the original strains on the same plant genotype.

Assessing gene expression levels of IOS1 and RNS1 in seedlings and stems illuminated potential biological pathways underlying T6SS' role in limiting virulence on seedlings, while promoting tumor formation on stems. A tentative mechanistic pathway is proposed to explain these phenomena, centered around T6SS suppression or induction of IOS1; further experimental validation is required to confirm the relevance of these pathways to our model system.

Investigating the Ability of a dCas9-DNMT3A Fusion Protein to Induce Targeted DNA Methylation in Danio rerio

Daniel Patrick Gainey

DNA methylation is an epigenetic mark placed onto the cytosine base of CpG dinucleotides throughout the genome. The presence of DNA methylation on the promoter region of genes has been linked to decreased transcription, and this system of gene regulation may play a role in maintaining or establishing the tissue-specific expression patterns observed in development. However, as most previous studies investigating the effects of DNA methylation have been either correlative in nature or have drawn conclusions from phenotypes associated with changes in global methylation levels, the validity of many of these claims is still highly debated. This study aimed to adapt to zebrafish a dCas9-DNMT3A fusion protein system that has been shown to induce targeted DNA methylation in human embryonic kidney cells, in order to better investigate the effects of specific, local DNA methylation on developmental processes. A region of exon 1 of hspb7 contains CpGs that are methylated in non-cardiac tissues in adult fish. We co-injected sgRNAs that target this region with mRNA or plasmids encoding dCas9-DNMT3A. Fluorescence stere-

oscopy revealed that neither mRNA nor DNA injection resulted in expression of the fusion protein, indicating that the coding sequence for this protein is likely not well optimized for expression in zebrafish. We conclude that this system cannot easily be used in zebrafish without major modification. Additionally, the presence of extensive developmental abnormalities upon injection of mRNA encoding a DNMT3A cofactor, DNMT3L, indicates that this cofactor is not a useful mechanism for increasing fusion protein functionality in the context of developmental studies.

The metabolic and physiological effects of long-chain base reintroduction in physcomitrella patens

Yanira Guerra

The purpose of this project was to further the understanding of what effects the reintroduction of sphingolipid long-chain bases would have on the cellular physiology and metabolism of Physcomitrella patens in the presence of an inhibitor of long-chain base synthesis. This was done through growth analysis, microscopy, and long-chain base analysis to characterize different aspects of moss. The long-chain bases of interest were d18:0, t18:0, d17:0, d18:1 and the inhibitor used was myriocin. Upon analysis the results indicated that t18:0 was the long-chain base that best increased survivability.

Assessing the role of IP3 Signaling and Autophagy in Drosophila wing development

Maria Guzman

This thesis explores the role of IP3 signaling and autophagy in Drosophila wing development using the x-linked mutation wavy as a a model. wavy is a wing mutation characterized by a bend in the costal vein. The mutation was recently mapped to the gene IP3K2 and found to interact with IP3R. Our goals focused on better defining the interaction between IP3K2 and IP3R, and better defining the events downstream of that interaction that lead to the mutant phenotype. We found evidence that factors from the autophagy complex PI3K (III) interact with wavy and our findings encourage further exploration of the role of autophagy in wing development.

Codon Influence Models: A Comparative Genomics Approach Using Bioinformatic Tools

Intekhab Hossain

The degeneracy of the genetic code implies that the same protein sequence can be coded for in multiple ways, which allows for an additional layer of information to be encoded into the genome, via variations in synonymous codon usage. Although codon usage bias has been studied for several decades, much of its mechanistic underpinning remains a conundrum, and only lately have statistical tools been employed to investigate the phenomenon. In this study we use multi-parameter regression models on a large collection of expression datasets measuring protein and/or mRNA levels from Escheria coli, Bacillus subtilis, Prochlorococcus marinus and Saccharomyces cerevisiae, sourced from various investigations in the literature, to perform a comparative genomics analysis of codon usage bias and its link to gene expression. Interestingly, we found that even though many mRNA features affect gene-expression in a species and expression-platform dependent manner, there are notable trends in the magnitudes, directions and functional forms of influence. Many mRNA features are heavily cross-correlated with each other and thus, upon multiple regression analysis, these terms were eliminated from our models. However even after adjusting as such for cross-correlations, the multi-parameter regression coefficients exhibited correlations between themselves, an observation that was reinforced by the predictive power of each metric across datasets that originated from organisms and levels of Central Dogma, different from those of its training set. This study provideS insight into the general influence of sequence features on gene-expression at a global level, as well the specific differences in these influences between different organisms and the different levels of the Central Dogma.

Investigating light stress and photosynthetic genomics in Prochlorococcus

Roya Huang

Prochlorococcus is a genus of photosynthetic cyanobacterium. Specialized populations of Prochlorococcus called ecotypes show different abundances within the ocean column, reflecting potential adaptation to different light levels. These differences may be in part attributed to differential expression and binding of Pcb proteins, which bind chlorophyll molecules and act as light harvesting complexes. Because the ocean is turbulent, however, cells may need to be able to acclimate to short-term changes in light. Here, we investigate strain MIT9313 and find that it grows faster at 10 μmol photons m-2 s-1(doubling time = 60.±7 hours) than at 2 μmol photons m-2 s-1 (doubling time = 140.±5 hours). Upon exposure to 24-hour 50 μmol photons m-2 s-1 light stress (5x), MIT9313 cells experi-

ence drastic losses in chlorophyll fluorescence but are able to recover rapidly. Notably, chlorophyll fluorescence is recovered faster than cell division rates, indicating that cells restore chlorophyll levels before dividing. Together, these data suggest that the cells do not experience permanent damage in these light stress conditions. Sequence analysis of pcbDgene neighbors shows that the protein sequences of several neighbors are moderately to highly conserved. These proteins are potential targets for future Pcb-protein interaction studies.

TRH neurons respond to cold exposure, but stimulation is not sufficient to increase body temperature

Sarah Lehmman

The hypothalamus-pituitary-thyroid (HPT) axis regulates organismal metabolism in mammals. In the hypothalamus, neurons in the paraventricular nucleus that synthesize thyrotropin-releasing hormone (TRH) integrate environmental information and affect HPT axis activity to regulate metabolic parameters such as body temperature and locomotor activity. Until recently, TRH neurons have been difficult to study due to their location amongst a heterogeneous population of hypothalamic neurons. To investigate the effect of TRH neuron activity on body temperature and locomotion, we use optogenetic and chemogenetic tools for targeted stimulation of TRH neurons. Here, we show that genetically-targeted TRH neurons are active during cold exposure. Furthermore, we show that both optogenetic and chemogenetic stimulation are not sufficient to increase body temperature or locomotion. This study therefore challenges the role of TRH neurons in the regulation of body temperature and energy expenditure, and suggests future experiments for the study of the HPT axis.

Effect of island geography and pollinator composition on population genetics of Isle Royale National Park Primula mistassinica

Jonathan MacDougall

Understanding the effect of habitat fragmentation on the population genetics of flowering plants is an increasingly important aspect of conservation efforts for endangered plants. We studied locally endangered Primula mistassinica populations on Isle Royale National Park, Keewenaw County, Michigan, collecting leaf samples across 29 subpopulation sites and using cameras to capture near-complete insect visitation records at eight sites on four islands. Most subpopulations displayed low levels of population differentiation and slight tendencies towards inbreeding. No evidence of isolation by distance was found between subpopulations across the archipelago or between individuals within Edwards, North Government, Second, or Third Islands, showing that increasing geographic distance has no effect on the rate of gene flow. Significant differences in insect taxa occurrence and number of insect visits were seen between the eight camera sites. The majority of insect taxa observed only appeared at a single site, but the five taxa that were present at all eight sites (Calliphorid flies, Toxomerus sp. flies, medium Anthomyiid flies, tiny black flies, and crane flies) performed exponentially more visits to inflorescences. The differences in the composition of insect visitors between sites support the observations made in a study of Cornus canadensis on Isle Royale National Park that documented local neighborhoods of generalist pollinators (McEntee 2014). These generalist pollinators are faithful to their specific geographic area, as evidenced by the large number of insects that appeared at only one site, and restrict gene flow between subpopulations because of this. Additionally, the five insect taxa seen at all eight sites are largely unable to travel long distances, further restricting the rate of gene flow beyond a single subpopulation. These pollinator neighborhoods could potentially explain the enormous variety of angiosperm species around the world, and properly defining the occurrence and composition of pollinator neighborhoods will continue to be an integral part of pollination ecology.

Characterization of The Population Genetic Structure Of Select Local Subpopulations Of Publilia Concava

Tsaina Mahlen

Publilia concava (treehoppers) are insects native to the Northeastern United States that live and feed on Solidago altissima L. goldenrods, and are notably involved in a protection mutualism with ants. Here, we collect and analyze a total of 282 individual treehoppers from three major sites at different elevations on either side of Petersburg Pass across the border between New York and Massachusetts. One site was composed of three subpopulations to probe any hierarchical structure. Through the use of nine previously identified and characterized microsatellites unique to treehoppers, we determine the population genetic structure of these populations. We find that there is some gene flow (FST = 0.0404) between all three populations but that it is much more restricted between the two with biggest difference in elevation, perhaps due to an isolation by elevation phenomenon. We also find high levels of inbreeding

(FIS = 0.288) within each population, indicating that inbreeding plays the largest role in forming population structure and that genetic purging may have evolved in treehoppers as a response to historic founder events and large hatch sizes.

Characterizing the cold-sensitivity phenotype of the julius seizure (jus) mutants in Drosophila

Emma McAvoy

The bang-sensitive mutations in Drosophila cause seizure sensitivity in response to mechanical shock. One such bang-sensitive mutation, julius seizure, (jus) was recently mapped to the 98F13-99A1 region of the 3rd chromosome. It has been shown to be expressed in the nervous system. The mutated sequence is not known nor is any significant homology to any other known genes . jus function is required during metamorphosis, making it a potential model to study epileptogenesis. The classic phenotype of bang-sensitive is induced through vortezxing, however in this study it was found that cold shock can induce seizures in jus mutants as well. jus mutants that have seized due to cold shock take a longer period to recover than those who seized due to vortexing. jus mutants, who have seized are also less refractory when their second seizure is induced through cold shock as opposed to vortexing. The most effective GAL4 drivers for inducing cold sensitive seizures in jus mutants were Cha (cholinergic), elav (post mitotic), and tsh (ventral nerve cord-specific.) These results indicate that the ventral nerve cord, cholinergic neurons, and post mitotic cells may be part of the neuronal subpopulation responsible for the cold-sensitive phenotype of jus.

Proteomic signatures evocative of Prochlorococcus ecotypes and their roles in niche differentiation in the open ocean

Ian Outhwaite

The ecologically important marine cyanobacterium Prochlorococcus thrives in subtropical and tropical open ocean regions. Variable light, temperature, and nutrients within the water column create different ecological niches and these in turn will favor the growth of Prochlorococcus cells with particular phenotypes/genotypes (ecotypes). The set of genes (i.e. core genes) that are conserved among different Prochlorococcus isolates are suggestive of essential properties necessary for survival. Conversely, differences in gene content, or the flexible genes that are particular to a subset of isolates, indicate which genes might allow isolates to adapt to a particular ecological niche.

Here, we identify proteomic signatures within Prochlorococcus isolates in order to determine their role in niche differentiation, and to gain insight on the evolution of niche differentiation in this lineage. We find that ecotypes associated with the large clade of recently differentiated lineages have less genomic variability, as defined by relative core genome size, compared to deeply branched ecotypes. Genes associated with cell wall/membrane/envelope biogenesis are highly represented within the set of flexible genes for all isolates, which is strongly supported by prior Ting lab studies of significant dissimilarities in Prochlorococcus isolate cell wall morphologies. We also examine the representation and prevalence of Prochlorococcus within 40 m and 100 m open ocean metagenomic samples collected by the Ting lab from the Sargasso Sea and demonstrate that the distribution of Prochlorococcus genes within these samples are consistent with our predictions of ecotype distributions and abundances at these depths.

Stimulation of Paraventricular Hypothalamic TRH Neurons is Insufficient to Increase Metabolic Function

Rachel O'Sullivan

Metabolism is the sum total of the energetic reactions occurring within each cell in the body. In mammals, metabolism is regulated by the hypothalamic-pituitary-thyroid (HPT) axis. In response to intrinsic and extrinsic signals, the hypothalamic paraventricular nucleus (PVN) releases thyrotropin-releasing hormone (TRH) into the pituitary gland. In the pituitary gland, TRH triggers the release of thyroid-stimulating hormone (TSH), which circulates to the thyroid gland to cause the release of the thyroid hormones T3 and T4. These hormones have a broad range of effects on metabolic physiology. Exogenous administration of TRH, TSH, T3, or T4 increases indices of metabolism, but the effects of directly stimulating hypothalamic TRH neurons is unknown. Here, we tested the hypothesis that TRH neuron stimulation is sufficient to increase indices of metabolic physiology. We successfully targeted TRH neurons in the PVN with pharmacogenetic and optogenetic constructs in a TRHCre/+ mouse line. Using telemeter implants and an indirect calorimetry apparatus we determined the effects of pharmacogenetic and optogenetic TRH neuron stimulation on body temperature, locomotion, oxygen consumption, and carbon dioxide elimination. Contradictory to our hypothesis, we found that TRH neuron stimulation is insufficient to increase metabolic output.

Influence of the Agrobacterium tumefaciens type VI secretion system on biofilm levels and host attachment.

Adam Resnick

The type VI secretion system (T6SS) influences Agrobacterium tumefacienshost-cell attachment and biofilm regulation. Biofilms are aggregates of bacteria held together through attachments within a polysaccharide-containing dense matrix. In A. tumefaciens, strains deficient in the T6SS or a T6SS substrate, amidase, exhibit elevated biofilm formation relative to a wildtype strain or a strain lacking two other T6SS effectors, DNase1 and DNase2. In this thesis, adding conditioned media (CM) of various A. tumefaciens strains to T6SS mutants indicated that regulatory components are secreted. The secreted soluble factor that regulates biofilm formation is absent in the amidase mutant. We hypothesize that the biofilm lowering factor may be peptidoglycan (PGN), a molecule that is released through cleavage by amidase. Scanning electron microscopy (SEM) showed attachment differences between the mutant strains, with amidase mutants forming hyper-polar attachment to a plant surface. This difference is likely due to an effect on the regulation of unipolar polysaccharide (UPP), a substance crucial in forming polar attachments. Nets were observed among all strains by SEM but were most prevalent in the double DNase mutants, potentially indicating that these nets are composed of extracellular DNA (eDNA), which would be a novel finding in A. tumefaciens. eDNA is known to block UPP attachment in closely related species, and this could suggest a mechanism to explain decreased polar attachments in DNase1-,DNase2-compared to amidase-. Overall, the effects of the T6SS on biofilms are important, as the consequences of biofilm formation can impact medical and industrial sectors.

Roles of ASAP1 and Non-Muscle Myosin 2 in Ovarian Cancer Progression

Christine Reed

Epithelial ovarian cancer is the most lethal gynecological cancer and the fifth most common form of cancer in women. With an average mortality rate of 55% and a unique route of metastasis via spheroid (i.e. cell aggregate) dispersal through the peritoneal cavity, understanding the mechanisms involved in ovarian cancer progression is of critical importance. Non-muscle myosin 2 (NM2), an actin binding protein important for cellular contractility and motility, has been implicated in promoting ovarian cancer metastasis by facilitating clearance of the mesothelium during spheroid invasion. Expression of ASAP1, a member of the Arf GAP family of proteins and a positive upstream regulator of NM2, is highly correlated with poor ovarian cancer prognosis. We hypothesized that ASAP1 promotes ovarian cancer metastasis through upstream positive regulation of NM2. Using four human ovarian cancer cell lines and spheroid invasion techniques, we found that ASAP1 expression levels correlated with invasion potential of ovarian cancer cells. siRNA-mediated knockdown of ASAP1 or inhibition of NM2 reduced the distance of spheroid invasion. In addition, ASAP1 inhibited ovarian cancer cell proliferation, as ASAP1 knockdown spheroids were on average 19-25% larger than control counterparts due to increased cell number. The effect of ASAP1 on proliferation was cell-density dependent and was only observed under conditions of substantial cell-cell adhesion. Additionally, ASAP1 and NM2 were both found to be important for promoting spheroid survival. Taken together, this study points to a trade-off between proliferation, survival, and invasion behaviors in ovarian cancer progression that is mediated in part by ASAP1.

Lagged Effects of Herbivory and Mutualism on Performance and Oviposition of the Treehopper *Publilia concava*

Diana Sanchez

Mutualisms are ecologically important relationships between species that are beneficial to both. The treehopper Publilia concava is a univoltine, herbivorous insect found primarily on goldenrod (Solidago altissima L.) that interacts with ants in a protection mutualism. In this mutualism, treehoppers benefit by receiving predator protection and feeding facilitation from the ants, and in return, the ants collect carbohydrate-rich honeydew excreted by the treehopper. Previous research has suggested the existence of lagged effects of herbivory and mutualism. Investigating whether a prior history of treehopper feeding impacts future treehopper host choice and survivorship on the same plant, the results of this study suggest that the presence or absence of treehoppers or of ants on a plant one year may affect their presence on the same plant the next year, but more work is needed to better support the hypothesis.

Mutants vs Morphants: Determining the effect of CRISPR/Cas9 targeted knockout of hspb7 in Danio Rerio

Maeve Serino

The breaking of symmetry is an integral developmental step for all vertebrates. It is believed that internal left-right asymmetry is driven by the activities of a conserved, fluid-filled, ciliated organ, known as Kupffer's Vesicle (KV) in zebrafish. Left-right asymmetry defects contribute to cardiac abnormalities and are present in humans. Previous thesis students in the Marvin lab utilized morpholino oligonucleotides (MO) to knock down expression of hspb7, a small heat shock protein shown to be expressed in the heart at 24 hours post-fertilization (hpf). MO knockdown of hspb7 resulted in laterality defects; in particular, morphants displayed right-sided and middle-aligned hearts. However, recent advances in genome editing techniques have shed light on MO inconsistencies. In fact, 80% of MO-induced phenotypes are not recapitulated when using targeted genomic deletion. To determine whether the hspb7 MO phenotype is legitimate and to further explore the role hspb7 plays in left-right asymmetry, we created two independent lines of transgenic zebrafish with a CRISPR/Cas9 targeted deletion of hspb7, herein referred to as mutants as opposed to the MO-induced morphant. We expected to find mutants with the left-right asymmetry defects previously observed in the morphants. However, in both lines, the mutant homozygotes were phenotypically normal. To further investigate whether the MO phenotype was due to off-target effects, we injected F2 mutant embryos with the hspb7 MO and found a Mendelian distribution of genotypes amongst those exhibiting cardiac defects in one line and a uniform distribution of genotypes amongst those with cardiac defects in the other. The presence of MO-injected mutant homozygotes displaying the morphant phenotype strongly suggests that the left-right asymmetry defects were caused by off-target effects, as the MO should depend on the deleted hspb7 transcript. Together, these results indicate that hspb7 does not contribute to left-right asymmetry as was previously believed.

PIP2-Induced ASAP1 Oligomerization as a Molecular Switch for Control of Nonmuscle Myosin 2 Filament Assembly

Jeffrey Sload

The ADP-ribosylation factor (Arf) family of proteins are involved in the control of membrane metabolism, vesicle formation, and cellular movements. Arfs are GTP- binding proteins, and their activity depends upon their regulatory GTPase activating proteins (GAPs) and guanine exchange factors (GEFs). In addition to the role these three protein families play in membrane dynamics, previous work has suggested a number of potential links between these proteins and control of the actomyosin network, most recently demonstrating that the Arf GAP ASAP1 binds nonmuscle myosin 2A (NM2A), and appears to function as an upstream regulator of NM2A filament formation.

This study describes the use of co-sedimentation assays to determine the effect of ASAP1 binding on NM2A filament formation, as well as the effect of another ASAP1- binding partner, the phospholipid PIP2, on ASAP1-NM2A interaction. Results showed that partial ASAP1 constructs BAR-PH and BAR-PZA interacted with an NM2A construct containing only the coiled-coil, or rod, region. Increasing concentrations of BAR-PH and BAR-PZA increased the proportion of non-filamentous NM2A, potentially through competitive inhibition and stabilization of previously formed NM2A filaments. PIP2 promoted BAR-PH and BAR-PZA oligomerization, and repressed the effect of ASAP1 on NM2A filament formation. Taken together, these data support a model in which ASAP1 functions as a lock on NM2A during times of stasis, preventing filament assembly or disassembly, while PIP2 "unlocks" NM2A from ASAP1, freeing NM2A filaments to respond to changing cellular conditions.

Dopamine Modulates Visual Motion Perception, Sensory Integration and Arousal State in the Drosophila Melanogaster Optomotor Response

Kelly Tellez

Arousal is not a single behavior; instead, it is understood as a general physiological and psychological "drive state" that alters sensory processing, cognition and the execution of behaviors; therefore, it is measured as increased locomotor activity, sensitivity and neural activity (van Swinderen et al 2003). Drosophila exhibit attention-like processes that are modulated by the voluntary and stimulus-driven selection of information (van Swinderen et al 2011). For complex tasks where attention is divided between various competing stimuli, arousal state has been shown to influence behavioral performance in an Inverted-U manner (Nityanada et al 2016, Diamond 2005).

Populations of wild type flies perform the optomotor response - a walking behavior guided by light stimulus - better at a mechanically induced heightened state of arousal; alternatively, dopamine receptor mutants (DopR flies)

perform the optomotor response worse compared to wild type flies, independent of arousal state conditions (Berry Thesis 2012). We show that the Fly Stampede can be used to observe and replicate the optomotor response in individual flies and groups of flies. The optomotor performance is regulated by parameters such as the speed of the visual motion stimulus, conditions of mechanical startle and population size. Selective restoration of dopamine expression in just the Ellipsoid Body fails to rescue the optomotor response, suggesting that DopR is required in multiple regions of the Drosophila brain for this complex visual locomotor behavior.

Immunomodulation of Pathogenic CD69+ CD86+ Lung Tissue-Resident Memory B Cells in Allergic Asthma

Jacob Verter

Tissue-resident memory T (TRM) cells have been identified recently as a crucial population of cells that drive allergic asthmatic inflammation due to their proximity to barrier surfaces. Given that B cells secrete IgE antibodies that mediate histamine release and the classical symptoms of allergies, it is possible that a parallel subset of tissue-resident memory B (BRM) cells exists alongside TRM cells in the lung to help promote allergic inflammation. Sublingual immunotherapy (SLIT), an emerging treatment for allergic asthma, is thought to shift the allergic immune system from an inflammatory to a suppressive state hinging on the tolerogenicity of the oral mucosa. Administration of SLIT was predicted to reduce RM lymphocyte frequency in the lung and to induce the proliferation of regulatory B and T cells. A house dust mite (HDM)-induced mouse model of asthma was established to evaluate the characteristics of the RM cell populations in the lung and to probe the efficacy and mechanisms of SLIT. Mice sensitized to HDM exhibited increased inflammation and frequencies of BRM and TRM. Lung RM lymphocytes were re-activated following rest upon re-exposure to allergen. HDM SLIT was not effective at reducing BRM and TRM populations in the lung, but did promote the induction of a purported regulatory subset of B cells that express CD5 and CD1d surface proteins. Taken together, these data establish the presence and pathogenic role of BRM in allergic asthma, and support the continued study of SLIT and its effects on regulatory lymphocytes.

Chemistry

Progress Towards Isolation of the RedU Phosphopantetheinyl Transferase from Streptomyces Coelicolor A3(2)

Varun Bhadkamkar

Streptomyces is a genus of Gram-positive, soil-dwelling bacteria known for their pro- lific production of secondary metabolites. Many secondary metabolites isolated from streptomycetes have been adapted in clinical settings and include antibiotics, an- ticancer agents, immunosuppressants, and antifungals. Many of these secondary metabolites are biosynthesized by polyketide synthase (PKS) or nonribosomal pep- tide synthetase (NRPS) enzymes, whose function is contingent upon the posttransla- tional attachment of a 4'-phosphopantetheine cofactor to their carrier proteins. Phos- phopantetheinylation of carrier proteins is conducted by phosphopantetheinyl trans- ferase (PPTase) enzymes. The genome of the model streptomycete Streptomyces coelicolor A3(2) encodes three PPTases: AcpS, SCO6673, and RedU. Both AcpS and SCO6673 demonstrate promiscuous activity towards a variety of carrier proteins in vitro. The RedU PPTase, however, has eluded isolation in past studies, thus its in vitro substrate specificities have yet to be determined. In the present study, progress was made towards the purification and characterization of the RedU PPTase. Difficulty with heterologous expression of redU in E. coli was initially believed to be a mat- ter of sub-optimal codon usage, although here it is demonstrated that RedU is most likely cytotoxic to E. coli. Although RedU has yet to be isolated, a RedU-GST fusion protein may potentially be purified from inclusion bodies using improved refolding techniques, and redU overproduction may be more successful in more closely related organisms such as Streptomyces lividans.

The Synthesis of Hepialone and Hepialone Derivatives

Paige Chardavoyne

Many structural elements are shared by a vast array of natural products. One common structure in nature is the tetrahydropyran moiety, present in the naturally occurring compound enigmazole A, isolated from the marine sponge Cinachyrella enigmatica. Retrosynthetic analysis of enigmazole A by the T. Smith group has revealed that this tetrahydropyran element could arise from a simpler pyran-enone moiety. These types of pyran-enone subunits are available

from lactone precursors that are rapidly synthesized using reactions previously utilized in our group's work with kavalactones. With these lactones in hand, a variety of unique enones can be formed via nucleophilic addition to the lactone carbonyl. One small pyran-enone synthesized in this work is of interest in its own right because is a natural product. This compound is known as hepialone, a sex pheromone produced by the male Ghost Moth Hepialus californicus B. This work outlines the synthesis of racemic hepialone and related butyl- and allyl-substituted structures. A search for possible stereoselective reducing agent for these systems was also initiated. This work has implications for the synthesis of enigmazole A and other structurally related tetrahydropyran-based natural products.

Adaptable Copolymers for the Encapsulation and Delivery of Ferroptotic Therapeutics

Hannah Cole

Ferroptosis is an iron-dependent form of regulated cell death that is initiated by the coincident depletion of glutathione and/or GPX4 inactivation, and the toxic build-up of oxidized phospholipids. It's iron dependence garners ferroptosis naturally selective for cancerous cells, which harbor an overactive metabolism that allows for excessive iron accumulation. Many researchers have posited that synthetic induction of ferroptosis may be a potent chemotherapeutic. So far, this realization has been limited by the poor bioavailability and off-target effects of such ferroptotic agents, and a system which can solubilize and target these drugs is in high demand.

Herein we present an adaptable platform for ferroptotic drug delivery built from a RAFT polymerized copolymer core of p(SAME)-b-(DMA)-CTA12. The copolymer platform allows for both ligand conjugation through the terminal CTA12 group and hydrophobic block optimization through substitution at the activated ester moiety of p(SAME). As proof of concept, we synthesized a library of three block copolymers – p(SAME)23-b-(DMA)88-CTA12, p(SAME)36-b-(DMA)88-FA, and p(BAm)23-b-(DMA)88. Characterization by GPC, DLS and TEM revealed that all three samples were relatively monodisperse and formed micellar structures at concentrations as low as 0.0053 – 0.011 mg/mL. Drug loading capacity was modeled with Sorafenib, and all polymers demonstrated promising results, with encapsulation efficiencies ranging from 43 - 73% and loading capacity (% w/w) ranging from 4.3 – 7.3%.

Study of Dipicolinic Acid-Based Gemini Surfactants for Luminescent Lanthanide Ion Bioprobes

Laura Elmendorf

Optical imaging is a valuable tool for research and medical diagnosis, but many of the probes currently in use possess clear disadvantages with regard to detection or toxicity. Lanthanide(III) ion complexes provide a promising alternative, with favorable luminescent properties like sharp emission bands, long luminescence lifetimes, and large Stokes shifts. In order to work effectively as a bioprobes, the lanthanide complexes must also be able to permeate into the cell or tissue of interest. One approach to this consideration is to use gemini surfactants, which form aggregates in solution that have been shown to increase cell permeation and drug delivery. By incorporating the structural features of a gemini surfactant into a dipicolinic acid (DPA) based ligand, we hoped to increase cell permeability while retaining DPA's ability to sensitize lanthanide ion luminescence. This study discusses the synthesis and characterization of DPA-based gemini surfactant ligands and their corresponding lanthanide(III) ion complexes. The cationic series, denoted [LCn]Br2 (n = 8, 12, or 18), where n represents the length of the carbon tails, was found to have CMC values in the range of 10-5 M to 10-7 M. The series was relatively ineffective at binding and sensitizing lanthanide (III) ions, although we observed weak sensitization of terbium and europium luminescence by [LC12] Br2. We also developed a synthetic route for the synthesis of an analogous neutral surfactant ligand series. Finally, using the two synthetic precursors of the cationic and neutral ligand series, we were able to compare differences in lanthanide(III) ion binding and sensitization. We found that the cationic DPA-based precursor sensitizes terbium emission more effectively than it sensitizes europium emission.

Zinc-Mediated Deuteration: Mechanistic Studies and Expansion of a Family of Deuterated Compounds

Matthew Goss

The selective incorporation of deuterium into an organic molecule has broad applications ranging from mechanistic study to drug design. Zinc-mediated deuteration, developed, and improved-upon previously in the Richardson/Thoman lab represents a promising synthetic method for the installation of deuterium in place of an iodine substituent. This work greatly broadens the range of synthesized deutero-compounds from their corresponding iodo-compounds, encompassing primary, secondary, and tertiary sp3-hybridized substrates, aromatic substrates,

and substrates featuring acidic and basic functional groups. Deuteration selectivity in the presence of a C-Br bond and tolerance of ether and ester functional groups is also demonstrated. This work also introduces the use of acetic acid-d as an alternative source of deuterium, successfully reducing the formation of side products and accelerating reaction rates for most substrates. In the second part of this work, an attempt was made to investigate the stereochemical outcome of the deuteration reaction via deuteration of two substrates featuring a stereochemically well defined trans-relationship between methyl- and iodosubstituents. While these substrates, a bicyclic and a monocyclic iodoether, were synthesized in high purity on a gram scale, attempts to deuterate them ultimately failed as a Boord elimination reaction predominated due to the presence of an internal oxygen leaving group in both substrates. Thought to proceed through a Grignard-type species via an E1cB elimination mechanism, this unexpected elimination reaction under these conditions gives significant support for a Grignard-type mechanism for the deuteration process.

1,5-Biaryl Pyrazoles Target the ATP-Binding Pocket of the PhoQ Histidine Kinase Bearing Two Point Mutations

Garrick Gu

Antibiotic resistance is increasing quickly in the US, while novel antibiotic development has slowed considerably. Two-component signaling systems are necessary for bacterial response to their local environment and are composed of histidine kinases and their cognate response regulators. Histidine kinases are well-conserved surface receptor proteins that are not found in higher eukaryotes and are a promising novel target for inhibition. We co-crystallized small molecule inhibitors with the ATP-binding domain of double mutant R440A Q443T PhoQ, a histidine kinase crucial to Salmonella typhimurium's ability to detect and invade epithelial cells. We found that our inhibitors co-crystallized in the same relative orientation in the ATP-binding site. We were also able to demonstrate kinase activity and inhibition in wildtype, R440A, Q443T, and double mutant R440A Q443T. Our results indicate that these inhibitors can be modified to have potential in inhibiting the ATP hydrolysis site in Salmonella PhoQ.

The Synergistic Anticancer Effects of Lysozyme-Polymer Conjugates: Functionalized Copolymers to Protect Therapeutic Proteins in the Body

Emily Hoyt

The reusability, efficiency, and specificity of therapeutic proteins provide a highly valuable platform for the use of such proteins as drugs. However, because of short circulation times in the body due to processes such as proteolytic digestion, therapeutic proteins need to be modified in some way to allow them to both circulate for a longer time and remain active in the body. Many studies have used the strategy of PEGylation to protect potential therapeutic protein drugs. By conjugating polymers such as PEG to proteins, the protection against proteolytic digestion, circulation time, thermal stability, and solubility all increased. While PEGylated polymers have become more widely explored, an increasing number of protein-polymer conjugates have been created using smart polymers. The study presented here focuses on the therapeutic protein, lysozyme, with both its reported antibacterial and anticancer effects, and the synthesis of smart polymers that present a sensitivity synergistic to lysozyme's bioactivity. Copolymers of N-isopropylacrylamide (NIPAAm), acrylic acid (AA), methyl-salicylate acrylate (SAME), and dimethylaminoethyl acrylate (DMAEA) were synthesized and characterized. Additionally, EDC/NHS-promoted bioconjugation conditions were optimized to covalently attach NIPAAm and AA copolymers to lysozyme's lysine residues. FPLC gel filtration chromatography was successful at purifying polymer-lysozyme conjugates to 92-95%. LCST values for p(NIPAAm-co-AA) were observed in H2O, depending on copolymer composition, and not observed for copolymers in 20 mM PBS at pH 8. Purified samples of p(NIPAAm-co-AA)-lysozyme conjugates were tested for enzymatic activity against Micrococcus lysodeikticus and were found to be inactive (0.15% compared to native lysozyme activity) likely due to the steric hindrance that the polymers create between the lysozyme and target substrate.

Synthesis and Characterization of Phenanthroline Derivatives and Their Luminescent Europium Ion Complexes

Luis (David) Jaramillo

Several fields such as biology and medicine are in constant need of improved cellular imaging technologies for in vivo studies. Emissive bioprobe technologies present a promising means of meeting this need. Given the strong and vast use of lanthanide luminescence across the consumer and healthcare industries, lanthanide ion complexes are

promising candidates for the development of emissive bioprobe technology. Here, we proposed the synthesis of cationic amino- and anionic phosphate-based gemini surfactants containing the sensitizing moiety, 1,10-phenanthroline, as ligands for lanthanide ion complexes. Two ligand precursors have been successfully prepared in moderately high yields. Unfortunately, while we were unsuccessful in the final synthetic step to yield surfactants, we ultimately used the precursors as ligand for the synthesis and characterization of their Eu(III) ion complexes, [Eu(TTA)3(L)]. Compared to phenanthroline, these ligands show promising sensitizing capacity. The photophysical characterization of the ligands showed surprising shifts in emission of more than 100 nm due to the phenanthroline core modifications. Consequently, the Eu(III) ion complexes all show excellent sensitization efficiencies as compared to the standard phenanthroline complex. Though we have laid the foundation for the new ligands, studies into the electronic structure with phenanthroline modification, quantum yield determination, and further synthetic experimentation is required to understand if these ligands hold promise as luminescent bioprobes.

Synthesis and Characterization of a New Class of Versatile Diblock Copolymers

Hanson Koota

Nanoparticles have emerged as a promising new tool to effectively treat cancer. With the limiting factor of most chemotherapeutics being their adverse side effects, nanoparticles have the ability to encapsulate drugs and deliver them to cancerous tissue with minimal effect to normal cells. These particles can be designed to take advantage of cancer cell physiology to preferentially target cancerous tissue over normal tissue. We used RAFT polymerization to explore the versatility of poly[(N,N-diethylaminoethyl) acrylamide] (p(DEEN)) when functionalized as a diblock copolymer. Diblock polymers are composed of p(DEEN), which is cationic at neutral pH, with poly(n-butyl acrylate) (pnBuA) or monomethoxypolyethylene glycol (mPEG) to yield p(DEEN)-co-p(nBuA) and p(DEEN)-co-mPEG. In aqueous solutions both polymers form aggregates 100-200 nm in diameter above their critical aggregate concentrations. The p(DEEN)-co-p(nBuA) amphiphilic diblock copolymer demonstrated resistance to pH change and the p(DEEN)-co-mPEG doubly hydrophilic diblock copolymer demonstrating a change in aggregate size, a decrease in stability, and a change in morphology over a pH range of 5.8 and 8.0.

p(DEEN)-co-p(nBuA) was shown to effectively bind to Cu(II), forming a polymeric metal network corona and a hydrophobic core and causing an increased average aggregate diameter. p(DEEN)-co-mPEG was shown to effectively encapsulate plasmid DNA through ionic interactions, demonstrating a potential use as a non-viral DNA vector. The encapsulation of DNA decreased the average aggregate size and increased stability in aqueous solution. We hope that the versatility of p(DEEN) demonstrated in the construction of these diblock copolymers will have an impact on the design of oncological treatments in the future.

Investigating the Broader Role of Carrier Protein Phosphodiesterase SCO6672 in Streptomyces coelicolor A3(2) Secondary Metabolism

Lia Lee

Streptomyces are a genus of soil-inhabiting, Gram-positive bacteria that produce a wide variety of secondary metabolites, many of which exhibit antibiotic activity. The proper functioning of enzymatic complexes that produce these bioactive compounds depends on the posttranslational attachment of a 4'-phosphopantetheine (Ppant) group onto their carrier protein (CP) domains, which is catalyzed by phosphopantetheinyl transferases (PPTases). The CP phosphodiesterase SCO6672 facilitates the cleavage of this prosthetic group via hydrolysis, and in vitro it has been demonstrated to utilize carrier proteins from multiple antibiotic biosynthetic pathways as substrates. The primary aim of this study was to investigate whether such CP phosphodiesterase activity could be extended to substrates from other primary or secondary metabolic pathways, such as fatty acid synthases, cryptic polyketide synthases, and iron-chelating siderophore synthetases. In addition, the physiological function of SCO6672 was also investigated within the context of CDA antibiotic production. Preliminary results showed that the phosphodiesterase SCO6672 may exhibit activity in vitro against the fatty acid synthase ACPs SCO0126 and Type I PKS SCO6827 as well as the CDA ACP SCO3249, and that it may play a specific role in regulating CDA production in vivo.

Free-Radical Polymerization for the Synthesis of Amphiphilic Copolymers

Jose Lopez

Renewable, plant-based materials offer a promising alternative to commonly used petroleum-based synthetic polymers. Plant-based building block of particular interest are fatty acids. Previous studies have focused on utilizing the alkene on unsaturated fatty acids to synthesize linear polymers via epoxide-ring opening polymerization. Another synthetic application to explore is the synthesis of acrylate and methacrylate monomers with fatty acid side chains. In this work, the transesterification of acrylates with the fatty acids caprylic acid, lauric acid, and stearic acid and the control acetic acid produced monomers with fatty-acid side chains in 40 to 70% yield. Free-radical homopolymerizations of these hydrophobic monomers yielded polymers with molecular weight ranges between 7300 and 28000 with PDI's in the range of 1.3 and 4.6. Next, our studies focused on the copolymerizations of these monomers with structurally related hydrophilic monomers methacrylic acid, acrylic acid, hydroxyethyl methacrylate, or hydroxyethyl acrylate to synthesize random, amphiphilic copolymers, with the aim to study aggregate formation in aqueous media. However, free-radical polymerizations of these monomers resulted in intractable products that were not readily characterized in commonly employed solvents.

Particle in a Corrugated Box: Simple Approximation for the HOMO-LUMO Transition

Erica Myers

Three models were chosen to be examined to give a range of approximations and potential accuracy. The squares, triangles, and sine wave perturbation models were each examined in two different patterns, using two different methods. A first order perturbation approximation and the Wentzel-Kramers-Brillouin (WKB) approximation were applied to the models, and the accuracy of each result was examined. Some of the models were solved mathematically, rather than extrapolated and solved using discrete functions. Regardless, whether the models were solved using summation or discrete approximation, the result was compared to data taken from the research of Peacock-Villada and Christensen. Finally, the appropriateness of each method was examined to determine whether the first order approximation was more accurate than the WKB method, and which method was most costly in terms of time and difficulty.

Combatting Antibiotic Resistance Identification and Characterization of SOS Response Inhibitors in E. coli and B. subtilis

Richard (Alex) Ruberto

The rapid development of bacterial resistance to antibiotics poses a serious threat to human health. The aim of the current project is to develop a lead compound for a drug that could combat antibiotic resistance by targeting the bacterial SOS system, which has been shown to enable bacteria to acquire resistance to antibiotics. Specifically, the Lovett lab targets the two regulatory proteins of the system, LexA and RecA, which are directly involved in activation of the SOS response and are highly conserved across nearly all bacterial strains. To validate the SOS response as a novel target in combatting antibiotic resistance, we have isolated a viable sample of LexA protein, whose self-cleavage acts as the prerequisite for induction of the SOS response. Over 100 compounds have been analyzed in vitro to determine whether their presence inhibits LexA autocleavage. Further, the efficacy of six compounds shown by past lab members to successfully inhibit LexA cleavage in vitro were analyzed in vivo in both Bacillus subtilis and Escherichia coli, and their IC50 values were determined in order to better understand the relative potency of these compounds across these two distantly related strains.

Characterizing Biaryl Pyrazole Binding Interactions and Affinity to Histidine Kinases

Hanna Shebert

The rising global use and overuse of antibiotics has favored the evolution of antibiotic resistant bacteria. Our focus for antibacterial discovery is to target a class of membrane-bound signaling proteins called histidine kinases. Histidine kinases are highly conserved among bacteria, and they bind ATP and catalyze autophosphorylation in response to environmental stimuli. They are involved in cell functions such as cell wall metabolism, virulence, and sporulation; and while they are found throughout all species of bacteria, they are largely absent in eukaryotes. We believe that disrupting bacterial response to environmental changes by inhibiting histidine kinases is a promising strategy for developing broad-spectrum antibiotics. Because of histidine kinases' structural similarity to the Hsp90 molecular chaperone, we screened Hsp90 inhibitors for lead molecules that could inhibit histidine kinases and discovered

that biaryl pyrazoles were effective inhibitors. Using differential scanning fluorimetry, we measured drug binding to PhoQ, a model histidine kinase, and we recently characterized the binding mode of the Hsp90 inhibitor radicicol and PhoQ using X-ray crystallography. Finally, we demonstrated that these molecules weakly inhibit bacterial growth of E. coli, Caulobacter crescentus, and B. subtilis. These small molecules could prove to be precursors of new antibiotics, which are a desperate need as more and more bacteria gain resistance.

Characterizing the sigma factors of Streptomyces coelicolor A3(2): SCO1723 and SCO4409

Zihan Su

The activities of two group IV sigma factors in S. coelicolor, SCO1723 and SCO4409, putative downstream sigma factors to SigU, are characterized here. Both SCO1723 and SCO4409 have cognate anti-sigma factors belonging to the ZAS family, SCO1722 and SCO4408, respectively. Anti-sigma factor mutant strains as well as sigma factor overexpression strains of S. coelicolor were constructed to study the effects of the activities of these two sigma factors on S. coelicolor. SCO1723 and SCO4409 activities did not contribute to the growth defects, lack of sporulation, and enhanced protein secretion aspects of the bald phenotype associated with unregulated SigU activity. However, both sigma factors seemed to play a role in regulating the production of undecylprodigiosin and actinorhodin, two antibiotics produced by S. coelicolor during the growth process.

Synthesis of Lanthanide Ion Coordination Complexes for Arsenic Detection

Suyee Win

Arsenic contamination of ground water is a major global problem, especially for Bangladesh. The majority of this developing country's main source for drinking water contains toxic levels of arsenic. We are interested in developing an affordable, reliable, sensitive, and in-field method to detect low levels of arsenic in aqueous environments. Many small molecular sensors have been shown to detect metal ions, but most are plagued with relatively short signal lifetimes and variable sensitivities. We believe the luminescent properties of trivalent lanthanide ions will allow the development of a novel small molecule sensor to detect As(III) in water. The goal of this thesis was to synthesize pyridine-based ligands that contain both lanthanide-binding and arsenic-binding components for use as ligands in lanthanide ion complexes that will sense arsenic in aqueous solutions. We attempted to synthesis derivatives of dimethyl 2,6-pyridine dicarboxylate and pyridine-2,6-bis(oxazoline) (Pybox) with various arsenic-binding moieties. While most of our synthetic attempts were unsuccessful, a new pybox ligand, 2,2'-(4-((2,2-dimethyl-1,3-dithiolan-4-yl) methoxy)pyridine-2,6-diyl)bis(4,5-dihydrooxazole) or Pybox(thioether), was successfully synthesized and characterized. Europium and terbium complexes were prepared and preliminary metal detection studies have suggested that this luminescent probe has the ability to detect arsenic at μM levels. Although more detailed studies are required, we believe that these new ligand-complexes are viable as possible small molecular sensors to detect arsenic. This thesis presents the synthetic efforts towards derivatives of dimethyl 2,6-pyridine dicarboxylate and Pybox, characterization of the products, metal complexation of the new pybox ligand, along with metal complexation studies, photophysical studies, and preliminary metal sensing studies.

Computer Science

Using Text Abstraction and LSTM Language Models for Domain-Independent Narrative Generation

Melanie Subbiah

The task of generating original stories is not only a proving ground for artificial intelligence, but also has important applications in gaming, education, and the media. There are many existing systems that tackle the problem of narrative generation. However, these systems are lacking in several key areas. First, they generally require extensive background knowledge about characters, actions, and settings that has been authored and formatted specifically for this task. Second, the few systems that learn background knowledge have distinct limitations on their training stories, such as requiring all stories in the training corpus to be human-annotated or to follow the same overall plot. Lastly, while there is new research addressing some of these limitations, there does not currently exist a pipeline that would allow many of these techniques to be leveraged for the task of narrative generation. In this thesis I propose a new pipeline for narrative generation and identify its strengths and limitations through a series of experiments. This pipeline is significant in that it provides the ability to learn from any domain or type of fiction, outlines a framework for considering the challenges involved with open narrative generation, and easily accommodates the incorporation of future technologies and techniques.

"rvv: An Intuitive and Principles Version Control System"

Alexander Majercik

Versioning systems (a.k.a. version control, revision control, etc.) are pervasive and essential software development tools for both individual work and coordination on large teams. The most popular systems historically include rcs, cvs, Subversion (svn), git, and Perforce. These systems arose from acute need rather than a prior design, and were largely designed to mimic previous systems with extension to support a specific, newly-desired feature. As primarily command-line systems, they also sit at an awkward intersection between the Unix design of chaining small, functionally-unique tools and the user experience principle of mapping workflow tasks 1:1 to commands. Given this history, it is not surprising that even the latest systems have incomplete feature coverage, are hard to learn, and often yield confusing error states [#Shihab2012].

There has recently been academic interest in improving this situation [#Bhattacharya2012] [#Jackson2015]. For example, De Rosso and Jackson proposed gitless [#DeRosso2016], which leverages modern user experience principles to extend git into an easier-to-learn system. My advisor has written a partial specification for rvv, a new versioning system that combines the features of svn and git. Specifically, it combines git's local commits, svn's partial checkouts and large binary handling, and Mercurial's user experience.

In this thesis, we provide an abstract analysis of version control as a data structure by building on previous work [#Swierstra2014] [#Cesario2016]. We also present a complete specification and

implementation for a new version control system, rvv, based on this analysis.

rvv features local commits, local branching, partial checkouts, efficient upload and storage of large binary files, atomic commits, client and server side hooks, and per-repository ignore rules. To allow the user to intuitively reason about the state of versioned data, rvv features graph representations for visualizing versioned data history and repository structure. This thesis will include examples of these graph representations mapped to lists of rvv commands that caused the represented state. We present anecdotal results from an informal user study, and a design for a more rigorous user study that could be used to evaluate rvv. We plan to release rvv as open source.

rvv is implemented in Python using stock svn clients and servers to provide transactional and authentication functionality (much in the way that cvs was implemented on top of rcs, and compilers build language stacks). It will provide a unique feature set among version control systems, and its design will be grounded in aforementioned analysis, making it easy to learn and understand.

Making Tsunami in a Wave Tank: Experiments on Boulder Transport

Kyrien R. Edwards

Impressive boulder deposits occur all over the world. Many of these boulder deposits are evidence of past climate events but it can be difficult to say for certain how some of them got there. Specifically, it is hard to tell whether some coastal boulder deposits were deposited by storm waves or tsunami. A common but contested theory is that the occurrence of boulder ridges is a characteristic indicative of storm waves. We present a wave-tank study of singular bore interactions with loose clasts in hopes of testing this theory. We use a dam-break set up to create tsunami-like singular bores. Our set–up within the tank consists of a stepped environment, resembling that seen on the Aran Islands, one specific cite of boulder ridges. This stepped model allows us to compare tsunami mechanics to an area normally afflicted by storm wave activity. We monitored the interaction of the bore with the cliff face and found 4 main phases of flow: unidirectional below the first step, upward jetting, bidirectional flow (maelstrom), and unidirectional flow above the first step. We found that the step severely impacts clast transport, acting to cause clasts to rapidly drop out of transport as well as causing a strong back wash that can affect clast deposition. Although we saw some organizational abilities, we did not see, in any tests, the occurrence of a boulder ridge.

From on High: Geochemistry of Alpine Springs, Niwot Ridge, Colorado Front Range

Jordan F. Fields

Springs in the alpine zone of Colorado's Front Range provide important contributions to the quantity and chemical composition of water delivered to downstream basins. This study reports the geochemistry of snowmelt-driven spring waters in the alpine zone of Niwot Ridge and examines how rock type, contact time, and hydrologic mixing affect the chemistry of springs and surface and groundwater from the same area. In the past most precipitation in the alpine and subalpine zones of the intermountain west has fallen as snow, but warming global temperatures are causing more precipitation to fall as rain. In years of low snowpack, groundwater is an important source of water in the alpine and subalpine zones and for areas downstream. Better understanding how water moves through and interacts with subsurface materials is of vital importance to planning for an uncertain water future. In this study, geochemistry is first used to characterize the water discharged from springs on Niwot Ridge and then to infer the major influences on these dilute calcium bicarbonate waters. Rock materials exert a significant control. Spring concentrations of sodium are predicted by the stoichiometric relationship expected from the weathering of oligoclase to kaolinite. Calcium, however, occurs in excess of concentrations predicted by plagioclase weathering and therefore must have other sources such as eolian material, interstitial calcite, or minor minerals. Contact time seems to be a significant control of chemistry only in groundwater systems and in certain rock types in the shallow subsurface. Solute concentrations increase with contact time and silica provides the best measure of residence time in the waters draining from Niwot Ridge. The chemistry of water moving down through the upper Boulder Creek Basin is largely determined once these waters exit the alpine zone. Solute concentrations measured downstream in Boulder Creek are relatively stable for 25 km downstream, changing dramatically only when water from sedimentary rocks and runoff from the Betasso Water Treatment Plant flow into the creek some 4 km above the city of Boulder. Finally, mixing is also important and the chemistry of water sent downstream is a mix of the shallow groundwater from the springs we sampled, meltwater, and deeper groundwater. The data presented in this study highlight the disproportionate influence of the alpine zone on the volume and geochemistry of water in mountainous regions.

Reconstructing Jökulhlaup Discharge using the Morphology of Eroded Volcanic Rootless Cones

Krystina M. Lincoln

Jökulhlaups are low frequency, high magnitude outburst flood events with incredible landscape altering potential resulting from their catastrophic discharge, high velocities, and ability to mobilize sediment. In this study, we recalculated flood conditions using high water marks recorded on volcanic rootless cones within a braided segment of the river Skaftá in central Iceland. The largest and most recent jökulhlaup in the Skaftá reached peak flow on October 2nd, 2015. Using high resolution aerial imagery, terrain models, and field studies, we mapped high water marks and constructed an interpolated flood surface representing the peak flow height. Discharge values calculated along three cross profiles of the flood area were well within one order of magnitude of the estimated discharge at the glacier margin (3,000 m3/s) and measured at an upstream gauging site (2,100 m3/s). The calculated values ranged

between 2,163 m3/s and 7,771 m3/s, with two cross sections resulting in discharges within 25% of the observed upstream values. Discharge reconstruction at the most downstream cross section results in an approximate doubling of discharge when compared to the measured values. Given the challenges of constraining hydraulic variables and the imprecision of traditionally measured discharge values, the results of this method prove promising.

Flood reconstruction is complicated by the non-uniform geometry of the field site, with numerous obstacles to flow. Additionally, jökulhlaups transport and deposit a vast amount of sediment, which has a multi-fold effect on our calculations. The effective depth of peak flow is likely underestimated in our study because of high sediment deposition, perhaps during the waning period of the flood. Field evidence suggests that at least 68 cm of river sands were deposited in some areas. We further suggest that velocity (and thus discharge) could be overestimated using Manning's equation (particularly at the downstream cross section), because sediment-laden flows have lower velocity/depth relations than clear water, which is assumed in Manning's equation. Calculations assume that flow velocity accommodates all of the transport energy, but in reality, the energy driving the flow velocity would be less because some would be used to transport the sediment. Discharge reconstructions have inherent uncertainty, but high quality aerial imagery and terrain models, coupled with field observations, can successfully estimate peak flood discharge within two to three times the true flood magnitude, and often better.

Petrology and Geochemistry of Enigmatic ca. 1.4 Ga Plutons in the Southern Front Range of Colorado: Implications for Petrogenesis and Tectonic Setting

Matthew S. Marcarelli

Granitic plutons of ca. 1.4 Ga age are known throughout much of North America, from the southwestern United States, through the midcontinent and Great Lakes region, and as far north as Labrador. This study focuses on a particular series of these plutons in the southern Front Range of Colorado that have gone largely unstudied in terms of their geochemistry and petrology. Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine the major and trace element geochemical compositions of 20 samples collected from the Elevenmile and Cripple Creek plutons, as well as from two pluton groups, the Firefly and Tarryall-Elkhorn. In addition to being analyzed geochemically, the textures and mineralogical characteristics of the sampled rocks were analyzed at the outcrop, hand specimen, and thin section scales.

Results from the geochemical analysis show that samples from each of the plutons and pluton groups are peraluminous, predominantly calc-alkalic to alkali-calcic, and ferroan. The peraluminous nature of the samples is apparent in their mineral assemblages, which include the aluminous minerals garnet and muscovite. The presence of two micas and abundant intergrowths of myrmekite suggests the plutons crystallized from hydrous magmas. Field indicators, which include abundant pegmatite dikes and hydrothermally altered wall rock minerals, confirm this interpretation. The hydrous and peraluminous character of these plutons is consistent with S-type granites derived from the partial melting of crustal rocks. Concentrations of the trace elements Nb, Y, Ta, Yb, Rb, Zr, and Ga, when plotted on well-established tectonic discrimination diagrams, also suggest an orogenic, S-type petrogenesis.

While the results presented in this thesis show strong support for a petrogenetic model involving the partial melting of sedimentary source rocks in an orogenic tectonic environment, additional geochemical data is needed to confirm this interpretation. That said, the modal and geochemical data reported here offer new insights into ca. 1.4 Ga plutonism in the southern Front Range. These results fill in a crucial gap in the available data on 1.4 Ga plutons, and they will help to inform larger scale studies on ca. 1.4 Ga plutonism more broadly.

Reinterpretation of Putative Tintinnid Lorica Fossils from the Neoproterozoic Tsagaan Olom Group, Mongolia

Maoli N. Vizcaino

The Neoproterozoic Era was an important time for life on Earth, as major lineages of eukaryotes originated and diversified while simultaneously surviving global glaciations during the Snowball Earth events. Carbonate successions have become an important new taphonomic window into the fossil record of Neoproterozoic eukaryotes. One of the most notable examples is the ca. 662–635 Ma Taishir Formation (Tsagaan Olom Group, Zavkhan Terrane, Mongolia). Here, we examine more closely the morphology and potential taxonomic affinity of organic eukaryotic fossils previously interpreted as remains of ciliate tintinnid loricae from the Taishir Formation and the overlying Ediacaran Ol Formation of the Tsagaan Olom Group via physical measurements of the fossils. We examined 230

samples from the Taishir formation and found that 18 contain fossils of these putative ciliates. We demonstrate that the fossils' original interpretation as ciliate organisms may need revising in light of new ultrastructural data coupled with comparisons to macroscopic organic warty sheets (MOWS). MOWS were identified within the Taishir formation by Cohen et al. (2015) and interpreted as putative marine red algae fossils. Our new comparison suggests that instead of ciliates, these fossils may be red algal reproductive structures and thus related to the coeval MOWS fossils. A new interpretation of the fossils in this study as organic spore-like microfossils (OSMs) has broad implications for our understanding of biodiversity in the Neoproterozoic and help to reconstruct what ecosystems were like during the interglacial Cryogenian.

Infiltration Variability and Shallow Groundwater Response to Snowmelt in Headwater Catchments, Niwot Ridge, Colorado

Noah N. Williams

Interactions between surface and groundwater area a central component of the water budget for snowmelt-dominated headwater catchments of the western United States. Flow into alpine and subalpine aquifers in the Colorado Front Range is changing as climate warms, precipitation patterns evolve and downstream demands for water increase. In this study of alpine and subalpine Niwot Ridge hydrology, I report and analyze hydraulic conductivity (K) values from (1) soil infiltration measurements on 13 transects and (2) falling head slug tests conducted on closely spaced piezometers at the C-1 well field. Hydraulic conductivity (K) values at the atmosphere-soil interface are similar to those measured in the shallow aquifer. Infiltration values are variable (transect medians range from 2.09x10-7 to 7.74x10-5 ms-1) and increase with elevation. Estimates of infiltration capacity that account for up to 23% coverage of rocky alpine periglacial deposits (patterned ground) are positively correlated with elevation, suggesting a "leaky roof " that allows soils to absorb the maximum rapid rate of snowmelt. Hydraulic conductivities also vary in the subalpine C-1 unconfined aquifer (modified Hvorslev K values range from 4.86x10-7 to 1.77x10-4 ms-1), which is composed of late-Pleistocene glacial till. Groundwater K-values rates overlap with infiltration K-values from lower elevations. Analysis of groundwater flow during the 2016 snowmelt season suggests that channel infiltration from Como Creek, a snowmelt-fed, seasonally connected stream, contributes more to groundwater recharge at C-1 than direct infiltration through the unsaturated zone. These findings, combined with my infiltration results, indicate an elevation progression from (alpine) high infiltration capacity where groundwater feeds surface water in periglacial deposits to (subalpine) lower infiltration capacity and surface water feeding groundwater in glacial till deposits. This study illustrates how interactions between surface and groundwater differ based on elevation because of vegetation, snowpack distribution, and either glacial or periglacial materials.

Mathematics and Statistics

Periodic Paths on the Triangle and Hexagon Billiard Tables

Megumi Asada

Imagine a frictionless, air resistance-less fantasy world with completely elastic collisions. For some reason, you decide to play billiards in this world except your billiard ball contains an infinite supply of paint that it releases as it travels. You also decide to play on equilateral triangle and hexagon billiard tables, because why not? Interestingly, you notice that depending on the angle with which you release the ball, the path drawn in paint on the billiard table starts to repeat itself, fixing the path drawn in paint after some period of time. I'm interested in these types of paths, which we call periodic. Specifically, given a direction vector that you know is periodic, what is the period? How many times will the billiard ball hit the walls of the table before repeating its trajectory? We'll resolve this case for the triangle billiard table and explore progress towards understanding the hexagon billiard table.

Properties of Finite Systems of Fixed-Length Cranks

Paul Pierre Baird-Smith

I consider the paths of circular cranks that rotate at fixed speeds in a plane. For a single crank, this is simple: move in a circle; but when one crank is attached to another, a whole new family of curves appears. This talk will focus on surprising properties of these systems in R2, including commutativity and minimality of systems and their curves. Notably, we show that we can draw any polynomial on any bounded interval with these systems.

Probabilistic Bounds On Binary Classification with Dependent Experts

David Burt

Weighted expert voting is central to the areas of decision theory and statistical learning. In the classical Naive Bayes' framework, it is assumed each expert votes independently. We investigate a model of expert voting in which votes are no longer assumed to be independent. We give an optimal decision rule for this model in the case when the dependencies between experts, as well as expert competences are known. We give error estimates for this decision rule. We also investigate the case in which the dependencies between experts are unknown. Under the model assumptions, we show the asymptotic correctness of the spectral clustering algorithm with certain weights as the number of samples tends to infinity. Additionally, we give explicit lower bounds in a small case for the probability spectral clustering succeeds.

Simultaneous Variable and Factor Selections Via Sparse Group Lasso in Factor Analysis

Yuanchu Dang

This thesis investigates applications of penalization techniques to factor analysis models. In a factor analysis model one assumes that there is a linear relationship between the manifest variables (i.e. observable variables) and the hidden factors of interest. Depending on the structure of the factor loading matrix, it can be further classified as either an Exploratory Factor Analysis (EFA) model or a Confirmatory Factor Analysis (CFA) model. Previous research (Hirose and Konishi, 2012) applies the Group Lasso method, a penalization technique with group-wise sparsity, to EFA in determining the number of observable variables. In this thesis we consider adapting the Sparse Group Lasso penalty to a factor analysis model, which is a more flexible approach that allows both group-wise and parameter-wise sparsity of the factor loadings. With the help of the Sparse Group Lasso technique, one can achieve selecting both the number of observable variables and the number of factors for each observable variable. Therefore, it can be used in CFA models. We show that the proposed method can better identify the true underlying structure of a factor analysis model. Moreover, our simulation studies show that the new method gives more accurate estimation of the model parameters than the existing method.

Benford's Law Beyond Independence: Copulas and Detecting Fraud

Rebecca Durst

Benford's law describes a common phenomenon among many naturally occurring data sets and many common distributions, such as the exponential distribution, in which the leading digits of the data points are distributed according to log_{B}[(d+1)/d]. It is so common, in fact, that it is often applied in practice to detect fraud in fields related to science, finance, and even politics. Thus, significant effort has been made to understand when and how distributions will display Benford behavior. Most of the previous work on Benford's law, however, has been restricted to cases of independent variables, and very little is known about its potential application in situations involving dependence. In this paper, we employ the theory of Copula distributions to investigate the Benford behavior of a product of two random variables that may be dependent. Using this copula theory, we provide a method for quantifying and numerically approximating the Benford behavior of a product of two random variables whose joint distribution function is modeled by the copula C. We then develop a concept of distance from a Benford distribution for products in which one or more of the marginals is a Benford distribution and provide an upper bound for this distance that depends only on the copula C. We then conclude our investigations with a consideration of a concept of goodness of fit for the Benford behavior of a data set that is being fit to a particular copula model.

A New Connection Between the Pólya-Vinogradov and Burgess Inequalities

Elijah Fromm

The Pólya-Vinogradov inequality bounds sums over Dirichlet characters without taking the length of the sum into account. For a character χ with modulus q, this bound becomes trivial when the sum is shorter than a constant multiple of $q \log q$. Burgess' bound, which takes the length of the sum into account, remains nontrivial as long as the sum is longer than some constant multiple of $q\ ¼ + \in$. Vinogradov conjectured that character sums of length longer than q^{ϵ} exhibit cancellation, for any $\in > 0$. Here, we show that a modest improvement of the Pólya-Vinogradov bound for primitive even quadratic characters would give nontrivial bounds implying Vinogradov's conjecture on all primitive odd quadratic characters with prime modulus. We also show that whenever the mean of a completely multiplicative function $f : N \rightarrow [-1,1]$ is large, the logarithmic mean of f must also be large.

A Comparison of Bayesian and Frequentist Model Averaging in Predicting the Demographics of Voter Turnout

Kathryn Grice

Better performing than its constituent models, a model average can preempt the dangers of choosing a single model when model specification is uncertain. Model averaging can take place under either the frequentist or Bayesian paradigm, although the underlying assumptions and methodology are vastly different. Here, we evaluate the performance of these approaches to model averaging in the context of voter turnout in US general elections. Using county-level demographic data to predict the turnout of various demographic groups in six states, frequentist and Bayesian model averages see differing levels of success, indicating that a comparison of these approaches is more complex. Further, this study seeks to debunk myths of homogeneity in the voting habits of these demographic groups: indeed, groups that show highly varied trends in turnout between states, in particular those defined by race, are more difficult to predict using model averaging. In the context of a broadening role of statistical analysis before, during, and after elections, both approaches to model averaging offer strengths for demographic analysis and bespeak the inadequacy of generalizations based on demographic group alone.

Investigating Central-Point Vanishing of Families of L-Functions Using the 2-Level Density

Anand Hemmady

In the 1970s, Dyson and Montgomery discovered an unexpected connection between the zeros of the Riemann zeta function and the eigenvalues of families of random matrices. Further work uncovered deep relationships between random matrix theory and the zeros of L-functions in general. We expand upon previous work to use this connection between Number Theory and Random Matrix Theory to study the low-lying zeros (that is, zeros near the central point) of L-functions. In particular, we use the 2-level density to find upper bounds on the average order of vanishing of families of L-functions at the central point.

Efficient Calculation of RNA Secondary Structures with Terminal Stacking

Nikolaus H.R. Howe

An RNA sequence can adopt an immense number of secondary structures (distinct combinations of base pairs), however is often represented by only a handful of minimum free energy (MFE) microstates. These few MFE microstates paint an incomplete picture of the thermal ensemble of folds of a given molecule. To predict what will be observed in experiments of RNA folding it is necessary to consider the whole thermal ensemble of microstates, not just the MFE. The properties of the thermal ensemble and probabilities of each microstate are described with a partition function sum over all the microstates or a Boltzmann-weighted sample of microstates. In this thesis we build an algorithm to compute both more efficiently.

The multiplicity of secondary structures scales exponentially with length as the often-quoted O(1.8N). Additionally, however, because an unpaired base adjacent to a base pair can either stack on the pair or not, for any secondary structure there are also many possible ways of stacking unpaired bases. Here we show that including terminal stacking configurations increases the multiplicity to O(2.09N).

The partition function and its multiplicity can be obtained with recursion, so we employ a dynamic programming algorithm, which allows us to sum the contributions of exponentially many states in O(N3) time. Our novel formulation of the recursion relations allows us to recompute the partition function in O(N2) time and to sample a microstate consistent with its Boltzmann probability in O(N) time per sample.

Meta-Analysis of Risk Differences Under Random Effects

Hae-Min Jung

Meta-analysis combines the results of multiple studies to infer an overall treatment effect. Random Effects methods are popular in dealing with variance between the treatment effects estimated by each study. Of the three most common effect measures for 2x2 contingency tables, the Risk Difference remains the least understood for Random Effects. Existing popular methods are structurally awed and use assumptions inappropriate for the Risk Difference.

We propose a new, unbiased estimate of the between-study variance under minimal assumptions. This new estimate is used to construct a Wilson Score-type confidence interval for the common Risk Difference. The new method is advantageous over existing methods due to its closed-form solution, lack of distributional assumptions, and flex-

ibility regarding the selection of weights. Simulation studies show that it performs well under both low and high between-study variance.

The Isomorphism and Centralizer Problems for Partially Bounded Transformations

Alexander Kastner

Ergodic theory is the study of measure-preserving transformations which map a measure space into itself. One of the central problems in the field is the isomorphism problem, which asks whether two given transformations are isomorphic. A somewhat related problem is the centralizer problem, which asks which transformations commute with a given transformation. While it can be shown that, in a precise sense, both the isomorphism and centralizer problems are intractable in general, there is hope that a complete characterization may be possible if we restrict our attention to the generic class of rank-one transformations. We investigate these questions for the newly defined class of partially bounded transformations, which encompasses many well-known infinite rank-one transformations such as the infinite Chacón and Hajian-Kakutani transformations. In particular, we establish that the only transformations that commute with a partially bounded transformation T are the powers Tn for integers n. Further, we characterize exactly when a partially bounded transformation is isomorphic to its inverse. Finally, we discuss generalizations to rank-one flows.

On Trace Ideals, Duals of Ideals, and Annihilators

Nina Pande

Let M be a module over a ring R. The trace ideal of M is an ideal of R obtained from the set of homomorphisms from M to R: it is the sum of the images of each homomorphism in R. We present results that describe the trace ideals of ideals (viewing these ideals as modules over R) satisfying various conditions. We determine several sufficient conditions for an ideal to be equal to its trace ideal. The set of homomorphisms from M to R is called the dual of M. We examine duals of ideals in terms of particular maps contained in the dual, in terms of grade, and in terms of generators of ideals. In addition, we characterize dimension zero Gorenstein rings in terms of their trace ideals. Throughout we explore the rich relationship between trace ideals and annihilators.

Entropy Computation for Measure-Preserving Transformations

Matthew James Quinn

Entropy provides a notion of how random partitions and measure-preserving transformations are by looking at how many bits of information we can expect to gain from an experiment that is represented by them. In this paper, we provide original proofs that lead to showing that the generalized odometer, with an arbitrary sequence of cuts, has zero entropy. We likewise consider the Hajian-Kakutani Skyscraper transformation. However, entropy is traditionally defined on a finite measure space. Therefore, in studying the Hajian-Kakutani Skyscraper transformation, we suggest a new adjustment for entropy to be defined over a space of infinite measure. We then discuss an extension of our arguments to all rank-one transformations.

Human Performance and Aging: A Statistical Approach

John Robert Shuck

Previous studies of aging do not take into account the inherent uncertainty associated with aging across the lifespan. This thesis explores the deterioration of performance times in masters athletes with a new statistical approach. Uncertainty in performance deterioration with age is accounted for by more precise modelling techniques and through construction of empirical confidence intervals. Through the statistical methods proposed in this thesis, it is possible to quantify which age ranges show similar rates of performance deterioration across different masters athletic events. Ultimately, it is found that deterioration is similar in the 55-70 age range across many different sports, indicating the existence of a universal aging mechanism that is not mediated by sport specific selection variables.

New Classes of Orthogonal Polynomials on the Unit Circle and Bernoulli Distributed Verblunsky Coefficients

Andy Yu Zhu Yao

My thesis presents the general theory for orthogonal polynomials on the unit circle (OPUC) and reviews some classic examples of OPUC. I study and characterize new examples of orthogonal polynomials on the unit circle. Furthermore, I prove properties relating Bernoulli random Verblunsky coefficients and the zeros of the orthogonal polynomials.

Neuroscience

Effects of central nervous system inflammation on contextual memory in mice

Terrance Mensah

Inflammation in the central nervous system (CNS) leads to various impairments in brain physiology and function. Memory processing is one of the functions most affected by CNS inflammation. The aim of this study was to assess the effects of CNS inflammation on performance of a context object discrimination task, which assesses contextual memory, in mice. Peripheral immune activation induced by lipopolysaccharide, and repetitive mild traumatic brain injury (mTBI) were used to induce CNS inflammation. The results demonstrated that LPS had no effect on COD performance in singly housed mice, and also did not lead to increased levels of activated microglia, a common marker for CNS inflammation. However, in female group housed mice, LPS lead to a significant decrease in COD performance. In mice impacted by mTBI, male and female mice receiving repetitive mTBI did not exhibit intact context memory 8 days after mTBI, while control mice did; however, there were no significant differences between the mTBI and sham conditions. These results demonstrate that administration of LPS impairs contextual memory processing in female mice, and that repetitive mTBI may also impair contextual memory in mice as well.

Physics

An Unusual Derivation of the Boltzmann Distribution for a Particle in a 1D Box

Jaeho Choi

Consider a one-dimensional particle confined to a box with infinite walls. In thermal equilibrium with a large heat bath, this system has a quantum distribution of position that is remarkably uniform across most of the box's length. In my thesis, I lay the mathematical groundwork for an unusual derivation of the Boltzmann distribution for this system. In particular, I show, up to one technical conjecture yet to be proved, that, given squares of the position eigenfunctions for the system, one can derive the quantum Boltzmann distribution for the system, which consists of the energy eigenvalues for the system and the exponential skeleton of the Boltzmann distribution, by insisting that the average of the squares of the position eigenfunctions for the system weighted by a probability distribution be as flat as possible.

To put this surprising phenomenon, first observed by Alterman and Wootters in 2016, on a firm mathematical footing, I introduce a special probability distribution called the quasi-Boltzmannian distribution. I show that the average of the squares of the position eigenfunctions for the system is flattened when weighted by the quasi-Boltzmannian distribution under certain conditions in which some parts of the distribution are set to zero. Moreover, I show that the quasi-Boltzmannian distribution approaches the Boltzmann distribution for the system in a specific sense. It is shown that while the average of the squares of the position eigenfunctions for the system is well-flattened when weighted by either the quasi-Boltzmannian distribution or the Boltzmann distribution for the system, it is better-flattened when weighted by the quasi-Boltzmannian distribution. Lastly, I lay the groundwork to potentially show that an optimal probability distribution, if it exists, cannot deviate much from the Boltzmann distribution for the system by presenting a tight lower bound for a probability distribution at least as optimal as the quasi-Boltzmannian distribution. If a similarly good upper bound can be found, it is expected that any probability distribution at least as optimal as the quasi-Boltzmannian distribution approaches the Boltzmann distribution for the system in the same sense in which the quasi-Boltzmannian distribution approaches the Boltzmann distribution for the system.

Towards a Precise Measurement of the Electric Quadrupole Amplitude Within the 6s26p2 3P0 → 3P2 Transition in Atomic Lead

Eli V. Hoenig

We present a measurement of the 6s26p2 3P0 → 3P2 electric quadrupole (E2) transition amplitude relative to the 3P0 → 3P1 magnetic dipole (M1) transition amplitude in 208Pb. The motivation for this measurement stems from recent advancements in wavefunction calculations that have renewed lead's viability to test the electroweak interaction in an atomic physics based experiment. Our measurement aims to guide further refinement of the theory, and improve the calculation of the nu-clear weak charge. Our preliminary value for the E2 amplitude relative to the known M1 amplitude is E2/M1 = 0.148 (2)(8) where the first error is statistical and the second systematic. We employ Faraday optical rotation techniques with two external cavity diode lasers, one operating at 939 nm and one at 1279 nm, to measure the line-strengths for the E2 and M1 transitions, respectively. We find that this technique is capable of detecting optical rotations below the level of 1μrad, easily re-solving the E2 transition. We also present a measurement of the hyperfine structure splitting of the 6s26p2 3P1 state and the 6s26p2 3P0 → 3P1 isotope shift between 208Pb and 207Pb.

Codon Influence Models: A Comparative Genomics Approach Using Bioinformatic Tools

Intekhab Hossain

The degeneracy of the genetic code implies that the same protein sequence can be coded for in multiple ways, which allows for an additional layer of information tobe encoded into the genome, via variations in synonymous codon usage. Although codon usage bias has been studied for several decades, much of its mechanistic underpinning remains a conundrum, and only lately have statistical tools been employed to investigate the phenomenon. In this study we use multi-parameter regression models on a large collection of expression datasets measuring protein and/or mRNA levels from Escheria coli, Bacillus subtilis, Prochlorococcus marinus and Saccharomyces cerevisiae, sourced from various investigations in the literature, to perform a comparative genomics analysis of codon usage bias and its link to gene expression. Interestingly, we found that even though many mRNA features affect gene-expression in a species and expression-platform dependent manner, there are notable trends in the magnitudes, directions and functional forms of influence. Many mRNA features are heavily cross-correlated with each other and thus, upon multiple regression analysis, these terms were eliminated from our models. However even after adjusting as such for cross-correlations, the multi-parameter regression coefficients exhibited correlations between themselves, an observation that was reinforced by the predictive power of each metric across datasets that originated from organisms and levels of Central Dogma, different from those of its training set. This study provideS insight into the general influence of sequence features on gene-expression at a global level, as well the specific differences in these influences between different organisms and the different levels of the Central Dogma.

MacroFold: Efficient Recursion Relations for RNA Partition Function

Nikolaus Howe

An RNA sequence can adopt an immense number of secondary structures (distinct combinations of base pairs), however is often represented by only a handful of minimum free energy (MFE) microstates. These few MFE microstates paint an incomplete picture of the thermal ensemble of folds of a given molecule. To predict what will be observed in experiments of RNA folding it is necessary to consider the whole thermal ensemble of microstates, not just the MFE. The properties of the thermal ensemble and probabilities of each microstate are described with a partition function sum over all the microstates or a Boltzmann-weighted sample of microstates. In this thesis we build an algorithm to compute both more efficiently. The multiplicity of secondary structures scales exponentially with length as the often-quoted O(1.8N). Additionally, however, because an unpaired base adjacent to a base pair can either stack on the pair or not, for any secondary structure there are also many possible ways of stacking unpaired bases. Here we show that including terminal stacking configurations increases the multiplicity to O(2.09N). The partition function and its multiplicity can be obtained with recursion, so we employ a dynamic programming algorithm, which allows us to sum the contributions of exponentially many states in O(N3) time. Our novel formulation of the recursion relations allows us to recompute the partition function in O(N2) time and to sample a microstate consistent with its Boltzmann probability in O(N) time per sample.

Improvements to a System for Trapping 40Ca+

Sierra E. Jubin

We aim to use chains of trapped 40Ca ions as analog quantum simulators to explore heat transport in nanoscale systems. Ions were successfully trapped after a number of improvements were made to the experimental setup. This setup involves a surface electrode RF Paul trap housed inside a vacuum chamber, as well as a variety of external cavity diode lasers used to ionize and cool the 40Ca. Equipment was modified to enable a deeper trapping pseudopotential well, and the laser frequency-stabilization system was improved by making it less responsive to temperature fluctuations. Optical isolators were installed to prevent optical feedback from interfering with the frequency-stabilization of the lasers. In addition, adjustments were made to minimize RF signal pick-up in both the DC signals sent to the Paul trap and the laser frequency-stabilization systems. Finally, an additional reference point for the laser frequency was added to the setup. Much remains to be done before heat transport experiments can begin; in particular, many of the tasks that are currently executed manually need to be automated.

A Practical Quantum Schur Transform

William M. Kirby

We describe an efficient quantum algorithm for the quantum Schur transform. The Schur transform is an operation on a quantum computer that maps the standard computational basis to a basis composed of irreducible representations of the unitary and symmetric groups. We improve on the algorithm of Bacon, Chuang, and Harrow, and provide a new and simplified practical construction as well as sharp theoretical and practical analyses. Our algorithm decomposes the quantum Schur transform on n qubits into O(n^4 log(n/ϵ)) operators in the Clifford+T fault-tolerant gate set. For n qudits of dimension d, we describe how to extend our algorithm to decompose the Schur transform into O(d^3 n^(2d+1) (log(d n/ϵ))^p) operators from any universal gate set, for p $\approx$ 3.97.

The Dirac Equation from Quantum Cellular Automata

Michael M. May, III

We explore the relationship between quantum cellular automata (QCAs) and the free Dirac and Weyl equations in two and three dimensions. First, we derive then characterize localized, positive energy solutions of the Dirac equation in two and three dimensions. We find their moments and conditions on their spinor components for symmetric propagation. Next we derive cellular automata on square and hexagonal lattices, thus countering D'Ariano and Perinotti's New No-Go Lemma, supposedly restricting QCAs to only the square lattice in two-dimensions. Finally, we consider the recovery of the Weyl equation from our numerical simulations of two-dimensional automata. We find that in the long wavelength limit, using the same spinor conditions found for the Dirac and Weyl equations for symmetric propagation, that the hexagonal lattice is isotropic, and its automaton yields a dispersion relation identical to that of the Weyl equation.

The Impact of Electron Neutrino Disappearance on Fermilab's Short-Baseline Neutrino Experiment

Maria V. Prado

The Short-Baseline Neutrino (SBN) experiment, located at the Fermi National Accelerator Laboratory, is looking for sterile neutrinos by searching primarily for muon neutrino to electron neutrino oscillations. The experiment consists of a beam flux of 99.5% muon neutrinos and 0.5% electron neutrinos aimed at three liquid argon time projection chamber (LArTPC) detectors at different baselines: SBND (110 m), MicroBooNE (470 m), and ICARUS-T600 (600 m). If oscillations at a short baseline exist, there is a non-zero probability for the intrinsic electron neutrinos from the beam to oscillate to a different neutrino flavor, canceling some of the muon neutrino to electron neutrino signal. This thesis delves into quantifying the effect of intrinsic electron neutrino disappearance on the SBN sensitivity, which probes the preferred parameter space by the LSND anomaly and other short-baseline existing neutrino data. We use the 3+1 (PrGLO) global fit preferred parameter regions, which are formed from preferred regions of past short-baseline experiments. We find that the significance of a large part of the LSND preferred region is reduced for values of (sin(2*theta_ee))^2 around 0.1 and above, where it is observed that SBN will have less than 5σ sensitivity to portions of the parameter space preferred by LSND at 90% CL. Considering that (sin(2*theta_ee))^2 = 0.1 is the best fit (sin(2*theta_ee))^2 value of the 3+1 PrGLO preferred region, this analysis conveys that the electron neutrino disappearance significantly impacts the SBN sensitivity for well-motivated parameters, and should be included in future analyses.

Measurement of the Indium 7P Excited-State Polarizabilities Using Two-Step Atomic Beam Spectroscopy

Nathaniel B. Vilas

We have made progress towards a series of precise measurements of the indium 7P1/2 and 7P3/2 polarizabilities using two-step atomic beam spectroscopy. Preliminary analyses give scalar polarizabilities of 0(7P1/2) = 1.8064(32) x105 a03 and 0(7P3/2) = 2.852(30)x105 a03. Both results are in reasonable agreement with recent theoretical calculations and significantly more precise, though we require more data collection and error analysis in each case. In the experiment, we lock a 410 nm diode laser to the indium 5P1/2 – 6S1/2 resonance and overlap a counter-propagating 685-690 nm diode laser, tuned to one of the 6S1/2 – 7P1/2,3/2 transitions, through a collimated beam of indium atoms. We then use lock-in demodulation techniques to detect two-step transitions an order of magnitude weaker than those previously measured in our group. Alongside this experimental progress, we have developed a theoretical treatment of the Stark shift in a many-level atomic system coupled by two laser fields. This work allows for numerical lineshape simulations instrumental in the successful extraction of the 7P3/2 tensor polarizability from atomic beam data. With continued refinements to theory and more data collection and systematic error analysis, we hope to achieve final measurements at or below the 1% level for all three quantities.

RNA in Translation

Daniel P.G.H. Wong

This thesis details work in two projects connected under the theme of mRNA in translation. First, we introduce new methods to optimize mRNA for high protein expression, based on a binary logistic regression model trained on 6348 mostly heterologous overexpression experiments in E. coli [1]. The model defines two regions to an mRNA: the first 16 codons which are highly influential per capita due to their role in translation initiation, and the remainder. We call these regions the head and tail. Our methods produce cheap, head-only optimizations as well as full sequence optimizations. Experiments validate the full sequence optimizations. Second, we examine ribosome profiling, a new experimental technique that uses ribonu- clease to digest exposed mRNA, leaving only ribosome-protected fragments. These frag- ments can provide detailed information on the kinetics of translation elongation as well as the mechanisms of ribosome pausing. In bacteria, theprotocol is hampered by an in- efficient and sequence-dependent ribonuclease, MNase, that creates fragments of variable length, complicating assignment of ribosome occupancy. The 3'-assignment method utilized in Woolstenhulme et al. [2], but sequence features near the 3' end bias fragment information. We characterize the biases introduced by this assignment method and explore two possible methods of correction: (1) pooling out of frame reads back in frame and (2) a Bayesian Network approach.

Psychology

Effects of Mixed Training Schedules and Category Structure on Accuracy and Visual Attention in a Single-Task Categorization Paradigm

Claire Bergey

Recent research on stimulus order in visual categorization tasks has demonstrated that order can impair or enhance category learning, possibly by directing attention to certain dimensions of stimuli through juxtaposition. Here, a new approach examines whether differential spacing of interrelated categories learned in a single task can result in differential accuracy at test. The combination of learning schedules in a single task allows for detection of category-specific, rather than task-specific, learning schedule effects, contradicting extant models (Noh et al., 2016) while reinforcing a discriminative-contrast account. Subsequent experiments examine whether changing the structure of the categories to be more isolated can reverse these accuracy differences; here, we do not find support for Goldstone's (1996) account of a blocking advantage for isolated categories. Finally, we look to eyetracking to provide more direct evidence that learning schedule results in attentional shifts between features due to juxtaposition.

Interaction of Early Adversity and Additive Genetic Risk from Five Serotonin System Polymorphisms to Predict Depression and Stress Generation: Examining Rumination as an Underlying Mechanism

Julia Cheng

An emerging body of literature has demonstrated that genetic variants within the serotonin system interact with early adversity (GxE) to predict both depressive symptoms (Karg, Burmeister, Shedden, & Sen, 2011) and stress generation (Harkness, Bagby, et al., 2015). Few studies, however, have taken a polygenic approach in which additive genetic risk from several genetic variants contribute to this GxE effect. Additionally, the mechanisms underlying the GxE effects on both depressive symptoms and stress generation have yet to be explored. To address these gaps, we examined whether rumination acted as a mechanism through which early adversity and serotonergic vulnerability interact (GxE) to predict depressive symptoms and stress generation. This moderated mediation model was examined in a two-year longitudinal study of 105 adolescent girls (M age = 12.35 years). Diagnostic interviews were used to assess current and past depressive symptoms. Contextual objective life stress interviews with adolescents and their primary caregivers were used to assess acute and chronic interpersonal stress generation (Rudolph & Hammen, 1999), as well as the accumulation of early adversity within the family environment over approximately the first 11.5 years of adolescents' lives (Rudolph & Flynn, 2007). An additive multilocus profile (MLP) score obtained from five serotonin system polymorphisms was used to represent serotonergic vulnerability (Vrshek-Schallhorn et al., 2015), and ruminating about interpersonal difficulties was assessed via adolescent self-report (Connor-Smith et al., 2000). Results indicated that among girls who experienced greater levels of early adversity, higher serotonergic MLP scores were associated with greater rumination, which in turn predicted greater depressive symptoms. Conversely, among girls who experienced greater levels of early adversity, higher serotonergic MLP scores were associated with greater rumination, which in turn predicted increases in each acute and interpersonal stress generation. However, these indirect effects were not significant among girls who experienced lower levels of early adversity. Findings suggest that early adolescent girls with greater serotonergic vulnerability who have experienced a greater levels of early adversity are more likely to develop rumination, and that this leads to subsequent increases in depressive symptoms as well as in acute and chronic interpersonal stress generation. Such findings support the use of prevention approaches targeting adolescents' tendency to ruminate with the goal of reducing stress generation, and ultimately, risk for depression.

Are We Doomed? The Role of Attention in Healthy Eating Behavior

Jane Dai

In this study, we examined the role of attention as measured by visual salience in healthy eating behavior. We conducted two-alternative forced choice tests of competing food stimuli that also paired healthy and unhealthy foods in populations both on MTurk and in a laboratory setting. We predicted that there would be main effects of salience type and taste rating, such that people would choose the salient food more frequently than the non-salient food and the tastier food more frequently than the competing food. Our results showed that people are more likely to select healthy foods when they are salient, when they are tastier than unhealthy foods, and when they have previously made a healthy food decision.

Why They Do the Things That They Do: Thin Slicing Trait and State Anxiety

Gabrielle Gauthier

Previous research has suggested that people can come to extremely accurate judgments of others' internal states on the basis of very minimal exposure to aspects of their behavior—a process referred to as thin slicing (Ambady & Rosenthal, 1992). However, sometimes it is important to not just understand whether a person is experiencing an internal state or not, but also why they are experiencing it. In this thesis, I explore the extent to which people can accurately perceive a person's internal state that may be resulting from two distinct sources: aspects of their more enduring disposition or ephemeral features of their current situation. On the basis of evidence from the causal attribution literature, I predicted that individuals will generalize perceptions of a person's state to their trait ratings. However, the results suggest that it is actually trait anxiety that individuals are picking up on and generalize to their ratings of the targets' state. These findings suggest that people can be both accurate and inaccurate in their assessments of the sources of other people's anxiety, sometimes accurately perceived dispositional aspects of anxiety, while simultaneously confusing the sources of someone else's internal state in person perception processes.

Asymmetric Switch Costs between Color and Shape and the Influence of Contextual Information

Benjamin Lin

Categorization literature has demonstrated the presence of a cost when participants switch between sorting dimensions (Diamond & Kirhkam, 2005). Some work has been done on examining asymmetric switch costs (Ellefson, Shapiro & Chater, 2006), but it still a relatively unexplored field of study. Using the Dimensional Change Card Sort (DCCS), we sought to reveal a consistent asymmetry in the switch cost incurred from switching between the dimensions of color and shape. Additionally, we explored whether this asymmetry in switch cost could be influenced by providing information about one, but not both, of the sorting dimensions. Our initial findings showed a consistent prioritization of color over shape, where participants had more difficulty switching from color to shape than from shape to color. However, by providing more context to categorizing by a particular dimension, the magnitude of the switch cost could be reduced when switching to the manipulated dimension. These results demonstrate that prioritizations of sorting dimensions do exist and that they are flexible, and paves the way for future studies to explore different factors that might influence asymmetries in switch cost. This work also provides a framework to further study how prioritizations develop in children, as well as how to study prioritizations of social categories.

Examining Empathy: Revealing Differential Effects of Empathy and Compassion on Emotion Recognition Accuracy

Ananya Mayukha

The ability to read the emotions of others is an important element of social interaction. It allows us to adapt our own responses, cultivating a sense of interpersonal harmony. Intuitively, it might seem that empathy, the tendency to mirror the emotions of others, enhances our ability to read other people. The current work directly challenges this intuition, in favor of a slightly different form of stepping into other people's shoes: compassion. In Study 1, I explore the possibility that, when exposed to another person's suffering, those with high empathy will share in this experience to such an extent that it hinders their ability to read the facial expressions of subsequent others. Unexpectedly, results indicated that this detrimental effect of empathy was not specific to the circumstance of prior exposure to another person's suffering, but rather, remained consistent even without such exposure. In contrast, compassion was beneficial to emotion recognition ability across exposure conditions. In Study 2, I demonstrate that these opposite implications of empathy and compassion for social perception hold not just in the case of facial expressions, but also for emotion recognition in voices.

Prioritization of Visual Dimensions in Categorization of Objects and Ensembles

Jose Rivera-Aparicio

Using a task-switching paradigm, we examined whether certain feature dimensions are prioritized over others in visual processing of objects and ensembles. In Experiments 1 and 2, participants sorted individual objects and homogeneous ensembles. As expected, switches in the sorting dimension led to increased reaction times. Furthermore, participants incurred a larger cost when switching from color to shape than vice versa, suggesting that color may be prioritized over shape for both objects and for homogeneous ensembles. In Experiment 3, participants sorted individual objects and heterogeneous ensembles. Switch costs were observed; however, participants did not exhibit asymmetric switch costs for color or shape. In Experiment 4, participants again sorted individual objects and heterogeneous ensembles. However, the stimuli were altered in the hopes of making the ensemble sorting task easier in order to increase accuracy and obtain more reliable data. Switch costs were observed. Furthermore, participants demonstrated a significant cost when switching by color to shape and vice-versa in both the object and ensemble sorting task. In Experiment 5, we examined the effect of development by having elementary school-aged children sort individual objects and heterogeneous ensembles. Children did not demonstrate any switch costs and did not prioritize color over shape nor shape over color when sorting objects nor when sorting ensembles. Together, these results suggest that the pattern of prioritization of visual dimensions is context-dependent.

Sequence as Context in Category Learning

Isabella Salmi

Categorization is one of our most essential cognitive processes and begins at a very young age. Categorization research often assumes that categories are either learned in a vacuum or all at once. This is not how items are actually encountered in real learning scenarios. Previous research has shown that the context in which an item is encountered influences how it is classified and that the order in which exemplars from different categories are viewed influences how well they are learned. We believe that the context effect in fact motivates the sequence effect, resulting in objects that are identified by the features that distinguish them from objects to which they often occur in close proximity. We designed a four-category structure in which pairs of categories could be perfectly distinguished using one feature. When they had undergone a learning task in which pairs of categories were more likely to occur in succession, participants attended more to the features that differentiated the paired categories than to the other, equally diagnostic features. This is evidence that the sequence and proximity of objects during learning can influence how we conceptualize the categories to which they belong.

Exonerees on Trial: Do People Give Prior Wrongful Convictions Their Proper Weightlessness?

Scott Shelton

As of May 9, 2017, the National Registry of Exonerations has a record of 2,023 exonerees, all of whom were wrongfully convicted and subsequently exonerated of a crime. However, no research has investigated whether these individuals receive fair trials if they ever find themselves in court again. Past research has shown that knowledge of a defendant's prior rightful conviction increases the likelihood that that defendant is found guilty of a new crime (Greene & Dodge, 1995; Wissler & Saks, 1985), but it is unclear whether a defendant's prior wrongful conviction might similarly inflate jurors' perceptions of a defendant's guilt. Using the fundamental attribution error as a theoretical framework, the present research sought to test whether knowledge of an exoneree's prior wrongful conviction increases the likelihood that he or she is convicted of a new offense. Across two experiments, participants were consistently more likely to convict exoneree defendants than they were to convict defendants with no prior criminal record. Furthermore, a number of individual difference characteristics − i.e., belief in a just world, system justification, authoritarianism, political orientation, and trust in police − had significant, positive relationships with participants' judgments of guilt. This research represents an important first step in examining whether exonerees are treated fairly when on trial for new crimes.

Using ALCOVE to Understand Sequence Effects in Category Learning: An Eyetracking Study

Stephanie Stacy

Using eyetracking as a direct measure of overt attention, we tested the hypothesis that the temporal juxtaposition of exemplars affects attentional allocation in category learning. Even when each feature of a category exemplar is equally diagnostic of category membership, the order in which the stimuli are presented can highlight a target feature of the exemplar. Participants were found to quickly and dramatically shift their attention to unduly weight this target dimension despite the fact that it provided no advantage in learning. We were then interested if we could model this learning trajectory using a popular exemplar-based neural network model, ALCOVE, which is designed to approximate human learning. We found ALCOVE was unable to capture the same allocation of attention observed in eyetracking data, but posit that this could be due to participants using suboptimal learning strategies, something ALCOVE does not have the capacity to take into account.

Adverse Childhood Experiences and Physiological Responding to Stress in Young Adults

Gabriela Suarez

Current research supports robust, well-established associations between retrospective report of adverse childhood experiences (ACEs) and risk of poor physical and mental health outcomes across the lifespan. The biological mechanisms that underlie these associations remain underspecified. Early rearing environments that expose the individual to childhood adversity may prime biological systems to respond defensively, in an adaptive way to promote survival in the context of adversity but that become maladaptive in the context of safety (Hane & Fox, 2016). This study sought to identify the biological mechanisms involved in the associations between childhood adversity and health in a selected sample of young adults recruited from a small, residential liberal arts college campus. In Wave 1 of this study, a total of 239 students completed an online screening questionnaire, used to identify 39 participants with 4 or more ACEs (ACEs group) and 91 participants without ACEs (control group). In Wave 2, selected subjects (15 controls, 14 ACEs) participated in a laboratory visit during which ambulatory ECG was acquired to examine sympathetic (heart rate; HR) and parasympathetic (respiratory sinus arrhythmia; RSA) responding to various types of laboratory stressors. Laboratory stressors included two somatic stressors: the cold presser test and a finger stick blood sample; and three social stressors: A five-minute speech sample about their childhood, an interview about disappointing experiences, and the speech portion of the Trier Social Stress Test). Group differences on biometric markers of health risk and behavioral risk were also examined. Relative to controls, the ACEs group reported significantly more trait anxiety, less hours of sleep per night, and demonstrated less tolerance for pain in the cold presser test. Importantly, the groups did not significantly differ on biomarkers of health risk, including blood pressure, HDL cholesterol, percent body fat, or BMI. However, important differences were found in terms of ANS responding during laboratory stressors. The control group showed a coherent pattern of healthy responding, showing a significant reciprocal relationship between HR and RSA across all tasks. In contrast, the ACEs group exhibited a profile of ANS responding that either represented a form of nonreciprocal responding (HR and RSA were positively correlated) or a fundamental disconnect between the two branches of the ANS (HR and RSA were uncorrelated), which varied based on type of task. These results provide evidence that shortly after leaving childhood adversity behind, and before health indicators reach the level of risk, autonomic dysregulation is robustly evident and may be a key biological mechanism involved in the elevated risk for stress-related illness across the lifespan for those who have a history of substantial childhood adversity.

Abstracts from Presentations and Publications

Astronomy

John Bevis's 18th-century Atlas Celeste: An Oft-Overlooked Treasure

Pasachoff, Jay M., and Kevin J. Kilburn

Proceedings of the Ninth meeting on the Inspiration of Astronomical Phenomena, INSAPIX (insapix.org), London, held in 2015, ed. Nicholas Campion (Sophia Centre Press), in press in: Campion, Nicholas and Chris Impey (eds.), Dreams of Other Worlds, Papers from the Ninth Conference on the Inspiration of Astronomical Phenomena (Lampeter: Sophia Centre Press, 2017).

One of the most beautiful star atlases of all time was prepared by John Bevis, who had earlier discovered the Crab Nebula, but was never formally published because of the bankruptcy of his printer. Several of the printed pages were bound in 1750 while further copies were released in 1786. We discuss these unpublished atlases, especially the copy in the library of Manchester Astronomical Society and a newly discovered atlas in the library of the Duke of Devonshire. We maintain a list of the approximately 30 copies of the atlases, both 1750 and 1786, which are now known.

Haze in Pluto's atmosphere: Results from SOFIA and ground-based observations of the 2015 June 29 Pluto occultation

Bosh, Amanda S., Michael J. Person, Carlos A. Zuluaga, Amanda A. Sickafoose, Stephen E. Levine, Jay M. Pasachoff, Bryce A. Babcock, Edward W. Dunham, Ian S. McLeane, Jürgen Wolf, Fumio Abe, Eric E. Becklin, Thomas A. Bida, Len P. Bright, Tim Brothers, Grant Christie, Peter L. Collins, Rebecca F. Durst, Alan C. Gilmore, Ryan T. Hamilton, Hugh C. Harris, Chris Johnson, Pamela M. Kilmartin, Molly Kosiarek, Karina Leppik, Sarah E. Logsdon, Robert Lucas, Shevill Mathers, C. J. K. Morley, Peter Nelson, Haydn Ngan, Enrico Pfüller, Tim Natusch, Hans-Peter Röser, Stephanie Sallum, Maureen L. Savage, Christina H. Seeger, Ho Chit Siu, Chris Stockdale, Daisuke Suzuki, Thanawuth Thanathibodee, Trudy Tilleman, Paul J. Tristram, Jeffrey Van Cleve, Carolle Varughese, Luke W. Weisenbach, Elizabeth Widen, Manuel Wiedemann,

Results from SOFIA and ground-based observations of the 2015 June 29 Pluto occultation," Icarus, in preparation

We report on the successful observations of the 29 June 2015 with the High Speed Imaging Photometer for Occultations (HIPO), First Light Infrared Test Camera (FLITECAM), and the the Focal Plane Imager (FPI+). The instruments were mounted on the 2.5-m telescope on NASA's/DLR's Stratospheric Observatory for Infrared Astronomy (SOFIA). The mission was mounted from Christchurch, New Zealand, and used last minute astrometry to adjust the plane's track, giving a central flash in the light curve that allows Pluto's atmosphere to be probed to a lower altitude than otherwise possible. During the occultation, SOFIA was only 22.8 km south of the central line, after its last-hour adjustment of its flight path.

The longest total occultation of the Sun of the 21st century at Tianhuangping (Zhejiang), China: Air-temperature observations and its theoretical analysis under adverse meteorological conditions

Peñaloza-Murillo, Marcos A., and Jay M. Pasachoff

J. Geophys. Res., submitted, under revision, 2016

The lack of comprehensive solar radiation monitoring during the longest total solar eclipse (TSE) of the 21st century at Tianhuangping (Zhejiang), China, on July 22, 2009, has led to this investigation, in which we have evaluated cloudiness in order to estimate its impact on global solar radiation during the eclipse. In doing so, a cloud cover empirical model has been applied to obtain the global solar radiation and, at the same time, a theoretical model has been deduced to find the direct solar radiation. This eclipse's occultation and obscuration functions were used, taking limb-darkening and atmospheric transmission into account. Though forecasts for that day called for clouds and some rain, for our observation site at Tianhuangping the total phase of the eclipse could be observed. This experience suggests that for coming eclipses, a recording in situ observation protocol of cloudiness is mandatory. The results for global solar radiation indicates that our TSE radiation model is quite acceptable and representative of that which could have happened at that time.

Intricacies of the 2013 November 3 Hybrid-Eclipse White-Light Corona

Pasachoff, Jay M., Vojtech Rusin, Metod Saniga, Allen B. Davis, and Daniel B. Seaton

Astrophys. J., submitted, under revision, 2016

We analyze the structure and dynamics of the white-light corona (WLC) as observed in Gabon during the annular-total ("hybrid") solar eclipse of 2013 November 3 (total across Africa, including our location). The eclipse occurred between the double maxima (2012 and 2014) of cycle 24, which ranks among the weakest in many decades. Even though the cycle amplitude, in terms of sunspot number, was very low, the WLC had a typical cycle maximum shape with many helmet streamers or long rays uniformly distributed around the solar limb and filled with many loops, arcades or thin rays. This distribution yields the flattening index of 0.04, appropriate for its phase of the cycle. We observed two coronal mass ejections (CMEs) and an eruptive prominence during the eclipse. Their positions are rather atypical (far away from active regions): the first is located at position angle (PA) 19º and at a height of 2.7 solar radii (its lower edge was located at 2.13 solar radii). The second was located on the opposite side at PA 196º at a height of 3.90 solar radii. The projected speed of the first CME was approximately 140 km s-1; that of the second CME was about 120 km s-1 (these speeds were derived using SOHO/LASCO C2 observations, of much lower resolution). Attention is also drawn to a possible relation between the fine structure of the WLC and a dynamic prominence seen above the NE solar limb. Finally, a brief comparison of the WL and EUV coronas is given.

Pluto Occultation on 2015 June 29 UTC With Central Flash and Atmospheric Spikes Just Before the New Horizons Flyby

Pasachoff, Jay M., Bryce A. Babcock, Rebecca F. Durst, Christina H. Seeger, Stephen E. Levine, Amanda S. Bosh, Michael J. Person, Amanda A. Sickafoose, Carlos A. Zuluaga, Molly R. Kosiarek, Fumio Abe, Masayuki Nagakane, Daisuke Suzuki, Paul J. Tristram

Icarus, in press, 2016

We observed the occultation by Pluto of a 12th magnitude star, one of the two brightest occultation stars ever in our dozen years of continual monitoring of Pluto's atmosphere through such studies, on 2015 June 29 UTC. At the Univ. of Canterbury Mt. John Observatory (New Zealand), in clear sky throughout, we used a POETS frame-transfer CCD at 10 Hz with GPS timing on the 1-m McLellan telescope as well as an infrared camera on an 0.6-m telescope and three-color photometry at a slower cadence on a second 0.6-m telescope. At the Auckland Observatory, we used a POETS and a PICO on 0.5-m and 0.4-m telescopes, with 0.4 s and 2 s cadences, respectively, obtaining ingress observations before clouds moved in. The Mt. John light curves show a central flash, indicating that we were close to the center of the occultation path. Analysis of our light curves show that Pluto's atmosphere remains robust. The presence of spikes at both sites in the egress and ingress show atmospheric layering. We coordinated our observations with aircraft observations (Bosh, Person, Zuluaga et al., 2016) with the Stratospheric Observatory for Infrared Astronomy (SOFIA). Our chords helped constrain the path across Pluto that SOFIA saw. Our ground-based and airborne stellar-occultation effort came only just over two weeks of Earth days and two Pluto days before the flyby of NASA's New Horizons spacecraft.

Terrestrial atmospheric responses on Svalbard to the 20 March 2015 Arctic total solar eclipse under extreme conditions

Pasachoff, Jay M., Marcos A. Peñaloza-Murillo, Allison L. Carter, and Michael T. Roman

Phil. Trans. Roy. Soc. A 374: 20160188

This article reports on the near-surface atmospheric response at the High Arctic site of Svalbard, latitude 78◦ N, as a result of abrupt changes in solar insolation during the 20 March 2015 equinox total solar eclipse and notifies the atmospheric science community of the availability of a rare dataset. Svalbard was central in the path of totality, and had completely clear skies. Measurements of shaded air temperature and atmospheric pressure show only weak, if any, responses to the reduced insolation. A minimum in the air temperature at 1.5 m above the ground occurred starting 2 min following the end of totality, though this drop was only slightly beyond the observed variability for the midday period. Eclipse- produced variations in surface pressure, if present, were less than 0.3 hPa.

This article is part of the themed issue ‘Atmospheric effects of solar eclipses stimulated by the 2015 UK eclipse’

Analysis of Co-Spatial UV/Optical HST STIS Spectra of Planetary Nebula NGC 3242

T.R. Miller, R.B.C. Henry, B. Balick, K.B. Kwitter, R.J. Dufour, R.A. Shaw, R.A., & R.L.M.Corradi

The Astrophysical Journal, 830, 9, 2016

This project sought to consider two important aspects of the planetary nebula NGC 3242 using new long-slit HST/STIS spectra. First, we investigated whether this object is chemically homogeneous by spatially dividing the slit into different regions and calculating the abundances of each region. The major result is that the elements of He, C, O, and Ne are chemically homogeneous within uncertainties across the regions probed, implying that the stellar outflow was well-mixed. Second, we constrained the stellar properties using photoionization models computed by CLOUDY and tested the effects of three different density profiles on these parameters. The three profiles tested were a constant density profile, a Gaussian density profile, and a Gaussian with a power-law density profile. The temperature and luminosity were not affected significantly by the choice of density structure. The values for the stellar temperature and luminosity from our best-fit model are89.7(+7.3/-4.7)kK and log(L/L(SUN)=3.36(+0.28/-0.22), respectively. Comparing to evolutionary models on an HR diagram, this corresponds to an initial and final mass of 0.95 (+0.35/-0.09) SOLAR MASSES and 0.56 (+0.01/-0.01) SOLAR MASSES respectively.

Biology

Attack and Parry: Genetic Dissection of Interbacterial and Host-Microbe Dueling by the Type VI Secretion System (T6SS) of *Agrobacterium tumefaciens*

Lois Banta, Aubrey Kenefick, Breanna Nguyen, Jacob Kim, Ruby Froom, Adam Resnick, and Janis Bravo. .

37th Annual Crown Gall Conference, Bloomington, IN (Nov. 2016)-Oral presentation

The type VI secretion system (T6SS) is a widespread molecular weapon deployed by many Proteobacteria to target effectors/toxins into both eukaryotic and prokaryotic cells. We report that *Agrobacterium tumefaciens*, a soil bacterium that triggers tumorigenesis in plants, produces a family of type VI DNase effectors (Tde) that are distinct from previously known polymorphic toxins and nucleases. Tde exhibits an antibacterial DNase activity that relies on a conserved HxxD motif and can be counteracted by a cognate immunity protein, Tdi. In vitro, A. tumefaciens T6SS could kill Escherichia coli but triggered a lethal counterattack by *Pseudomonas aeruginosa* upon injection of the Tde toxins. However, in an in planta coinfection assay, A. tumefaciens used Tde effectors to attack both siblings cells and P. aeruginosa to ultimately gain a competitive advantage. Such acquired T6SS-dependent fitness in vivo and conservation of Tde-Tdi couples in bacteria highlights a widespread antibacterial weapon beneficial for niche colonization.

Modulation of host defenses by the Type VI Secretion System (T6SS) of *Agrobacterium tumefaciens*

Lois Banta, Aubrey Kenefick, Breanna Nguyen, Jacob Kim, Adam Resnick, and Janis Bravo

International Molecular Plant-Microbe Interactions Congress, Portland, OR (July, 2016)-Invited Talk

Bacteria frequently cause disease in plants or animals by using secretion systems to deliver protein or DNA factors that manipulate normal host cell functions and/or subvert host defenses. The soil bacterium Agrobacterium tumefaciens transports both protein and DNA into a variety of plants, resulting in tumors or “plant cancer” on infected plants. The investigators recently discovered that Agrobacteria lacking one such secretion system, the Type VI Secretion System (T6SS), are compromised in their ability to cause tumors compared to normal bacteria. The goal of this project is to determine how the factors delivered through the Agrobacterium T6SS alter or dampen the host plants? defenses. The investigators will measure the amount of specific defense compounds produced by the plant, and will monitor the extent to which the plants turn on defense-related genes in response to the normal or the T6SS-deficient bacteria. The results will reveal new information about how plants protect themselves from diseases such as plant cancer. Because similar T6SS have recently been found in a wide variety of other bacteria, including several that cause serious diseases in humans, the findings may well have relevance to these other infectious agents as well. In addition to its role in causing plant disease, Agrobacterium is widely used to introduce new genes into plants, but its utility is limited by the fact that some plants, including many economically important grain crops, are poor hosts. This project will yield new insights into the factors that make some plant species better able to resist Agrobacteria. The project fully integrates research and education, in that the experiments will be performed primarily by undergraduate students, thereby providing them with the opportunity to take a leadership role in cutting-edge research.

Fly Stampede 2.0: A next generation optomotor assay for walking behavior in *Drosophila melanogaster*

Kim S., Tellez K., Buchan G., Lebestky T.

Mol. Neurosci., 27 December 2016 | https://doi.org/10.3389/fnmol.2016.00148

Optomotor behavior represents a stereotyped locomotor response to visual motion that is found in both vertebrate and invertebrate models. The Fly Stampede assay was developed to study an optomotor response in freely walking populations of *Drosophila*. Here we share optimized assay designs and software for production of a modified stampede assay that can be used for genetic screens, and improved tracking outputs for understanding behavioral parameters of visual-motion responses and arousal state of individual animals. Arousal state influences behavioral performance in the stampede assay. As proof of principle experiments we show parametric modulation of visual stimuli and startle stimuli in both wildtype and mutant flies for the type I family dopamine receptor Dop1R1 (DopR). DopR mutants are hyperactive and perform poorly in the stampede assay, suggesting a potential role in visual perception and/or arousal. The stampede assay creates an efficient platform for rapid screening of mutant animals or circuit manipulations for investigating attentional processes in *Drosophila*.

***Drosophila* grooming behavior. Journal of Visualized Experiments**

Barradale F.*, Sinha K.*, and Lebestky T.

Manuscript accepted August 14, 2016.

Drosophila grooming behavior is a complex multi-step locomotor program that requires coordinated movement of both forelegs and hindlegs. Here we present a grooming assay protocol and novel chamber design that is cost-efficient and scalable for either small or large-scale studies of *Drosophila* grooming. Flies are dusted all over their body with Brilliant Yellow dye and given time to remove the dye from their bodies within the chamber. Flies are then deposited in a set volume of ethanol to solubilize the dye. The relative spectral absorbance of dye-ethanol samples for groomed versus ungroomed animals are measured and recorded. The protocol yields quantitative data of dye accumulation for individual flies, which can be easily averaged and compared across samples. This allows experimental designs to easily evaluate grooming ability for mutant animal studies or circuit manipulations. This efficient procedure is both versatile and scalable. We show work-flow of the protocol and comparative data between WT animals and mutant animals for the *Drosophila* type I Dopamine Receptor (DopR).

Direct functional interaction of the kinesin-13 family member kinesin-like protein 2A (Kif2A) and Arf GAP with GTP-binding protein-like, ankyrin repeats and PH domains 1 (AGAP1)

Luo R, Chen P.W., Wagenbach M, Jian X, Jenkins L, Wordeman L, Randazzo P.A.

J Biol Chem (2016). . doi:10.1074/jbc.A116.732479

The molecular basis for control of the cytoskeleton by the Arf GTPase-activating protein AGAP1 has not been characterized. AGAP1 is composed of G-protein-like (GLD), pleckstrin homology (PH), Arf GAP and Ankyrin repeat domains. Kif2A was identified in screens for proteins that bind to AGAP1. The GLD and PH domains of AGAP1 bound the motor domain of Kif2A. Kif2A increased GAP activity of AGAP1 and a protein composed of the GLD and PH domains of AGAP1 increased ATPase activity of Kif2A. Knockdown (KD) of Kif2A or AGAP1 slowed cell migration and accelerated cell spreading. The effect of Kif2A KD on spreading could be rescued by expression of Kif2A-GFP or Flag-AGAP1, but not by Kif2C-GFP. The effect of AGAP1 KD could be rescued by Flag-AGAP1, but not by an AGAP1 mutant that did not bind Kif2A efficiently, ArfGAP1-HA or Kif2A-GFP. Taken together, the results support the hypothesis that the Kif2A·AGAP1 complex contributes to control of cytoskeleton remodeling involved in cell movement.

Small GTPases (2017) Arf GAPs: A family of proteins with disparate functions that converge on a common structure, the integrin adhesion complex

Vitali T, Girald-Berlingeri S, Randazzo PA, Chen PW

doi: 10.1080/21541248.2017.1299271

ADP-ribosylation factors (Arfs) are members of the Ras GTPase superfamily. The function of Arfs is dependent on GTPase-activating proteins (GAPs) and guanine nucleotide exchange factors (GEFs), which allow Arfs to cycle between the GDP-bound and GTP-bound forms. Arf GAPs have been shown to be present in integrin adhesion complexes, which include focal adhesions. Integrin adhesion complexes are composed of integrins, scaffolding proteins

and signaling proteins and regulate cell proliferation, survival, differentiation and migration. Understanding the role of Arf GAPs in the regulation of integrin adhesion complexes is relevant to understanding normal physiology and cancer. In this review, we will discuss the contribution of the Arf GAP family members to the regulation of integrin adhesion complexes, examining the diverse mechanisms by which they control integrin adhesion complex formation, maturation and dissolution. GIT1 and ARAP2 serve as GAPs for Arf6, regulating Rac1 and other effectors by mechanisms still being defined. In contrast, GIT2 regulates Rac1 independent of Arf6. AGAP2 binds to and regulates focal adhesion kinase (FAK). ARAP2 and ACAP1, both Arf6 GAPs, regulate membrane trafficking of integrins through different endocytic pathways, exerting opposite effects on focal adhesions. ASAP1 not only regulates actin cytoskeleton remodeling through its interaction with nonmuscle myosin 2A, but is also important in integrin recycling. These examples illustrate the diversity and versatility of Arf GAPs as regulators of integrin adhesion complex structure and function.

Arf GAPs and molecular motors

Luo R., Reed C.E., Sload J.A., Wordeman L, Randazzo P.A., Chen P.W.

Small GTPases doi: 10.1080/21541248.2017.1308850, 2017

Arf GTPase-activating proteins (Arf GAPs) were first identified as regulators of the small GTP-binding proteins ADP-ribosylation factors (Arfs). The Arf GAPs are a large family of proteins in metazoans, outnumbering the Arfs that they regulate. The members of the Arf GAP family have complex domain structures and some have been implicated in particular cellular functions, such as cell migration, or with particular pathologies, such as tumor invasion and metastasis. The specific effects of Arfs sometimes depend on the Arf GAP involved in their regulation. These observations have led to speculation that the Arf GAPs themselves may affect cellular activities in capacities beyond the regulation of Arfs. Recently, 2 Arf GAPs, ASAP1 and AGAP1, have been found to bind directly to and influence the activity of myosins and kinesins, motor proteins associated with filamentous actin and microtubules, respectively. The Arf GAP-motor protein interaction is critical for cellular behaviors involving the actin cytoskeleton and microtubules, such as cell migration and other cell movements. Arfs, then, may function with molecular motors through Arf GAPs to regulate microtubule and actin remodeling.

Central activation of the A1 adenosine receptor in fed mice recapitulates only some of the attributes of daily torpor

Vicent, M.A., Borre, E.D. & Swoap, S.J.

J Comp Physiol B. doi:10.1007/s00360-017-1084-7, 2017

Mice enter bouts of daily torpor, drastically reducing metabolic rate, core body temperature (Tb), and heart rate (HR), in response to reduced caloric intake. Because central adenosine activation has been shown to induce a torpor-like state in the arctic ground squirrel, and blocking the adenosine-1 (A1) receptor prevents daily torpor, we hypothesized that central activation of the A1 adenosine receptors would induce a bout of natural torpor in mice. To test the hypothesis, mice were subjected to four different hypothermia bouts: natural torpor, forced hypothermia (FH), isoflurane-anesthesia, and an intracerebroventricular injection of the selective A1 receptor agonist N6-cyclohexyladenosine (CHA). All conditions induced profound hypothermia. Tb fell more rapidly in the FH, isoflurane-anesthesia, and CHA conditions compared to torpor, while mice treated with CHA recovered at half the rate of torpid mice. FH, isoflurane-anesthesia, and CHA-treated mice exhibited a diminished drop in HR during entry into hypothermia as compared to torpor. Mice in all conditions except CHA shivered while recovering from hypothermia, and only FH mice shivered substantially while entering hypothermia. Circulating lactate during the hypothermic bouts was not significantly different between the CHA and torpor conditions, both of which had lower than baseline lactate levels. Arrhythmias were largely absent in the FH and isoflurane-anesthesia conditions, while skipped beats were observed in natural torpor and periodic extended (>1 s) HR pauses in the CHA condition. Lastly, the hypothermic bouts showed distinct patterns of gene expression, with torpor characterized by elevated hepatic and cardiac Txnip expression and all other hypothermic states characterized by elevated c-Fos and Egr-1 expression. We conclude that CHA-induced hypothermia and natural torpor are largely different physiological states.

Chemistry

Process for Electrospinning Chitin Fibers from Chitinous Biomass Solution

Richard P. Swatloski, Patrick S. Barber, Terrance Opichka, Jonathan R. Bonner, Gabriela Gurau, Christopher S. Griggs, Robin D. Rogers

US 9683309 B2, June 20, 2017.

Disclosed are methods for electrospinning chitinous biomass solution to form chitin fibers, using ionic liquids or other ion-containing liquids as solvent. Chitin fibers produced thereby and articles containing such chitin fibers are also disclosed. The chitin fiber thus obtained has very high surface area and improved strength over currently commercially available chitin materials.

Coagulation of Biopolymers from Ionic Liquid Solutions Using CO2

Robin D. Rogers, Patrick S. Barber, Chris S. Griggs, Gabriela Gurau, Xingmei Lu, and Suojiang Zhang

US 9663589 B2, May 30, 2017.

Disclosed herein are processes for providing a biopolymer from a biomass or source of chitin using ionic liquids. The processes involve contacting a biomass or source of chitin with an ionic liquid to produce a biopolymer comprising solution and precipitating the biopolymer from the solution with supercritical CO2, gaseous CO2, or combinations thereof.

Pulping of Crustacean Waste Using Ionic Liquids: To Extract or Not To Extract

J. L. Shamshina, Patrick S. Barber, G. Gurau, C. S. Griggs, and R. D. Rogers

ACS Sustainable Chemistry & Engineering, 4(11), 6072-6081, 2016.

Ionic liquids (ILs), such as hydroxylammonium acetate ([NH3OH][OAc]), can reactively demineralize and remove proteins from shrimp shells in an efficient one-pot pulping process, thus allowing the isolation of native chitin with >80% purity and a high degree of acetylation and crystallinity. Compared to a previously reported IL extraction using 1-ethyl-3-methylimidazolium acetate, [C2mim][OAc], these less expensive ILs can achieve comparable chitin yields and purity, at up to ten times the biomass loading, although potentially result in lower molecular weight (MW) chitin. Because the IL is not recovered or recycled, the cost can additionally be further reduced by the sequential addition of hydroxylamine and acetic acid (or vice versa) to conduct the pulping process in situ. Though each methodology results in a comparable yields and purity of chitin material, the varying production costs and process safety issues are still unknown. This work presents a step toward narrowing the choices for chitin isolation technologies that can lead to an economically and environmentally sustainable process replacing the current hazardous, energy consuming, and environmentally unsafe process.

A Cell Cycle Kinase with Tandem Sensory PAS Domains Integrates Cell Fate Cues

Thomas H. Mann, W. Seth Childers, Jimmy A. Blair, Michael R. Eckart, and Lucy Shapiro

Nature Communications, 7, 11454, 2016.

All cells must integrate sensory information to coordinate developmental events in space and time. The bacterium Caulobacter crescentus uses two-component phospho-signalling to regulate spatially distinct cell cycle events through the master regulator CtrA. Here, we report that CckA, the histidine kinase upstream of CtrA, employs a tandem-PAS domain sensor to integrate two distinct spatiotemporal signals. Using CckA reconstituted on liposomes, we show that one PAS domain modulates kinase activity in a CckA density-dependent manner, mimicking the stimulation of CckA kinase activity that occurs on its transition from diffuse to densely packed at the cell poles. The second PAS domain interacts with the asymmetrically partitioned second messenger cyclic-di-GMP, inhibiting kinase activity while stimulating phosphatase activity, consistent with the selective inactivation of CtrA in the incipient stalked cell compartment. The integration of these spatially and temporally regulated signalling events within a single signalling receptor enables robust orchestration of cell-type-specific gene regulation.

The Quest for Confirmatory Data in Crime Scene Investigations

A Bakarr Kanu and Lawrence J. Kaplan

Chemical Educator, 21, 231-239, 2016.

In today's complex world a forensic chemist may prefer any physical evidence linking or exonerating a suspect from a crime scene to a false confession. This article utilizes forensic chemistry experimental approaches designed and implemented in an instructional workshop setting to present a unique perspective of certain facets of a crime scene investigation. An incident from a staged crime scene was investigated and physical evidence were collected, processed, and analyzed. The authors used modern techniques available in the field to analyze evidence recovered from the crime scene and the results were used to establish a link to one of three suspects. In our previous article, physical evidence collection, handling, analysis and evaluation were reviewed, as were challenges associated with carrying out these tasks. The information was presented 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. This article presents the experimental data generated from the analysis of physical evidence collected at the crime scene. The results can be classified as either presumptive or confirmatory. Some of the evidence recovered and analyzed such as fingerprints, bullets and casings, drugs, and DNA were shown to possess individual characteristics and when properly processed and analyzed can be used to exonerate or convict a suspect. Analysis of physical evidence with two methods Fourier transform infrared spectroscopy (FTIR) and gas chromatography-mass spectrometry (GC-MS) classified as confirmatory test instruments in forensic analysis is also presented. The GC-MS data presented, illustrates cocaine separations and identification in one analysis, and FTIR data illustrates identification of functional groups in fabric and cocaine. This information can be used by instructors to fully explain to students the science behind the techniques of GC-MS and FTIR as they relate to confirmatory identification. We have presented the information in a way that may help students identify the differences between presumptive and confirmatory tests as well as individual and class characteristics.

Bistability and Bifurcation in Minimal Self-replication and Nonenzymatic Catalytic Networks

A N. Wagner, R. Mukherjee, I. Maity, E. Peacock-Lopez, G. Ashkenazy

Physical Chemistry Chemical Physics, 18, 1-10, 2017.

Bistability and bifurcation, found in a wide range of biochemical networks, are perceived to be central to the function of living systems. We investigate here systems of minimal self-replication and non-enzymatic autocatalytic networks, new models derived from related systems that have been used previously for investigating catalytic growth, chemical logic operations, and processes of self-organization and complexification. By solving for their steady-state solutions using various analytical and numerical methods, we show, for the first time, how these systems yield bistability and bifurcation, and we further discover the specific cases and conditions which produce bistability. Our analysis shows that the onset of bistability requires at least second order catalysis, and is strengthened by certain parameters and rate constants and weakened by several others. Furthermore, our findings appear to confirm the intuitive explanation that bistability is due to a mismatch between the various forward and reverse processes, and requires the forward processes to be dominated by higher order catalysis.

Seasonality and the Logistic Map

Emily Silva '17 and Enrique Peacock-López

Chaos, Fractals, and Solitons, 95, 152-156, 2017.

Nonlinear difference equations, such as the logistic map, have been used to study chaos and also to model population dynamics. Here we propose a model that extends the ``lose + lose = win" behavior found in Parrondo's Paradox, where switching between chaotic parameters in the logistic map yields periodic behavior (``chaos + chaos = order"). The model uses twelve parameters each reflecting the conditions of one of the twelve months. In this paper we study the effects of smooth-transitioning parameters and the robust system that emerges.

Did Middle Stone Age Khargan Peoples Leave Structural Features? 'Site J', The Forgotten Settlement of the 'Empty Desert', Kharga Oasis, Egypt: 1933 and 2011

Mary M.A. McDonald, Marcia F. Wiseman, Maxine R. Kleindienst, Jennifer R. Smith, Nicholas Taylor, Andrew J. Wreschnig, Anne R. Skinner, and Bonnie A.B. Blackwell

Journal of African Archaeology, 14(2), 155-179, 2016.

G. Caton-Thompson and E.W. Gardner designated new Pleistocene cultural units at Kharga Oasis in the 1930's: both were originally termed 'pre-Sebilian', but were later locally named the 'Levalloiso-Khargan' and 'Khargan' industries. High on the Bulaq scarp race, a puzzling cluster of stone 'alignments' was discovered in 1931-2, with a reported, but discounted, association with 'Levalloiso-Khargan' artefacts. Gardner excavated some features in 1933. Members of the Kharga Oasis Prehistory Project relocated 'Site J' in 2011, and verified the reported Khargan associations with the features. In 2008, the project found structural features associated with Khargan artefacts in the northern Gebel Yebsa survey area, confirming earlier finds in the southern oases of Kurkur and Dunguyl. Evidence there, and then found in Kharga and Dakhleh oasis, is now designated as the Khargan Complex. The associated built stone features of the included cultural units appear to be unique in Late Pleistocene Africa, especially at Bulaq.

ESR in the 21st Century: From Buried Valleys and Deserts to the Deep Ocean and Tectonic Uplift

Bonnie A.B. Blackwell, Anne R. Skinner, Joel I.B. Blickstein, Andres C. Montoya, Jonathan S. Florentin, Shaunte M. Baboumian, Isray J. Ahmed, Aislein E. Deely

Earth Science Reviews, 158, 125-159, 2016.

Electron spin resonance (ESR) dating can date many materials, including hydroxyapatite in enamel and some fish scales, aragonite and calcite in corals, molluscs, some travertine and calcrete, and quartz from ash, fluvial deposits, and some flint. Dating studies using these materials have numerous potential applications in many varied Quaternary settings. ESR dating uses signals resulting from trapped charges created by radiation in crystalline solids. Ages are calculated by comparing the accumulated radiation dose in the dating sample with the internal and external radiation dose rates produced by natural radiation in and around the sample and produced by cosmic radiation. When compared to other dating techniques, age agreement has been excellent for teeth, corals, molluscs, and quartz. Recent improvements have included using a more complex modelling technique to calculate the cosmic dose rates and more detailed modelling techniques for dealing with variable external dose rates. Methods in development include using quartz from buried fluvial valleys to date geomorphic surfaces and using the signals in barnacles and benthic foraminifera for dating fossils or their associated sediment. New chronometer applications recently developed include using coral and mollusc dates to build sealevel curves and to monitor volcanic activity and tectonic uplift, using tooth and mollusc dates to assess water availability in deserts, and using isochron data to assess U uptake processes into teeth. When coupled with other geochemical and geomorphological techniques, ESR can provide the chronometric control to build paleoclimatic and other paleoenvironmental records. Many other applications are possible, from heating studies for artefacts to dating sulphates and other minerals on distant planets.

Shell We Date: ESR Dating Sangamon Interglacial Episode Deposits at Hopwood Farm, IL

Bonnie A. B. Blackwell, Danny M. K. Kim, B. Brandon Curry, David A. Grimley, Joel I. B. Blickstein, and Anne R. Skinner

Radiation Protection Dosimetry, 172(1-3), 383-295, 2016.

During the Sangamon Interglacial Episode, North America occasionally experienced warm climates. At Hopwood Farm, IL, a small kettle lake filled with sediment after the Illinois Episode glaciers retreated from southern Illinois. To date those deposits, 14 mollusc samples newly collected with associated sediment from three depths at Hopwood Farm were dated by standard ESR (electron spin resonance) dating. ESR can date molluscs from ~ 0.5 ka to > 2 Ma in age with 5-10% precision, by comparing the accumulated radiation dose with the total radiation dose rate from the mollusc and its environment. Because all molluscs contained ≤ 0.6 ppm U, their ages do not depend on the assumed U uptake model. Using five different species, ESR analyses for 14 mollusc subsamples from Hopwood Farm showed that Unit 3, a layer rich in lacustrine molluscs, dates at 102 ± 7 ka to 90 ± 6 ka, which correlates with Marine (Oxygen) Isotope Stage (MIS) 5c-b. Thus, the period with the highest non- arboreal pollen at Hopwood also correlates with the European Brørup, Dansgaard-Oeschger Event DO 23, a period when climates were cooling and drying somewhat over the same period.

Computer Science

Argument Mining with Structured SVMs and RNNs

Vlad Niculae, Joonsuk Park and Claire Cardie

In Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics 2017

We propose a novel factor graph model for argument mining, designed for settings in which the argumentative relations in a document do not necessarily form a tree structure. (This is the case in over 20% of the web comments dataset we release.) Our model jointly learns elementary unit type classification and argumentative relation prediction. Moreover, our model supports SVM and RNN parametrizations, can enforce structure constraints (e.g., transitivity), and can express dependencies between adjacent relations and propositions. Our approaches outperform unstructured baselines in both web comments an argumentative essay datasets.

Lazy Analytics: Let Other Queries Do the Work For You

William Jannen, Michael A. Bender, Martin Farach-Colton, Rob Johnson, Bradley C. Kuszmaul, Donald E. Porter

Proceedings of the 8th USENIX Workshop on Hot Topics in Storage and File Systems

We propose a class of query, called a derange query, that maps a function over a set of records and lazily aggregates the results. Derange queries defer work until it is either convenient or necessary, and, as a result, can reduce total I/O costs of the system.

Derange queries operate on a view of the data that is consistent with the point in time that they are issued, regardless of when the computation completes. They are most useful for performing calculations where the results are not needed until some future deadline. When necessary, derange queries can also execute immediately. Users can view partial results of in-progress queries at low cost.

File Systems Fated for Senescence? Nonsense, Says Science!

Alexander Conway, Ainesh Bakshi, Yizheng Jiao, William Jannen, Yang Zhan, Jun Yuan, Michael A. Bender, Rob Johnson, Bradley C. Kuszmaul, Donald E. Porter, and Martin Farach-Colton.

Proceedings of the 15th USENIX Conference on File and Storage Technologies, 45-58, February 2017.

File systems must allocate space for files without knowing what will be added or removed in the future. Over the life of a file system, this may cause suboptimal file placement decisions which eventually lead to slower performance, or aging. Traditional file systems employ heuristics, such as collocating related files and data blocks, to avoid aging, and many file system implementors treat aging as a solved problem.

However, this paper describes realistic as well as synthetic workloads that can cause these heuristics to fail, inducing large performance declines due to aging. For example, on ext4 and ZFS, a few hundred git pull operations can reduce read performance by a factor of 2; performing a thousand pulls can reduce performance by up to a factor of 30. We further present microbenchmarks demonstrating that common placement strategies are extremely sensitive to file-creation order; varying the creation order of a few thousand small files in a real-world directory structure can slow down reads by 15–175x, depending on the file system.

We argue that these slowdowns are caused by poor layout. We demonstrate a correlation between read performance of a directory scan and the locality within a file system's access patterns, using a dynamic layout score.

In short, many file systems are exquisitely prone to read aging for a variety of write workloads. We show, however, that aging is not inevitable. BetrFS, a file system based on write-optimized dictionaries, exhibits almost no aging in our experiments. BetrFS typically outperforms the other file systems in our benchmarks; aged BetrFS even outperforms the unaged versions of these file systems, excepting Btrfs. We present a framework for understanding and predicting aging, and identify the key features of BetrFS that avoid aging.

Writes Wrought Right, and Other Adventures in File System Optimization

Juan Yuan, Yang Zhan, William Jannen, Prashant Pandey, Amogh Akshintala, Kanchan Chandnani, Pooja Deo, Zardosht Kasheff, Leif Walsh, Michael A. Bender, Martin Farach-Colton, Rob Johnson, Bradley Kuszmaul, Donald E. Porter

ACM Transactions On Storage 13 (1), 3:1-3:26, 2017.

File systems that employ write-optimized dictionaries (WODs) can perform random-writes, metadata updates, and recursive directory traversals orders of magnitude faster than conventional file systems. However, previous WOD-based file systems have not obtained all of these performance gains without sacrificing performance on other operations, such as file deletion, file or directory renaming, or sequential writes.

Using three techniques, late-binding journaling, zoning, and range deletion, we show that there is no fundamental trade-off in write-optimization. These dramatic improvements can be retained while matching conventional file systems on all other operations.

BetrFS 0.2 delivers order-of-magnitude better performance than conventional file systems on directory scans and small random writes and matches the performance of conventional file systems on rename, delete, and sequential I/O. For example, BetrFS 0.2 performs directory scans 2.2x faster, and small random writes over two orders of magnitude faster, than the fastest conventional file system. But unlike BetrFS 0.1, it renames and deletes files commensurate with conventional file systems and performs large sequential I/O at nearly disk bandwidth. The performance benefits of these techniques extend to applications as well. BetrFS 0.2 continues to outperform conventional file systems on many applications, such as as rsync, git-diff, and tar, but improves git-clone performance by 35% over BetrFS 0.1, yielding performance comparable to other file systems.

Real-Time Global Illumination using Precomputed Light Field Probes

Morgan McGuire, *Michael Mara '12*, Derek Nowrouzezahrai, and David Luebke

ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games, Feb 2017, 11 pages

We introduce a new data structure and algorithms that employ it to compute real-time global illumination from static environments. Light field probes encode a scene's full light field and internal visibility. They extend current radiance and irradiance probe structures with per-texel visibility information similar to a G-buffer and variance shadow map. We apply ideas from screen-space and voxel cone tracing techniques to this data structure to efficiently sample radiance on world space rays, with correct visibility information, directly within pixel and compute shaders. From these primitives, we then design two GPU algorithms to efficiently gather real-time, viewer-dependent global illumination onto both static and dynamic objects. These algorithms make different tradeoffs between performance and accuracy. Supplemental GLSL source code is included.

Hashed Alpha Testing

Chris Wyman and Morgan McGuire

ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games, Feb 2017, 11 pages

Renderers apply alpha testing to mask out complex silhouettes using alpha textures on simple proxy geometry. While widely used, alpha testing has a long-standing problem that is underreported in the literature, but observable in commercial games: geometry can entirely disappear as alpha mapped polygons recede with distance. As foveated rendering for virtual reality spreads this problem worsens, as peripheral minification and prefiltering also cause this problem for nearby objects.

We introduce two algorithms, stochastic alpha testing and hashed alpha testing, that avoid this issue but add some noise. Instead of using a fixed alpha threshold, $\alpha\tau$, stochastic alpha testing discards fragments with alpha below randomly chosen $\alpha_\tau \in (0..1]$. Hashed alpha testing uses a hash function to choose $\alpha\tau$ procedurally, producing stable noise that reduces temporal flicker.

With a good hash function and inputs, hashed alpha testing maintains distant geometry without introducing more temporal flicker than traditional alpha testing. We describe how hashed and stochastic alpha testing apply to alpha-to-coverage and screen-door transparency, and how they simplify stochastic transparency.

Phenomenological Transparency

Morgan McGuire and *Michael Mara '12*

IEEE Transactions on Visualization and Computer Graphics, 2017

Translucent objects such as fog, clouds, 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 render in real-time and have thus previously been rendered poorly compared to opaque surfaces.

This paper describes a model for a real-time rasterization algorithm that can simultaneously approximate the following transparency phenomena: wavelength-varying ("colored") transmission, translucent colored shadows, caustics, volumetric light and shadowing, partial coverage, diffusion, and refraction. All render efficiently with order-independent draw calls and low bandwidth. We include source code.

Aggregate G-Buffer Anti-Aliasing

Cyril Crassin, Morgan McGuire, Kayvon Fatahalian, and Aaron Lefohn

IEEE Transactions on Visualization and Computer Graphics, 2016

We present Aggregate G-Buffer Anti-Aliasing (AGAA), a new technique for efficient anti-aliased deferred rendering of complex geometry using modern graphics hardware. In geometrically complex situations where many surfaces intersect a pixel, current rendering systems shade each contributing surface at least once per pixel. As the sample density and geometric complexity increase, the shading cost becomes prohibitive for real-time rendering. Under deferred shading, so does the required framebuffer memory. Our goal is to make high per-pixel sampling rates practical for real-time applications by substantially reducing shading costs and per-pixel storage compared to traditional deferred shading. AGAA uses the rasterization pipeline to generate a compact, pre-filtered geometric representation inside each pixel. We shade this representation at a fixed rate, independent of geometric complexity. By decoupling shading rate from geometric sampling rate, the algorithm reduces the storage and bandwidth costs of a geometry buffer, and allows scaling to high visibility sampling rates for anti-aliasing. AGAA with 2 aggregates per-pixel generates results comparable to 32x MSAA, but requires 54% less memory and is up to 2.6x faster (-30% memory and 1.7x faster for 8x MSAA).

Deep G-Buffers for Stable Global Illumination Approximation

Michael Mara '12, Morgan McGuire, Derek Nowrouzezahrai, and David Luebke

ACM SIGGRAPH/EuroGraphics High Performance Graphics, June 2016, 11 pages

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.

Predicting Expressive Bow Controls for Violin and Viola

Lauren Jane Yu '16 and Andrea Danyluk

Computational Intelligence in Music, Sound, Art, and Design (EvoMUSART 2017).

Though computational systems can simulate notes on a staff of sheet music, capturing the artistic liberties professional musicians take to communicate their interpretation of those notes is a much more difficult task. In this paper, we demonstrate that machine learning methods can be used to learn models of expressivity, focusing on bow articulation for violin and viola. First we describe a new data set of annotated sheet music with information about specific aspects of bow control. We 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.

On Partitioning the Edges of 1-Plane Graphs

W. Lenhart, G. Liotta, and F Montecchiani

Theoretical Computer Science, Vol. 662, February 2017.

A 1-plane graph is a graph embedded in the plane such that each edge is crossed at most once. A 1-plane graph is optimal if it has maximum edge density. A red–blue edge coloring of an optimal 1-plane graph G partitions the edge set of G into blue edges and red edges such that no two blue edges cross each other and no two red edges cross each other. We prove the following: (i) Every optimal 1-plane graph has a red–blue edge coloring such that the blue subgraph is maximal planar while the red subgraph has vertex degree at most four; this bound on the vertex degree is worst-case optimal. (ii) A red–blue edge coloring may not always induce a red forest of bounded vertex degree. Applications of these results to graph augmentation and graph drawing are also discussed.

Geosciences

Vase-shaped Microfossils from the Tonain Callison Lake Formation of Yukon, Canada: Taxonomy, Taphonomy, and Stratigraphic Paleobiology

Phoebe A. Cohen, Spencer Irvine '16, and Justin V. Strauss

Palaeontology 39, 643-19, 2017

Vase-shaped microfossils (VSMs), interpreted as the remains of testate amoebae, are found in late Tonian sedimentary rocks around the world. Here we explore the taxonomy, taphonomy and stratigraphical occurrence of VSMs from the Callison Lake Formation of the Coal Creek inlier, Yukon, Canada. Found in silicified black shale horizons and stromatolitic dolostone, sedimentological data suggest these VSMs inhabited a series of marine embayments characterized by lagoonal and/or shelf interior depositional environments. The fossiliferous strata have recently been dated with Re–Os geochronology at c. 753–740 Ma, which indicates they are not only coeval with diverse VSM assemblages described in the Chuar Group of Grand Canyon, Arizona, but also provides supportive evidence for the early diversification of eukaryotic clades prior to the Sturtian age Snowball Earth event (c. 717– 660 Ma). Petrographic examination of well-preserved specimens reveal taxa comparable to those from the Chuar Group, as well as two previously undescribed species. Species overlapping with Chuar Group VSMs are Bonniea dacruchares, Bonniea pytinaia, Cycliocyrillium simplex, Cycliocyrillium torquata, Melanocyrillium hexodiadema and Palaeoarcella athanata. New taxa described here are Bonniea makrokurtos and Cycliocyrillium rootsi. Energy dispersive x-ray spectroscopic data reveal that the Callison Lake microfossils are preserved through a variety of taphonomic pathways, including silicification, infilling, authigenic mineralization and dolomitization. We explore the utility of M. hexodiadema as a latest Tonian biostratigraphical marker and examine the role of Callison Lake sequence stratigraphy as a control on the distribution and abundance of VSMs in the Coal Creek inlier and other global sedimentary successions.

Climate Dynamics of Snowball Earth and Cryogenian Geology–Geobiology

Paul F. Hoffman , Dorian S. Abbot, Yosef Ashkenazy, Douglas I. Ben, Phoebe A. Cohen, Grant M. Cox, Jessica R. Creveling, Yannick Donnadieu, Douglas H. Erwin, Ian J. Fairchild, David Ferreira, Jason C. Goodman, Galen P. Halverson, Malte F. Jansen, Guillaume Le Hir, Gordon D. Love, Francis A. Macdonald, Adam C. Maloof, Gilles Ramstein, Brian E. J. Rose, Catherine V. Rose, Eli Tziperman, Aiko Voigt, and Stephen G.Warren

Science Advances, in press, 2017

Geological evidence indicates that grounded ice sheets reached sea level at all latitudes during the long-lived Sturtian (717–659 Ma) and Marinoan (ca 645–635 Ma) glaciations. Combined U-Pb and Re-Os geochronology suggests that the Sturtian glacial onset and both terminations were globally synchronous. Geochemical data imply that atmospheric pCO2 was 102x modern at the Marinoan termination, consistent with Snowball Earth hysteresis. Sturtian glaciation followed the breakup of a tropical supercontinent, and its onset coincided with the equatorial emplacement of a large igneous province. Modeling shows that the small thermal inertia of a globally frozen surface reverses the annual-mean Hadley circulation, resulting in equatorial net sublimation and net deposition elsewhere. Oceanic ice thickens, forming a sea glacier that flows gravitationally toward the equator, sustained by the hydrologic cycle and by basal freeze-on and melting. Tropical ice sheets flow faster as CO2 rises, but lose mass and become sensitive to orbital forcing. Dust accumulation in the equatorial zone engenders supraglacial oligotrophic meltwater ecosystems, favorable for cyanobacteria and many eukaryotes. Meltwater flushing through moulins enables organic burial and submarine deposition of subaerially-erupted volcanic ash. The subglacial ocean is turbulent and well-mixed, in response to geothermal heating and conductive heat loss through the ice cover, increasing with latitude. Cap carbonates, unique to Snowball Earth terminations, are products of intense weathering and ocean stratification. Whole-ocean warming and ice-sheet forebulge collapse allow marine coastal inundations to progress long after ice-sheet disappearance. The evolutionary legacy of Snowball Earth is perceptible in fossils and living organisms.

Controlled Hydroxyapatite Biomineralization in an ~810 Million Year Old Unicellular Eukaryote

Phoebe Cohen, Nicholas Tosca, and Alan Rooney

Science Advances 3, e1700095

Biomineralization marks one of the most significant evolutionary milestones among the Eukarya, but its roots in the fossil record remain obscure. We report crystallographic and geochemical evidence for controlled eukaryotic biomineralization in Neoproterozoic scale microfossils from the Fifteenmile Group of Yukon, Canada. High-resolution transmission electron microscopy reveals that the microfossils are constructed of a hierarchically organized interwoven network of fibrous hydroxyapatite crystals each elongated along the [001] direction, indicating biological control over microstructural crystallization. New Re-Os geochronological data from organic-rich shale directly below the fossil-bearing limestone constrain their age to <810.7 ± 6.3 million years ago. Mineralogical and geochemical variations from these sedimentary rocks indicate that dynamic global marine redox conditions, enhanced by local restriction, may have led to an increase in dissolved phosphate in pore and bottom waters of the Fifteenmile basin and facilitated the necessary geochemical conditions for the advent of calcium phosphate biomineralization.

The First Appearance of Controlled Eukaryotic Biomineralization in the Neoproterozoic Fossil Record

Phoebe Cohen, Justin Strauss, Alan Rooney, Mukul Sharma, and Nichols Tosca

Geological Society of America Abstracts with Programs 48 (7), 2016

Biomineralization marks one of the most significant evolutionary milestones among the eukarya. Although metazoan mineralized skeletons are abundant in the post-Ediacaran fossil record, the advent of biologically-controlled mineralization, and the role of environment in prompting this innovation, are poorly understood. Here, we report crystallographic and geochemical evidence for controlled eukaryotic biomineralization in early Neoproterozoic (Tonian) apatitic scale microfossils (ASM) from the Fifteenmile Group of Yukon, Canada. High-resolution transmission electron microscopy reveals that the ASMs are constructed of a hierarchically-organized interwoven network of fibrous hydroxyapatite crystals each elongated along [001], indicating biological control over microstructural crystallization. New Re-Os geochronological analyses from organic-rich shale directly below the fossil-bearing limestone improve the age constraints on the fossiliferous unit by an order of magnitude. Mineralogical and geochemical data from these fine-grained strata indicate that locally dynamic redox conditions increased dissolved phosphate in pore and bottom waters, thus making hydroxyapatite biomineralization a permissible option for the ASM organism. This interplay between environment and evolution therefore may have opened an early window of opportunity for the first known biomineralizing eukaryotes.

Taxonomic Affinity of Late Devonian Organic-Walled Microfossils: Interpretations and Implications

Phoebe Cohen, *Abigail Kelly '16*, and Robin Kodner

Geological Society of America Abstracts with Programs 48 (2), doi: 10.1130/abs/2016NE-272430, 2016

Devonian strata host a diverse assemblage of organic-walled microfossils (OWM). Most of the microfossils found in Devonian shales are characterized as acritarchs: OWM of uncertain taxonomic affinity. Many smooth-walled OWM from the Paleozoic are inferred to be reproductive structures, called phycoma, made by a single genus within the green algal group Prasinophycea. The inferred green algal affinity of these OWM forms is often used as the basis for various proxies, including phytoplankton diversity and levels of primary production. However, these inferences are often made without a complete understanding of the factors that lead to the formation and preservation of resistant organic structures in the fossil record. Organisms may alter the production and/or morphology of recalcitrant structures in response to varying levels of oxygen, and oxygen levels in sediments also affect the likelihood of such structures being preserved. In addition, some acritarchs may not represent photosynthetic taxa, but instead may be the resting stages of metazoan eggs, which in the modern can form in response to deleterious environmental conditions including low oxygen. This induced resting stage phenomenon is especially interesting in light of evidence that acritarch diversity and abundance may correlate with stressful environmental events. For example, the acritarch resurgence documented at the Triassic-Jurassic extinction event is interpreted as a bloom of "disaster taxa". Thus, the patterns of diversity and abundance in OWM seen across the late Devonian may reflect a combination of a biological response to deleterious environmental conditions, the selective rise of "bloom" taxa, and a taphonomic signal of high preservation in low oxygen settings. Here, we will discuss the possible taxonomic affinities of Devonian OWM found in New York, detail potential controls on their diversity and abundance, and explore the implications of various affinities on reconstructions of late Devonian marine ecosystems.

Organic-Walled Microfossil Assemblage Variation Through the Late Devonian Kellwasser Events in New York State

Phoebe Cohen and *Abigail Kelly '16*

Geological Society of America Abstracts with Programs 48 (7), doi: 10.1130/abs/2016AM-281556, 2016

The Kellwasser Events are globally expressed as two black shale horizons associated with the Late Devonian Extinction and the Frasnian/Famennian transition and 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.

Here we assess microfossil morphology, diversity, and abundance through the Kellwasser Events at two main localities in New York State. In all localities, microfossil diversity is very low relative to surveys of Devonian palynoflora, a trend indicative of ecological stress. The Upper Kellwasser horizon assemblages included only simple smooth-walled 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 the 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, yet conflicting with the biological pattern in Europe. Additionally, the palynological record may show evidence of algal bloom events, and associated eutrophication, co-occurring at the sea level maximum and the peak in preserved organic carbon. These findings contribute to a better understanding of environmental conditions during their Kellwasser Events and their possible role in the Late Devonian Extinction.

Modification of River Meandering by Tropical Deforestation

A.J. Horton, J.A. Constantine, T.C. Hales, B. Goosens, M.W. Bruford, and E.D. Lazarus

Geology 45 (6), 511-514, 2017

Tropical forests are the only forest biome to have experienced increased rates of forest loss during the past decade because of global demands for food and biofuels. The implications of such extensive forest clearing on the dynamics of tropical river systems remain relatively unknown, despite significant progress in our understanding of the role of trees in riverbank stability. Here, we document rates of deforestation and corresponding average annual rates of riverbank erosion along the freely meandering Kinabatangan River in Sabah, Malaysia, from Landsat satellite imagery spanning A.D. 1989–2014. We estimate that deforestation removed over half of the river's floodplain forest and up to 30% of its riparian cover, which increased rates of riverbank erosion by >23% within our study reaches. Further, the correlation between the magnitude of planform curvature and rates of riverbank erosion only became strongly positive and significant following deforestation, suggesting an important role of forests in the evolution of meandering rivers, even when riverbank heights exceed the depth of root penetration.

The Role of Mass Wasting in the Progressive Development of Submarine Channels (Espírito Santo Basin, SE Brazil)

Y. Qin, T. Alves, J.A. Constantine, and D. Gamboa

Journal of Sedimentary Research 87, 500-516, 2017

A Pliocene–Quaternary submarine channel system, influenced by localized mass wasting, is investigated using high-resolution 3D seismic data from offshore Espírito Santo Basin, SE Brazil. Three abandoned channels, a channel belt, and a mass-transport deposit (MTD) are recognized in the channel system in a confluence region confined by salt diapirs. In this confluence region, the cross-sectional area (CSA) of the channel system can be up to 1.2 km2, i.e., 4 to 10 times larger than other parts of the study area. These significant changes in the architecture and morphology of the channel system resulted from the interaction between mass-wasting processes and turbidity flows. We postulate that a basal erosional scar created by mass-wasting processes was later filled with an MTD. This basal scar was then used as a preferential pathway for turbidity flows, which were captured by its headwall and lateral margins. The interpreted data show that the captured turbidity flows greatly widened the basal scar but caused only small modifications in scar height. This predominance of widening processes over channel incision occurred because part of the MTD in the basal scar was removed downslope by turbidity flows and replaced by channel-fill deposits. This paper shows that important flow-capture processes can predominate in channel-confluence regions of continental slopes. Basal scars can capture turbidity flows and facilitate flow channelization, which are key processes for submarine-channel initiation. Importantly, the replacement of MTDs by channel-fill deposits has profound implications for reservoir volumes and net-to-gross ratios in channel systems and partly depends on the properties of the turbidity flows, such as their erosive ability and frequency. The more erosive and frequent flows are captured by the basal scar, the larger is the accommodation space created for subsequent sand-prone turbidites.

Quantitative Seismic Geomorphology of a Submarine Channel System in SE Brazil (Espírito Santo Basin): Scale Comparison with Other Submarine Channel Systems

Y. Qin, T. Alves, J.A. Constantine, and D. Gamboa

Marine and Petroleum Geology 78, 455-473, 2016

Detailed morphological analyses of a Pleistocene-Holocene submarine channel system in terms of its hierarchical framework, were carried out using a 3D seismic volume from offshore Espírito Santo, SE Brazil. The channel morphology shows marked variations, with five segments (Segments a to e) being identified along its full length. For example, the cross-sectional area of the channel decreases by a factor of 70 from Segment a to Segment c, and is then followed by a nearly four-fold increase from Segment c to Segment d. The significant changes in channel morphology relate to temporal and spatial variations in flow volume within the channel. In the same channel system, the valley reveals three distinct segments (Segments A to C), with similar aspect ratios but marked variations in morphology along the valley distance. Valley morphological changes are chiefly affected by erosional processes. Segment B is characterised by the largest valley-base width, valley width, and cross-sectional area compared to the other two segments. Valley enlargement in Segment B results from relatively high degrees of lateral channel migration and associated cut bank erosion, leading to the widening of the valley, especially the valley base. In Segment C,

the valley is characterised by inner bank erosion in the form of shallow-seated mass failures, which only enlarged the upper part of the valley wall. The spatial variations in both channel and valley morphology documented here suggest an important role of local factors (e.g. salt diapirs, tributaries, overbank collapse) in the development of channel systems. Hence, the morphological analyses developed in this work provide an effective tool for studying channels and valleys on continental slopes around the world.

Glacial Water Mass Structure and Rapid δ18O and δ13C Changes During the Last Glacial Termination in the Southwest Pacific

Elisabeth Sikes, Aurora Elmore, Katherine Allen, Mea Cook, and Thomas Guilderson

Earth and Planetary Science Letters 456, 87–97, 2016

Changes in ocean circulation are thought to have contributed to lowering glacial atmospheric CO2 levels by enhancing deep ocean sequestration of carbon that was returned to the atmosphere during glacial terminations. High-resolution benthic foraminiferal δ13C and δ18O records from a depth transect of cores in the Southwest Pacific Ocean presented here provide evidence that both wind- and thermohaline-driven circulation drove CO2 from the ocean during the last deglaciation. Shallow geochemical stratification in the glacial Southern Ocean was followed by a short pulse of rapid δ13C enrichment to intermediate water depths during Heinrich Stadial 1, indicative of better-ventilated intermediate waters co-occurring with documented wind-driven upwelling in the Southern Ocean. Intermediate depth δ13C enrichment paused at the start of the Antarctic Cold Reversal (~14.7 ka), implying a brief shallow restratification, while deeper layers were progressively flushed of δ13C -depleted and δ18O -enriched waters, likely caused by the increasing influence of deep waters sourced from the North Atlantic. The coincidence of atmospheric CO2 increases with these geochemical shifts in both shallow and deep cores suggests that shifts in both atmospheric and oceanic circulation contributed to the deglacial rise of CO2.

Reduced Deep Ocean Ventilation in the Southern Pacific Ocean During the Last Glaciation Persisted into the Deglaciation

Elisabeth Sikes, Mea Cook, and Thomas Guilderson

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Marine radiocarbon (^{14}C) is widely used to trace ocean circulation and the ^{14}C levels of interior ocean water masses can provide insight into atmosphere–ocean exchange of CO2 the since the last glaciation. Using tephras as stratigraphic tie points with which to estimate past atmospheric ^{14}C, we reconstructed a series of deep radiocarbon ages for several time slices from the last glaciation through the deglaciation and Holocene in the Southwestern Pacific. Glacial ventilation ages were much greater in magnitude than modern and had a strong mid-depth ^{14}C minimum centered on ~2500 m. Glacial radiocarbon ages of intermediate depth waters (600–1200 m) were ~800 to 1600 ^{14}C years, about twice modern and persisted through the early deglaciation. Notably, in the glaciation shallower depths were significantly more enriched in ^{14}C than waters between 1600 and 3800 m, which were ~4000 to 6200 ^{14}C years, or about 3–5 times older than modern. Abyssal waters deeper than 4000 m were also more ^{14}C rich than the overlying deep water. With radiocarbon ages of 1800–2300 ^{14}C years, this was similar to modern values. In the early deglaciation, ^{14}C depleted waters were flushed from shallower depths first and replaced with progressively younger waters such that by ~18 ka, the deep to intermediate age difference was reduced by half, and by ~14 ka a modern-type ^{14}C profile for deep ocean water masses was in place. Our results 1) confirm a deep ^{14}C depleted water mass during the LGM and early deglaciation, and 2) constrain the extent of this “old” water in the Southern Pacific as between 1600 m and 3800 m. The availability of atmospheric ages from tephras reveals that the presence of older surface reservoir ages in the glaciation caused the estimation of ventilation ages from simple benthic–planktonic offsets to significantly underestimate the depletion of ^{14}C in deep waters. This may have had a role in masking the large change in reservoir ages since the glaciation when using benthic–planktonic reservoir age estimates.

Bering Sea Surface Water Conditions During Marine Isotope Stages 12 to 10 at Navarin Canyon (IODP Site U1345)

Beth Caissie, Julie Brigham-Grette, Mea Cook, and Elena Colmenero-Hidalgo

Climate of the Past 12(9), 1739, 2016

Records of past warm periods are essential for understanding interglacial climate system dynamics. Marine Isotope Stage 11 occurred from 425 to 394 ka, when global ice volume was the lowest, sea level was the highest, and terrestrial temperatures were the warmest of the last 500 kyr. Because of its extreme character, this interval has been considered an analog for the next century of climate change. The Bering Sea is ideally situated to record how opening or closing of the Pacific–Arctic Ocean gateway (Bering Strait) impacted primary productivity, sea ice, and sediment transport in the past; however, little is known about this region prior to 125 ka. IODP Expedition 323 to the Bering Sea offered the unparalleled opportunity to look in detail at time periods older than had been previously retrieved using gravity and piston cores. Here we present a multi-proxy record for Marine Isotope Stages 12 to 10 from Site U1345, located near the continental shelf-slope break. MIS 11 is bracketed by highly productive laminated intervals that may have been triggered by flooding of the Beringian shelf. Although sea ice is reduced during the early MIS 11 laminations, it remains present at the site throughout both glacials and MIS 11. High summer insolation is associated with higher produc- tivity but colder sea surface temperatures, which implies that productivity was likely driven by increased upwelling. Multiple examples of Pacific–Atlantic teleconnections are presented including laminations deposited at the end of MIS 11 in synchrony with millennial-scale expansions in sea ice in the Bering Sea and stadial events seen in the North Atlantic. When global eustatic sea level was at its peak, a series of anomalous conditions are seen at U1345. We examine whether this is evidence for a reversal of Bering Strait throughflow, an advance of Beringian tidewater glaciers, or a turbidite.

Comparison of Coastal Boulder Deposits (Holocene Age) on Eleuthera, Bahamas, with Storm-Transported Boulders On Aran Islands, Ireland

Rónadh Cox, Paul Hearty, Daniel Russell, and *Kyrien Edwards '17*

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/, 2016

Eleuthera, on the northeastern side of the Bahamas archipelago, has a steep ocean-facing coastline fully exposed to Atlantic storms. Cliffs of Pleistocene limestone rising to about 20 m a.s.l. are topped with modern boulder deposits that include (in order of increasing clast concentration) isolated clasts, scattered-boulder fields, and boulder ridges. Although some sit close to the cliff edge, most have been transported 10s of m inland. The boulders have mass up to several 10s of tonnes.

These deposits have previously been interpreted as tsunamigenic, but recent analysis suggests that they are more likely to have been emplaced by storms. Boulder dimensions were measured in the field, and samples were collected for density measurement in the lab. Volume estimates were checked by photogrammetry: for a subset of the boulders we took suites of images with a GPS-enabled camera, and built 3D models using the Agisoft PhotoScan Pro software. The 3D models returned volumes within 15% of those estimated from XYZ dimensions. We measured elevations and inland distances by laser rangefinder, and corrected the data for tide height to yield topographic positions relative to high water. We compared the boulder masses and topographic settings with analogous data from known storm deposits on the other side of the Atlantic, along Ireland's west coast.

The Irish data come from boulders transported on the Aran Islands during the winter 2013-2014 "storm factory" events. The largest clasts in the Irish dataset define clear mass-topography relationships with which boulders data from other locations can be compared. The coastal topographies of Eleuthera and the Aran Islands are very similar (steep limestone coasts passing rapidly into deep waters offshore), so they are likely to have similar storm wave dynamics. The Eleuthera Holocene boulders plot along or close to mass-elevation and mass-steepness regression lines defined by the Irish boulder data. This suggests that there is no need to call on extraordinary events such as tsunami to move these clasts.

Erosion and Channel Changes Due to Extreme Flooding in the Fourmile Creek Catchment, Colorado

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Geomorphology, http://dx.doi.org/10.1016/j.geomorph.2017.03.030, 2017

Infrequent, large magnitude geomorphic events generate quantifiable change on geologically short timescales and are crucial to understanding landscape evolution. Airborne lidar surveys and field measurements were used to investigate floodplain erosion and deposition along a 19.5 km reach of Fourmile Creek, Colorado that was devastated by severe flooding in 2013 that followed a 2010 wildfire. >350 mm of rain fell on the Fourmile catchment from September 9–15, 2013, generating discharge that exceeded bankfull for >120 h at the Orodell gage, with local unit stream power >300 W m−2 throughout the study reach. Debris flows occurred on steep hillslopes and tributary channels in the most intensely burned areas. Lidar difference measurements and field studies highlight zones of local deposition along the study reach, but demonstrate overall net erosion of ~ 0.25 m for the 19.5 km reach of Fourmile floodplain, mainly by channel widening. Tributary junctions where debris-flow sediment entered the floodplain and local decreases in unit stream power controlled some zones of deposition. Overall, mass balance calculations show that a total sediment loss of ~91,000–161,000 m3 from the Fourmile Creek floodplain and hillslopes, which is broadly consistent with channel sediment flux estimates of 71,000–111,000 m3. Measurements from the Fourmile catchment demonstrate that floodplain erosion was a major source of sediment in the 2013 flood and demonstrate that infrequent events marked by long-duration flooding and high total energy expenditure can account for a large fraction of total sediment transport in mountain streams.

Architecture of Relict Charcoal Hearths in Northwestern Connecticut, USA

T. Raab, F. Hirsch, *W. Ouimet '01*, K. Johnson, David Dethier, and A. Raab

Geoarchaeology. 2017:00:1–9. doi: 10.1002/gea.21614, 2017

Relict charcoal hearths are round or elliptical earthen platforms up to 11 m in diameter and a widespread feature of historical industry that supplied charcoal used in the production of iron in furnaces or smelters. The Iron industry dominated Litchfield County, Connecticut, and surrounding areas in the northeast United States throughout the 19th century, peaking in ~1850. The large number of charcoal hearths in this region is a relic of >150 years of widespread iron production. In this study, we describe the architecture and soil stratigraphy of 26 charcoal hearths in Litchfield County. This contribution aims to (1) compare soils that comprise the charcoal hearths with "natural" adjacent soils, (2) measure the thickness of topsoil developed upon the hearths, and (3) characterize the stratigraphy associated with these features. Results indicate that the black topsoils overlying the charcoal hearths contain residual charcoal and are on average 2.6 times thicker than adjacent Cambisols. Charcoal hearths display two or more black, charcoal-rich strata separated by layers of reddish-brown soil low in charcoal content indicating multiple episodes of use. We also find that many charcoal hearths have been stabilized with boulders on the downslope side during construction and repeated use. Overall, the results presented here provide significant information regarding the construction, use, and associated impacts of earthen platforms for charcoal production in the northeast United States, with further relevance to other areas where historical charcoal production occurred.

Measuring the Legacy of 19th- and 20th-Century Gold Mining Using Lidar, Geomorphic and Geochemical Evidence, Fourmile Canyon, Colorado

David Dethier, *William Ouimet '01*, and Sheila Murphy

Geological Society of America Abstracts with Programs 48, (7), doi: 10.1130/abs/2016AM-284303, 2016

Legacy deposits from mineral exploration, mining, and milling record anthropogenic production and redistribution of sediment that may affect hillslopes and channels for many generations. We used 1- and 2-m lidar digital elevation models (DEMs) to map waste piles and other land surface modifications produced by mine-related activity in the 63-km2 Fourmile catchment, Colorado Front Range (USA), during the gold rush that began in 1859. We coupled lidar analysis with study of historic photos, extensive sampling of floodplain sediment deposited in 2011-13 and reconnaissance sampling of historic mine waste rock and mill tailings. Anthropocene events, particularly placer operations, control floodplain stratigraphy, and waste rock piles, particularly from vein mining and road-building before 1942, have volumes exceeding 106 m3 and cover >5% of steep Fourmile hillslopes and gullies. Sediment exposed by mining activities that was subsequently mobilized by flood events in the Fourmile catchment exceeds steady-state measures of erosion by >50X. Anthropocene deposits largely obscure the record of Holocene floodplain

evolution, which was characterized by lateral erosion and minor downcutting. High concentrations of As and Au in the <150 micron fraction of hillslope soil, mining-related deposits, and tributary and floodplain sediment record the pervasive signature of mining activity. Future large floods similar to that in 2013 will rework sediment and produce local erosion along Fourmile Creek channels, but transport of mining legacy sediment from hillslopes by smaller events is likely to continue supplying sediment rich in As and Au to the floodplain. Lowering concentrations of As and other contaminants in floodplain sediment will probably take hundreds of years to millennia.

Permeability of Oceanic Crustal Rock Samples from IODP Hole 1256D

Lisa A. Gilbert and *Miranda L. Bona '13*

Geophys. Geosyst 17, 3825-3832, 2016

Permeability is an important parameter of oceanic crust: it controls hydrothermal circulation and influences the exchange of heat and chemicals between seawater and the crust. Using the most complete section of intact, in situ normal oceanic crust, this paper presents the first permeability measurements of samples from Integrated Ocean Drilling Program (IODP) Hole 1256D in a relatively undisturbed section through lavas, dikes, and into gabbros. At in situ pressures, saturated gabbro from Hole 1256D is about half as permeable as basalt (2.4 × 10−20 m2 and 4.0 × 10−20 m2, respectively). Although fresh basalt samples have higher permeabilities, the basalts at Hole 1256D contain saponite, an alteration mineral which drastically reduces permeability. These measurements represent an opportunity for comparison to models that predict permeability at IODP Hole 1256D. Similar to model predictions, sample permeability generally decreases with depth. However, even after applying the scaling rule, models predict higher permeabilities than exhibited by the samples, suggesting large-scale cracks still control permeability in the 15 My old crust at Hole 1256D.

Systems Thinking

Lisa Gilbert, Deborah Gross, and Karl Kruetz

InTeGrate Module, http://serc.carleton.edu/integrate/teaching_materials/syst_thinking/index.html

The Systems Thinking Module provides a foundation for systems thinking throughout the InTeGrate materials. Units 1 and 2 of this module are designed to be used early within a course and then reinforced later; Units 3-5 give students data-rich modeling experiences; Unit 6 is an interactive summative activity. Specifically, this module prepares students to address complex systems issues for a sustainable future by 1) identifying the parts of a system and explaining how the parts interact, 2) developing skills to model complex systems using data and examples relevant to the course and 3) applying a systems approach to evaluate a societal challenge. This InTeGrate module fills a key need to educate students about the importance of the systems approach, uses examples that involve data and the construction and manipulation of systems models, and helps students approach complex, interdisciplinary problems.

Assessing Student Learning about the Earth Through the InTeGrate Project

Ellen Iverson, Lisa Gilbert, David Steer, Stuart Birnbaum, and *Cathy Manduca '80*

American Geophysical Union Fall Meeting, ED11F-03, 2016

InTeGrate, a five-year community-based project comprised of faculty in the sciences and other disciplines, educational specialists, and evaluation experts at diverse institutions, instills learning about Earth in the context of societal issues through teaching materials developed into 2-3 week modules or courses. Materials were tested by over 135 materials authors and faculty interested in using these materials in undergraduate courses at a range of institution types across the US in geoscience, engineering, humanities, and social science courses. To assess impact on student learning, the InTeGrate project has collected student work from over 4,600 students enrolled in courses using these materials.

To evaluate the influence of the materials on learning gains related to geoscience literacy, a set of 8 multiple choice items were developed, tested, and then administered in the first and last week of class in approximately 180 courses. The items were developed by 14 community members with assessment expertise and address content and concepts in the Earth, Climate, Atmosphere, and Ocean Science literacy documents. In a sample of 2,023 paired first and last week responses, students exhibit a 10% normalized gain (equivalent to 1 point of a 12 point total) regardless of their initial score. Students in the lowest quartile at the beginning of the course demonstrate the highest gains (4th quartile gain of 1.8) versus the higher quartile where a ceiling effect is present.

In addition, a free-response essay was administered in the last week of the course which tests students' understanding for how Earth system interactions influence people's ability to make decisions about global societal challenges. Analysis of these essays demonstrates a strong relationship between the InTeGrate content and the subject matter of the student essay. These preliminary findings suggest that the use of InTeGrate materials increases students' understanding of geoscience literacies and the materials give students a topical hook for connecting learning about Earth to societal challenges.

A New Model for the Preparing for an Academic Career in the Geosciences Workshop

Lisa Gilbert, Erika Marin-Spiotta, Lynsey LeMay, David E. Reed, Ankur R. Desai, and R. Heather Macdonald

American Geophysical Union Fall Meeting, ED34A-06, 2016

The NAGT/On the Cutting Edge program has offered annual workshops on Preparing for an Academic Career in the Geosciences since 2003, providing professional development for more than 800 graduate students and post-docs. In July 2016, the multi-day workshop was modified to be integrated into a larger conference, the Earth Educators' Rendezvous. This new format brought both challenges and opportunities. Like prior workshops, participants engaged with peers and workshop leaders from a range of educational settings to improve their application and interview skills for academic jobs, become more effective at goal-setting and time management, and broaden their network of colleagues and resources to jump-start teaching and research as a faculty member. They learned about academic careers in different educational settings (two-year colleges, primarily undergraduate institutions, and research-focused universities), and developed plans and goals for their next career stage.

The biggest challenge of the new workshop format was paring down material from 2.5 full days. Thus, in addition to the 3 morning sessions allocated for the workshop, leaders added a 3-hour teaching statement review dinner, an optional evening session to discuss finances and work-life balance, and optional small group lunch discussions on all 3 days, which were all well attended. Participants were then able to take advantage of afternoon sessions at the Rendezvous, including demonstrations of exemplary teaching, plenary talks, poster sessions, and mini-workshops on topics from curriculum design to proposal writing.

Participant reviews were positive and nearly all aspects were ranked as most valuable, with an overall satisfaction mean of 9.1 on a scale from 1-10, with 10 being "Very satisfied." Participants particularly valued the sessions related to careers and the job search process. Some wished the workshop had been longer to cover more material. Participants enjoyed the opportunity to gain more skills at the Rendezvous afternoon sessions and several participants mentioned the Rendezvous afforded them the possibility of attending the Career Prep workshop. Our experiment showed that a career preparation workshop can survive when embedded into a larger conference.

Miocene to Pleistocene Transatlantic Dispersal of Ceratoconcha Coral-Dwelling Barnacles and North Atlantic Island Biogeography

B.G. Baarli, M.C. Maley, A. Santos, M.E. Johnson, C.M. Silva, J. Meco, M. Cachão, and E.J.Mayofral

Palaeogeography,Palaeoclimatology Palaeoecology 468, 520-528, 2017

Coral-dwelling pyrgomatid barnacles (subfamily Ceratoconchinae) were widely dispersed throughout the Paratethys and Mediterranean seas as well as the Atlantic Ocean during the Neogene, but today are limited to the Western Atlantic. Herein, the paleobiogeographic origin and dispersal of the genus Ceratoconcha is studied based on a combination of field, taxonomic, and literature studies. The first confirmed appearances of Ceratoconcha occur in lower Miocene strata (Burdigalian) with two closely related species on both sides of the Atlantic in western France and Florida. Fossils from the Miocene of Lanzarote in the Canary Islands and Pleistocene of Maio in the Cape Verde islands extend the known geographical and temporal range of the Ceratoconcha barnacles in the eastern Atlantic. During the Neogene, dispersal of marine taxa was a two-way process due to tectonic changes both influencing oceanic circulation and appearance and disappearance of oceanic islands. During the early Miocene, gyre formation was weak and the Atlantic Ocean mid-latitudes were warmer than today. This resulted in increased hurricane activity and the expansion of hermatypic coral hosts farther north in the North Atlantic. Normal ocean circulation transported barnacle larvae from east to west, but currents generated by hurricanes may have transported them in the opposite direction towards the margins of the northeastern Atlantic. Islands in between abetted barnacle

contact and dispersal. The temporal range for Ceratoconcha is extended considerably in the eastern Atlantic from the early Pliocene to the Pleistocene. The hermatypic host corals of Ceratoconcha suffered a severe decline in the eastern Atlantic and the Mediterranean after the Miocene. Corals were present during the Pliocene and Pleistocene in the Cape Verde Islands. This suggests that the southernmost oceanic islands acted as a tropical refuge for host corals and their likely barnacle symbionts.

Growth of the Ballena Fan Delta on the Gulf of California (Mexico) at the Close of the Pliocene Warm Period

Markes E. Johnson, D.H. Backus and J. Ledesma-Vázquez

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Tectonic uplift on the shores of Bahía San Rafael in Mexico's upper Gulf of California exposed a Pliocene delta system that covers a map area of 4 km2. Subaerial dissection by arroyos entrenched during Pleistocene and post-Pleistocene time carved cross-sectional slices through the delta, showing its dominant construction resulting from massive transfers of siliciclastic sand derived from the breakdown of igneous rocks (tonolite) in a well-defined terrestrial basin. Restoration of the sedimentary structure by elimination of Pleistocene arroyos and linkage of former topographic lines reveals a triangular shape recognizable as a classic fan delta. The complex includes an alluvial fan that immerges from a small opening in the landscape connected to a semi-circular, high-walled basin with a map area of 2.6 km2. Through a strictly longitudinal sequence, estimates of the excavated basin's volume and the delta's sedimentary volume were conducted as a mass-balance exercise that yielded a strong match. The lower central part of the delta features dense concentrations of sand dollars (Dendraster granti) that form a distinct limestone coquina not previously recognized elsewhere in Baja California. Through the regional biostratigraphy of concurrent range zones supplemented by absolute age dates from inter-bedded volcanics in other places, a later Pliocene age around 3 to 2 Ma is suggested for the sand dollars and the delta complex in which they are buried. Such timing corresponds to the close of the Pliocene Warm Period, during which a persistent El Niño climate brought tropical storms and excessive rainfall to the upper Gulf of California. Comparisons with other Pliocene deltas throughout the Gulf of California underscore the unique status of the complex named the Ballena Fan Delta.

Taphonomic Range and Sedimentary Dynamics of Modern and Fossil Rhodolith Beds: Macaronesian Realm (North Atlantic Ocean)

Markes E. Johnson, J. Ledesma-Vazquez, R.S. Ramalho, C.M. Silva, A.C. Rebelo, A. Santos, B.G. Baarli, C.M. Silva, E.J. Mayoral, and M. Cachão

In R. Riosmena-Rogriguez, W. Nelson, and J. Aguirre (Eds.), Rhodolith/Maërl Beds: A Global Perspective. Coastal Research Library 15 (pp. 221-261). Switzerland: Springer International Publishing (2017)

Distribution of living rhodoliths in the Macaronesian realm is limited by extensive rocky shores and narrow insular shelves that rapidly drop off beyond the 50-m isobath. Wind and wave erosion is most intense on north and northeast-facing shores due to the prevailing northeasterly trade winds over much of the region. Southern shores offer more sheltered, leeward settings. Rhodolith beds tend to thrive on eastern shores with strong long-shore currents and southeastern shores that benefit from wave refraction. Rhodoliths are not entirely absent off northern shores, but may fail to reach maximum size before being washed ashore to make berms and beaches. Islands considered in greater detail in this survey include Santiago, Maio, and Sal from the Cape Verde Islands, Fuerteventura and the related islet of Lobos in the Canary Islands, Selvagem Grande and Pequena from the Savage Islands, Porto Santo in the Madeira Islands, and Santa Maria in the Azores. This contribution expands on the concept that living rhodoliths enter the fossil record through a range of taphofacies defined by the degree of breakage and corrosion and further characterized by sedimentological criteria regarding the amount of matrix and packing among bioclasts. Rhodolith deposits in Macaronesia seldom reflect settings under natural growth conditions. Rather, rhodoliths are subject to transportation and post-mortem disintegration resulting in the accumulation of rhodolith materials captured by subtidal storm deposits, tidal pools and platform over-wash deposits, as well as beachrock, beach, berm, hurricane, tsunami, and coastal dune deposits. Some of this material is transferred farther offshore, but exposed island strata show a tendency for shoreward migration of taphofacies. Rhodolith beds provide a habitat for some species of marine invertebrates, including epifaunal and infaunal elements directly associated with whole rhodoliths and these features play a role in rhodolith biostratinomy.

Intense Hurricane Transports Sand Onshore: Example from the Pliocene Malbusca Section on Santa Maria Island (Azores, Portugal)

Markes E. Johnson, A. Uchman, P.J.M. Costa, R.S. ramalho, and S.P. Ávila

Marine Geology 385, 244-249, 2017

Southern cliffs on Santa Maria Island in the Azores archipelago (North Atlantic Ocean) feature submarine volcanic sequences inter-bedded with Pliocene coralline algal limestone, shelly coquinas, and mixed volcaniclastic-calcarenite sandstone. Within the 20-m sedimentary succession at Malbusca, a singular, 5-m sandstone bed is distinguished by dark and light laminae dominated alternately by heavy minerals and carbonate detritus. Carbonate grain-size varies between that of coarse silt and very fine sand. The basal part shows coarser and more poorly sorted sand in an upward transition to increasingly finer carbonates. Accessible over a lateral space of 34 m, the big bed is shouldered against and overlaps the remnants of a drowned rocky shore with a paleorelief of 4 m that preserves intertidal to shallow subtidal biotas. Extrapolated from the big bed's rock face (1,830 m2) and the width of the eroded shelf on which it resides (8 m), calculations yield a projected volume of 14,500 m3. Unique to the island, the big bed is interpreted as a major hurricane deposit that moved sand from an offshore bar in an onshore path. Such an event fits the context of the Pliocene Warm Period, during which global El Niño conditions were more intense than today.

Rocking Around a Volcanic Island Shelf: Pliocene Rhodolith Beds from Malbusca, Santa Maria Island (Azores, NE Atlantic)

A.C. Rebelo, M.W. Rasser, A. Kroh, Markes E. Johnson, R.S. Ramalho, C. Melo, A. Uchman, B. Berning, L. Silva, V. Zanon, A.I. Neto, M. Cachão, and S.P. Ávila

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Rhodoliths are a common producer of carbonates on modern and ancient shelves worldwide, and there is growing evidence that they thrive on volcanic insular shelves. However, little is still known on how rhodoliths cope with the demands of this particularly dynamic environment. In this study, the focus is placed on fossil rhodoliths from a Pliocene sequence at Santa Maria Island, Azores, in order to gain further insight into the life cycle (and death) of rhodolihis living in a mid-ocean active volcanic setting. These rhodoliths occur as a massive accumulation within a larger submarine volcano-sedimentary sequence that was studied from the marco- to the micro-scale in order to reconstruct the paleoenviornmental conditions under which the rhodolith accumulation was deposited and buried. All fossil rhodoliths from this setting are multi-specific and demonstrate robust growth forms with a lumpy morphology. Morevover, taphonomical analyses show the succession of several destructive events during rhodolith growth, suggesting life under a highly dynamic system prior to stabilization and burial. The rhodoliths therefore tell a story of an eventful life, with multiple transport and growth stages, owing to the environment in which they lived. Transport and deposition to their final resting place was storm-associated, as supported by the general sedimentary sequence. In particular, the sequence features an amalgamation of tempestites deposited under increasing water depths, sediment aggradation, and before burial by volcanic activity. This transgressive trend is also attested by the overall characteristics of the volcano-sedimentary succession, which exhibits the transition to subaerial environment in excess of 100 m above the rhodolith bed.

3D Models and Animations for Teaching Structural Geology and Tectonics

Paul Karabinos

http://serc.carleton.edu/NAGTWorkshops/structure/2016-Forum/abstracts/153813.html 2016

Interactive 3D models help students visualize and apply fundamental concepts in structural geology and tectonics. Trimble SketchUp is a useful way to create such models and animations; there is a free version and the professional version is free to educators. Interactive SketchUp models show how the stereographic projection is used to plot the trend and plunge of lines and the strike and dip of planes, and how to measure angles between geometric features. 3D models also illustrate how to use structure contours to test if a contact is planar or folded, find the true thickness of a formation, determine strike and dip of planar features, estimate slip on faults, and create cross-sections. SketchUp models can simulate plate tectonic geometry on the surface of a sphere, and be used to demonstrate the Euler

pole of rotation between two plates. Models can be exported as COLLADA digital asset exchange (.dae) files and incorporated into an iBook or uploaded to a web service designed to share 3D models such as Sketchfab. It is also possible to export models as 3D PDFs, and animations can be exported in a variety of movie formats to facilitate sharing and dissemination.

Tectonic Exhumation of Mid-Crustal Rocks Recorded by Textural Unconformities in Garnet from the New England Appalachians

Paul Karabinos

Geological Society of America Abstracts with Programs 48 (7), doi: 10.1130/abs/2016AM-285612, 2016

Neoproterozoic (Z) to Ordovician (O) rocks in the Appalachians of western New England record deformation from both the O Taconic and Devonian (D) Acadian orogenies. In contrast, Silurian (S) and D rocks in the region were only affected by the Acadian. Rosenfeld (1968) documented garnets in the older rocks that preserve a two-stage growth history, and he argued that the older cores grew during Taconic metamorphism and that the younger rims were Acadian. Thompson et al. (1977) suggested that the garnets could have formed during a single prograde event in which an intermediate garnet-consuming reaction partially resorbed garnet.

Garnets with textural unconformities are widespread in the Z Gassetts Schist in VT, but are not found in S to D rocks. Inclusions of rutile are ubiquitous in garnet cores but absent in the second stage rims and matrix, indicating that the first stage of garnet growth occurred under higher P conditions than the second. A critical observation is that the hiatus in garnet growth is not correlated with metamorphic grade but it is texturally linked to the formation of a new cleavage. Thus, the textural unconformity cannot be explained by an intermediate garnet-consuming reaction during a single prograde event.

Isograd maps for each stage of garnet growth, created using inclusion and matrix assemblages, reveal a strong correlation between the high-grade areas during each stage. Thus, it seems more likely that both growth stages occurred during a single orogeny rather than during two events separated by 80 m.y. Mineral assemblages and chemical zoning suggest that garnet growth in the older rocks occurred during decompression of ca. 3 kbars, whereas metamorphism of S and D rocks occurred during increasing P conditions.

The two-stage garnet growth history records a cleavage-forming event that tectonically exhumed the older sequence of rocks, together with underlying Grenvillian basement rocks at 380 Ma, the time of peak metamorphic conditions. The boundary between rocks with different metamorphic histories coincides with a high strain zone with normal displacement that separates structurally lower rocks with complex garnets from structurally higher rocks with simple garnets. The lower rocks were extruded northward and upward, parallel to the orogen, into west-directed nappes during the Acadian orogeny.

Exploring the Reasons for the Seasons Using Google Earth, 3D Models, and Plots

D.G. De Paor, M.M. Dordevic, Paul Karabinos, S. Burgin, F. Coba, and S.J. Whitmeyer

International Journal of Digital Earth

http://www.tandfonline.com/eprint/svGUd9i77gAEhfMdk8Kw/full, http://dx.doi.org/10.1080/17538947.2016.1239770, 2016

Public understanding of climate and climate change is of broad societal importance. However, misconceptions regarding reasons for the seasons abound amongst students, teachers, and the public, many of whom believe that seasonality is caused by large variations in Earth's distance from the Sun. Misconceptions may be reinforced by textbook illustrations that exaggerate eccentricity or show an inclined view of Earth's near-circular orbit. Textbook explanations that omit multiple factors influencing seasons, that do not mesh with students' experiences, or that are erroneous, hinder scientifically valid reasoning. Studies show that many teachers share their students' misconceptions, and even when they understand basic concepts, teachers may fail to appreciate the range of factors contributing to seasonal change, or their relative importance. We have therefore developed a learning resource using Google Earth, a virtual globe with other useful, weather- and climate-related visualizations. A classroom test of 27 undergraduates in a public research university showed that 15 improved their test scores after the Google Earth-based laboratory class, whereas 5 disimproved. Mean correct answers rose from 4.7/10 to 6/10, giving a paired t-test value of 0.21. After using Google Earth, students are helped to segue to a heliocentric view.

Color Vision Deficiency and the Geosciences

D.G. De Paor, Paul Karabinos, G. Dickens, and C. Atchison

GSA Today 27, doi: 10.1130/GSATG322GW.1, 2017

Color Vision Deficiency (CVD) is a common workplace disability. People with CVD read our papers and are most likely in all of our classes. Here we discuss the common forms of CVD, assistive technologies, instructional strategies, and guidelines for illustrations that will look great to everyone.

Strain Gradients in the Day Mountain Thrust Sheet, Massachusetts, USA: Implications for Deformation During Thrusting and Strain Localization

E.L. Pierce and Paul Karabinos

in Law, R.D., Thigpen, J.R., Merschat, A.J., and Stowell, H.H.(Eds), Linkages and Feedbacks in Orogenic Systems: Geological Society of America Memoir 213 (pp. 1–16). 2017

The Berkshire massif in western Massachusetts is one of several external basement massifs in the New England Appalachians. The Day Mountain thrust is a segment of the western frontal thrust of the Berkshire massif that carried Mesoproterozoic basement gneisses and unconformably overlying cover rocks of the Neoproterozoic (?) Dalton Formation and Cambrian Cheshire Quartzite over the Cambrian to Ordovician Stockbridge Formation. The basal unit of the Dalton Formation is a distinctive deformed quartz-pebble conglomerate. We made 27 strain estimates at 18 locations using the deformed conglomerate to investigate the strain field in the Day Mountain thrust sheet and test the plane-strain model of thrust emplacement. Although the strain ellipsoids vary from prolate to oblate shapes over distances as small as 200 m, and the orientations of the principal directions of strain range widely, a remarkably simple strain pattern, broadly consistent with simple shear, emerges when the strain data are plotted on contoured stereograms. The preferred orientation of the maximum elongation direction plunges gently and approximately coincides with the westnorthwest transport direction of the thrust sheet, the preferred orientation of the intermediate principal strain axis is nearly horizontal and perpendicular to the transport direction, and the preferred orientation of the short axis plunges steeply. Most of the strain ellipsoids fall in the prolate field, which is indicative of constrictive flow, especially in the northern part of the thrust sheet. We suggest that the steep gradients in three-dimensional strain type were caused by flow of the more ductile conglomerate over an irregular surface of relatively rigid basement rocks, which were little affected by Paleozoic deformation. The constrictive flow conditions that dominate the strain field in the northern part of the thrust sheet may reflect the irregular paleotopography.

Bridging the Gap Between the Foreland and the Hinterland I: Geochronology and Plate Tectonic Geometry of Ordovician Magmatism and Terrane Accretion on the Laurentian Margin of New England

P. Karabinos, F.A. Macdonald, and J.L. Crowley

American Journal of Science 317, 515-554, 2017

U-Pb dates on magmatic and detrital zircon from samples in the hinterland of the Taconic orogen place new constraints on the timing and plate tectonic geometry of terrane accretion and magmatic arc activity. The Moretown terrane, a Gondwanan-derived exotic block, extends from the Rowe Schist-Moretown Formation contact in the west to the Bronson Hill arc in the east. Arc-related plutonic and volcanic rocks formed above an east-dipping subduction zone under the western leading edge of the Moretown terrane from approximately 500 to 475 Ma, until collision with hyperextended distal fragments of Laurentia, represented by the Rowe

Schist, at 475 Ma. Magmatic arc rocks formed during this interval are primarily located in the Shelburne Falls arc, although some are also located in the Bronson Hill arc to the east. Metasedimentary rocks in the Shelburne Falls arc contain detrital zircon derived from mixing of Gondwanan, Laurentian, and arc sources, suggesting that the Moretown terrane was proximal to Laurentia by 475 Ma. Explosive eruptions at 466 to 464 Ma preserved in the Barnard Volcanic Member of the Missisquoi Formation in Vermont and as ash beds in the Indian River Formation in the Taconic allochthons may record slab-breakoff of subducted lithosphere following collision of the Moretown terrane with distal Laurentian crustal fragments. Between 466 and 455 Ma a reversal in subduction polarity lead to a west-dipping subduction zone under Laurentia and the

newly accreted Moretown terrane. Magmatic arc rocks in the Bronson Hill arc formed above this west-dipping subduction zone along the eastern trailing edge of the Moretown terrane at approximately 455 to 440 Ma. The western boundary of Ganderia in New England is east of the Bronson Hill arc, buried beneath Silurian and Devonian rocks deformed during the Acadian orogeny.

Bridging the Gap Between the Foreland and Hinterland II: Geochronology and Tectonic Setting of Ordovician Magmatism and Basin Formation on the Laurentian Margin of New England and Newfoundland

F.A. Macdonald, Paul Karabinos, J.L. Crowley, E.B. Hodgin, P.W. Crockford, and J.W. Delano

American Journal of Science 317, 555–596, 2017

Ordovician strata of the Mohawk Valley and Taconic allochthon of New York and the Humber margin of Newfoundland record multiple magmatic and basin-forming episodes associated with the Taconic orogeny. Here we present new U-Pb zircon geochronology and whole rock geochemistry and neodymium isotopes from Early Paleozoic volcanic ashes and siliciclastic units on the northern Appalachian margin of Laurentia. Volcanic ashes in the Table Point Formation of Newfoundland and the Indian River Formation of the Taconic allochthon in New York yield dates

between 466.16 0.12 and 464.20 0.13 Ma. Red, bioturbated slate of the Indian River Formation record a shift to more juvenile neodymium isotope values suggesting sedimentary contributions from the Taconic arc-system by 466 Ma. Eight ashes within the Trenton Group in the Mohawk Valley were dated between 452.63 0.06 and 450.68 0.12 Ma. These ashes contain zircon with Late Ordovician magmatic rims and 1.4 to 1.0 Ga xenocrystic cores that were inherited from Grenville basement, suggesting that the parent magmas erupted through the Laurentian margin. The new geochronological and geochemical data are integrated with a subsidence model and data from the hinterland to refine the tectonic model of the Taconic orogeny. Closure of the Iapetus Ocean by 475 Ma via collision of the peri-Gondwanan Moretown terrane with hyperextended distal fragments of the Laurentian margin is not clearly manifested on the autochthon or the Taconic allochthon other than an increase in sediment accumulation.

Pro-foreland basins formed during the Middle Ordovician when these terranes were obducted onto the Laurentian margin. 466 to 464 Ma ashes on the Laurentian margin coincide with a late pulse of magmatism in both the Notre Dame arc in Newfoundland and the Shelburne Falls arc of New England that is potentially related to break-off of an east-dipping slab. Following slab reversal, by 455 Ma, the Bronson Hill arc was established on the new composite Laurentian margin. Thus, we conclude that Late Ordovician strata in the Mohawk Valley and Taconic allochthon of New York and on the Humber margin of Newfoundland were deposited in retro-foreland basins.

Modeling Lava Dome Collapse Using Correlation Between Porosity and Unconfined Compressive Strength

Martin Keenan '17 and Paul Ashwell

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/2016AM-284238, 2016

Unconfined compressive strength (UCS) is a strong control on lava dome stability and can be used to model domes and study the possibility of their collapse. Connected porosity measurements were taken on rhyolite cores from the Tarawera and Ngongotaha lava domes and subsequent strength tests determined the UCS for each core. The data were then analyzed to produce a negative exponential function relating UCS to connected porosity. The relationship between these two variables make it possible to examine changes in lava strength from changes in porosity. The exponential function, along with data on the porosity, thickness and density of the Cordón Caulle obsidian flow and Unzen lava dome, was used to generate models for lava dome collapse. These models compare estimated UCS of the rock to the load of the lava dome and predict the risk of collapse. Higher dome load relative to estimated UCS will create less stability and increase the risk of collapse. Despite the exclusion of other relevant factors, e.g. tensile strength and seismicity, it is concluded that porosity, via UCS, is significant to provoking collapse.

Monitoring Evolution of Lavakas (Gullies) in the Alaotra-Mangoro District of Eastern Madagascar Using 20th Century Air Photos and 21st Century Ortho-Imagery

Ezekiel King Phillips ’17, Rónadh Cox, and Joshua Harrington ‘16

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/2016AM-283682, 2016

Madagascar’s highlands are characterised by unusual gullies known as lavakas. Conventional wisdom links hillslope erosion and lavaka formation with slash-and-burn agriculture and overgrazing, but there are few data on rates of lavaka initiation and evolution, and how those relate to population dynamics is not known. The Alaotra-Mangoro district is particularly sensitive, both because of the ecological importance of Lac Alaotra and because it is Madagascar’s most important rice-growing region. The population has grown exponentially in recent decades, doubling from about 0.3 million in mid 20th C to 0.6 million in 1993, and doubling again to >1 million in 2013 (density increase of 6 to 19 and then to 31 people/km2). The hills in the watershed have many lavakas; the question is whether increasing human activity has driven an increase in lavaka erosion.

We studied a 450 km2 area in the steep treeless uplands of the Lac Alaotra watershed, just east of the district capital (Ambatondrazaka). We used low-altitude aerial photograph suites taken in 1949, 1957 and 1969, georectified and overlaid on 2006 Bing orthoimagery in ArcGIS. For each time-slice, all identifiable lavakas were outlined, and their areas measured.

Despite the dramatic increase in human activity, there has been almost no initiation of new lavakas since 1949. In the 438 km2 covered by 1949 and 2006 imagery, 525 out of 527 lavakas were present in 1949. Lavakas range in size from 325 m2 to 460,000 m2. The median lavaka area increased by about 6% between 1949 and 2006, from 12,000 to 12,700 m2. This does not necessarily mean that overall erosion increased, however, because as lavakas evolve through time from young and active to old and inactive they also change from narrow and deep to wide and shallow as their walls collapse and the gully fills in. Examination of the ratio of vegetation to bare earth in the lavakas suggests that there has been an overall lessening of lavaka activity since 1949.

There are many unvegetated, active lavakas in the study area, but the data suggest that lavaka activity is in fact less overall than it was in the mid-20th C. These results are counter to expectations, given prevailing narratives linking human activities to increased lavaka formation in Madagascar, and demonstrate the importance of decadal-scale analysis of regional landscape histories.

Structural Control on Rockfall: A Geolithological and Geomechanical Characterization of Miocene Volcanics

Krystina Lincoln ’17, Josh Borella, Samuel Hampton, and Marlene Villeneuve

Geological Society of America Abstracts with Programs 48 (7) doi: 10.1130/abs/2016AM-282544, 2016

Rockfall releases, or detachment zones, are controlled by planes of weakness in a rock mass such as bedding planes, faults, foliation, joints, and cleavage. Little work has examined the relationship between primary structures (cooling joints and bedding) and detachment zones in volcanic rock. The February 22 and June 13, 2011 events of the Canterbury Earthquake Sequence triggered widespread rockfall within Lyttelton Volcanic Group deposits. This study attempts to isolate primary structural controls on rockfall in volcanic rock by characterizing the geomechanical and geolithological properties of a single rockfall source above Rapaki, New Zealand. The source rock is inaccessible due to the continuing seismic hazard, so a scanline was conducted on an outcrop proximal to the source cliff face and an Unmanned Aerial Vehicle (UAV) collected images of the exposure. The source cliff contains both coherent and brecciated lava flows, which are not equally distributed on the face and show unique joint patterns and rock strengths. Scanline data and rock mass characterization investigated the orientation and persistence of discontinuities within a coherent lava unit and bounding breccias. Images of the cliff face taken by the UAV were collated into a single orthomosaic image, and used to map and classify the cliff exposure and detachment zones. Detachment zones were classified based on the lithologies, the presence of visible joint release, and lithologic contacts at the boundaries of the detachment zone.

Image analysis estimates that roughly 9% of volcanic cliff above Rapaki detached as rockfall boulders in the recent seismic sequence. Detachment zones are semi-randomly distributed across the cliff face, with notable absences where the slopes are shallow or the cliff face is concave into the slope. Detachments are often defined by lithologic boundaries, which is in part due to a decrease in Geological Strength Index values because of the increase

of tightly spaced subhorizontal joints. Changes in primary cooling joints in both coherent and brecciated lava flows near lithologic contacts are the strongest control on rockfall detachment zones. This study highlights the importance of understanding the primary structures, which directly influence mechanisms of release both during seismic events and under static conditions.

Using Crystal Size Distributions and Qualitative Textural Analysis to Deduce the Crystallization Histories of Trachytic Domes and Dykes In the Akaroa Volcanic Complex, New Zealand

Matthew Marcarelli '17

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/2016AM-282463, 2016

Study of silicic domes and dykes located in predominantly basaltic volcanic complexes is crucial to the understanding of late-stage volcanic plumbing systems. Crystal size distribution (CSD) analysis—when substantiated with qualitative petrographic observations and crystal damage assessment—can be used to construct models for the storage, ascent, and emplacement of such structures. Moreover, estimates of residence time for related feeder magmas can be calculated from CSD regression slopes. In the case of the Akaroa Volcanic Complex (AVC), an intraplate composite shield volcano active during the Miocene on New Zealand's Banks Peninsula, CSDs and petrographic evidence for three trachytic structures—Mount Sinclair dome, Panama Rock dyke, and Devil's Gap Senior dome—show that late-stage trachyte magma faced at least two different paths of ascent after fractionating from a hawaiite reservoir at depths of 10-15 km: (1) a direct and constant ascent, which is reflected in the linear CSD trends of Mount Sinclair dome and Panama Rock dyke, and (2) a stalled ascent, which is reflected in the downward inflections observed in Devil's Gap Senior dome CSDs. The steeper CSD regression slopes for Panama Rock dyke and Mount Sinclair dome— -0.0236 and -0.0215, respectively—show that magma ascended relatively rapidly compared to Devil's Gap Senior dome, which has an average CSD regression slope of -0.0127. The steeper regression slopes for Mount Sinclair dome and Panama Rock dyke also yield estimates of magma residence time over 4.5 times greater on average than those calculated for Devil's Gap Senior dome—a disparity likely the result of Devil's Gap Senior dome having crystallized from a larger body of magma. Furthermore, crystal damage assessments show that Devil's Gap Senior dome likely breached the surface as an effusive lava dome, while Panama Rock dyke and Mount Sinclair dome solidified in the subsurface as shallow intrusions. In addition to increasing our understanding of the crystallization dynamics of the individual units considered in this study, the research methods proposed here will serve as an easily adaptable framework for future research on trachytic domes and dykes—both in the AVC and in modern analogues abroad.

Inland Migration of Coastal Boulder Deposits on Inishmaan, Ireland, Measured Using Structure-From-Motion Photogrammetry

Timothy Nagle-McNaughton '18 and Rónadh Cox

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/2016AM-281197, 2016

Coastal boulder deposits (CBD) accumulate above the high-water mark along steep coastlines with open-ocean exposure. They include megagravel with masses in the many 10s of tonnes, and therefore preserve a record of high-energy events; but because they are activated only by very large waves they can be essentially dormant for long periods of time, and undergo substantial changes only episodically. Thus their dynamics are not well known. The 2013-2014 "storm factory" in the northeastern Atlantic region brought a series of extreme wave events to western Ireland, and in its aftermath we used structure-from-motion photogrammetry to map CBD on Inishmaan, one of the Aran Islands off Ireland's west coast. We used image analysis to make quantitative comparisons between t the photogrammetric data and pre-existing orthophotography so that we could measure changes in the CBD.

Photogrammetric images were captured in June 2016 using a DJI Phantom II flying at 60 m altitude above the coastal platform. Vertical images were acquired along programmed flight paths with 80% in-track overlap between successive photographs and 60% sidelap between adjacent parallel tracks. The 3D structure-from-motion models were created in Agisoft PhotoScan Pro. We georectified and registered the photogrammetric model with 2012 orthoimagery (available in Bing Maps).

The CBD on Inishmaan are dominated by coast-parallel boulder ridges 2-5 m high and 10s of m wide, and although they are constructed predominantly of cobble to boulder-sized material, they also contain megagravel clasts up to 80 t mass. The ridges sit at elevations up to 25 m above high water, and up to 220 m inland. Most of

the boulder ridges had undergone some reorganisation, and several segments showed substantial inland migration. Clasts were transported from the front of the boulder ridges over the ridge crest and onto the landward side. We measured up to 6m inland displacement of seaward faces of the boulder ridges. On the landward side of the ridges, walls were knocked down and over-run by boulders, and newly-deposited boulders carpeted adjacent fields. Most of the moved boulders were fairly small (<1 t) but several were in the range 10- 40 t. These findings underscore the role of storm waves in building and modifying coastal boulder deposits.

Geomorphology of Mountains n Io Provides Insights into Mountain-Patera Relationships

Christina Seeger '16 and Rónadh Cox

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/2016AM-282270, 2016

Io, the solar system's most volcanically active body, also has distinctive mountains, most of which are not volcanoes. The majority of Io's lavas emanate from low-relief paterae and form extensive flows rather than edifices, whereas the ~140 Ionian mountains are high-standing massifs, rising several km above the plains. The mountains appear to be tectonic in origin, and the connection between them and Io's volcanism is unclear. We used a geomorphologic approach to try and address this question.

Seismic activity and gravity are the predominant erosional forces on Io. Fresh or newly-uplifted mountains should maintain high peaks and craggy bedrock topography, with little evidence for slope failure. More degraded mountains should lack jagged peaks, have fewer steep slopes, and show well-developed debris aprons. Of the 140 identified mountains, 71 were imaged at sufficient resolution for geomorphic classification.

We developed an erosion index (EI) ranging from 1 ("fresh" mountains, with sharp ridges, smooth and steep slopes) to 5 (very degraded mountains, lacking bedrock escarpments, dominated by hummocky and furrowed surfaces and more gentle slopes). The index is qualitative in nature, being based on visual examination of Galileo images; but we demonstrated that it is reproducible by having a group of 27 people independently classify a varied set of 25 mountains at a range of image resolutions.

Few Ionian mountains are pristine. Fewer than 15% had EI of 1 or 2, and only 4% had EI=1. The majority of the mountains were moderately to substantially degraded (EI 3 to 5). We found a statistically significant (p=0.001) inverse correlation between EI and relief: more eroded mountains are substantially shorter, with average elevation of 8 km for EI=1 mountains, decreasing to an average of 4.6 km for those with EI=5.

Statistically (p=0.03) the more degraded mountains tend to be closer to paterae. Mountains with EI=5 are on average only 16 km away (range 0-68 km), whereas the freshest mountains (EI=1) are on average 98 km from the nearest patera (range 30-190 km). If we assume that the freshest mountains are most recently formed, the observation that they tend to be the ones most distant from paterae suggests that mountain uplift is either decoupled from patera formation, or precedes it.

Morphology and Stratigraphic Distribution of Putative Tintinnid Fossils from the Tsagaan Olom Group, Mongolia

Maoli Vizcaino '17, Ross P Anderson, Francis A. MacDonald, and Phoebe Cohen

Geological Society of America Abstracts with Programs 48 (7) doi: 10.1130/abs/2016AM-283416, 2016

Neoproterozoic carbonate successions have become an important new taphonomic window into the fossil record of eukaryotes. One of the most notable examples is the ca. 662–635 Ma Taishir Formation (Tsagaan Olom Group, Zavkhan Terrane, Mongolia), which has yielded multiple organic and agglutinated eukaryotic fossil forms. Here, we examine more closely the morphology and taxonomy of organic eukaryotic fossils interpreted as remains of putative ciliate loricae from the Taishir Formation and the overlying Ediacaran Ol Formation of the Tsagaan Olom Group. We document morphological diversity in fossils recovered from carbonate macerates through both external shape and size as well as wall ultrastructure, and compare our data to morphological studies on both fossil and modern tintinnid loricae. In addition, we document the occurrence and morphology of macroscopic organic warty sheets (MOWS) which are interpreted as putative red algae. We also present the first high resolution record of fossiliferous versus non-fossiliferous samples through 231 samples from the Taishir and Ol Formations; this record helps to reveal potential controls on fossil preservation in these cap carbonate successions. The Tsagaan Olom Group fossils increase the diversity of eukaryotic fossils from the Cryogenian and early Ediacaran and indicate the presence and persistence of diverse ecosystems during this critical period of Earth history.

Reconstructing the Growth of an Ancient Volcano from its Erosional Landscape Using Geomorphic and Petrologic Techniques - Akaroa Volcanic Complex, New Zealand

Noah Williams '17, Benson Worthington, Samuel Hampton, and Darren Gravley

Geological Society of America Abstracts with Programs 48(7) doi: 10.1130/abs/2016AM-284332, 2016

Heterogeneities in the architecture of constructional volcanoes impart a complex control on how the volcano will ultimately respond to deconstructional forces. Here, we present a geomorphic and petrologic study of the Miocene-aged Akaroa Volcanic Complex on the east coast of the South Island of New Zealand. Landscape features include lava domes, volcanic plugs, dykes, scoria cones and thick packages of stacked lavas that are most prominent in sea cliffs and in the walls of deeply eroded stream valleys. These valleys propagate radially from the inferred central vent region, and conspicuously, both valley walls and intervening ridges have a step-like geomorphology visible as what we refer to as 'benches'. Benches coincide with contacts between lava flows and/or where there are thin soil/ash horizons between lava flows. In addition, the dip of the benches fit within the range of possible lava flow dip directions as measured from their apparent dips. Lavas were sampled systematically up through stacked sequences (bracketed by benches) for petrographic and bulk-rock geochemical analysis. Using Google Earth Pro, the benches observed in the field were visualized in three dimensions and their traces were drawn. Google files were then exported to ArcMap where benches were color-coded based on elevation above sea level. Lavas sampled above and below benches record variation in porphyritic and aphyric textures, and evolving geochemical trends (i.e. primitive picrites and hawaiites to evolved mugearites). In comparing the geomorphic and rock chemistry data, two important preliminary results have been identified that will guide future research. Firstly, primary volcanic textures and compositions may be an important control on bench formation. Specifically, erosion may occur more laterally on aphyric and compositionally evolved lavas and more vertically on porphyritic and primitive lavas; however, more research will need to focus on the physical rock properties and erodability. Secondly, it may be possible to correlate benches around the volcano and, from bench/lava dip directions, these erosional structures could act as stratigraphic markers to help unravel the evolution of the volcanic complex by identifying relative ages of bracketed lava sequences from one valley to the next.

Mathematics and Statistics

Multi-Crossing Number for Knots and the Kauffman Bracket Polynomial

Colin Adams, Jesse Freeman '15, J. Daniel Irvine, Samantha Petti '15, Daniel Vitek, Ashley Weber, Sicong Zhang

Mathematical Proceedings of the Cambridge Philosophical Society, 1-32. Doi:10.1017/S0305004116000906, 2016.

We find a lower bound on the n-crossing number in terms of the span of the bracket polynomial, for any n. A multi-crossing (or n-crossing) is a singular point in a projection of a knot or link at which n strands cross so that each strand bisects the crossing. We generalize the classic result of Kauffman, Murasugi, and Thistlethwaite relating the span of the bracket polynomial to the double-crossing number of a link, span(<K>) ≤ 4c2, to the n-crossing number. We find a lower bound on the n-crossing number in terms of the span of the bracket polynomial for any n ≥ 3. Further, we present the first extensive list of calculations of n-crossing number for knots.

Volume and Determinant Density of Hyperbolic Rational Links

Colin Adams, Aaron Calderon, Xinyi Jiang, Alexander Kastner '17, Gregory Kehne '16, Nathaniel Mayer, Mia Smith '16

Journal of Knot Theory and its Ramifications, Vol. 26, 1750002, pages, 2016.

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,voct]. We construct sequences of alternating knots whose volume and determinant densities both converge to any x in [0,voct]. We also investigate the distributions of volume and determinant densities for hyperbolic rational links, and establish upper bounds and density results for these invariants.

The Galactic Math Repository

Colin Adams

Mathematical Intelligencer, Vol. 38, No. 2, 1-3, 2016.

How will our mathematical achievements compare to the rest of the galaxy when we join the Galactic Union?

Mathematicus

Colin Adams

Mathematical Intelligencer, Vol. 38, No. 3, 11-13, 2016.

What happens when students lead a "slave revolt" against mathematics?

The Math Museum

Colin Adams

Mathematical Intelligencer, Vol. 38, No. 4, 23-27, 2016.

A tale of a museum that is mathematical, but unfortunately, the exhibits do all they can to kill you.

The Topology Terrors

Colin Adams

Mathematical Intelligencer, Vol. 39, No. 1, 2017.

A dark tale of a murderous function that tears topological spaces asunder, and the detective who brings it to justice.

Predicting Bat Colony Survival Under Controls Targeting Multiple Transmission Routes of White-Nose Syndrome

Julie Blackwood, A.D. Meyer, D.F. Stevens '15,

Journal of Theoretical Biology, 409, 60-69, 2016.

White-nose syndrome (WNS) is a lethal infection of bats caused by the psychrophilic fungus Pseudo-gymnoascus destructans (Pd). Since the first cases of WNS were documented in 2006, it is estimated that as many as 5.5 million bats have succumbed in the United States — one of the fastest mammalian die-offs due to disease ever observed, and the first known sustained epizootic of bats. WNS is contagious between bats, and mounting evidence suggests that a persistent environmental reservoir of Pd plays a significant role in transmission as well. It is unclear, however, the relative contributions of bat-to-bat and environment-to-bat transmission to disease propagation within a colony. We analyze a mathematical model to investigate the consequences of both avenues of transmission on colony survival in addition to the efficacy of disease control strategies. Our model shows that selection of the most effective control strategies is highly dependent on the primary route of WNS transmission. Under all scenarios, however, generalized culling is ineffective and while targeted culling of infected bats may be effective under idealized conditions, it primarily has negative consequences. Thus, understanding the significance of environment-to-bat transmission is paramount to designing effective management plans.

The Role of Interconnectivity in Control of an Ebola Epidemic

Julie Blackwood, and L.M. Childs

Scientific Reports, 6, 29262, 2016.

Several West African countries - Liberia, Sierra Leone and Guinea - experienced significant morbidity and mortality during the largest Ebola epidemic to date, from late 2013 through 2015. The extent of the epidemic was fueled by outbreaks in large urban population centers as well as movement of the pathogen between populations. During the epidemic there was no known vaccine or drug, so effective disease control required coordinated efforts that include both standard medical and community practices such as hospitalization, quarantine and safe burials. Due to the high connectivity of the region, control of the epidemic not only depended on internal strategies but also was impacted by neighboring countries. In this paper, we use a deterministic framework to examine the role of movement between two populations in the overall success of practices designed to minimize the extent of Ebola epidemics. We find that it is possible for even small amounts of intermixing between populations to positively impact the control of an epidemic on a more global scale.

Dynamics Done With Your Bare Hands

Diana Davis with Bryce Weaver, Roland K.W. Roeder, and Pablo Lessa

European Mathematical Society, 2017.

This book arose from four lectures given at the Undergraduate Summer School of the Thematic Program Dynamics and Boundaries, held at the University of Notre Dame. It is intended to introduce (under)graduate students to the field of dynamical systems by emphasizing elementary examples, exercises, and bare hands constructions.

Negative Refraction and Tiling Billards

Diana Davis with Kelsey DiPietro, Jenny Rustad, and Alexander St. Laurent

Advances in Geometry, 2017.

We introduce a new dynamical system that we call tiling billiards, where trajectories refract through planar tilings. This system is motivated by a recent discovery of physical substances with negative indices of refraction. We investigate several special cases where the planar tiling is created by dividing the plane by lines, and we describe the results of computer experiments.

Big Data and the Missing Links

Richard De Veaux with Ron Snee and R. W. Hoerl

Statistical Analysis and Data Mining, Volume 9, Issue 6, pp 411–416, December 2016

Curriculum Guidelines for Undergraduate Programs in Data Science

Richard De Veaux with Mahesh Agarwal, Maia Averett, Benjamin S. Baumer, Andrew Bray,5Thomas C. Bressoud, Lance Bryant, Lei Z. Cheng, Amanda Francis, Robert Gould, Albert Y. Kim, Matt Kretchmar, Qin Lu, Ann Moskol, Deborah Nolan, Roberto Pelayo, Sean Raleigh, Ricky J. Sethi, Mutiara Sondjaja,Neelesh Tiruviluamala, Paul X. Uhlig, Talitha M. Washington, Curtis L. Wesley, David White, and Ping Ye

The Annual Review of Statistics and Its Application, Vol. 4:15-30, Volume publication date March 2017

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Stern Sequences for a Family of Multidimensional Continued Fractions: TRIP-Stern Sequences

Thomas Garrity with Amburg '14, Dasaratha, Flapan, Lee '12, Mihaila, Neumann-Chun '13, Peluse and Stoffregen

Journal of Integer Sequences, Article 17.1.7, 2017

The Stern diatomic sequence is closely linked to continued fractions via the Gauss map on the unit interval, which in turn can be understood via systematic subdivisions of the unit interval. Higher dimensional analogues of continued fractions, called multidimensional continued fractions, can be produced through various subdivisions of a triangle. We define triangle partition-Stern sequences (TRIP-Stern sequences for short), higher-dimensional generalizations of the Stern diatomic sequence, from the method of subdividing a triangle via various triangle partition algorithms. We then explore several combinatorial results about TRIP-Stern sequences, which may be used to give rise to certain well-known sequences. We finish by generalizing TRIP-Stern sequences and presenting analogous results for these generalizations.

A Proof of the Peak Polynomial Positivity Conjecture

Alexander Diaz-Lopez, Pamela E. Harris, Erik Insko, and Mohamed Omar

Journal of Combinatorial Theory, Series A, 149, 21-29, 2017.

We say that a permutation $\pi = \pi 1 \pi 2 \ldots \pi n \in S_n$ has a peak at index i if $\pi i\text{-}1 \bullet \pi i \bullet \pi i{+}1$. Let $P(\pi)$ denote the set of indices where π has a peak. Given a set S of positive integers, we define $P_S(n) = \{\pi \in S_n : P(\pi) = S\}$. In 2013 Billey, Burdzy, and Sagan showed that for subsets of positive integers S and sufficiently large n, $|P_S(n)| = p_S(n)2^{n-|S|-1}$ where $p_S(x)$ is a polynomial depending on S. They gave a recursive formula for $P_S(x)$ involving an alternating sum, and they conjectured that the coefficients of $p_S(x)$ expanded in a binomial coefficient basis centered at max(S) are all nonnegative. In this paper we introduce a new recursive formula for $|P_S(n)|$ without alternating sums and we use this recursion to prove that their conjecture is true.

Individual Gap Measures from Generalized Zeckendorf Decompositions

Robert Dorward, Pari Ford, *Eva Fourakis '16*, Pamela E. Harris, Steven J. Miller, Eyvi Palsson, and Hannah Paugh

Uniform Distribution Theory, vol. 12, No. 1, 27-36, 2017.

Zeckendorf's theorem states that every positive integer can be uniquely decomposed as a sum of nonconsecutive Fibonacci numbers. The distribution of the number of summands converges to a Gaussian, and the individual measures on gaps between summands for m ∈ [Fn, Fn+1) converge to geometric decay for almost all m as n ® ∞. While similar results are known for many other recurrences, previous work focused on proving Gaussianity for the number of summands or the average gap measure. We derive general conditions which are easily checked yield geometric decay in the individual gap measures of generalized Zeckendorf decompositions attached to many linear recurrence relations.

Peak Sets of Classical Coxeter Groups

Alexander Diaz-Lopez, Pamela E. Harris, Erik Insko, and Darleen Perez-Lavin

Involve, a Journal of Mathematics, Vol. 10, no. 2, pp. 263-290, 2017

We say a permutation $\pi = \pi 1 \pi 2 ... \pi_n$ in the symmetric group $\mathcal{S}_n$ has a peak at index i if $\pi_{i-1} < \pi 1 > \pi_{i+1}$ and we let $P(\pi) = \{i \in \{1, 2, \ldots, n\} | i \text{ is a peak of } \pi\}$. Given a set S of positive integers, we let $P(S;n)$ denote the subset of $\mathcal{S}_n$ consisting of all permutations π, where $P(\pi) = S$. In 2013, Billey, Burdzy, and Sagan proved $|P(S;n)| = p(n)2^{n-|S|-1}$, where $p(n)$ is a polynomial of degree $\max(S) - 1$. In 2014, Castro-Velez et al. considered the Coxeter group of type B_n as the group of signed permutations on n letters and showed that $|P_B(S;n)| = p(n)2^{2n-|S|-1}$ where $p(n)$ is the same polynomial of degree $\max(S) - 1$. In this paper we partition the sets $P(S;n) \subset \mathcal{S}_n$ studied by Billey, Burdzy, and Sagan into subsets $P(S;n)$ of permutations with peak set S that end with an ascent to a fixed integer k or a descent and provide polynomial formulas for the cardinalities of these subsets. After embedding the Coxeter groups of Lie type C_n and D_n into $\mathcal{S}_{2n}$, we partition these groups into bundles of permutations $\pi_1\pi_2 \ldots \pi_n \mid \pi_{n+1} \ldots \pi_{2n}$ such that $\pi_1\pi_2 \ldots \pi_n$ has the same relative order as some permutation $\sigma_1\sigma_2 ... \sigma_n \in Sn$. This allows us to count the number of permutations in types C_n and D_n with a given peak set S by reducing the enumeration to calculations in the symmetric group and sums across the rows of Pascal's triangle.

A Generalization of Zeckendorf's Theorem Via Circumscribed m-gons

Robert Dorward, Pari Ford, *Eva Fourakis '16*, Pamela E. Harris, Steven J. Miller, Eyvi Palsson, and Hannah Paugh

Involve, a Journal of Mathematics, 10-1, 125-150, 2017.

Zeckendorf's theorem states that every positive integer can be uniquely decomposed as a sum of nonconsecutive Fibonacci numbers, where the Fibonacci numbers satisfy Fn = Fn -1 + Fn-2 for n ≥ 3, F1 =1 and F2 =2. The distribution of the number of summands in such decomposition converges to a Gaussian, the gaps between summands converges to geometric decay, and the distribution of the longest gap is similar to that of the longest run of heads in a biased coin; these results also hold more generally, though for technical reasons previous work needed to assume the coefficients in the recurrence relation are non-negative and the first term is positive.

We extend these results by creating an infinite family of integer sequences called the m-gonal sequences arising from a geometric construction using circumscribed m-gons. They satisfy a recurrence where the first m+1leading terms vanish, and thus cannot be handled by existing techniques. We provide a notion of a legal decomposition, and prove that the decompositions exist and are unique. We then examine the distribution of the number of summands used in the decompositions and prove that it displays Gaussian behavior. There is geometric decay in the distribution of gaps, both for gaps taken from all integers in an interval and almost surely in distribution for the individual gap measures associated to each integer in the interval. We end by proving that the distribution of the longest gap between summands is strongly concentrated about its mean, behaving similarly as in the longest run of heads in tosses of a coin.

Legal Decompositions Arising from Non-positive Linear Recurrences

Minerva Catral, Pari Ford, Pamela E. Harris, Steven J. Miller, and Dawn Nelson

Fibonacci Quart. 54, no. 4, 348-365, 2016.

Zeckendorf's theorem states that any positive integer can be written uniquely as a sum of non-adjacent Fibonacci numbers; this result has been generalized to many recurrence relations, especially those arising from linear recurrences with leading term positive. We investigate legal decompositions arising from two new sequences: the (s,b)-Generacci sequence and the Fibonacci Quilt sequence. Both satisfy recurrence relations with leading term zero, and thus previous results and techniques do not apply. These sequences exhibit drastically different behavior. We show that the (s,b)-Generacci sequence leads to unique legal decompositions, whereas not only do we have non-unique legal decompositions with the Fibonacci Quilt sequence, we also have that in this case the average number of legal decompositions grows exponentially. Another interesting difference is that while in the (s,b)-Generacci case the greedy algorithm always leads to a legal decomposition, in the Fibonacci Quilt setting the greedy algorithm leads to a legal decomposition (approximately) 93% of the time. In the (s,b)-Generacci case, we again have Gaussian behavior in the number of summands as well as for the Fibonacci Quilt sequence when we restrict to decompositions resulting from a modified greedy algorithm.

Multiple Regression Analysis: Understanding the Impact of Offensive and Defensive Contributions to Team Performance

Steven Miller (with Kevin D. Dayaratna)

The Hockey Research Journal, 41-43, 2014/2015.

From evaluating team performance to predicting outcomes of particular matchups to understanding individual player contributions, rigorous statistical analysis has become increasingly useful in hockey over the past several decades. In recent years, there has been a variety of research projects offering quantitative assessments from a variety of perspectives. This study adds to those efforts.

A Probabilistic Approach to Generalized Zeckendorf Decompositions

Steven Miller with Iddo Ben-Ari

SIAM Journal on Discrete Mathematics, 30, no. 2, 1302-1332, 2016.

Generalized Zeckendorf decompositions are expansions of integers as sums of elements of solutions to recurrence relations. The simplest cases are base-b expansions, and the standard Zeckendorf decomposition uses the Fibonacci sequence. The expansions are finite sequences of nonnegative integer coefficients (satisfying certain technical conditions to guarantee uniqueness of the decomposition) and which can be viewed as analogues of sequences of variable-length words made from some fixed alphabet. In this paper we present a new approach and construction for uniform measures on expansions, identifying them as the distribution of a Markov chain conditioned not to hit a set. This gives a unified approach that allows us to easily recover results on the expansions from analogous results for Markov chains, and in this paper we focus on laws of large numbers, central limit theorems for sums of digits, and statements on gaps (zeros) in expansions. We expect the approach to prove useful in other similar contexts.

Lower-Order Biases in Elliptic Curve Fourier Coefficients in Families

Steven Miller (with B. Mackall '16, C. Rapti and K. Winsor)

Frobenius Distributions: Lang-Trotter and Sato-Tate Conjectures

(David Kohel and Igor Shparlinsky, editors)

Contemporary Mathematics 663, AMS, Providence, RI, 2016.

Let $E : y^2 = x^3 + A(T)x + B(T)$ be a nontrivial one-parameter family of elliptic curves over Q(T), with A(T), B(T) in Z[T], and consider the k-th moments $A_{k,E}(p) := \text{sum}_{t \bmod p}\, a_{Et}(p)^k$ of the Fourier coefficients $a_{Et}(p)$. Rosen and Silverman proved a conjecture of Nagao relating the first moment to the rank of the family over Q(T), and Michel proved that the second moment is equal to p2 + O (p3/2). Cohomological arguments show that the lower order terms are of sizes $p^{3/2}$, p, $p^{1/2}$, and 1. In every case we are able to analyze, the largest lower order term in the second moment expansion that does not average to zero is on average negative. We prove this "bias conjecture" for several large classes of families, including families with rank, complex multiplication, and unusual distributions of functional

equation signs. We also identify all lower order terms in large classes of families, shedding light on the arithmetic objects controlling these terms. The negative bias in these lower order terms has implications toward the excess rank conjecture and the behavior of zeros near the central point of elliptic curve L-functions.

From Quantum Systems to L-Functions: Pair Correlation Statistics and Beyond
Steven Miller (with Owen Barrett, Frank W.K. Firk, and Caroline Turnage-Butterbaugh)

Open Problems in Mathematics
(John Nash, Jr. and Michael Th. Rassias, editors)
Springer-Verlag, 2016.

The discovery of connections between the distribution of energy levels of heavy nuclei and spacings between prime numbers has been one of the most surprising and fruitful observations in the twentieth century. The connection between the two areas was first observed through Montgomery's work on the pair correlation of zeros of the Riemann zeta function. As its generalizations and consequences have motivated much of the following work, and to this day remains one of the most important outstanding conjectures in the field, it occupies a central role in our discussion below. We describe some of the many techniques and results from the past sixty years, especially the important roles played by numerical and experimental investigations, that led to the discovery of the connections and progress towards understanding the behaviors. In our survey of these two areas, we describe the common mathematics that explains the remarkable universality. We conclude with some thoughts on what might lie ahead in the pair correlation of zeros of the zeta function, and other similar quantities.

Some Results in the Theory of Low-Lying Zeros
Steven Miller (with Blake Mackall '15, Christina Rapti, Caroline Turnage-Butterbaugh and Karl Winsor and an Appendix with Megumi Asada '17, Eva Fourakis '16, Kevin Yang)

In Families of Automorphic Forms and the Trace Formula
(Werner Muller, Sug Woo Shin and Nicolas Templier, editors)
Simons Symposia Series, Springer-Verlag, 2016.

While Random Matrix Theory has successfully modeled the limiting behavior of many quantities of families of L-functions, especially the distributions of zeros and values, the theory frequently cannot see the arithmetic of the family. In some situations this requires an extended theory that inserts arithmetic factors that depend on the family, while in other cases these arithmetic factors result in contributions which vanish in the limit, and are thus not detected. In this chapter we review the general theory associated to one of the most important statistics, the n-level density of zeros near the central point. According to the Katz-Sarnak density conjecture, to each family of L-functions there is a a corresponding symmetry group (which is a subset of a classical compact group) such that the behavior of the zeros near the central point as the conductors tend to infinity agrees with the behavior of the eigenvalues near 1 as the matrix size tends to infinity. We show how these calculations are done, emphasizing the techniques, methods and obstructions to improving the results, by considering in full detail the family of Dirichlet characters with square-free conductors. We then move on and describe how we may associate a symmetry constant to each family, and how to determine the symmetry group of a compound family in terms of the symmetries of the constituents. These calculations allow us to explain the remarkable universality of behavior, where the main terms are independent of the arithmetic, as we see that only the first two moments of the Satake parameters survive to contribute in the limit. Similar to the Central Limit Theorem, the higher moments are only felt in the rate of convergence to the universal behavior. We end by exploring the effect of lower order terms in families of elliptic curves. We present evidence supporting a conjecture that the average second moment in one-parameter families without complex multiplication has, when appropriately viewed, a negative bias, and end with a discussion of the consequences of this bias on the distribution of low-lying zeros, in particular relations between such a bias and the observed excess rank in families.

Crescent Configurations
Steven Miller (with David Burt '17, Eli Goldstein, Sarah Manski, Eyvindur Ari Palsson and Hong Suh, editors)
Integers (Electronic Journal of Combinatorical Number Theory) 16, #A38, 2016

In 1989, Erdos conjectured that for a sufficiently large n it is impossible to place n points in general position in a

plane such that for every 1 < = i < = n - 1 there is a distance that occurs exactly i times. For small n this is possible and in his paper he provided constructions for n = 8. The one for n = 5 was due to Pomerance while Palasti came up with the constructions for n = 7, 8. Constructions for n = 9 and above remain undiscovered, and little headway has been made toward a proof that for sufficiently large n no configuration exists. In this paper we consider a natural generalization to higher dimensions and provide a construction which shows that for any given n there exists a sufficiently large dimension d such that there is a configuration in d-dimensional space meeting Erdos' criteria.

The Emergence of 4-Cycles in Polynomial Maps Over the Extended Integers

Steven Miller with *Andrew Best '15*, Patrick Dynes, Jasmine Powell and Ben Weiss)

Minnesota Journal of Undergraduate Mathematics 2, no. 1, 14 pages, 2016-2017.

Let f(x) in Z[x]; for each integer alpha it is interesting to consider the number of iterates nα, if possible, needed to satisfy $f^n_\alpha(\alpha) = \alpha$. The sets $\{\alpha, f(\alpha), ..., f^{h-1}(\alpha)\}$ generated by the iterates of f are called cycles. For Z[x] it is known that cycles of length 1 and 2 occur, and no others. While much is known for extensions to number fields, we concentrate on extending Z by adjoining reciprocals of primes. Let $Z[1/p_1, ..., 1/p_n]$ denote Z extended by adding in the reciprocals of the n primes $p_1, ..., p_n$ and all their products and powers with each other and the elements of Z. Interestingly, cycles of length 4, called 4-cycles, emerge under the appropriate conditions for polynomials in $Z[1/p_1, ..., 1/p_n][x]$. The problem of finding criteria under which 4-cycles emerge is equivalent to determining how often a sum of four terms is zero, where the terms are pm 1 times a product of elements from the list of n primes. We investigate conditions on sets of primes under which 4-cycles emerge. We characterize when 4-cycles emerge if the set has one or two primes, and (assuming a generalization of the ABC conjecture) find conditions on sets of primes guaranteed not to cause 4-cycles to emerge.

The Probability Lifesaver

Steven Miller

Princeton University Press, 2017.

Welcome to "The Probability Lifesaver". My goal is to write a book introducing students to the material through lots of worked out examples and code, and to have lots of conversations about not just why equations and theorems are true, but why they have the form they do. In a sense, this is a sequel to Adrian Banner's successful "The Calculus Lifesaver". In addition to many worked out problems, there are frequent explanations of proofs of theorems, with great emphasis placed on discussing why certain arguments are natural and why we should expect certain forms for the answers. Knowing why something is true, and how someone thought to prove it, makes it more likely for you to use it properly and discover new relations yourself. The book highlights at great lengths the methods and techniques behind proofs, as these will be useful for more than just a probability class. See, for example, the extensive entries in the index on proof techniques, or the discussion on Markov's inequality in §17.1. There are also frequent examples of computer code to investigate probabilities. This is the 21st century; if you cannot write simple code you are at a competitive disadvantage. Writing short programs helps us check our math in situations where we can get a close form solution; more importantly, it allows us to estimate the answer in situations where the analysis is very involved and nice solutions may be hard to obtain (if possible at all!).

Isoperimetric Symmetry Breaking: A Counterexample to a Generalized Form of the Log-Convex Density Conjecture

Frank Morgan

Anal. Geom. Metr. Spaces 4, 314 - 316, 2016

We give an example of a smooth surface of revolution for which all circles about the origin are strictly stable for fixed area but small isoperimetric regions are nearly round discs away from the origin.

Isoperimetry with Density

Frank Morgan

CIRM Audiovisual Mathematics Library video

http://library.cirm-math.fr/Record.htm?idlist=21&record=19281860124910090429

A video of my talk at the CIRM conference on "Shape Optimization and Isoperimetric and Functional Inequalities," Luminy, November, 2016. The talk featured open questions and recent results on the isoperimetric problem in the presence of a density, including some by my students.

Symmetries of Cairo-Prismatic Tilings

Frank Morgan, *John Berry '16*, Matthew Dannenberg, Jason Liang, Yingyi Zeng

Rose-Hulman Und. Math. J. 17, http://scholar.rose-hulman.edu/rhumj/vol17/iss2/3,2016

Morgan's 2014 NSF SMALL undergraduate research Geometry Group studies and catalogs isoperimetric, planar tilings by unit-area Cairo and Prismatic pentagons. In particular, in counterpoint to the five wallpaper symmetry groups known to occur in Cairo-Prismatic tilings, they show that the five with order three rotational symmetry cannot occur.

Isoperimetric Regions in R^n with Density r^p

Frank Morgan, *Wyatt Boyer '15*, Bryan Brown, Gregory Chambers, Alyssa Loving, and Sarah Tammen

Anal. Geom. Metr. Spaces 4, 236–265, 2016

Morgan's 2015 NSF SMALL undergraduate research Geometry Group proves the conjectured most efficient regions in Rn with density rp.

Math in Cuba

Frank Morgan

Huffington Post blog, March 6, 2017.

A report on the state of mathematics in Cuba, including undergraduate research, after my visit.

The Tropical Commuting Variety

Ralph Morrison and Ngoc M. Tran

Linear Algebra and its Applications 507, 300-321, 2016

We study tropical commuting matrices from two viewpoints: linear algebra and algebraic geometry. In classical linear algebra, there exist various criteria to test whether two square matrices commute. We ask for similar criteria in the realm of tropical linear algebra, giving conditions for two tropical matrices that are polytropes to commute. From the algebro-geometric perspective, we explicitly compute the tropicalization of the classical variety of commuting matrices in dimension 2 and 3.

Weak Rational Ergodicity Does Not Imply Rational Ergodicity

Cesar Silva with Terrence Adams

Israel Journal of Mathematics, 214, 491 – 506, 2016

We construct an uncountable family of rank-one infinite measure-preserving transformations that are weakly rationally ergodic, but are not rationally ergodic, thus answering an open question by showing that weak rational ergodicity does not imply rational ergodicity.

The Mathematical Work of John C. Oxtoby

Cesar Silva with Steve Alpern and Joseph Auslander

Contemporary Mathematics 678, 43—51, 2016

We describe the mathematical work of John C. Oxtoby.

Ergodic Theory, Dynamical Systems, and the Continuing Influence of John C. Oxtoby

Cesar Silva with Joseph Auslander and Aimee Johnson, Editors

Contemporary Mathematics, American Mathematical Society 678, 2016

Proceedings of the three conferences: Oxtoby Centennial Conference held at Bryn Mawr College, Bryn Mawr, PA, October 30–31, 2010; Williams Ergodic Theory Conference held at Williams College, Williamstown, MA, July 27–29, 2012; AMS Special Session on Ergodic Theory and Symbolic Dynamics held in Baltimore, MD, January 17–18, 2014.

If a Prime Divides a Product

Cesar Silva with Steven J. Miller

The College Mathematics Journal, 48, 123-128, 2017

One of the greatest difficulties encountered by all in their first proof-intensive class is subtly assuming an unproven fact in a proof. The purpose of this note is to describe a specific instance where this can occur, namely in results related to unique factorization and the concept of the greatest common divisor.

Orthogonal Polynomials on the Unit Circle, CMV Matrices, and the Distribution of Their Eigenvalues

Mihai Stoiciu, Associate Professor of Mathematics

Memoria - Seminario de Operadores y Fisica-Matematica, IIMAS-UNAM, Vol. 1, 41-62, 2016

We give a brief introduction to the theory of orthogonal polynomials on the unit circle (OPUC) and the associated CMV matrices. From the point of view of orthogonal polynomials, the CMV matrices are unitary analogues of the Jacobi matrices. We consider various classes of random and deterministic CMV matrices and study the distribution of their eigenvalues. More precisely, we consider CMV matrices with random decaying coefficients and CMV matrices associated to hyperbolic reflection groups. As the spectral measures approach an absolutely continuous measure, the repulsion between the eigenvalues increases and the eigenvalue distribution converges to the "clock" (or "picket fence") distribution.

Asymptotics for Scaled Kramers-Smoluchowski Equations

Peyam Tabrizian and Lawrence C. Evans

SIAM Journal of Mathematical Analysis, 84, no. 4, 2944-2961, 2016.

We offer fairly simple proofs of the asymptotics for the scaled Kramers-Smoluchowski equation in both one and higher dimensions. For the latter, we invoke the sharp asymptotic capacity estimates of Bovier-Eckhoff-Gayrard-Klein.

Mixed Data and Classification of Transit Stop

Laura L. Tupper, David S. Matteson, and John C. Handle

Proceedings of the 2016 IEEE International Conference on Big Data: 2nd International Workshop on Big Data for Sustainable Development, Washington, DC, pp 2225-2232, December 5-8, 2016

An analysis of the characteristics and behavior of individual bus stops can reveal clusters of similar stops, which can be of use in making routing and scheduling decisions, as well as determining what facilities to provide at each stop. This paper provides an exploratory analysis, including several possible clustering results, of a dataset provided by the Regional Transit Service of Rochester, NY. The dataset describes ridership on public buses, recording the time, location, and number of entering and exiting passengers each time a bus stops. A description

of the overall behavior of bus ridership is followed by a stop-level analysis. We compare multiple measures of stop similarity, based on location, route information, and ridership volume over time.

Automated Parameter Blocking for Efficient Markov Chain Monte Carlo Sampling
Daniel Turek, Perry de Valpine, Christopher Paciorek and Clifford Anderson-Bergman

Bayesian Analysis, 12, 2, 465-490, 2017

We propose an automated procedure to determine an efficient MCMC block-sampling algorithm for a given model and computing platform. Our procedure dynamically determines blocks of parameters for joint sampling that result in efficient MCMC sampling of the entire model.

Programming with Models: Writing Statistical Algorithms for General Model Structures with NIMBLE
Perry de Valpine, Daniel Turek, Christopher Paciorek, Clifford Anderson-Bergman,
Duncan Temple Lang and Rastislav Bodik

Journal of Computational and Graphical Statistics, 26, 2, 403-413, 2017

We describe NIMBLE, a system for programming statistical algorithms for general model structures within R. NIMBLE is designed to meet three challenges: flexible model specification, a language for programming algorithms that can use different models, and a balance between high-level programmability and execution efficiency.

Physics

Codon Clarity or Conundrum?
Daniel P. Aalberts, Grégory Boël, and John Hunt

Cell Systems 4, 16–19 (2017)

Synonymous variations in protein-coding sequences alter protein expression dynamics, which has important implications for cellular physiology and evolutionary fitness, but disentangling the underlying molecular mechanisms remains challenging.

Automatic quantum experiment control: from circuit compiler to ion routing
Stevens, K. E., Amini, Jason M., Doret, S. Charles, Volin, Curtis, and Harter, Alexa

Quant. Inf. Proc. 16, doi:10.1007/s11128-016-1454-1 (2017)

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 complex. 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.

Effect of input phase modulation to a phase-sensitive optical amplifier
Kevin Jones et. al.

Optics Express 17, 19871-19880 (2016)

Many optical applications depend on amplitude modulating optical beams using devices such as acousto-optical modulators (AOMs) or optical choppers. Methods to add amplitude modulation (AM) often inadvertently impart phase modulation (PM) onto the light as well. While this PM is of no consequence to many phase-insensitive applications, phase-sensitive processes can be affected. Here we study the effects of input phase and amplitude modula-

tion on the output of a quantum-noise limited phase-sensitive optical amplifier (PSA) realized in hot 85Rb vapor. We investigate the dependence of PM on AOM alignment and demonstrate a novel approach to quantifying PM by using the PSA as a diagnostic tool. We then use this method to measure the alignment-dependent PM of an optical chopper which arises due to diffraction effects as the chopper blade passes through the optical beam.

Measurement of the scalar polarizability of the indium 6p1/2 state using two-step atomic-beam spectroscopy

Benjamin L. Augenbraun '15, Allison Carter '16 , P. M. Rupasinghe, and P. K. Majumder

Phys. Rev. A 94, 022515 (2016)

We have completed a measurement of the Stark shift within the 115In 6s1/2 → 6p1/2 excited-state transition using two-step laser spectroscopy in an indium atomic beam. By combining this measurement with recent experimental results we determine the scalar polarizability α0 of the 6p1/2 state to be 7683 ± 43 a03 (in atomic units), a result which agrees very well with recent theoretical calculations. In this experiment, one laser, stabilized to the 5p1/2 → 6s1/2 410 nm transition, was directed transversely to the atomic beam, while a second, overlapping laser was scanned across the 1343 nm 6s1/2 → 6p1/2 transition. We utilized two-tone frequency-modulation spectroscopy of the infrared laser beam to measure the second-step absorption in the interaction region, where the optical depth is less than 10−3. In the course of our experimental work we also determined the hyperfine splitting within the 6p1/2 state, improving upon the precision of an existing measurement.

One qubit and one photon: The simplest polaritonic heat engine

Q. Song, S. Singh, K. Zhang, W. Zhang, and P. Meystre

Phys. Rev. A 94, 063852 (2016)

Hybrid quantum systems can often be described in terms of polaritons. These are quasiparticles formed of superpositions of their constituents, with relative weights depending on some control parameter in their interaction. In many cases, these constituents are coupled to reservoirs at different temperatures. This suggests a general approach to the realization of polaritonic heat engines where a thermodynamic cycle is realized by tuning this control parameter. Here we discuss what is arguably the simplest such engine, a single qubit coupled to a single photon. We show that this system can extract work from feeble thermal microwave fields. We also propose a quantum measurement scheme of the work and evaluate its backaction on the operation of the engine.

Detecting continuous gravitational waves with superfluid 4He

S. Singh, L.A. DeLorenzo, I. Pikovski, and K.C. Schwab

arXiv:1606.04980 [gr-qc] (2016)

Direct detection of gravitational waves is opening a new window onto our universe. Here, we study the sensitivity to continuous-wave strain fields of a kg-scale optomechanical system formed by the acoustic motion of superfluid helium- 4 parametrically coupled to a superconducting microwave cavity. This narrowband detection scheme can operate at very high Q-factors, while the resonant frequency is tunable through pressurization of the helium in the 0.1-1.5 kHz range. The detector can therefore be tuned to a variety of astrophysical sources and can remain sensitive to a particular source over a long period of time. For thermal noise limited sensitivity, we find that strain fields on the order of h ~ 10−23/√Hz are detectable. Measuring such strains is possible by implementing state of the art microwave transducer technology. We show that the proposed system can compete with interferometric detectors and potentially surpass the gravitational strain limits set by them for certain pulsar sources within a few months of integration time.

Quantum state synthesis of superconducting resonators

Roshan Sharma and Frederick W. Strauch

Phys. Rev. A 93, 012342 (January 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 (March 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.

Electroweak baryogenesis from a dark sector

James M. Cline, Kimmo Kainulainen, and David Tucker-Smith

Phys. Rev. D 95, 115006 (2017)

Adding an extra singlet scalar S to the Higgs sector can provide a barrier at tree level between a false vacuum with restored electroweak symmetry and the true one. This has been demonstrated to readily give a strong phase transition as required for electroweak baryogenesis. We show that with the addition of a fermionic dark matter particle coupling to S, a simple UV-complete model can realize successful electroweak baryogenesis. The dark matter gets a CP asymmetry that is transferred to the standard model through a CP portal interaction, which we take to be a coupling of χto τleptons and an inert Higgs doublet. The CP asymmetry induced in left-handed τleptons biases sphalerons to produce the baryon asymmetry. The model has promising discovery potential at the LHC, while robustly providing a large enough baryon asymmetry and correct dark matter relic density with reasonable values of the couplings.

Merging contradictory laws: Imagining a constructive derivation of quantum theory

William K. Wootters

Ian T. Durham and Dean Rickles (Eds.), Information and Interactions: Eddington, Wheeler, and the Limits of Knowledge (pp. 167-180). Springer (2017)

In quantum theory, a probability is computed by squaring the magnitude of a complex probability amplitude, which is often computed by summing other complex probability amplitudes. As familiar as this procedure has become, it remains puzzling that nature should be constructed in this way. A number of authors have sought to make quantum theory less mysterious by providing an axiomatic basis for the theory. In this paper I explore a different, admittedly speculative approach to deriving quantum theory, not directly through axioms but rather by formulating a hypothetical underlying theory. The approach I follow focuses on the problem of making the connection between objects that appear in the theory and objects that appear in the world. I explore a particular toy model of binary measurements, in which the probabilistic law of nature is obtained by merging all the different "classical" laws imaginable in a certain setting. The merging is done by judiciously identifying preparations and measurements referred to in the classical laws with devices that exist in the toy world. The toy model does not lead to quantum theory, even for qubits. But it is interesting to see in what ways it fails.

Psychology

Childhood Precursors of Adult Borderline Personality Disorder Features

Phebe Cramer

Journal of Nervous and Mental Disease, 204, 494 – 499, 2016.

This study identifies childhood personality traits that are precursors of adult Borderline Personality Disorder (BPD) features. In a longitudinal study, childhood personality traits were assessed at age 11 (N = 100) using the California Child Q-set (CCQ: Block and Block, 1980). A number of these Q-items were found to be significantly correlated ($p < 0.001$) with a prototype based measure of BPD features at age 23. Factor analysis of these Q-items suggested that they could be characterized by two underlying personality dimensions: Impulsivity and Nonconformity/Aggression. The findings thus provide evidence that childhood personality traits predict adult BPD features. Identifying such childhood precursors provides an opportunity for early intervention.

Defense Mechanism Card Pull in TAT Stories

Phebe Cramer

Journal of Personality Assessment, 2016.

This study investigates the question of whether different Thematic Apperception Test (TAT; Murray, 1943) cards are likely to prompt stories that are characterized by different defense mechanisms. This condition is known as card pull and refers to the probability that different TAT cards elicit different personality scores for the same variable. If so, the assessment of defense use would be importantly influenced by the TAT cards used in an assessment. TAT stories from 3 different community samples were examined (Ns D 91,98, 121), using a statistical method developed by Stein et al (2014). The results indicated that different TATcards pull for different defenses, as assessed by the Defense Mechanism Manual (DMM: Cramer, 1991b). However, the nature of card pull was not always consistent across samples. These dissimilarities could be due to group differences, or to the presence of different TAT cards used in the test battery, indicating that card pull is importantly determined by context.

Identity Change Between Late Adolescence and Early Adulthood

Phebe Cramer

Personality and Individual Differences, 104, 538-543, 2017.

Change in Identity status between age 18, age 22, and age 35 was studied. Longitudinal change in four identity statuses – Diffused, Foreclosed, Moratorium and Achieved – was examined using Hierarchical Linear Modeling (HLM). The results indicated that the developmental level of identity generally progressed between age 18 and age 35. However, there was significant variability among the participants in the degree to which they had changed. Age 18 personality variables of Narcissism and Defense Mechanisms were found to predict both the direction and magnitude of change at age 35. However, these personality variables, when assessed at subsequent ages (22, 35), were not associated with identity change.

Defense Mechanisms and Utilization in Cancer Patients Undergoing Radiation Therapy: A Pilot Study

John H. Porcerelli, Phebe Cramer, Daniel J. Porcerelli & V. Elayne Arterbery

Journal of Nervous and Mental Disease, 2017.

A group of 49 patients who had been diagnosed with cancer during the preceding year and who were receiving radiation therapy were assessed for their use of defense mechanisms, as well as for their level of psychological distress. In addition, their utilization of medical services was determined. It was predicted that the use of services that were under the patients' control-namely, requesting extra outpatient visits and making trips to the emergency department-would be related to the patients' use of defense mechanisms, whereas a treatment option not under the patients' control-overnight hospitalization based on physicians' assessment of condition-would not be related to defense use. The findings confirmed the hypotheses. Outpatient visits were strongly predicted by defense use, whereas hospitalization was determined by psychological distress. However, emergency department visits were determined by both defense use and psychological distress. In addition, an interaction between defense and distress was found to predict hospitalization.

Self-Esteem, Skin Color a Rural/Urban Residence: Specially Annotated Methods of a Quasi-experimental Design Utilizing Child and Interviewer Ratings

Gail. M. Ferguson & Phebe Cramer

In L. Cook & T. Bastick (Eds.), Annotated Research Methods in Caribbean Research, Quantitative (Vol 1). Champaign, IL: Common Grounds (2017)

Local Terms and Understandings of Mental Health Problems in Burundi

P. Irankunda '13, L. Heatherington & J.J. Fitts '13

Journal of Transcultural Psychiatry, 54, 66-85, 2017.

A pilot study and two intensive studies were conducted to document the local vocabularies used by Burundians to describe mental health problems and their understandings about the causes. The pilot study—in which 14 different large groups of community members awaiting appointments at a village health clinic were engaged in open-ended discussions of the local terminology and causal beliefs about mental health problems—suggested three key syndromes: akabonge (a set of depression-like symptoms), guhahamuka (a set of trauma-related symptoms), and ibisigo (a set of psychosis-like symptoms). In Study 1 (N = 542), individual interviews or surveys presented participants with the names of these syndromes and asked what they considered to be the symptoms and causes of them. Study 2 (N = 143) cross-validated these terms with a different sample (also in individual interviews/surveys), by presenting the symptom clusters and asking what each would be called and about their causes. Findings of both studies validated this set of terms and yielded a rich body of data about causal beliefs. The influence of education level and gender on familiarity with these terms was also assessed. Implications for the development of mental health services and directions for future research are discussed.

Mental Health Treatment Outcome Expectancies in Burundi

P. Irankunda '13 & L. Heatherington

Journal of Transcultural Psychiatry, 54, 46-65, 2017.

Best practices in global mental health stress the importance of understanding local values and beliefs. Research demonstrates that expectancies about the effectiveness of a given treatment significantly predicts outcome, beyond the treatment effect itself. To help inform the development of mental health interventions in Burundi, we studied expectancies about the effectiveness of four treatments: spiritual healing, traditional healing, medication, and selected evidence-based psychosocial treatments widely used in the US. Treatment expectancies were assessed for each of three key syndromes identified by previous research: akabonge (a set of depression-like symptoms), guhahamuka (a set of trauma-related symptoms), and ibisigo (a set of psychosis-like symptoms). In individual interviews or written surveys in French or Kirundi with patients (N = 198) awaiting treatment at the clinic, we described each disorder and the treatments in everyday language, asking standard efficacy expectations questions about each ("Would it work?" "Why or why not?"). Findings indicated uniformly high expectancies about the efficacy of spiritual treatment, relatively high expectancies for western evidence-based treatments (especially cognitive behavior therapy [CBT] for depression-like symptoms), lower expectancies for medicine, and especially low expectancies for traditional healing (except for traditional healing for psychosis-like symptoms). There were significant effects of gender but not of education level. Qualitative analyses of explanations provide insight into the basis of people's beliefs, their explanations about why a given treatment would or would not work varied by type of disorder, and reflected beliefs about underlying causes. Implications for program development and future research are discussed.

Police Interrogation Elicits a Biphasic Process of Resistance from Suspects

Stephanie Madon, Max Guyll, Yueran Yang, Laura Smalarz, Justin Marschall, and Daniel Lannin

Law and Human Behavior, 41, 159-172.

We conducted two experiments to test whether police interrogation elicits a biphasic process of resistance from suspects. According to this process, the initial threat of police interrogation mobilizes suspects to resist interrogative influence in a manner akin to a fight or flight response, but suspects' protracted self-regulation of their behavior during subsequent questioning increases their susceptibility to interrogative influence in the long-run. In Experiment 1 (N = 316), participants who were threatened by an accusation of misconduct exhibited responses indicative of mobilization and more strongly resisted social pressure to acquiesce to suggestive questioning than did participants who

were not accused. In Experiment 2 (N = 160), self-regulatory decline that was induced during questioning about misconduct undermined participants' ability to resist suggestive questioning. These findings support a theoretical account of the dynamic and temporal nature of suspects' responses to police interrogation over the course of questioning.

Miranda at 50: A Psychological Analysis

Laura Smalarz, Kyle Scherr, and Saul Kassin

Current Directions in Psychological Science, 25(6), 455–460.

In 1966, the U.S. Supreme Court handed down a controversial ruling in Miranda v. Arizona, which required police to inform suspects, prior to custodial interrogation, of their constitutional rights to silence and to counsel. In commemoration of the 50th anniversary of Miranda, we present a psychological analysis of the Court's ruling. We show how the Court's assumption that the provisions of the Miranda ruling would enable suspects to make knowing, intelligent, and voluntary decisions regarding whether to invoke or waive their constitutional rights has not been borne out by scientific research. Hence, we argue that even well-adjusted, intelligent adults are at risk of succumbing to police pressure during custodial interrogation. We conclude with policy implications and directions for future Miranda research.

The Perfect Match: Do Criminal Stereotypes Bias Forensic Evidence Analysis?

Laura Smalarz, Stephanie Madon, Yueran Yang, and Sarah Buck

Law and Human Behavior, 40, 420-429.

This research provided the first empirical test of the hypothesis that stereotypes bias evaluations of forensic evidence. A pilot study (N = 107) assessed the content and consensus of 20 criminal stereotypes by identifying perpetrator characteristics (e.g., sex, race, age, religion) that are stereotypically associated with specific crimes. In the main experiment (N = 225), participants read a mock police incident report involving either a stereotyped crime (child molestation) or a nonstereotyped crime (identity theft) and judged whether a suspect's fingerprint matched a fingerprint recovered at the crime scene. Accompanying the suspect's fingerprint was personal information about the suspect of the type that is routinely available to fingerprint analysts (e.g., race, sex) and which could activate a stereotype. Participants most often perceived the fingerprints to match when the suspect fit the criminal stereotype, even though the prints did not actually match. Moreover, participants appeared to be unaware of the extent to which a criminal stereotype had biased their evaluations. These findings demonstrate that criminal stereotypes are a potential source of bias in forensic evidence analysis and suggest that suspects who fit criminal stereotypes may be disadvantaged over the course of the criminal justice process.

Childhood Adversity Moderates the Influence of Proximal Episodic Stress on the Cortisol Awakening Response and Depressive Symptoms in Adolescents

L. Starr, K. Dienes, C.B. Stroud, Z.A. Shaw, Y.I. Li, F. Mlawer '14 & M Huang

Development & Psychopathology, in press.

Childhood adversity (CA) is known to predict sensitization to proximal stressors. Researchers have suggested that disruptions in hypothalamic-pituitary-adrenal axis functioning may be a biological mechanism. If so, CA may predict altered associations between proximal life stress and markers of cortisol secretion. We examined whether CA moderates associations between recent episodic stress and a) the cortisol awakening response (CAR), and b) depressive symptoms, in 241 adolescents aged 14-17 years (cortisol n = 196). Salivary cortisol was sampled at 0, 30, and 60 minutes post-awakening for two days. The CAR was calculated as the area under the curve with respect to increase and waking cortisol. CA and episodic stress were assessed using contextual-threat-method-coded objective interviews. CA significantly interacted with episodic stress to predict both the CAR and depression. Among those with low CA, episodic stress predicted increased CAR but did not predict depression. For adolescents with high CA, episodic stress predicted lower CAR and higher depression. These interactions were found only for independent (uncontrollable, fateful) events, and not for dependent (self-generated) stress. Increased allostatic load resulting from CA exposure may interfere with adolescents' ability to optimally regulate their CAR in relation to recent stress, contributing to increased depression risk.

Interpersonal Dysfunction in Personality Disorders: A Meta-Analytic Review

S. Wilson, C. B. Stroud & C. E. Durbin

Psychological Bulletin, in press.

Personality disorders are defined in the current psychiatric diagnostic system as pervasive, inflexible, and stable patterns of thinking, feeling, behaving, and interacting with others. Questions regarding the validity and reliability of the current personality disorder diagnoses prompted a reconceptualization of personality pathology in the most recent edition of the psychiatric diagnostic manual, in an appendix of emerging models for future study. To evaluate the construct and discriminant validity of the current personality disorder diagnoses, we conducted a quantitative synthesis of the existing empirical research on associations between personality disorders and interpersonal functioning, defined using the interpersonal circumplex model (comprising orthogonal dimensions of agency and communion), as well as functioning in specific relationship domains (parent–child, family, peer, romantic). A comprehensive literature search yielded 127 published and unpublished studies, comprising 2,579 effect sizes. Average effect sizes from 120 separate meta-analyses, corrected for sampling error and measurement unreliability, and aggregated using a random-effects model, indicated that each personality disorder showed a distinct profile of interpersonal style consistent with its characteristic pattern of symptomatic dysfunction; specific relationship domains affected and strength of associations varied for each personality disorder. Overall, results support the construct and discriminant validity of the personality disorders in the current diagnostic manual, as well as the proposed conceptualization that disturbances in self and interpersonal functioning constitute the core of personality pathology. Importantly, however, contradicting both the current and proposed conceptualizations, there was not evidence for pervasive dysfunction across interpersonal situations and relationships.

Daily and Trait Rumination: Diurnal Cortisol Patterns in Adolescent Girls

L. M. Hilt, M. S. Sladek, L. D. Doane & C. B. Stroud

Cognition & Emotion, in press.

Rumination is a maladaptive form of emotion regulation associated with psychopathology. Research with adults suggests that rumination covaries with diurnal cortisol rhythms, yet this has not been examined among adolescents. Here, we examine the day-to-day covariation between rumination and cortisol, and explore whether trait rumination is associated with alterations in diurnal cortisol rhythms among adolescent girls. Participants (N = 122) provided saliva samples 3 times per day over 3 days, along with daily reports of stress and rumination, questionnaires assessing trait rumination related to peer stress, and diagnostic interviews assessing depression and anxiety. Greater rumination than usual during the day was associated with lower cortisol awakening responses the following morning, but this effect was not significant after accounting for wake time and an objective measure of adherence to the saliva sampling protocol. Trait rumination was associated with lower average cortisol levels at waking and flatter diurnal slopes, accounting for wake time, protocol compliance, and other factors. These patterns may help to explain why rumination is related to the development of psychopathology.

Coping and Diurnal Cortisol Patterns among Early Adolescent Girls: Between- and Within-Person Associations

M. Sladek, L. Doane & C.B. Stroud

Journal of Youth and Adolescence, in press.

Prior work has identified alterations in activity of the hypothalamic-pituitary-adrenal axis as a potential mechanism underlying stress-induced emotional health problems, which disproportionately impact girls beginning in mid-adolescence. How adolescent girls differ from one another in dispositional coping tendencies and shift specific coping strategies in response to varying stressors have been theorized as important predictors of their adaptation, health, and well-being during this dynamic period of development. The goal of this study was to examine whether individual and day-to-day (within-person) differences in adolescent girls' coping responses are associated with daily patterns of hypothalamic-pituitary-adrenal axis activity, indexed by cortisol. Participants were 122 early adolescent girls (M age = 12.39) who provided three saliva samples per day for 3 days and completed daily coping reports, as well as a standard coping survey. Participants and primary caregivers also completed objective life stress interviews. On average, girls who were more likely to respond to interpersonal stress with voluntary engagement (active) coping exhibited generally adaptive daily physiological regulation—steeper diurnal cortisol slopes, lower total diurnal

cortisol output, and lower cortisol awakening responses. Chronic interpersonal stress level significantly moderated these associations in different ways for two distinct components of the diurnal pattern—the slope and cortisol awakening responses. Regarding within-person differences, using active coping more than usual was associated with higher waking cortisol the following morning, which may help to prepare adolescent girls for perceived daily demands. These findings highlight the interactive influence of stress and coping in the prediction of daily hypothalamic-pituitary-adrenal axis activity and support the stress-buffering role of active coping for adolescent girls.

Rumination, Excessive Reassurance Seeking and Stress Generation Among Early Adolescent Girls

C. B. Stroud, *E. E. Sosoo '13* & S.Wilson

Journal of Early Adolescence, in press.

Nolen-Hoeksema (1991) proposed that rumination increases stressful events and circumstances; however, few studies have examined this question. Thus, we explored whether a) rumination predicted increases in the generation of chronic and acute stress; b) excessive reassurance seeking (ERS) mediated links between rumination and stress generation; c) rumination increased exposure to acute independent (uncontrollable) stress; and d) rumination predicted chronic stress generation in certain domains, but not others. These questions were examined in a one-year study of 126 early adolescent girls (M age = 12.39 years) using contextual objective stress interviews. Findings indicated that rumination predicted increases in acute dependent interpersonal stress and chronic interpersonal stress, and ERS mediated these associations. Moreover, rumination was not associated with acute independent stress. Finally, the effect of rumination on chronic stress generation was most salient in adolescents' romantic lives and in parent-adolescent relationships. These findings suggest that ruminators create stressful interpersonal environments.

Mood Disorders and Anxiety

J. Davila, L. R. Starr, C.B. Stroud & I. Li

In B.H. Fiese, M. Celano, K. Deater-Deckard, E. Jouriles & M Whisman (Eds.), APA Handbook of Contemporary Family Psychology, Volume II: Applications of Contemporary Family Psychology, Washington, DC: American Psychological Association (in press)

Mood and anxiety disorders are highly prevalent among youth and adults (Kessler, Ruscio, Shear & Wittchen, 2009; Kessler et al., 2014). They also are associated with significant interpersonal impairment both as a cause and a consequence. Nowhere has this been more evident than in the context of functioning in romantic and family relationships. This chapter provides an overview of the literature on mood (specifically depression and bipolar disorder), and anxiety disorders in these contexts, briefly describes couple and family interventions for these disorders, and highlights directions for future research.

Pubertal Timing

C. B. Stroud & J.Davila

In R.J. Levesque (Ed.), Encyclopedia of Adolescence, 2nd Ed. New York: Springer (in press)

There is a great deal of variation in the timing of pubertal maturation across adolescents. Pubertal timing refers to individuals' level of development relative to a defined group. Both genetic and environmental factors contribute to the onset of pubertal maturation, and a substantial body of research indicates that variations in pubertal timing have psychological, social, and health consequences (e.g., Mendle et al. 2007, Mendle and Ferrero 2012; Negriff and Susman 2011). In particular, research consistently demonstrates that early timing is associated with negative consequences for adolescent girls. The links between pubertal timing and social, psychological, and health outcomes are less consistent among adolescent boys. Directions for future research are highlighted.

Neonatal lipopolysaccharide treatment alters hippocampal neuroinflammation, microglia morphology and anxiety-like behavior in rats selectively bred for an infantile trait

L.D., Claypoole '16, B., Zimmerberg & L.L.Williamson

Brain Behavior and Immunity, 59, 135-146, 2017.

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 investigated 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 either high or low anxiety-like phenotypic behavior. On postnatal day (P)3 and P5, male and female neonates were injected with saline or lipopolysaccharide (LPS). Brains were collected from a subset of neonates following injections. At P7, one male and one female per litter were tested for ultrasonic vocalizations (USVs). In adulthood, remaining litter mates were tested on the open field apparatus and the elevated zero maze (EZM) or on the EZM following 3 days of acute stress. Overall, we saw differences between the high and low lines in neonatal anxiety-like behavior (USVs), neonatal peripheral immune response, adult anxiety-like behavior on the EZM, and adult anxiety-like behavior after stress induction, such that the high line rats display significantly more anxiety-like behavior than the low line. Furthermore, we observed an effect of neonatal LPS during the neonatal peripheral immune response (e.g., increased inflammatory cytokine expression) 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.