Report of Science at Williams College

2017-2018

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

Williamstown, Massachusetts

Front Cover Image:

View of the new South Science Building from the south-west corner. The new building includes office and research lab space for 27 faculty members in Biology, Chemistry, Physics (and Geosciences until their new space is complete in 2021). The building is also the new home of the expanded science shops, microscopy facility and a biochemistry teaching lab.

Rear Cover Image:

Night time view of the east side of the South Science Center from the Morley Circle. The *Large Bowl* sculpture by Ursula von Rydingsvard (1997) has been given a new home with improved landscaping and lighting.

The Science Executive Committee wishes to express its gratitude to the many contributors to this document and especially to the extensive efforts of all of the administrative assistants in the various science departments.

Editor: Norman Bell, Science Center Manager

This document is printed on recycled paper.

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

Table of Contents

We bid farewell to the Bronfman Science Center this year, seen here in photos taken shortly after the building opened in 1968. The building was designed to encourage collaboration between disciplines; an innovative concept when new which remains a core tenet of the sciences at Williams College to this day.

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 May of 2018 we completed phase I of a major expansion of the science center complex with the addition of a new facility to house 27 faculty offices and research labs in Biology, Chemistry and Physics. Geosciences will also share this space until phase II is complete in 2021. The new building greatly expands our microscopy and shop facilities to support all of the sciences and includes an updated teaching lab for biochemistry. Construction has now begun on the phase II of the science center addition which will be the home for the Geosciences, Math/Stats and Psychology departments. This addition is being constructed on the site of the Bronfman Science Center which was demolished in the summer of 2018 after 50 years of faithful serivice. This will complete the foundation for the sciences at Williams in the 21st century.

Our model of the entire science division as a cohesive programmatic unit continues to flourish. 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.

265 students majored in a science or mathematics discipline this year, and we continue to see about half of all students with at least one major in the sciences. The quality of the our science programs has nurtured this interest and this year 63 students were inducted into Sigma Xi as associate members. Williams has become a leader in the training of future scientists with more than 50 students entering 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.

A positive undergraduate research experience is the single most important inspiration for future scientists. More than 250 students are engaged in science research with Williams faculty each year. This year, 79 students completed theses and 190 were engaged in full-time research with science faculty during the summer of 2018. Dozens of Williams students participated in conferences where they presented the results of their research, and more than 65 students and recent graduates 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, our Science faculty have been awarded over 40 grants from NIH and NSF totalling over 6 million dollars. The 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 animal behavior, biochemistry, cellular biology, developmental biology, ecology and evolution, immunology, molecular biology, neurobiology, and physiology. 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. Those who elect to major in chemistry begin their studies with one of the Department's three gateway courses: CHEM 151 (Introductory Chemistry), CHEM 153 (the most commonly enrolled gateway course), or CHEM 155, depending on previous chemistry background and results of the Chemistry Placement Survey. The gateway course 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 Introduction to Computer Science (CSCI 134). Upper-level courses include computer organization, algorithm design and analysis, principles of programming languages, computer networks, digital design, digital media revolution, distributed systems, advanced algorithms, theory of computation, computer graphics, computer security, human computer interaction, 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 its physical and biological evolution and how it might change in the future. Internal forces shape mountain ranges and ocean basins. Waves, rivers, glaciers and wind sculpt the surface of the Earth, generating the landscapes all around us. Fossils entombed in sedimentary rocks supply the evidence for life's origins and evolution, and record Earth's changing climates. Introductory courses open to all students include The Co-Evolution of Earth and Life (GEOS 101); An Unfinished Planet (GEOS 102); Global Warming and Natural Disasters (GEOS 103); and Oceanography (GEOS 104). Geosciences courses provide the foundation for a professional career in the earth sciences, a background for economic pursuits such as the marketing of energy or mineral resources, or simply an appreciation of our human heritage and physical environment as part of a liberal arts education. Students may choose electives to focus in depth in a particular field: for example, students with life-science interests may choose courses concentrating on geobiological topics; those interested in the dynamic solid Earth may elect courses dealing with structure and tectonics; we also have a suite of climate related courses, in addition to ones that are environmentally themed. Most of our courses are accessible to both majors and non-majors.

The **Mathematics** major is designed to meet four learning objectives: (1) Learn central ideas of mathematics and mathematical thinking, (2) Improve problem solving ability by combining creative, critical, and abstract thinking with rigorous reasoning, (3) Communicate mathematical ideas effectively, both orally and in writing, to technical and non-technical audiences, and (4) Be exposed to the power of mathematics and mathematical thinking in applications, research, and beyond. The **Statistics** major is designed to meet four learning objectives as well: (1) Understand the central ideas of statistical thinking and data science, (2) Develop problem-solving abilities by working with real data, using them to make informed decisions and conclusions, (3) Increase interdisciplinary skills by applying statistical methods to an application area of interest and understanding the limits of statistical modeling, and (4) Communicate the results of statistical analyses to both technical and non-technical audiences. 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 Program in **Neuroscience** consists of five courses including an introductory course, three electives, and a senior course. In addition, students are required to take two courses, Biology 101 and Psychology 101, as part of the program. Neuroscience (Neuroscience 201) is the basic course and provides the background for other neuroscience courses. Ideally, this will be taken in the sophomore year. Either Biology 101 or Psychology 101 serves as the prerequisite. Electives are designed to provide in depth coverage including laboratory experience in specific areas of neuroscience. At least one elective course is required from among those cross-listed in Biology (Group A) and at least one is required from among those cross-listed in Psychology (Group B). The third elective course may also come from Group A or Group B, or may be selected from other neuroscience related courses upon approval of the advisory committee. The senior course, Topics in Neuroscience (Neuroscience 401) is designed to provide an integrative culminating experience.

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

The **Psychology** Department offers a wide variety of curricular and research opportunities for both major and non-major students. Courses are grouped into the areas of behavioral neuroscience, cognitive psychology, developmental psychology, social psychology, clinical psychology, and psychology of education. After completing Introductory Psychology (PSYC 101), majors take Research Methods and Statistics (PSYC 201), in which they learn the tools used to generate knowledge in psychology, and at least three 200-level courses, which are comprehensive surveys of each of the subfields. They then take the 300-level courses, which are advanced seminars. Many of these 300-level courses are lab courses in which students do an original empirical research study; others are discussion seminars, and some are also tutorials or writing intensive courses. In each, the professors expose students to their specialty areas in depth, and students read and discuss primary literature. The major sequence ends with a capstone course, Perspectives on Psychological Issues (PSYC 401), a discussion-oriented seminar. A variety of research opportunities are offered in the Psychology Department through research assistantships, independent study, senior thesis work, and the Summer Science Research 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, medicine and health, and numerous others. In addition to the psychology major curriculum, our students often become concentrators in related programs across the college including Cognitive Science, Justice and Law, Public Health, and Neuroscience.

The goal for our students to develop the following skills:

- Ability to generate hypotheses, to design methodologically sound research, and to collect, analyze, and interpret data
- Critically read and interpret scientific articles
- Think critically about psychological theory, data, and ideas
- Develop the ability to integrate scientific literature with observations and experiences in the real world
- Acquire knowledge of major theories, concepts, and findings in multiple sub-disciplines of psychology
- Learn to write well, including but not limited to scientific writing
- Learn to talk about psychology with others in formal and informal settings (give scientific presentations, engage in discussion and debate about ideas, research, and applications)

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.


The view looking out to the newly landscaped Morley Circle from the interior of the new South Science Building.

Winter Study 2017 Offerings

ASTR 16 An Infinity of Worlds: Planets and the Search for Life

Cross-listings: GEOS 16

Description: Less than a generation ago, we wondered, as we had for millions of years before, whether there were any other planets at all. Now, we are privileged to be in the first generation of humans to know that many of the points of light dusting our night sky are host to orbiting worlds, some of which may be like our Earth. In this course, we will explore the techniques that are being used to discover these new worlds. We will make our own contributions to this great age of discovery, by using remotely-operated telescopes in Australia to gather data on new planets. This course, meant for non-majors, will deal with the science of planet hunting, the astounding diversity of planets known to exist, the emerging science of astrobiology, and the enduring question of "are we alone?" through works of science fiction and cutting-edge research.

BIOL 11 Teaching 3rd Grade about Zebrafish – BioEYES

Description: BioEYES brings tropical fish to 3rd grade classrooms in Williamstown, North Adams, and Lanesborough Elementary schools, in a science teaching workshop. Elementary school students will breed fish in the classroom, then study their development and pigmentation during one week. Williams students will adapt BioEYES lesson plans to the science curriculum for the schools we visit, work with classroom teachers to introduce concepts in genetics and development, help the 3rd grade students in the classroom, and assess elementary student learning. No zebrafish experience is necessary; during the first week students will learn to set up fish matings, and learn about embryonic development and the genetics of fish pigmentation as well as practice teaching the 3rd grade BioEYES lesson plans with hands-on experiments using living animals. In the subsequent three weeks students will present lessons at the schools and review assessment data.

BIOL 13 Introduction to Animal Tracking

Description: This course is an introduction to the ancient art and science of animal tracking, and its use for ecological inventory. Participants will deepen their skills as naturalists, their awareness of the natural world, and discover that even the greens at Williams College are abundant with wildlife. Students will have field time in class at Hopkins Forest as well as through independent study at a convenient outdoor location of each student's choosing. Basic concepts of animal tracking, its history and use by indigenous people throughout the world will be discussed through video and slide show. Students are required to create journals and site maps of Hopkins and their personal study areas, including all major features of the landscape, flora and fauna activity. Evaluation will be based on attendance, participation and a final presentation of their maps and journals, with attention to detail and content. The course will meet twice a week for five hour sessions, primarily in the field. Students are also required to do extensive independent field study, demonstrating observations through journals and site maps, a field test and research paper.

BIOL 19 The Science of Sleep (and the Art of Productivity)

Description: Sleep deprivation is widespread throughout American society, especially at rigorous colleges where stressful schedules often interfere with a good night's sleep. Although improving sleep quality has been shown to dramatically increase physical and emotional health, as well as academic and athletic performance, most people don't understand why sleep is so beneficial and restorative. This Winter Study Course is dedicated to improving knowledge of sleep science and healthy sleep habits with three overarching goals: (1) First, we will learn about what happens in our brains and bodies when we sleep and what is meant by "a good night's sleep." We will survey some amazing new discoveries from cutting-edge sleep research labs and examine methods that successfully help many people get a better night's sleep. (2) Next, we will explore the relationship between sleep habits and a busy lifestyle. Frequently, a lack of sleep is caused by an attempt to be productive and attend to a busy schedule. We will explore proven strategies developed by highly successful scientists, business leaders, and athletes to achieve a work/sleep balance such that a person can be more productive during the day to enjoy more sleep each night. (3) Finally, to impact the college and community, we will develop a set of educational resources to teach others about the science of sleep and methods of improving sleep hygiene. These resources will include free public presentations to campus and off-campus groups (including local classrooms), brochures and posters with easy-to-understand "sleep facts," and a website offering information about sleep science. Taken together, students in this course will thoroughly learn about the science of sleep and a healthy work/sleep balance and then share this knowledge with the local and broader community. This course will meet approximately 10-20 hours each week and include outside readings. Evaluation will be based on a short research paper and final project to educate others about sleep. This course is partially funded by a grant from the National Science Foundation.

CHEM 13 Ultimate Wellness: Concepts For a Happy Healthy Life

Description: This course provides an opportunity to drastically improve your life by introducing concepts that can start making a difference in the way you feel today! We will approach nutrition, lifestyle, and happiness from a holistic perspective. Students will learn how to tune out mixed media messages and look within to find ultimate health and wellness. Topics include:

- Ayurveda
- Cleansing
- Preventative medicine
- Yoga and meditation
- Food intolerance awareness
- Healthy eating and meal planning
- Deconstructing cravings and overcoming sugar addiction
- Healthy skin care with oils
- Finding your happiness

Evaluation will be based on completion of assignments, class participation, reflective 5-page paper or equivalent creative project, and final presentation that demonstrates a level of personal growth. After signing up for this course please email Nicole at nicole@zentreewellness.com with a brief statement describing your interest in the course and what you hope to achieve in it. In the event of over-subscription, these statements will be used in the selection process. We will meet twice a week for three-hour sessions as a group. There will be several books and a DVD required for this class. Course will include two individual sessions. An initial health assessment and an additional session designed to personalize the course and assist the student in applying the learned techniques.

CSCI 10 Databases & Data Visualization

Description: Data has become big, so much so we now call it {Big Data}. What does it mean? How do we develop a database? How do we extract data so we can use it to make valuable decisions? How do we present it so non-technical people can understand it? Companies like Guess?, Harrah's Casino and the Weather Co have become leaders in their industry by leveraging their data. In this class we will look at ways companies gain value from their data, how one can organize data in a relationship database, and the basics of SQL and data visualization. We will learn to use {Tableau} and other database software to give you an understanding of databases and their use in business. This will be a hands on class that gives you time to learn to develop relational data models, use {SQL} to extract data, discuss case studies about how companies are using data and finally bringing this all together in a final where you will use a set of data to develop a dashboard and data visualizations through Tableau.

CSCI 11 eTextiles

Description: Digital data is being infused throughout the entire physical world, escaping the computer monitor and spreading to other devices and appliances, including the human body. Electronic textiles, or eTextiles, is one of the next steps toward making everything interactive and this course aims to introduce learners to the first steps of developing their own wearable technology devices. After completing a series of introductory eTextiles projects to gain practice in necessary skills, students will propose and design their own eTextiles projects, eventually implementing them with Lilypad Arduino components, and other found electronic components as needed. The scope of the project will depend on the individual's prior background, but can include everything from a sweatshirt with light-up turn signals for bicycling, to a wall banner that displays the current air quality of the room, to a stuffed animal that plays a tune when the lights go on, to whatever project you can conceivably accomplish with Lilypad Arduino inputs, outputs, and development board in a two-week time period. People with little computer programming experience will learn to edit snippets of Arduino code for their purposes. People with considerable computer programming background will learn some of the idiosyncrasies of programming for Lilypad Arduino which should be transferable to other Arduino platforms.

CSCI 12 Stained Glass Tiling: Quasicrystals and Geometric Solids, Building an Invisibility Cloak

Description: This course will begin with a group project to construct a mathematically precise model of a quasicrystal in stained glass. We will build a large, low-relief sculptural surface from hundreds of mirrored glass tiles oriented in ten different directions. This crystalline geometry is being explored at nanoscale for it's potential as a cloaking device. It also occurs in nature, wrapping the surface of some viruses and in the formation of galaxies. Students will learn how to cut glass tiles, wrap them in copper, assemble and solder three-dimensional forms. Instructional sessions on the use of tools and safe handling of materials are included where necessary. In the second part of the course students will build geometric figures of their choice from transparent colored glass tiles (unpainted).

CSCI 14 Creating a Roguelike Game

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

GEOS 12 Geology of the National Parks

Cross-listings: ENVI 12

Description: A vicarious trip through a variety of national parks in the US and Canada to appreciate the geological basis of their spectacular scenery. Areas to be included will be selected to portray a wide range of geological processes (volcanism, desert and coastal erosion, mountain-building, glaciation, etc.). The group will meet most mornings for the first two weeks for highly illustrated classes supplemented by the interpretation of topographic and geologic maps and by out-of-class study of rock samples. Reading will be from a paperbound text (PARKS AND PLATES) and from short publications by the U.S. Geological Survey and natural history associations linked to the parks. The second part of the month will involve independent study and meetings with the instructor to prepare an oral report about the geology of a park or monument of the student's choice.

GEOS 25 The Changing Landscape and Musical Geography of the Mississippi: Winter Study at Williams-Mystic

Description: The course will be based at Williams-Mystic, the College's renowned maritime studies program in Mystic, Connecticut. We will focus on learning about the geological history of the Mississippi River Delta, the history of human settlement in the region, and the musical record of the environmental and socioeconomic challenges faced by the communities of the delta. Experiential learning is important to the course, and we will spend two evenings enjoying Cajun and Zydeco music as well as the blues. Finally, the course will involve synthesizing the experiences and learning of the first two weeks into oral presentations in which students will propose solutions for improving the sustainability of habitats and communities that are threatened by rising sea levels. We will use the multidisciplinary Defining the Delta (Edited by Janelle Collins, The University of Arkansas Press, 2015) as our textbook for the course. This winter-study course thus aims to:

Explain the role of landscape change in controlling the sustainability of the environments upon which the communities and the economic infrastructure of the Mississippi River Delta have been built;

Examine the musical geography of the region as a means for understanding the legacy of landscape and socioeconomic changes for the people who call the delta their home.

MATH 11 A Taste of Austria

Description: 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 musicians i.e. Gustav Mahler, W.A. Mozart 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) as well as creating "The Imperial Pancake" alias "Kaiserschmarren" offered in most Austrian restaurants. The course will be conducted mainly in English, with some German. This year we are planning to have "Austrian Culture Ambassadors", high school students from a private high school visiting from Graz who will be available for part of the class for individual one on one German speaking/tutoring. Last years visiting musician young pianist Philipp Scheucher will perform a piano concert at Chapin Hall, allowing my students and their friends to hear Austrian works by Mozart, Schubert and Beethoven at Williams College live in concert. We will also have a guest lecture by Austrian brain scientist Gerwin Schalk, Ph.D. who is one of the leading neuroscientists in brain mapping. If time and weather permits, we will also pursue typical Austrian winter activities such as downhill or cross country skiing, sledding or skating.

MATH 12 The Mathematics of LEGO Bricks

Description: Since their introduction in 1949, LEGO bricks have challenged and entertained millions. In this course we'll explore some of the connections between LEGO bricks, mathematics and popular culture. Activities will range from trying to do a LEGO Idea challenge to teaching an Adventures in Learning class at Williamstown Elementary to building a bridge (hopefully over the gap on the 2nd floor of Paresky) for MLK day.

MATH 13 Seldom Told Stories of Women and Minorities in Science

Description: This course will be centered on learning about the achievements of women and minorities who have made significant contributions to science and the scientific community. We will discuss both historical and modern challenges faced by women and under-represented minorities in the sciences.

MATH 15 Pilates: Physiology and Wellness

Cross-listings: SPEC 15

Description: During the first half of the twentieth century, Joseph Pilates developed a series of exercises he called Contrology designed to strengthen core muscles and improve overall health. Now known as Pilates, these exercises are meant to increase flexibility, strength, endurance, and spinal health. In this course, we will study the physiology and origins of the Pilates exercises as well as how Pilates can be incorporated into an overall wellness plan.

MATH 18 Introduction to Python Programming

Description: Python has recently become one of the most prominent programming languages. Besides it's high degree of efficiency, it is primarily focused on readability and extensibility. Therefore, Python can be easily used to solve a wide array of problems in computer science, mathematics, business, and many other fields. In this course, we will be introduced to the syntax of Python and apply it to solve several basic (mathematical) problems. The course is intended as an introduction for non-computer science majors.

STAT 10 Data Visualization

Description: Through modern technology, our world is becoming increasingly quantifiable, and it is now easier than ever to collect accurate and timely data from sources of myriad variety. Data visualization provides one means to detect patterns and structure in "big data" which can translate into accessible information to further scientific knowledge and improve decision making. In this course, we will study techniques for creating effective static and interactive data visualizations based on principles of graphic design, visual art, perceptual psychology, and statistics/data science. The class will meet about 6 hours a week for lecture and discussion with two additional meetings for external speakers. In addition to reading assigned texts and participating in class discussions, students will be expected to complete daily data visualizations exercises in R as well as a final group project. Students will be expected to write up their process and present their final visualizations to the class. There are no prerequisites for the class. All academic backgrounds and programming experience are welcome and encouraged. Programming exercises will be tailored to past experience.

STAT 12 How (Not?) to Lie with Statistics

Description: Statistical analysis is a lot like a car. It's useful, it can do a lot of damage if you fall asleep at the wheel, and most people don't know the details of how it works but still go along for the ride. This is a course about responsible driving: how to communicate and interpret ideas based on data. We'll explore the choices and challenges involved in collecting, analyzing, visualizing, and explaining data-and the mistakes, accidental or not-so-accidental, that creep into the process. Along the way, we'll learn to recognize misleading and misinterpreted statistics in the real world.

STAT 19 Chess, Speed Chess, Bughouse

Description: This course will present a fast and fun introduction to chess, speed chess, and multi-player variants of classical chess. We'll begin with the rules of chess, and a study of classical openings, theory, checkmates, and endgames. These concepts will be practiced through in-class games. We will always make use of chess clocks, limiting a player's total thinking time. Chess clocks are an important part of tournament chess and speed chess, and are critically important in several chess variants we'll explore. This will open up your eyes to the high-paced, social, and extremely fun nature of recreational chess. Students will immensely enjoy learning and playing these variants, and will be surprised at how much fun chess can be. The course will culminate in a series of informal tournaments among the class.

NSCI 10 The Neuroscience of Learning

Description: An interactive and collaborative exploration of what neuroscience research reveals about how the brain learns and what factors can be influenced to facilitate successful learning and the neuroplastic development of highest brain potentials in learners. Topics include the neuroscience of attention, emotion, understanding, memory, and executive functions. Students will engage in collaborative research projects, that will develop their use of the medical model to evaluate primary neuroscience research studies for validity, and develop their own ideas about how the valid research could correlate with teaching strategies to promote successful learning and understanding for learners from early childhood through adulthood. These strategies include the use of project-based learning, development of learners' neural networks of executive functions, and opportunities to transfer of learning to novel applications so learners construct memory at the concept level that can be adapted (as facts, technology, jobs, and the world changes) and applied for novel problem solving and creative innovation.

PHYS 13 Electronics

Description: 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.

PHYS 14 Light and Holography

Description: 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.

PHYS 20 Loop d' Loop d' Loop d' Loop…

Cross-listings: MUS 20

Description: This class is about music, but you don't have to be a musician to take it. It is about recursion, but you don't have to be a computer scientist to get it. We will play with the subjective and social meanings of sound-art, but you don't have to be an artist to play along. Imagine that you record yourself speaking in a room; You record the sound of that recording as it plays back in that same room; You record the recording of the recording; You sit back and let this loop repeat and repeat. Eventually your words are smoothed out by the resonances of the room into a rich melody.In this class we will explore the world of sound-art. We will transmute audio samples by harnessing the resonances of architectural spaces in Williamstown, from dorm room to theater. Emphasizing hands-on projects, students will create, listen, and read their way to a new understanding of sound and recursion.

PSYC 10 Applied Sport and Performance Psychology

Description: This course will introduce theoretical framework and the application of psychological skills for performance in variety of settings including (but not limited to) athletics, theatre, and music. Topics include: motivation, goal setting, perseverance, attention, visualization, learning mindset, confidence and mindfulness.

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

Description: Seventy-two percent of college students report that they used alcohol at least once within the past 30 days. Where is the line between fun and danger? This course will examine the realities of the role of alcohol in the social lives of college students. Students will engage in active discussions of readings, videos, and myths vs. facts, as well as personal observations and opinions. Class structure will involve 3-hour classes that meet twice weekly. Participants will learn scientific facts about alcohol, including how it gets metabolized in the body differently in men and women, and how to recognize and respond to the signs of alcohol poisoning. Films will include evocative footage and interviews, such as "College Binge Drinking and Sober Reflections." We will hear from an expert in trauma and sexual assault and explore the significant role of alcohol in sexual assault on college campuses. We will discuss alcohol-related medical emergencies and problem-solve strategies to stay safe when choosing to use alcohol. Statistical data from colleges here in the Northeast will be reviewed, including survey results from the Core Institute and the Harvard School of Public Health Alcohol study.

PSYC 14 JA SelCom: A Case Study in Selection Processes

Description: This course will explore the nature of selection processes. What does an optimal selection process look like? How do our implicit biases materialize in selection? These are just a few of the questions that we will seek to understand through guest speakers from The Davis Center, Psychology Department, Admissions, and the Career Center. The majority of the time will be dedicated towards applying these ideas in selecting the next class of Junior Advisors, an undertaking that will allow students to examine selection processes in general.

PSYC 15 Ephquilts: An Introduction to Traditional Quilting

Description: This studio course will lead the student through various piecing, appliqué 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.

Assistant professor Alice Bradley prepares to deliver her talk during the Summer Science Research lunch to a full house in the Wege Auditorium.

The Science Center

The Science Center links the new South Science Building 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, 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 this 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 2017-18, 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.

2017-18 Science Lunch Colloquia

Tiku Majumder, Physics	Welcome and Introductions
Kate Jensen, Physics	Soft sticky stuff
Safa Zaki/Tom Smith	Presidential search
David Loehlin, Biology	How evolution shapes genes
Jeremy Cone, Psychology	Changing Your Implicit Mind: Exploring strategies for rapidly revising implicit first impressions
Daniel Barowy, Computer Science	Programming with the Wisdom of the Crowd
Henry Walker, Computer Science	Lab-Based Pedagogy with Collaboration: An Example of a Flipped Classroom
Pei-Wen Chen, Biology	How cells sense mechanical cues-regulation of motors and actin cytoskeleton by lipid-regulated enzymes
Rhon Manigault-Bryant	Student Workload and Credit Hours
Katie Hart, Chemistry	TBD
Iris Howley, Computer Science	Data-driven Feedback for Learning
Chad Topaz, Mathematics and Statistics	Minimal models of locust swarms
Dan Maser, Physics	Looking for Nasty Things with Lasers
Chip Lovett, Chemistry	TBD
David Dethier, Geosciences	Tracking effects of the Clean Air Act--positive evidence from Hopkins Memorial Forest
José Constantine, Geosciences	Climate Change and the Impacts of Raindrops
Anthony Carrasquillo, Chemistry	Formation and fate of atmospheric organic aerosol particles
Laurie Tupper, Mathematics and Statistics	Time, space, and how to tell the difference
Laura Smalarz, Psychology	The Psychology of Eyewitness Misidentification

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 190 individuals at Williams during the summer of 2018. 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 which this year funded six 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 also includes 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. Funding for our other students comes from generous grants from a many foundations, institutions and individual donors. The science community and the students who receive the grants are grateful to all of the donors for the generous support.

Summer Science Research Colloquia 2018

Norman Bell, Science Center	Lab Safety
Jay Pasachoff, Astronomy	The glory of Solar Eclipses
Tiku Majumder, Physics	Clocks, Navigation and Cold Atoms
Heather Williams, Biology	Social Context and Syntactical Rules in House Finch Song
Cesar Silva, Mathematics	Chaos in Kneading Dough
Kate Jensen, Physics	What Makes Things Wet and Sticky?
Tim Pusack, Williams Mystic	A Cause for Concern: Lionfish Invade Atlantic and Caribbean Coral Reefs
Dan Barowy, Computer Science	Spreadsheet Tools for Data Analysts
Alice Bradley, Geosciences	Sea Ice, The Arctic Ocean and Land: Telling the Difference from Space

2018 SSR Significant Funding Sources

Contributors	Number of Stipends Supported
APS Fellowship	1
Arnold Bernhard Foundation Summer Fellows Program	32
Bronfman Science Center Fund	5
Clare Boothe Luce Scholarships for Women in Science	6
Class of 1951	5
Computer Science Department	1
John & Louise Finnerty Fund for Applied Mathematical Research	6
Louis 1950 Summer Science Research Fellowship	1
Lowe 1940 Summer Science Research Fellows	5
Lowe 1973 Chemistry Fellowships	11
Markgraf JH 1952 Fellowships	6
MIT NASA	2
NSF/NIH grants to individual faculty	17
SMALL	9
Somers B&L 1948 Physics Internships	3
Sperry Family	1
Summer Science Program Alumni	7
Synnott 1958 Fund	1
Wege-Markgraf Chemistry Fellowships	7
Whitehead Scholars Program - Biology	3
Williams Bicentennial Psychology Scholarship	4
Williams Science Center Funding	38
Wilmers Fellowship	1
Total 10-week Student Stipends	**172**

Summer Science Students and their Faculty Advisors 2018

Astronomy

Nicole Ford	Anne Jaskot
Johnny Inoue	Anne Jaskot
Christian Lockwood	Jay Pasachoff
Connor Marti	Karen Kwitter
Erin Meadors	Jay Pasachoff
Cielo Perez	Jay Pasachoff
Ross Yu	Jay Pasachoff

Biology

Will Doyle	Lois Banta
Emily Burch	Ron Bassar
Ajar Dixit	Ron Bassar
Del Rose Hooker Newball	Ron Bassar
Megan Powell	Ron Bassar
Olivia Barnhill	Matt Carter
Erin Cohn	Matt Carter
Kenechukwu Odenigbo	Matt Carter
Louisa Goss	Pei Wen Chen
Ben Maron	Pei Wen Chen
Christine Tanna	Pei Wen Chen
Quenton Hurst	Derek Dean
Nebiyou Metaferia	Derek Dean
Kimberly Andreassen	Joan Edwards
Patrick Zhuang	Joan Edwards
Mikhayla Armstrong	Tim Lebestky
Thea Lance	Tim Lebestky
Eily Mixson	Tim Lebestky
Hafidh Hassan	David Loehlin
Kyung Shin Kang	David Loehlin
George Yacoub	David Loehlin
Francesca Barradale	Luana Maroja
Se Rin Kim	Luana Maroja
Sehwheat Manna	Manuel Morales
Paul Sheils II	David Smith
Cordelia Chan	Steve Swoap
Maia Hare	Steve Swoap
Morgan Harris	Steve Swoap
Sonia Nyarko	Steve Swoap
Gabrielle Martin	Steve Swoap
Darcie Caldwell	Claire Ting
Fiona Keller	Damian Turner
David Gorestky	Whitehead Institute
Anastasia Tishena	Whitehead Institute
Ashley Zhou	Whitehead Institute

Environmental Studies

Morgan Dauk	D. Dethier/J. Racela

Chemistry

Christopher Avila	Anthony Carrasquillo
Uriel Garcia	Anthony Carrasquillo
Kimberly Hadaway	Anthony Carrasquillo
Andrew Hallward-Driemeir	Anthony Carrasquillo
James Heinl	Anthony Carrasquillo
Gabrielle Wolfe	Nate Cook
Stephan Zhu	Nate Cook
Abraham Eafa	Chris Goh
Jennyfer Galvez	Chris Goh
Ching-Hsien Ho	Chris Goh
Angel Ibarra	Chris Goh
Astia Innis	Chris Goh
Jonathan Lee	Chris Goh
Mykel Miller	Chris Goh
Juan Peticco	Chris Goh
Brian Valladares	Chris Goh
Joseph Flores	Sarah Goh
Hyo Jung Ha	Sarah Goh
Orville Kirkland	Sarah Goh
Dasol Lee	Sarah Goh
Maria Noya	Sarah Goh
Ingrid Onul	Sarah Goh
Drew Cohen	Katie Hart
Faris Gulamali	Katie Hart
Emily Harris	Katie Hart
Cynthia Okoye	Katie Hart
Miranda Villanueva	Katie Hart
Lauren Vostal	Katie Hart

Maria Heredia	Dave Richardson
Katherine 1	Dave Richardson
John Velez	Dave Richardson
Hong Wang Chui	Anne Skinner
Eugene Cho	Jay Thoman
Jillian Jenkin	Jay Thoman

Computer Science

Abigail Miller	Jeannie Albrecht
Grace Murray	Jeannie Albrecht
Casey Pelz	Jeannie Albrecht
Kiersten Campbell	Dan Barowy
Emmie Hine	Dan Barowy
Alex Taylor	Dan Barowy
Louisa Nyhus	Steve Freund
Young Cho	Iris Howley
Grace Mazzarella	Iris Howley
Kelvin Tejeda	Iris Howley
Tongyu Zhou	Iris Howley
Markus Feng	Bill Jannen
Jiashen Lu	Bill Jannen
Matt Newman	Bill Jannen
Taylor Beebe	Tom Murtaugh
Phoebe Huang	Tom Murtaugh
Nicholas Weed	Tom Murtaugh

Geosciences/Williams Mystic

Lucas Estrada	Phoebe Cohen
Katherine Pippenger	Phoebe Cohen
Emmett Blau	Jose Constantine
Monica Bousa	Jose Constantine
Daniel Donahue	Jose Constantine
Molly Lohss	Jose Constantine
Summer-Solstice Thomas	Jose Constantine
Anna Black	Mea Cook
Matthieu Chicoye	Mea Cook
Madeline Rawson	Mea Cook
Dayana Manrique	Mea Cook
Ava Palmo	Mea Cook
Chen-Yi Hung	Lisa Gilbert
Erikka Olson	Bud Wobus

Mathematics and Statistics

Or Eisenberg	Colin Adams
Jonah Greenberg	Colin Adams
Kabir Kapoor	Colin Adams
Zhen Liang	Colin Adams
Kate O'Connor	Colin Adams
Natalia Pacheco-Tallaj	Colin Adams
Yi Wang	Colin Adams
Junyan Duan	Julie Blackwood
Mykhaylo Malakhov	Julie Blackwood
Jordan Pellett	Julie Blackwood
Ishan Phadke	Julie Blackwood
Anya Michaelsen	Susan Loepp
Hung Viet Chu	Steven Miller
Trajan Hammonds	Steven Miller
Casimir Kothari	Steven Miller
Benjamin Logsdon	Steven Miller
Noah Luntzlara	Steven Miller
Maria Rose Ross	Steven Miller
Leting Shao	Steven Miller
Mengxi Wang	Steven Miller
Hunter Wieman	Steven Miller
Madeleine Farris	Steven Miller
Ivan Aidun	Ralph Morrison
Frances Dean	Ralph Morrison
Samuel Rosofsky	Ralph Morrison
Teresa Yu	Ralph Morrison
Julie Yuan	Ralph Morrison
Hindy Drillick	Cesar Silva
Alonso Espinosa Dominguez	Cesar Silva
Jennifer Jones Baro	Cesar Silva
James Leng	Cesar Silva
Yelena Mandelshtam	Cesar Silva
Xiwei Yang	Cesar Silva
Michael Curran	Mihai Stoiciu
Eli Cytrynbaum	Mihai Stoiciu
Benjamin Foster	Mihai Stoiciu
Miriam Gordin	Mihai Stoiciu
Youngsoo Baek	Laurie Tupper
Alessandra Miranda	Laurie Tupper
Eric Rosenthal	Laurie Tupper
Daniel Woldegiorgis	Laurie Tupper

Physics

Sam Alterman	Fred Strauch
Ian Banta	Dave Tucker-Smith
Justin Berman	Kate Jensen
Iona Binnie	Catherine Kealhofer
Declan Daly	Kate Jensen
Kwasie Fahie	Kevin Jones
Kirby Gordon	Charlie Doret
Joseph Headley	Kate Jensen
Qiyuan Hu	Fred Strauch
Minwoo Kang	Kate Jensen
Sameer Khanbhai	Tiku Majumder
Hyeongjin Kim	Kate Jensen
Heather Kurtz	Kate Jensen
Felix Knollman	Charlie Doret
Abdullah Nasir	Catherine Kealhofer
Ashay Patel	Charlie Doret
Gabriel Patenotte	Tiku Majumder
Patrick Postec	Catherine Kealhofer
Anneliese Silveyra	Kate Jensen
Nyein Chan Soe	Fred Strauch
Emily Stump	Catherine Kealhofer
Jeremy Thaller	Kate Jensen
Mariam Ughrelidze	Dave Tucker-Smith

Psychology

Isabel Andrade	Jeremy Cone
Shaheen Currimjee	Jeremy Cone
Reuben Kaufman	Susan Engel
Matan Levine-Janach	Steve Fein
Selim Park	Steve Fein
Abby Brustad	Amie Hane
Olivia Carlson	Amie Hane
Danielle Faulkner	Amie Hane
Yeojin Choi	Nate Kornell
Abigail Yu	Nate Kornell
Juna Khang	Daniel Norton
Ziqing Zong	Daniel Norton
Tristan Colaizzi	Noah Sandstrom
Masen Boucher	Noah Sandstrom
Anna Leonard	Noah Sandstrom
Sierra Loomis	Noah Sandstrom
Jonathan Carrasco-Noriega	Safa Zaki
Simran Sohal	Safa Zaki

Summer Science Research Poster Session: August 10, 2018

Student Names	Advisor Names	Poster Title
Or Eisenberg, Jonah Greenberg, Kabir Kapoor, Zhen Liang, Kate O'Connor, Natalia Pacheco-Tallaj, Yi Wang	Colin Adams	Hyperbolic volumes of virual knots
Abigail Miller, Grace Murray, Casey Pelz	Jeannie Albrecht	Comparing Ambient Visualizations of Energy Use
Will Doyle	Lois Banta	Arabidopsis defense modulation by the Agrobacterium tumefaciens Type VI Secretion System
Kiersten Campbell, Emmie Hine, Alex Taylor	Daniel Barowy	Swell: Introductory Programming Using Prodirect Manipulation
Mykhaylo Malakhov, Ishan Phadke	Julie Blackwood	Efficacy of Control in a Spatially Dynamic Model of White-nose Syndrome
Jordan Pellett, Junyan Duan	Julie Blackwood	Federalism in Epidemic Modeling: Management of Interconnected Populations with Multiple Objectives
Christopher Avila, Andrew Hallward-Driemeier	Anthony Carrasquillo	Method Development and Characterization of Experimental Aerosol Reactors
Kimberly Hadaway	Anthony Carrasquillo	Examining the Photochemistry of Oxalic Acid-Iron Complexes through Spectrophotometric and Chromatographic Analysis

Olivia Barnhill, Erin Cohn, Kenechukwu Odenigbo	Matthew Carter	Characterization of the Parasubthalamic Nucleus as an Appetite Suppression Center
Ben Maron	Pei-Wen Chen	Effect of ASAP1 Expression on Integrin Adhesion Complexes in Rhabdomyosarcoma
Molly Lohss	Josè Constantine	Deforestation of Borneo
Gabrielle Wolfe, Stephan Zhu	Mea Cook	Antibiotic Tea? An ethnobotanical Investigation of the bioactivity of Turnera Diffusa
Madeline Rawson, Dayana Manrique	Mea Cook	Using Volcanic Ash Layers to Improve Marine Radiocarbon Dating
Morgan Dauk, Maya Spalding-Fecher, Zoe Loughman	David Dethier/Jay Racela	*Determining Water Quality in Springs of Hopkins Memorial Forest*
Kirby Gordon, Felix Knollmann, Ashay Patel	Charlie Doret	Robust Chains of Trapped Ions
Louisa Nyhus	Stephen Freund	Synthesizing Thread-Safe and Efficient Code from Sequential Specifications
Joseph Flores, Julie Ha, Dasol Lee, Ingrid Onul	Sarah Goh	*Amphiphilic Copolymers as Drug Delivery Applications*
Orville Kirkland, Maria Noya	Sarah Goh	Synthesis of Amphiphilic Amino Acid Block Copolymers via ATRP
Drew Cohen	Katie Hart	Structural characterization of a β-lactamase intermediate by fluorescence
Cynthia Okoye	Katie Hart	What drives clinically-relevant antibiotic resistance mutations?
Faris Gulamali	Katie Hart	Distinguishing between Clinical and Synthetic Bacterial Mutations
Miranda Villanueva	Katie Hart	Manipulating the energy landscapes of beta-lactamases CTX-M-9 and TEM-1
Grace Mazzarella	Iris Howley	Cracking Open the Black Box: Explaining BKT
Kelvin Tejeda	Iris Howley	*Experimental Education Platform*
Tongyu Zhou	Iris Howley	Manual and Automated Voice Gender Detection
Markus Feng	William Jannen	Efficiently Generating Files with Realistic Contents
Geoffrey Lu, Matt Newman	William Jannen	RNA Secondary Structure Energy Landscapes
Justin Berman	Katharine Jensen	Adhesive Detachment Dynamics
Declan Daly	Katharine Jensen	Scientific Waterbending: Electrical Manipulation of Contact Angles and Fluidics
Joseph Headley	Katharine Jensen	The Elastocapillary Physics of Silicone Microsphere Contact
Minwoo Kang	Katharine Jensen	Adhesion-Induced Phase Separation in Soft Silicone Gels
Hyeongjin Kim	Katharine Jensen	Dynamics of Making and Breaking Adhesive Contacts
Heather Kurtz	Katharine Jensen	The Jetting to Dripping Transition in Leaking Flows
Anneliese Silveyra	Katharine Jensen	Interface Interactions of M. Polymorpha
Jeremy Thaller	Katharine Jensen	Measuring Strain-Dependent Surface Stress via Adhesion
Aidan Duncan	Katharine Jensen	The Material Characteristics of Soft Silicone Gels
Iona Binnie, Patrick Postec	Catherine Kealhofer	Production of Tungsten Nanoemitters for Ultrafast Electron Diffraction

Abdullah Nasir	Catherine Kealhofer	Characterization of Femtosecond Laser Pulses from a Titanium Sapphire Oscillator
Emily Stump	Catherine Kealhofer	Concept for a monochromatic low-energy electron gun
Mikhayla Armstrong, Thea Lance, Eily Mixson	Tim Lebestky	Caffeine-dopamine interactions decrease nighttime sleep but have no effect on startle-induced arousal in Drosophila
Hafidh Hassan, George Yacoub	David Loehlin	Understanding the effects of Insulator and distance between genes on the pattern of expression of Tandem duplicate genes
Kyung Shin Kang	David Loehlin	Effect of gene duplicates on neighboring gene expression
Anya Michaelsen	Susan Loepp	Noetherian Rings with Unusual Prime Ideal Structures
Sameer Khanbhai, Gabriel Patenotte	Protik Majumder	Measuring Lead transition amplitudes using Faraday rotation polarimetry
Sehwheat Manna	Manuel Morales	Characterizing landscape genetics of Publilia concava through microsatellite markers
Phoebe Huang, Nicholas Weed	Tom Murtagh	Monitoring the Internal and External Behavior of a NAND-memory File System
Ross Yu	Jay Pasachoff	Williams College Expedition to the Willamette Valley, Oregon, to Observe the 2017 Total Solar Eclipse: Meteorological Measurements and Analysis
Tristan Colaizzi, Masen Boucher, Anna Leonard, Sierra Loomis	Noah Sandstrom	Learning and Anxiety-Like Behavior in a Mouse Model of Traumatic Brain Injury
Tristan Colaizzi, Masen Boucher, Anna Leonard, Sierra Loomis	Noah Sandstrom	The Effects of Immediate Forced Exercise After Mild Traumatic Brain Injury
Jennifer Jones Baro, James Leng, Yelena Mandelshtam	Cesar Silva	Type II_\infty Rank-one Totally Ergodic not Weakly Mixing Transformations
Dominic Chui	Anne Skinner	Electron Spin Resonance Dating of Teeth from Affad 23 in Sudan
Michael Curran	Mihai Stoiciu	The Rate of Convergence to the Circular Law for I.I.D. Matrix Ensembles
Eli Cytrynbaum	Mihai Stoiciu	Matrix Models for the Circular Beta Ensemble
Ben Foster	Mihai Stoiciu	The Eigenvalue Distribution for the Symmetric Bernoulli Ensemble
Mira Gordin	Mihai Stoiciu	Non-Hermitian Anderson Operators and their Spectral Properties
Qiyuan Hu, Nyein Chan Soe, Sam Alterman	Frederick Strauch	The Effects of Decoherence on Simple Quantum Systems
Ian Banta, Mariam Ughrelidze	David Tucker-Smith	Dynamics of the Electroweak Phase Transition
Youngsoo Baek	Laurie Tupper	Descriptive Spatiotemporal Modelling for QWI Data
Alessandra Miranda	Laurie Tupper	On Using Successive Random Samples to Cluster Global Climate Datasets
Eric Rosenthal	Laurie Tupper	Development and Validation of Lagged Spatiotemporal Clustering
Daniel Woldegiorgis	Laurie Tupper	Union-Find Parallel DBSCAN

Pre-First Year Summer Science Program

The Summer Science Program (SSP) provides an enriching and intensive five-week experience for talented incoming Williams students interested in the sciences who are from underrepresented minority groups and/or who are first-generation college students. The goal of the program is to encourage continuing participation by SSP students in science and science related studies at Williams and to promote careers in research science and science education.

In its thirty-first summer in 2018, twenty-two 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 classes, the students participated in a variety of extracurricular activities including a geology fieldtrip, a theater performance of the Barrington Stage Company and a trip to the Williams-Mystic program.

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. Several others 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 Chris Goh, and David Richardson (Chemistry), Professors Lori Pedersen and Mihai Stoiciu (Mathematics), Professor Dan Lynch (Biology), Professor Cassandra Cleghorn (English). Special thanks go to Professors Phoebe Cohen, Lisa Gilbert and Tim Pusack for leading field trips and hosting SSP at Williams-Mystic.

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. The Summer Science Program 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, staff and students of Williams College who over the years have contributed to the success of the program and of its participants.

Pre-First Year Summer Science Program Participants 2018

Students	Sanket Patel	**Faculty**
Emily Agreda McCaughin	Aniah Price	Cassandra Cleghorn
Omowunmi Awelewa	Irfa Qureshi	Phoebe Cohen
Olivia Behrens	Chelsea Romulus	Lisa Gilbert
Magdalena Blaise	Nicolas Schroeter	Chris Goh, Director
Eva Castagna	Blain Solomon	Dan Lynch
Jessica De Los Santos	Kira Stanfield-Pazmino	Lori Pedersen
Adam Dionne	Eric Tran	Tim Pusack
Amy Garcia	Mahlet Yirgu	David Richardson
Rianne Chelza Garcia	**Student Tutors**	Mihai Stoiciu
Amy Lam	Ajar Dixit	
Alan Lin	Uriel Garcia	
Marcelo Mazariego	Astia Innis	
Melissa Mendino	Sonia Nyarko	

Summer Science Lab Program

For the last twenty 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. In groups of four, elementary students 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 2018, fourteen students from Williams College and MCLA taught elementary students through hands-on experiments, which explore scientific processes. Seventy-two elementary students attended Summer Science Lab this year.

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 2018

Students	**Williams Faculty**
Naseema Amin (MCLA)	Chip Lovett
Mikhayla Armstrong '19	Dave Richardson
Abe Eafa '21	
Jennyfer Galvez '18	**Local Teachers**
Jessica Gutierrez '20	Stephen Bechtel - Director
Julie Ha '20	Tim Hermann - Lead Teacher
Kimberly Hadaway '21	
Maria Heredia '20	**Other Support**
Angel Ibarra '21	Jennifer Swoap - Administrator
Juan Peticco '21	Hazel Scullin - Assistant
Katie Mahoney '20	Miriam Bakija - Assistant
Brian Valladares '21	
John Velez '20	**And 72 elementary students!**
George Yacoub '21	

Williams College Sigma Xi Chapter and 2018 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 2017-2018 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, 2017 Fall – Kris Kirby, Psychology, "Weighing future consequences: the discounting theory of impulsive choices" & "Resolving the paradox of self-control"." In April, 2018 Spring – Leo Goldmakher, Mathematics." 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 Maddison Albert. (spelled with two d's)

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 63 newly elected associate members from the Class of 2018 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.

Biology	**Computer Science**	Sumun Iyer	**Physics**
Seema Amin	Matheus Cruz Correia de Carvalho Souza	Arjun Kakkar	Sam Alterman
Josselyn Barahona	James Hughes	Molly Knoedler	Ellery Galvin
Michael Chen	Wei Luo	Daniel Maes	Ashay Patel
Naomi Currimjee	Timothy Randolph	Eliza Matt	Emily Stump
Rebecca Gorelov	Carl Rustad	Daishiro Nishida	Bingyi Wang
Daniel Kirsch		Andrew Scharf	
Haley Lescinsky	**Geosciences**	Alex Semendinger	**Psychology**
Jonah Levy	Emmett Blau	Hallee Wong	Kendall Bazinet
Rebecca Smith	Jacob Cytrynbaum	Weitao Zhu	Anna DeLoi
Jung Min Suh	Samuel Gowen		Gabrielle Ilagan
	Ezekiel King Phillips	**Neuroscience**	Brenna Martinez
Chemistry	Timothy Nagle-McNaughton	Daisy Banta	Robert Rowledge
John Ahn		Syed Hussain Fareed Bukhari	Keiana West
Daniel Brandes	**Mathematics**	Marianna Frey	
Alexi McAdams	Jackson Barber	Anika Mitchell	**Statistics**
Jonathan Meng	Cody Cao	Rachel Oren	Anna Neufeld
Cynthia Okoye	Madeleine Elyze	Lauren Steele	
Katie Spence	Alyssa Epstein		
Miranda Villanueva	Sarah Fleming		
Allison Wong	Beatrix Haddock		
	Isabella Huang		

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.

With the pending retirements of Kwitter and Souza at the end of the 2017-18 academic year, job searches for both positions were carried out jointly with members of the Physics Department. *Anne Jaskot '08* was appointed Assistant Professor of Astronomy, which she will begin on July 1, 2019, at the completion of her NASA Hubble Fellowship, which she is spending at the University of Massachusetts, Amherst. Kevin Flaherty began his work as Lecturer in Astronomy on July 1, 2018, coming from Wesleyan University for an overlap year with Souza.

Professor **Jay Pasachoff** worked all of 2017-18 with his students in preparing, observing, and studying the data from the Great American Eclipse of August 21, 2017 with support from his NSF grant, his grant from the National Geographic Society's Committee for Research and Exploration, and the NASA Massachusetts Space Grant Consortium. Images and other information about eclipse efforts past and future appear at http://totalsolareclipse.org.

Williams College students who participated in the observation included *Cielo Perez '19, Charles Ide '20, Christian Lockwood '20, Connor Marti '20, Brendan Rosseau'19, Declan Daly'21, Erin Meadors '20,* and *Ross Yu '19*. They spent the summer of 2017 preparing for the eclipse in Williamstown with a final week spent at the eclipse site in arranging and making the observations. Also in Salem for the eclipse were former students *John Inouye '20, Tim Nagle-McNaughton '18, Muzou Lu '13, Allen Davis '14, Amy Steele '08, Duane Lee '01,* and *Marcus Freeman '08*. Perez, Lockwood, Meadors, and Yu spent the summer of 2018 working on the data and on other astronomical projects.

The Pasachoff team is particularly interested in the solar corona, which is now entering the minimum of the solar-activity cycle. This is most easily seen as the sunspot cycle, but it also affects the shape and temperature of the solar corona and other aspects of the sun. He closely collabortaes with *Daniel Seaton '01*, Ron Dantowitz of the Clay Center Observatory of the Dexter Southworth School of Brookline, Vojtech Rusin of the Astronomical Institute of the Slovak Academy of Sciences, Wendy Carlos of New York, John Seiradakis and Pavlos Gaintatzis of the Aristotle University of Thessaloniki, Greece, and Aristeidis Voulgaris of Optomechanics, Thessaloniki, Greece.

Former Fulbright visitor Marcos Peñaloza-Murillo of the Universidad de los Andes in Mérida, Venezuela, arrived in Williamstown in June 2018 for a 3-month visit, supported by Williams College and MIT. He worked with Pasachoff and Yu on the effect of the total solar eclipse on the terrestrial atmosphere.

For the August 21, 2017, eclipse, Pasachoff used grants from the Solar Terrestrial Program of the Atmospheric and Geospace Sciences Division of the NSF and from the Committee for Research and Exploration of the National Geographic Society. A website is maintained at http://eclipses.info, providing links to maps, safe-observing information, and other information about past, current, and future eclipses. He is a member of the Eclipse 2017 Task Force of the American Astronomical Society.

The PBS NOVA television show in which Pasachoff contributed, that was aired the night of the eclipse on public television stations nationwide and in revised form two days later, has since been released internationally in further-revised form. The video is entitled *Eclipse Over America* and is available at https://nova.wistia.com/medias/py80aesc2x. His additional outreach about the eclipse included webcasts for 365daysofastronomy.org and academicminute.org.

In 2017, a popular book, *The Sun*, by Pasachoff and Leon Golub of the Harvard-Smithsonian Center for Astrophysics was released as the first in a new series for the Science Museum in London. Pasachoff and Roberta Olson of the New-York Historical Society finished the manuscript of *Cosmos*, a highly illlustrated book on the overlap of art and astronomy.

Pasachoff observed the annular solar eclipse of February 16, 2018, from Buenos Aires, and lectured there at the Galileo Galilei Planetarium. Images and descriptions are available at http://eclipses.info = http://sites.williams.edu/eclipse/

Pasachoff continued his solar-system work, together with Bryce Babcock and MIT colleagues including Michael Person, Amanda Bosh, and Carlos Zuluaga as well as Southern African Astronomical Observatory colleague Amanda Sickafoose (also at MIT), on studying the atmosphere of Pluto and other objects in the outer solar solar system through the method of stellar occultations. Observations from Argentina on June 3, 2017, of a prospective occultation by the ~30 mile wide object 2014 MU69 (since named Ultima Thule) were coordinated with observations by MIT collaborator Michael Person aboard NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) airplane with its 2.5-m telescope flying from Christchurch, NZ. Subsequent occultation observations were made from Argentina and from SOFIA in July 2017. The results were used to swerve NASA's New Horizons spacecraft, which will fly close by outer solar system object on January 1, 2019. The occultation work has been supported by grants from NASA's Planetary Astronomy Program.

Pasachoff published a paper about prior observations of an occultation by Pluto were published in the journal Icarus: *Pluto Occultation on 2015 June 29 UTC With Central Flash and Atmospheric Spikes Just Before the New Horizons Flyby*.

Pasachoff completed several years as a Visitor in the Planetary Science Department at Caltech, spending occasional time there. He is now a Visitor at the Carnegie Observatories, Pasadena. This year, he brought four summer students for a week to a summer program of the Zwicky Telescope Facility (ZTF) at the Palomar Observatory at Caltech and provided an extra visit to the Big Bear Solar Observatory. Williams College is part of the ZTF educational program, which included a night at the 200" telescope at Palomar.

Pasachoff continued as Chair of the Working Group on Solar Eclipses of the IAU as part of the their reorganized division structure which placed the Interdivisional Working Group as part of both the *Education, Outreach, and Heritage* and the *Sun and Heliosphere* divisions. He was elected 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 a historical error in the crowdsourcing naming of exoplanets and their parent stars arranged by the IAU, he was added to the Executive Committee Working Group of the IAU: Star Names. He presented five papers at the August 2018 General Assembly of the IAU in Vienna, Austria including at the IAU's Centennial Symposium. He also worked with his students to prepare papers for the Solar Eclipse Conference in Genk, Belgium, in August 2018, and for the 200th-birthday celebration of the solar astronomer Fr. Angelo Secchi, 19th-century director of the Vatican Observatory and an expert on the Sun, held in Rome in September.

Following the Great American Eclipse, Pasachoff arranged special sessions or gave papers at the AAS Division of Planetary Sciences in Provo, Utah, in October; at the American Geophysical Union meeting in New Orleans in December; and at the AAAS meeting in Austin, TX in February, which followed observations of a partial solar eclipse from Buenos Aires. Pasachoff continues as representative of the AAS to the AAAS Astronomy Division.

Pasachoff participated 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 and now Sonoma State University. He was coauthor of a paper about the project given at the American Geophysical Union meeting in December, and of a paper for an Astronomical Society of the Pacific volume to be published in 2018.

In addition to the January 2018 231st meeting of the American Astronomical Society in Washington, DC, Pasachoff attended the AAS Division of Planetary Sciences meeting in October 2017 in Provo, Utah, and the 232nd meeting of the AAS in Denver in June 2018.

For information about Williams College's eclipse and transit expeditions:

http://www.eclipses.info and http://www.transitofvenus.info.

Pasachoff continued as President of Williams College's Sigma Xi chapter. Two graduate students, including *Allen Davis '14*, received Sigma Xi research grants based on Pasachoff's recommendation to participate in the Oregon eclipse expedition. Pasachoff continued as the Williams College representative to the NASA-sponsored Massachusetts Space Grant Consortium. The Consortium sponsored a portion of the support for three students to participate in the Oregon eclipse expedition and two additional students for their summer research.

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://thecosmos5.com), in press to be published in late 2018 with a 2019 copyright.

Pasachoff provided a major update to his *Peterson Field Guide to the Stars and Planets, 4th edition* (Houghton Mifflin Harcourt), including results from the 2017 eclipse and extending the predictions for a decade. He and Jay Anderson, a Canadian meteorologist, have provided the manuscript for a *Peterson Field Guide to the Atmosphere*.

Pasachoff continued as astronomy consultant for the McGraw-Hill Encyclopedia of Science and Technology and its AccessScience website. He also continued as physical-science book reviewer for *The Key Reporter*, the Phi Beta Kappa newsletter and as advisor to the children's magazine *Muse*. As a Fellow of the Society for Skeptical Inquiry, he is on the editorial board of the *Skeptical Inquirer*.

Pasachoff continued to supervise the activities at the Old Hopkins Observatory, which are scheduled by Michele Rech. Bi-annual repair/maintenance work has been done, the first in a 10-year extension of the original 10-year service contract on the Zeiss ZKP-3B planetarium projector. Students operating the planetarium during the 2017-18 academic year included Head Teaching Fellow *Diego Gonzalez '18; Glen Gallik '18; Cielo Perez '19;* and *Brendan Rosseau '19*.

At the October meeting of the Division of Planetary Sciences of the AAS, Pasachoff organized and chaired a session on the history of the New Horizons mission to Pluto and to the Kuiper Belt beyond, jointly between the DPS and the Historical Astronomy Division of the AAS. Later, he was on the Organizing Committee for the historical sessions at the October 2018 DPS meeting and organized a session on the history of the Cassini mission to Saturn.

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. Kwitter and Dick Henry (Oklahoma) plus other colleagues have studied the contribution of PN progenitor stars to the carbon and nitrogen content of the Milky Way, comparing observed abundances with theoretical model predictions; their paper appeared in Monthly Notices in January 2018. Kwitter and Henry have been invited to author a review paper on planetary nebulae for the Publications of the Astronomical Society of the Pacific for publication in 2020.

Kwitter continues to serve on the International Astronomical Union's Working Group on Planetary Nebulae. She worked with other members to organize a Focus Meeting on "Galactic Disk Metallicity Gradients" during the August 2018 General Assembly in Vienna, Austria. She completed her term on the van Biesbroeck Award Committee of the American Astronomical Society, awarded every two years on the basis of "long-term extraordinary or unselfish service to astronomy, often beyond the requirements of his or her paid position." She also finished her stint as the coordinator for the summer intern program of the Keck Northeast Astronomy Consortium (KNAC). Finally, Williams continues as a member of the Northeast Astronomy Participation Group, a consortium of small colleges that has contracted for 3.5-m and 20-inch telescope time at Apache Point Observatory. Kwitter and Steve Souza have used these facilities extensively, observing remotely with students for their research; our new faculty will continue have this opportunity.

Senior Lecturer **Steven Souza** conducts and supervises the astronomy observing program, indoor labs, and daytime observing. He hosted observatory visitors including planetarium groups, Visiting Prof. Ragep's Arabic Studies class, new faculty orientation participants, Family Days attendees, Science Blast 2018 participants (Mount Greylock HS students), a MGHS class, a group of underrepresented doctoral candidates and post-docs, Shannon O'Brien for the Office of Communications, the Southern Vermont (amateur) Astronomy Group, and numerous student previews and prospectives. He also organized and hosted an event to view the August 2017 partial solar eclipse from the roof of Thompson Physics.

Souza continues to maintain and improve the observatory, this year completing the modernization of the 0.6m DFM telescope facility begun in 2016. The goals of the project include long-term maintainability and the option of remote operation.

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. He continues to advise first-years and sophomores, and advised the newly-formed Astronomy Club on equipment and facilities issues. He attended the Keck Northeast Astronomy Consortium (KNAC) faculty meeting in June 2017 at Colgate University.

Lecturer **Kevin Flaherty** joined the faculty of the Astronomy and Physics departments in July, 2018 and over the next year he will be learning from Steve Souza as he prepares to take over the day-to-day operations of the observatory, as well as the astronomy lab instruction. Kevin comes to Williams from Wesleyan University, where he spent five years working as a research associate under the direction of Prof. Meredith Hughes. While at Wesleyan Kevin worked on, and will continue to work on at Williams, a number of research projects related to the formation of planets. With data from the Atacama Large Millimeter/submillimeter Array (ALMA) in the Atacama Desert of Chile, Kevin uses molecular line emission to constrain the turbulent motion within disks of gas and dust surrounding a handful of the brightest nearby young stars. He was recently awarded additional time on ALMA for follow-up measurements of one system that shows turbulence, in order to constrain its three-dimensional structure. Kevin is also interested in the debris left over from the collisions of Pluto-sized bodies in more mature systems. In particular, he has studied the peculiar debris disk around a low mass star, while working with students of Prof. Hughes on using a debris disk viewed nearly edge-on to constrain the total mass of Pluto-sized bodies, as well as the nature of the collisions that produce the debris.

Over the past year he has attended the American Astronomical Society Meeting in National Harbor, the KNAC fall symposium at Colgate University, the Star and Planet Formation in the Southwest II conference in Tucson, The Origin of Galaxies, Stars, and Planets in the Era of ALMA conference in Pasadena, and a Gordon Research Conference at Mt. Holyoke. He also helped organize the (partial) solar eclipse viewing at Wesleyan, which was attended by over 400 local residents, as well as numerous presentations for adults and children as part of Wesleyan's Space Night and Kids Night outreach events.

Post-Graduate Plans of Astronomy Majors

James M. Hughes	Ph.D. in computer science at University of Colorado, Boulder
Timothy Nagle-McNaughton	Ph.D. in earth and planetary sciences at University of New Mexico

Astronomy Colloquia

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

Off-Campus Astronomy Colloquia

Jay M. Pasachoff

"Eclipses del Sol"
Planetario Galileo Galilei, Buenos Aires February 2018

"The Great American Eclipse of 2017 and Others"
American Museum of Natural History, New York City, NY April 2018

"The Glory of Solar Eclipses"
Zwicky Telescope Facility Summer School, Caltech, Pasadena, CA June 2018

"The Glory of Solar Eclipses"
Trimble Fest, University of California, Irvine, CA June 2018

Biology Department

Working closely with many interdisciplinary programs on campus (The BIMO, Neuroscience, Environmental Studies, BiGP, and Public Health Programs), the Biology Department's goals are to provide students with the opportunity to do hands-on, one-on-one research with a professor while offering state of the art academic courses. To that end, the department had 26 honors students working in faculty labs this past year. Of these, 10 were inducted into the Sigma Xi Honors Society. For the academic year 2018-19, the department has 26 students conducting honors work. The department is committed to providing a positive research and learning experience for all biology students. As a result of this commitment, several of our students were awarded grants or fellowships to pursue their studies after graduation. *Michael Chen* and *Rebecca Smith* received a Stratton Fellowship to further their studies. The department also has 36 students doing summer research, either here at Williams or off campus. *David Gorestky '20* and *Ashley Zhou '20* will be working at the Whitehead Institute and *Anastasia Tishena '20* spent the summer at the Broad Institute. Funding for summer research comes from various sources including individual research grants and Division funding. At least half of the biology faculty has outside research funding from either NSF or NIH. This funding allows many students to travel to professional meetings throughout the year presenting posters on their research at Williams.

Each year at graduation, the Biology Department awards prizes to several outstanding majors. *Josselyn Barahona* and *Erica Chang* each received the Benedict Prize in Biology. *Peter Lugthart* received the Dwight Botanical Prize. *Hannah Weinstein* received the Conant-Harrington Prize for exemplary performance in the biology major, and *Rebecca Gorelov* received the William C. Grant, Jr. Prize for demonstrating excellence in a broad range of biological disciplines.

The Biology Department continued to participate in the Class of 1960 Scholars program. In the spring, we invited five biology alumni who gave poster presentations on their research and took part in a panel discussion covering topics ranging from graduate school to life after Williams. The poster session following the panel covered diverse topics and allowed our scholars to interact individually with our visiting scientists. Their research presentations covered these diverse topics:

- *Emily Maclary '10,* Postdoctoral Scholar, Biology Department, University of Utah: *Uncovering Genetic regulators of Hindlimb morphology in the Domestic Pigeon.*
- *Michael Abrams '11,* Miller Postdoctoral Fellow, UC Berkeley: *Self-Repair and Sleep: Ancient Conserved Processes Observed in Jellyfish.*
- *Gordon Smith '13.* Graduate student, Ecology and Evolutionary Biology, University of Arizona: *Intraspecific variation in floral foraging in hawkmoths.*
- *Betsy Hart '14,* Graduate student, Molecular Biology, Princeton University: *Altered conformations of the Escherichia coli beta-barrel assembly machine alleviate outer membrane protein assembly defects.*
- *Nitsan Goldstein '15,* Graduate student, Neuroscience, University of Pennsylvania: *Calories are required for sustained resuctions in hypothalamic hunger neurons.*

Class of 1960 Scholars in Biology

Eman Ali	Nebiyou Metaferia
Haelynn Gim	Rodsy Modhurima
Faris Gulamali	Tyma Nimri
Chen-Yi Hung	Alia Richardson
Kyung Shin Kang	Emma Rogowski
Julie Kim	Benjamin Wipper
Yang Lee	Ashley Zhou

Professor **Lois Banta** continued her research on the soil bacterium *Agrobacterium tumefaciens*. This plant pathogen is best known for its unique ability to deliver DNA and proteins to host plant cells, thus stably altering the genetic makeup of the plant and causing crown gall tumors ("plant cancer") to form at the infection site. One major goal of the lab's current research is to characterize the host defense responses elicited by the bacterium. Honors student *Rebecca Gorelov '18* and independent study student *Alonso Villasmil '18* pursued this line of investigation. They were joined by *Will Doyle '19* over winter study and *Joelle Troiano '20* in the spring. Both Rebecca and Alonso attended the 38th Annual Crown Gall Conference in Corvallis, Oregon; the conference included a field visit to three vineyards with the Program Coordinator of the Oregon Wine Research Institute. At the conference, Rebecca presented a poster and Professor Banta presented a talk on their research. Rebecca was the only undergraduate to receive a travel award sponsored by the USDA Agriculture and Food Research Initiative. Professor Banta also gave a talk at the Center for Carbohydrate Recognition and Signalling, Department of Molecular Biology and Genetics, Aarhus University in Denmark. This year marked the end of a four-year, $452,000 grant from the National Science Foundation to the Banta lab for *Characterization of Arabidopsis Defense Responses to the Agrobacterium tumefaciens Type VI Secretion System*.

During the fall semester, Professor Banta taught Microbiology. In the lab component of this literature-based course, the students explored microbial diversity in soil from ponds and agricultural sites locally and in California, and characterized unknown bacterial species isolated from a variety of artisanal cheeses. As part of a semester-long focus on the contributions of the bacterial communities in the animal gut to human health, immune system development, and obesity, students also compared the microbial composition of feces from a variety of animals. In the Spring, Professor Banta was on sabbatical to pursue her research. Last summer, Banta was awarded the Nelson Bushnell '20 Teaching Prize for her "especially collaborative, interdisciplinary, experiential, and rigorous coursework."

This year, Professor Banta concluded her 3.5-year term as 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 Microbe Interactions*, *Microbiology, New Phytologist, Physiological and Molecular Plant Pathology,* and *Frontiers in Microbiology*. Within Williams, she served on the Advisory Committees for Public Health, Biochemistry/Molecular Biology, Bioinformatics/Genomics/Proteomics, and Design Thinking at Williams. She was also a member of the search committee that chose the new director of the Williams College Art Museum, and gave guest lectures in the Dimensions of Public Health and Philosophy of Education courses. Finally, she is Secretary/Treasurer of the Williams College Chapter of the national science honor society Sigma Xi.

Assistant Professor **Ron Bassar** taught Ecology (BIOL/ENVI 203) in the Fall and Rapid Evolution in Ecology (BIOL 402) in the Spring. This year he continued to work on the Evolution of Species Coexistence grant from NSF that funds short and long term research at his study site on the Caribbean island of Trinidad (www.theguppyproject.weebly.com). He traveled to Trinidad three times to collect guppies to bring back to the new fish facility at Williams, to set up new experimental research facilities in Trinidad, and to conduct research with Williams College students.

When not teaching or in Trinidad, Bassar has been working with students (*Azar Dixit '20 and Del Rose Hooker-Newball '21*) at Williams to raise the guppies from Trinidad through multiple generations in the lab at Williams. These second generation lab born fish will then be used in common garden experiments to test for the genetic basis of local adaptation. Two students from the Bassar lab also traveled to Trinidad with him in the summer. *Emily Burch '19* is working in the field and the laboratory in Trinidad to address questions related to the demographic cost to female guppies of male sexual harassment. *Megan Powell '20* has been working on the monthly mark-recapture team. This work involves working with other students from the around the world in a team of researchers to capture, mark, and release guppies from four experimental streams in Trinidad. In addition to Emily Burch's project, Professor Bassar will advise *Emma Rogowski '19* and *Sophie Lu '19* (co-advised with Daniel Turek in Math/Stats) on their senior theses. Emma will be using the long term (10 year, monthly recapture data) population data from Trinidad to test for a role of intestinal parasites in driving population dynamics of fish. Sophie will also be using the long-term data to evaluate the role of El Nino events on the population dynamics of the guppies.

Professor Bassar published six papers in the last year in both theoretical and empirical ecology and evolution. He gave two talks at society meetings and gave one invited seminar on his research at the University of Texas. He was also invited to give a plenary lecture at the Evolutionary Demography Society meeting in Coral Gables, FL next January. He continues to serve as Associate Editor for the *Journal of Animal Ecology*.

Assistant Professor **Matt Carter** continued his research into the neural basis of food intake and sleep behaviors using mice as a model organism. In the past year, he published three scientific papers with Williams student co-authors. *AgRP neurons can increase food intake during conditions of appetite suppression and inhibit anorexigenic parabrachial neurons* was published in *The Journal of Neuroscience* and coauthors included *Rachel Essner '16, Alison Smith '15, Adam Jamnik '17, Anna Ryba '16,* and *Zoe Trutner '16. Identification of discrete, intermingled hypocretin neuronal populations* was published in The Journal of Comparative Neurology and coauthors included *Manasi Iyer '14, Rachel Essner '16*, and Professor of Mathematics and Statistics Bernhard Klingenberg. *POMC neurons in heat: A link between warm temperatures and appetite suppression* was published in *PLoS Biology* and coauthors included *Maria Vicent Allende '17* and *Conor Mook '16*. Professor Carter's students also presented two posters at the 2017 Society for Neuroscience Conference in Washington D.C. *Hypothalamic arcuate nucleus neurons that regulate energy homeostasis can also influence sleep/wake behavior* was presented by *Nitsan Goldstein '15, Kelsey Loy '15, Brian Levine '16, Will Duke '17, Olivia Meyerson '16,* and *Adam Jamnik '17*. *TRH neurons respond to cold exposure but stimulation is not sufficient to increase body temperature* was presented by *Sara Lehman '17* and *Rachel O'Sullivan '17*. Professor Carter also presented invited talks at The University of Pennsylvania, Harvard Medical School, Westfield State University, the European Chemoreception Research Organization, and Mount Sinai Medical School. Finally, Carter presented a talk about the importance of sleep at TEDx North Adams in January 2017. Carter's lab continues to be funded by research grants from the National Institutes of Health and the National Science Foundation.

Over the 2017-18 academic year, Carter worked with two thesis students: *Jacob Sperber '17* completed a thesis project titled *Characterization of the parasubthalamuc nucleus as an appetite suppression center*, and *Heidi Halvorsen '17* completed a thesis project titled *Hypothalamic neurons that regulate food intake and energy homeostasis are active during torpor*. Professor Carter taught Neural Systems and Circuits (BIOL 311) in Fall 2017 and The Neural and Hormonal Basis of Hunger (BIOL 412) in Spring 2018.

Lecturer **Derek Dean** uses Drosophila genetics as a model to study seizure disorders such as epilepsy. This past year he published a paper in the journal *Fly* with students *Hannah Weinstein '18, Seema Amin '18, Breelyn Karno '20,* and *Emma McAvoy '17* along with Cornell University colleague David Deitcher and members of Deitcher's lab. The paper was titled *Extending julius seizure, a bang-sensitive gene, as a model for studying epileptogenesis: Cold shock, and a new insertional mutation* and describes how mutations in the gene julius seizure (jus) cause flies not only to have seizures in response to mechanical shock (e.g. shaking of the culture vial), as was previously shown, but also in response to sudden exposure to cold temperature or strobe lighting. In addition, they created a new mutant allele for jus that allows researchers to track the location of the Jus protein in neurons. This will be useful because they have identified 23 proteins that bind to Jus, all with similar proteins in humans. They intend to determine how this complex of proteins is affected by loss of function in jus.

Hannah and Seema continued research on jus and, with generous funding from Williams College to support student research, presented a poster at the International Drosophila Conference in Philadelphia to describe genetic interactions between jus and some of the 23 genes that encode proteins that bind to Jus and are shared with humans.

Professor **Joan Edwards** completed her third and final year as Chair of the Biology Department. She taught The Tropics: Biology and Social Issues (BIOL 134) in spring 2018. In the summer of 2017, Professor Edwards worked with *Alexandra Griffin '19* and *Molly Knoedler'18* to study pollinator networks at Isle Royale Wilderness National Park using time-lapse video to film visitors to twenty-four different flower species at two different locations. Edwards also worked with *Natalia Miller '18* at Hopkins Memorial Forest (HMF) to study goldenrods and their pollinators. The focus of the Isle Royale study was to use time-lapse videos to film insect visitors to twenty-four flower species at two different locations in order to test for differences in flower visitors at different sites. They also collected data on arctic plant populations (for some sub-populations this is the 20th 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. We also looked at site differences by comparing visitors to four species of goldenrods at Hopkins Forest and on Hopper Road.

Alexandra and Natalia continued to work with Prof. Edwards throughout the year both completing senior theses in the Biology Department. Prof. Edwards also advised Molly completed a thesis in the Department of Mathematics and Statistics with Professor Julie Blackwood. The two studies both showed that there is spatial heterogeneity in flower visitors among sites strongly supporting a neighborhood model of pollination where insect forage in their home ranges for nectar and pollen and flowers draw on insects in their neighborhood as couriers of pollen.

Professor Edwards gave an invited talk at the annual meeting of the Entomological Society of America in Denver, Colorado (November 2017). Her talk entitled, “Near-Complete Observations of Flower Visitors Indicate Flowers Use Local Insects for Pollination Services” was part of a symposium on “Ecology in the sixth mass extinction: detecting and understanding rare biotic interactions”. At that same conference she and colleagues David Smith, *Julie Jung ’16,* and *Lane Davis’17* presented a poster *Countering Pollinator Decline by Increasing Floral Resources for Insect Visitors*. She also gave the address for the annual meeting of the Connecticut Botanical Society at the Connecticut Forest & Parks Association Headquarters in Rockfall, CT. The talk was entitled “Botanical Explosions: The Evolutionary Impact of Ultra-fast Plants”. She also gave a field talk at Hopkins Memorial Forest on fall blooming flowers organized by Bee Friendly Williamstown, a group advocating for a pollinator friendly community. The Field talk was attended by about 40 people who learned the diversity of the fall blooming flowers and their importance for pollinator health.

Professor Edwards attended the American Society of Naturalists conference in Asilomar, California in January 2018 with her students Alexandra Griffin and Molly Knoedler as well as former student *Molly McEntee ‘14.* They presented a poster *Near-complete records of floral visitors support a neighborhood model of pollination*.

Senior Lecturer **David Smith** completed his last year of teaching before retiring at the end of the Spring semester after thirty-nine years of teaching. He taught The Organism (BIOL 102) in spring 2018. In the summer of 2017, Professor Smith worked with *Tucker Lemos ’19* to continue his long-term study of the population biology of the boreal chorus frog along the rocky shoreline at Isle Royale Wilderness National Park.

Smith attended the annual meeting of the Entomological Society of America in Denver, Colorado in November 2017 where he presented a poster with Joan Edwards, *Julie Jung ’16,* and *Lane Davis’17* on *Countering Pollinator Decline by Increasing Floral Resources for Insect Visitors*. This work reports on mowing schedules to maximize flowering stems in New England fields. He also attended the American Society of Naturalists conference in Asilomar, California in January 2018. He and colleagues *Osama Brosh ‘17, Mekli Tesfaye ‘20* and Professor Luana Maroja presented a poster *Patterns of sibship structure along an ecological gradient*.

David’s retirement was celebrated with a symposium where his former students spoke about their time working with David at Williams along with their current work as scientists and educators. Among the attendees were: *James Meigs ‘81, Josh VanBuskirk ‘82, Neal Scott ‘82, Phil Coulling ’90, Evan Preisser ’93, Jamie Art ’93, Jeremy Fox ’95, Lindy McBride ’98, Josh Shapiro ’98, Ethan Plunkett ’00, Alan Brelsford ’01, Jess Purcell ’02, Malin Pinsky ’03, Dan Runcie ’05, Annie O’Sullivan ‘07, Emily Behrman ’09, Chuck Soucy ’09, Theresa Ong ’09, Luke Faust ’14,* and *Beth Cornett ’14*. The symposium was followed by a reception and dinner. A good time was had by all.

During the year Professor **Claire Ting** and her students continued pursuing their 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 the Ting 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 the Ting laboratory this past year included *Michael Chen ’18*, who joined her laboratory as an honors thesis research student. With the goal of understanding the evolution of niche differentiation within the *Prochlorococcus* lineage, Mike characterized the effects of key environmental factors on strains belonging to deeply branched clades within the *Prochlorococcus* lineage. Using flow cytometry to measure changes in cell densities and chlorophyll fluorescence characteristics, Mike demonstrated that strains have the capacity to acclimate rapidly to increased irradiance levels. This acclimation process is characterized by the adoption of a low chlorophyll fluorescence state, suggesting the degradation of chlorophyll pigments and/or an increased dissipation of excited state energy as heat. His data have important implications for *Prochlorococcus* cells in the open oceans, where mixing events within the water column can expose cells to large fluctuations in photon flux densities.

In addition, *Yang Lee '20* continued as a research assistant in the laboratory during the summer and academic year. She collaborated with Mike in characterizing the effects of irradiance level on the growth of different *Prochlorococcus* strains and continued her project on the Pcb light-harvesting complex proteins. *Gabby Martin '21* also joined the Ting laboratory this academic year and although the fall 2017 semester was the first time she worked in our lab, her brother, Kyle, had been a member of our laboratory eight years earlier.

Professor 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 Department 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.

Post-Graduate Plans of Biology Majors

Natasha Albaneze	Associate Consultant, Trinity Partners, New York, NY
Daisy Banta	Working as a lab technician in neurobiology until March, when she will start a Fulbright in Brazil
Josselyn Barahona	Research Fulbright in Chile
Brian Benitez	Research Assistant in the Department of Psychiatry at Boston Children's Hospital Boston, MA
Michael Cassidy	Research Technician I, Weill Cornell Medicine, New York, NY
Andy Castaneda	MPH in Epidemiology at University of Texas School of Public Health
Erica Chang	Attending UC Davis School of Veterinary Medicine (DVM)
Michael Chen	Research Assistant in Genomics, Broad Institute, Cambridge MA
Amar Dayal	Associate Consultant at Parthenon-EY
Katherine Fearey	Working as a U.S. Equities CPM Analyst, J.P. Morgan, New York, NY.
Shelby Fisher	Princeton in Asia Fellowship, Program Development at Rato Bangalo School, Kathmandu, Nepal
Marianna Frey	Education Research Assistant, Hospital for Special Surgery (Rheumatology department), New York City.
Rebecca Gorelov	Research assistant/technician at the Broad/Dana Farber Cancer Research Center
Megan Greiner	Data Optimization Analyst at Optum in Boston
Heidi Halvorsen	Training for the Norwegian Military, then will do an internship with Bain Capital.
Anna Harleen	Working as a medical assistant at CPMC in San Francisco.
Kathryn Kennedy	Healthcare consultant at Clarion Healthcare
Jeremiah Kim	Model Builder, William Rawn Associates, Architects Inc., Boston, MA
Daniel Kirsch	Awarded a Chandler Fellowship to explore: "A Comparative Evaluation of Multi-species Interaction at Zoos" which he will accomplish by visiting zoos in countries outside of the US.
Haley Lescinsky	Post-Bachelor Fellow at the Institute for Health Metrics and Evaluations (IHME)
Jonah Levy	Field work with David Reznick on guppy evolution in Trinidad; graduate school in ornithology
Candy Lu	Full Time Biology Teacher and Assistant Women's Ice Hockey Coach, New Hampton School, New Hampton, NH

Calvin Ludwig	Research assistant/technician at Boston Children's Hospital
Peter Lugthart	Development Economics Research Assistant, Northwestern University
Marianna Magidenko	M.D., Western Michigan University Homer Stryker M. D. School of Medicine
Ananya Mahalingam-Dhingra	Tufts Cummings School of Veterinary Medicine (DVM)
Kayley McGonagle	Visual Arts Teaching Fellowship at Riverdale Country School in the Bronx, NYC then pursuing a Masters in Education from the University of Pennsylvania
Christopher McLaughlin	Clinical Research Coordinator, Seaver Autism Center at the Icahn School of Medicine at Mt. Sinai, New York, NY
Rachel Oren	Research Assistant II in a neuroscience lab in the anesthesia dept at Brigham and Women's Hospital in Boston studying the effects of anesthesia on the aging brain.
Jensen Pak	Research Assistant, Boston Children's Hospital, Boston, MA
Thomas Riley	Herchel Smith Fellow studying for an Mphil. in the History and Philosophy of Science at Cambridge University.
Sophia Robert	IRTA Fellow, Lab of Brain and Cognition (NIH/NIMH), Bethesda, MD
Alexia Royal-Eatmon	Master's program in Food Science, Kingston, Jamaica.
Jean Salisbury	Research Lab Technician, University of Massachusetts Medical School Division of Infectious Diseases and Immunology, Worcester, MA
Danielle Sim	Working as a Research Assistant in the vascular biology department at Boston Children's Hospital (Boston, MA)
Rebecca Smith	M.Phil. in Biology, University of Cambridge
Payton Spencer	Associate Consultant, Clarion Healthcare, Boston, MA
Lauren Steele	Working at the Charles Nelson lab at Boston Children's Hospital
Timmy Suh	Working as a research at the Broad institute in Kevin Eggan's lab
Emily Sundquist	M.Phil. in Epidemiology at Cambridge University
Haley Tartell	Working as a consultant at Trinity Partners, a life sciences consulting firm in Waltham, MA.
Alonso Villasmil Ocando	Research assistant/technician at Mass General Hospital, studying mechanisms of immune control in persons infected with HIV
Emma Waddell	Working as a Clinical Research Coordinator at the University of Rochester Center for Health and Technology
Stella Worters	Teaching english in the Czech Republic

Biology Colloquia

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

Adam Siepielski, University of Arkansas
"A cautionary tale of woe and intrigue in explaining species diversity"

Zuzana Tothova ('01), Harvard
"Targeting cohesin mutations in leukemia"

Abhyudai Singh, University of Delaware
"Systems Biology in Single Cells: A Tale of Two Viruses"

Shaeri Mukherjee, UC San Francisco
"Lessons learned from intracellular bacteria—how to remodel and rewire the host cell"

Sonya Auer, Williams College
"The pace of life: Functional and evolutionary links between energy metabolism and the life history"

Beronda Montgomery, Michigan State University
"Seeing the Light: Color Vision and Developmental Acclimation in Cyanobacteria"

Nicholas Betley, University of Pennsylvania
"A Neural Circuit for the Suppression of Pain by a Competing Need State"

David Seward ('00), University of Vermont
"Parlez-vous VUS? Functional genomics in the age of clinical sequencing"

Off-Campus Biology Colloquia

Ron Bassar

"The evolution of coexistence: reciprocal adaptation promotes the assembly of a simple community."
Evolution Society Meeting. Portland, Oregon, August 2017.

"The evolution of coexistence: theoretical and empirical studies in a simple community."
Annual Meeting of the American Naturalist Society. Asilomar, California, January 2018.

"Evolution of population regulation and species interactions determine the trajectory of life history evolution."
Department of Biology, University of Texas, Arlington. April 2018.

Lois Banta

"Modulation of host defenses by the Type VI Secretion System (T6SS) of Agrobacterium tumefaciens"
Center for Carbohydrate Recognition and Signalling, Department of Molecular Biology and Genetics, Aarhus University in Denmark April 2018

"Suppression of Host Defense Expression by the A. tumefaciens Type VI Secretion System" at the 38th Annual Crown Gall Conference in Corvallis, Oregon, Sept. 2018.

Matt Carter

"Providing opportunities for undergraduates to experience anonymous peer review"
Faculty for Undergraduate Neuroscience Workshop, Chicago, IL., July 2017

"Interplay between appetite-stimulating and appetite-suppressing neuronal populations"
European Chemoreception Research Organization, Wellcome Genome Campus, Cambridge, U.K., Aug 2017.

"Strategies for designing and delivering a scientific presentation"
Department of Pharmacology, Mount Sinai Medical School, New York, NY. , Sept, 2017

“The role of inputs to the parabrachial nucleus in appetite and appetite suppression”
BIDMC Endocrinology Grand Rounds, Harvard Medical School, Boston, MA., Dec 2017.

“Why am I hungry? Interplay between appetite-stimulating and appetite-suppressing brain systems”
Westfield State University, Westfield, MA., Dec. 2017.

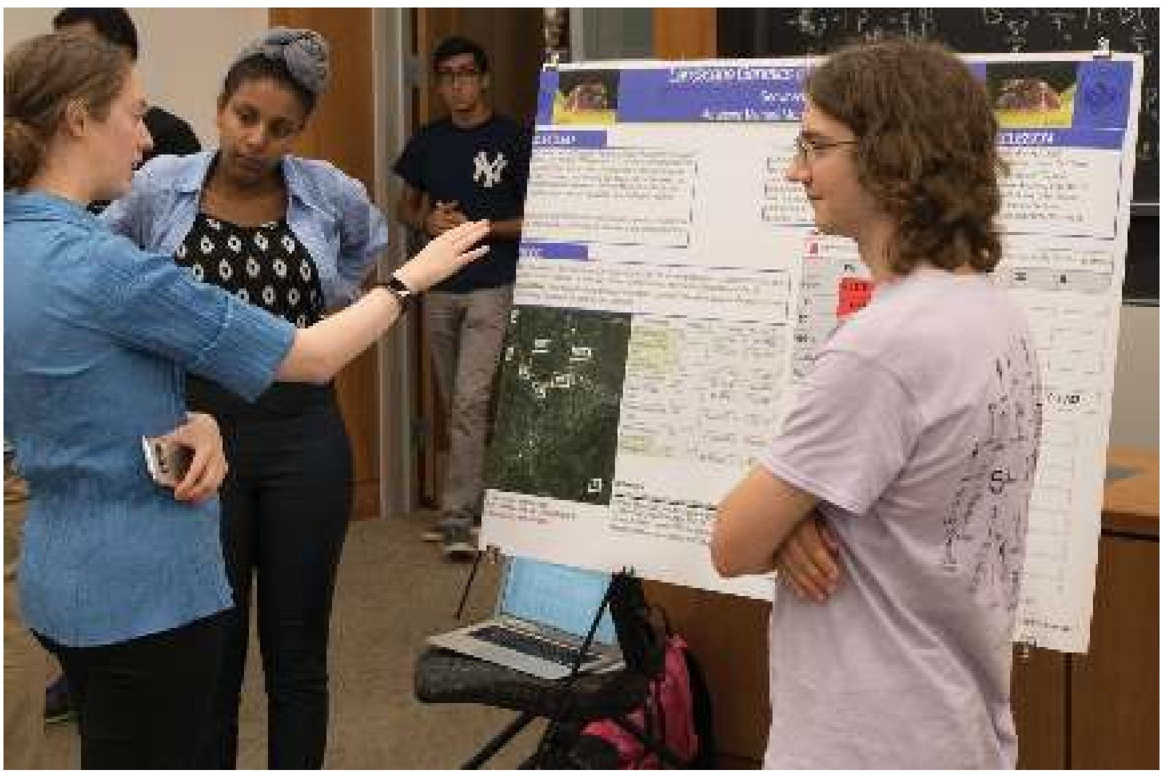
“The Science of Sleep and the Art of Productivity”
TEDX North Adams, North Adams, MA., Jan 2018.

“Interplay between appetite-stimulating and appetite-suppressing neuronal populations”
Institute for Diabetes, Obesity, and Metabolism, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, April 2018.

Joan Edwards

“Near-Complete Observations of Flower Visitors Indicate Flowers Use Local Insects for Pollination Services”
Annual Meeting of the Entomological Society of America, Denver, Colorado, November 2017.

“Botanical Explosions: The Evolutionary Impact of Ultra-fast Plants”
Annual Meeting of the Connecticut Botanical Society, Rockfall, Connecticut, December 2017.



Sehwheat Manna '19 (Morales lab) listens carefully during a disussion of her poster during the summer science poster session in August of 2018.

Chemistry Department

It was a year of transitions in the Chemistry Department. We welcomed a new faculty member, Assistant Professor Bob Rawle, a biochemist who will be teaching AIDS: The Disease and Search for a Cure (CHEM 115) in the fall and Biochemistry I: Structure and Function of Biological Molecules (CHEM 321) in the spring.

The department also celebrated the retirement of two beloved faculty members in 2018. After 47 years Halford R. Clark Professor of Natural Sciences Lawrence J. Kaplan has hung up his forensics and biochemistry hats and is looking forward to brightening the minds of students outside the Williams College walls. Philip and Dorothy Schein Professor of Chemistry Charles (Chip) Lovett, taught biochemistry for 33 years at Williams and served for many years as the Director of the Science Center, the Summer Science Program, and the Summer Science Camp and has now earned the chance to spend his retirement exploring his many other interests. We are grateful for the long and dedicated service that both Larry and Chip have given to the department and to Williams College over the years. We will miss them both and wish them well on their retirement journeys.

Due to the construction of the new science center, many of our faculty members had quite a busy spring semester. Along with teaching their normal course loads, they also had to pack up their offices and labs to move to the new South Science Building, which is now humming with activity.

Finally, Amy Gehring finished up her service as Chair of the Department. We're grateful to her for her for all her hard work. Professor Lee Park has returned to the department from Hopkins Hall, and will serve as Chair for the 2018-19 academic year.

As the Chemistry Department ended the 2017-18 academic year, we adorned graduation caps to 31 chemistry majors, with 11 of these students completing senior thesis research projects. As they depart from their four years, the remaining students will continue their studies in the newly constructed addition to the Science Quad in the "South Science Building" which opened in May 2018.

We are particularly proud of our seniors and their accomplishments. Each year, individual students are recognized with departmental awards. In the Class of 2018, the John Sabin Adriance prize went to *Jonathan Meng* for outstanding work throughout his chemistry career. The James F. Skinner prize was awarded to *Daniel Brandes* for his distinguished achievement in chemistry and future promise as a researcher. The Leverett Mears prize went to *Elizaveta Lavrova* in recognition of both her abilities in chemistry and her future in medicine. *John (Jack) Roberts IV* was awarded the American Chemical Society Connecticut Valley Section Award for his sustained scholastic excellence. *John Ahn* was awarded the American Institute of Chemists Student Award for outstanding scholastic achievement, *Cynthia Okoye* received the ACS Undergraduate Award in Inorganic Chemistry, *Tobias Muellers* was presented with the ACS Division of Organic Chemistry Award, *Allison Wong* was awarded the ACS Undergraduate Award in Physical Chemistry, and *Miranda Villanueva* was the recipient of the Frank C. Goodrich 1945 Award in Chemistry.

Over the course of the academic year, a number of additional awards were presented to undergraduate chemistry students for outstanding scholarship. *Dasol Lee '21* and *Wyndom Chace '21* received the CRC Awards as the outstanding students in CHEM 151 and CHEM 155, respectively. *Joe Bouvier '21* was presented with the Raymond Chang First-Year Chemistry Award for her exceptional work in CHEM 153. *Anna Ringuette '19* 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, *Brooke Horowitch '20* received the Polymer Chemistry Award and *Katherine Mahoney '20* was the recipient of the Harold H. Warren Prize.

We continued to participate in the Class of 1960 Scholars Program, with Professor Kathryn Riley from Swarthmore College and Professor Dharni Vasudevan from Bowdoin College as our distinguished scientists visiting campus to present a seminar and meet with our students during the 2017-18 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

Luke Cai	Anna Ringuette
Jonathan Hall	Bethel Shekour
Sung Kang	Alison Wong

During the summer of 2018, approximately 35 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.

Assistant Professor **Anthony Carrasquillo** joined the department in July 2017 as a physical/environmental/analytical chemist. In the Fall, he taught the Principles of Modern Chemistry (CHEM 155) lecture with 36 students and two 12-student lab sections. In the spring semester, he co-taught Introduction to Environmental Science (ENVI 102) with Professor Mea Cook (Geosciences) to 48 students in addition to teaching the laboratory component of Instrumental Analysis (CHEM 364).

Professor Carrasquillo brings a new research program in atmospheric organic chemistry to Williams. His research focuses on improving our understanding of how solid or liquid particulate matter, aerosol particles, form and chemically evolve in the atmosphere. During his first year he started four projects that examine the reactivity of organic molecules in three distinct atmospheric media: gas, organic aerosol, and aqueous phase. Thesis student *Katie Spence ’18* investigated the role of functional group identity in the formation of organic aerosol from gas-phase molecules, focusing on a comparison of a simple aldehyde and ketone. This work was continued during the summer by *Andrew Hallward-Driemeier ’21* and *Chris Avila ’21*. In addition, Andrew and Chris constructed a new flow-tube reactor which they will use to generate high concentrations of aerosol products that they can then isolate and characterize using the mass spectrometric and spectroscopic techniques available at Williams. Thesis student *Allison Wong ’18* examined reactions occurring in the atmospheric aqueous phase (water lenses on aerosol droplets, fog, clouds, etc.), focusing on the role of singlet oxygen in the degradation of proxies for natural organic matter. This Summer, *Kimberly Hadaway ’21* and *Uriel Garcia ’21* collected the first data on the role of transition metals in the photoactivation of aerosol organic matter. They will extend their preliminary work with oxalic acid-Fe complexes to include larger, more atmospherically relevant molecules this Fall. Finally, we are also interested in reactions that occur within aerosol particles when exposed to light or atmospheric oxidants. *James Heinl ’19* is the first student working on this project and began his thesis research this Summer by developing methods for the identification and quantification of individual molecules in aerosol particles. He will use these methods to study the reactions of model aerosol systems with the hydroxyl (OH) radical. This has been a very productive year for the Carrasquillo Lab and the work completed to date will serve as the foundation for new and exciting research projects this Fall.

Professor **Amy Gehring** enjoyed another busy year – completing her term as Chair of the Chemistry Department, teaching in both the introductory chemistry and biochemistry curriculum, and working with an enthusiastic group of research students in her lab. 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 upper-level course Enzyme Kinetics and Reaction Mechanisms (CHEM 324). After a six-year break from teaching this course, it was particularly exciting for Gehring to explore, together with her students, how the field of mechanistic enzymology has evolved in the interim.

Gehring had the opportunity to mentor a number of students pursuing biochemistry research in her laboratory. The Gehring lab continued its long-standing work to define the biochemical and genetic features of antibiotic production and development in the sporulating, antibiotic-producing soil bacterium, *Streptomyces coelicolor*. This species is representative of a large bacterial genus that is well known for its biosynthesis of molecules with important applications in medicine. Over the summer of 2017, Gehring was joined in this research by *Nicholas Bernier ’20, David Gorestki ’20, Grace Kromm ’20, Kenny Liu, Anastasia Tishena ’20,* and *Kevin Zhou ’20*, a lively group that worked effectively in teams to study the roles of several post-translational modification enzymes in antibiotic production and the regulation of the organism’s life cycle by sigma factor proteins. During the 2017-18 academic year, these projects were pursued by senior thesis students *John Ahn ’18, Esther Kim ’18,* and *Liza Lavrova ‘18*, who made good progress on all fronts. John completed a study of the substrate specificity of a phosphodiesterase enzyme involved in antibiotic production, Esther made progress towards isolating a recalcitrant *RedU* protein also involved in antibiotic production, and Liza studied the promoter specificity of an interesting sigma factor regulator. David, Grace and Kevin continued to ably assist on these projects, joined by new student *Ali Ladha ’21. Adam Calogeras ’18* also pursued a year-long independent study, and for the first time in our lab was able to generate a *Streptomyces* mutant via CRISPR-Cas9 technology. During January 2018, the lab welcomed four new students taking the Introduction to Research in Biochemistry (CHEM 18)

Winter Study course: *Drew Cohen '20, Michelle Garcia '21, Julie Ha '20* and *Jonathan Lee '20*. *Selin Gumustop '20* also continued the group's collaboration with Prof. Peacock-Lopez on a project to visualize oscillations in bacterial gene expression via fluorescence microscopy. It was another productive and fun year of research with a great group of students! As the academic year closed, the group also said good-bye to their well-loved lab (and table) in the Bronfman Science Center, and Professor Gehring has been spending the summer of 2018 moving into and setting up the beautiful new laboratory space in the South Science Building. She is looking forward to welcoming new and continuing research students back to the lab.

Gehring also participated in the broader scientific community by presenting a talk at the 2018 Microbial Stress Response Gordon Research Conference; this talk included the research results of a number of current and former students. She also served as a reviewer for the journals *JoVE, Microbiology, Open Life Sciences,* and *Scientific Reports* as well as a grant reviewer for the Research Corporation for Science Advancement.

Professor **Christopher Goh** taught Inorganic/Organometallic Chemistry (CHEM 335) in the fall semester, and Instrumental Methods of Analysis (CHEM 364) in the spring. In CHEM 335, students completed a multi-week research project probing the effects of modifying catalysts and reaction conditions on catalyst performance to introduce students to the nature of work in a research group. With the support of Tamra Hjermstad from Instructional Technology, students also designed and recorded educational videos explaining how foundational chemical principles apply to our understanding of research efforts described in the current literature. Topics covered included the use of poly-oxometallates in water purification and applications of metal complexes as medical drugs. The students' creativity and dedication to making these videos were impressive.

In the research laboratory, work is ongoing in the field of transition-metal mediated homogeneous catalysis and metal-binding polymers for environmental remediation, with *Jennyfer Galvez '18, Alexa Curt '18, Anna Ringuette '19, Justin Ho '20, Negasi Haskins '20, Astia Innes '20, Jonathan Lee '20, Janet Rodriguez '20, Conrad Wahl '20, Abraham Eafa '21, Angel Ibarra '21, Bariki Innes '21, Mykel Miller '21, Juan Peticco '21, Vanessa Quevedo '21* and *Brian Valladares '21* all contributing to progress and making the lab an active place. Prof. Goh also worked with the chemistry student group CSAC to organize events including an end-of-year bbq with a number of other departments. In addition to his role in the chemistry department, Prof. 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. Among other things, a SACNAS-affiliated student chapter was established. Over the summer, Professor Goh assumed the role of Director of the Summer Science Program, taking over these duties from Professor Chip Lovett, who retired after many years of spearheading this program.

The research of Professor **Sarah Goh** is focused on the design and synthesis of block copolymers for drug delivery applications. This year, many students honed their research skills in the final year of Polymer Lab North in the Bronfman Science Center: *Alexi McAdams '18* (thesis), *Wilson Wang '18, Luke Cai '19* (independent study and thesis), *Dasol Lee '21, Brian Valladares '21,* and *Maria Noyes '21*. Alexi put her own stamp on the lab's move into working with activated monomers from natural resources, looking at vanillin and syringaldehyde-based monomers. Luke started a calendar year thesis, designing amine-containing pH responsive copolymers. All of the students had a successful time in lab, and were immensely helpful in packing up the lab, with the move to the new South Science Center occurring in mid-May.

Professor Goh taught Polymer Chemistry (CHEM 348) in the fall of 2017. While the students appreciated learning how interwoven polymer chemistry is to other disciplines they have studied, it was the laboratory experiments that they enjoyed most. They had great fun exploring some of the more traditional methods of polymer synthesis (ring opening, radical copolymerization), as well as the processing methods of spin coating, compression molding, and 3-D printing. In the spring, Goh offered her tutorial Physical Organic Chemistry (CHEM 344T) again. The students spent the first part of the semester in an intensive and in-depth look at many organic concepts (stereochemistry, kinetics, molecular orbital theory, mechanisms). They then turned their heightened skills to a 6-week independent laboratory exercise of their choice, exploring SET reactions, Claisen rearrangements, Prins cyclizations, carbonyl reductions, and Aldol reaction. Most of the projects had reactions that were either too fast or too slow for them to quantitatively measure, so it also turned into a great exercise in redefining failure and thinking outside the textbook experiments to uncover the nuances of these transformations.

Assistant Professor **Katie Hart** started her first year at Williams College teaching Biochemistry I (BIOL/

CHEM/BIMO321) in the Fall and Biophysical Chemistry (CHEM 367) in the Spring. She established her lab in Bronfman and mentored two honor thesis students (*Cynthia Okoye '18* and *Miranda Villanueva '18*) as well as several research students (*Brandon Vuong '19, Emily Harris '19, Mei Liang '19*). After classes ended in the Spring, she packed up her equipment and moved to a brand-new lab space in the South Science Center. This summer, Cynthia and Miranda were joined by *Drew Cohen '20* and *Faris Gulamali '21* in the lab. Professor Hart, Cynthia and Miranda attended a conference in Boston focused on protein biochemistry, and both students had the opportunity to present their thesis projects to other experts in the field.

The Hart lab studies how drug resistance evolves at the molecular level with a particular focus on protein stability. Many forms of drug resistance depend upon a small number of mutations that result in changes to a protein's amino acid sequence. By investigating how these changes affect protein structure, stability and function, we can begin to understand how evolution works at the molecular level and leverage these insights to inform the design and implementation of new drug treatments. Current projects in the lab investigate drug resistant mutations in beta-lactamase, an enzyme critical for antibiotic resistance in bacteria, and HIV protease, an enzyme targeted by antiretroviral therapies using biophysical techniques (circular dichroism, UV-vis and fluorescence spectroscopies) and microbiology techniques (cell growth competitions, minimum inhibitory concentration measurements, screen development).

Professor Hart presented her research during the Tuesday Science lunch colloquium to Division III faculty in the Fall. This summer, both of her thesis students presented their projects at the Protein Society 32nd Annual Symposium in Boston, MA. Miranda was chosen to give a talk during the undergraduate symposium and Cynthia presented a poster and won a cash prize.

Professor **Lawrence Kaplan** taught Chemistry and Crime: From Sherlock Holmes to Modern Forensic Science (CHEM 113) in the fall semester. For the first time, he taught the course with a modified, shortened lab program since he also taught a lab for Biochemistrty I (CHEM 321) during the semester. He was on a sabbatical for the spring.

He administered the Center for Workshops in the Chemical Sciences (CWCS) 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 seventeen 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). With the earlier retirement of Professors Hill and Smith and with Professor Kaplan's retirement this year, the cCWCS will cease operations in the spring of 2019.

Kaplan taught a weeklong CWCS workshop in forensic science during the summer of 2017 at Williams. Sixteen participants from colleges, universities and community colleges became criminalists for the week. They processed crime scenes and analyzed evidence such as glass and soil, fibers and fingerprints, drugs and alcohol, blood and bullets, and, of course, DNA. Deborah Morandi, Administrative Assistant in the Chemistry Department, assisted Kaplan in the organization of the workshop.

Kaplan attended the 25th Biennial Conference on Chemical Education at the University of Notre Dame in Notre Dame, IN, in August 2018. He presented a paper, *Chemistry and Crime and the cCWCS Forensic Science Workshop for Introducing Chemical Concepts with a Forensic Science Theme* in the symposium entitled "Teaching Chemistry in the Context of Forensic Science" which was organized by Professor Amanda Harper-Leatherman from Fairfield University, an alum of Kaplan's forensic science workshop.

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

After 47 years Professor Kaplan has hung up his forensic science hat along with his biochemistry teachings and is looking forward to new challenges and brightening the minds of students outside the halls of Williams College.

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

Professor Lovett continued his research on the *Bacillus subtilis* SOS response to DNA damage, which comprises a set of DNA damage-inducible genes (SOS genes) that code for DNA repair and cellular survival functions. During the past 3+ decades Lovett and Williams' students working in his lab have discovered more than 30 SOS genes and characterized their genetic regulation in response to DNA damage. Based on recent evidence implicating the SOS response in the development of antibiotic resistance in bacteria, research in the Lovett lab has focused on finding SOS response inhibitors. Lovett and his research students developed a high throughput assay to search a library of 14,400 bioactive compounds for SOS response inhibitors and last year they developed an in vivo assay to test the inhibitors' ability to block the SOS response in bacteria. During the past year Lovett's students completed the screening of nearly 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 *Michael Green '18, David Azzara '19, Emily Harris '19, Si Hou Lon '19, Larissa Silva '19, Brandon Vuong '19, Natalie Albright '20, Nicholas Madamidola '20, Dylan Millson '20,* and *John Vélez '20. John (Jack) Roberts '18* worked as senior thesis student for the academic year and *Anna May Fitch '19* worked on an independent research project in the spring of 2018. Professor Lovett also supervised work study research students *Angel Ibarra ' 21, Cassie Deshong '21, Charles Laurore '19, Dylan Millson '20, George Yacoub '21, Shadae McClean '21, Joseph Flores '20, Nicholas Madamidola '20,* and *Oscar Merino '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 J*ournal of Bacteriology*, and as a consultant for the Sherman Fairchild Foundation's Scientific Equipment Grant Program.

Professor **Lee Park** returned from a sabbatical at Ewha Womens University in Seoul, South Korea in July of 2017. She then spent the 2017-18 year serving as interim Dean of Faculty. She'll be returning full-time to the chemistry department and will serve as chair for the 2018-19 academic year. She's looking forward to getting back into the classroom and starting on new research projects involving the self-assembly of gold nanoparticles with her students.

During the 2017-18 academic year Professor **Enrique Peacock-López** enjoyed a sabbatical leave. During spring semester Peacock-López dedicated some time to study non-fickian diffusion and self-replicating peptide networks. He assisted to the 83rd Israeli Chemical Society Annual Meeting in Tel-Aviv Israel during February 2018, and visited the Ben-Gurion University, where artificial peptide networks have been synthesized by Professor Gonen Ashkenazy's group. In collaboration with Nathaniel Wagner, Peacock-López analyzed the smallest closed peptide network that shows bistability.

As a result of the inclusion of MATHEMATICA in the curriculum, Peacock-López was able to submit one of the CHEM 361 final projects, Parrondo's paradox or chaos control in discrete two-dimensional dynamic systems developed by *Eliza Matt '18* and *Diego Guimarães-Blandón '18* to the journal *Chaos, Solitons & Fractals* for publication in January 2018.

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 2015-18 period for an amount of $244,117, research on pattern formation in the Morales model, and dynamics of an alternative model of mutualism.

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 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, Journal of Chemical Education, Nonlinear Dynamics, Physica Scripta,* and *Chaos, Solitons & Fractals*.

During the fall semester of the 2017-18 academic year, Professor **David Richardson** taught Introductory Chemistry (CHEM 151) with 39 students, and a 16-student lab section of the same course, for the second time, while in the spring semester he taught Toxicology and Cancer (CHEM 341) with 32 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 Environmental Chemistry (CHEM 022).

Together with Professor Jay Thoman he supervised the senior honors thesis research of *Jonathan Meng '18* 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 students on an assortment of research projects: during the fall semester, *Tobias Muellers '18* continued his ongoing efforts directed at development of analytical methods for the measurement trace-levels of PFOA in aqueous and soil samples using our department's newly installed LC-MS system through his enrollment as an independent study student in CHEM 497; throughout the spring semester, *Manami Tsuzuki-Diaz '18* and *Jon Velez '20* worked on conducting PCB measurements in a recently-acquired crayfish sample set as part of our on-going study of PCB contamination in the Hoosic River.

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.

Senior Lecturer emerita **Anne Skinner** received a Fulbright fellowship in 2017 to study early human settlement in the Americas. She used it to spend the spring semester in Brazil. After a month excavating an archaeological site in northeast Brazil, the rest of the time was spent at three different universities. At each she gave a series of lectures and classes, worked with colleagues on projects of common interest, and established collaborations to be continued at Williams. She was an invited lecturer at the fall (remember Brazil is south of the equator) meeting of the Brazilian Physics Society.

In the fall semester, she taught the advanced research section of second semester Organic Chemistry (CHEM 255). In Brazil she was a guest lecturer in the graduate physics seminar on spectroscopy, giving two classes on "Espectróscopia em Arqueológia".

Current research projects are teeth from Sudan, where there appears to be a late survival of Middle Stone Age technology, and megafaunal samples for a study of the role of humans in their extinction. Among journals requesting reviews were *Quaternary International* and *Quaternary Geochronology*.

Professor **Tom Smith** spent his twentieth year at Williams without a laboratory due to the demolition of his old lab before construction of its replacement was completed. As such, his research program 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—was on hold for a year. Smith taught Intermediate Organic Chemistry (CHEM 251) and completed his third and final year as a member of the Committee on Appointments and Promotions. He was also a member of the Williams Presidential Search Committee that helped to hire President Maud Mandel.

In the fall semester, Professor **Jay Thoman** taught Quantum Chemistry and Molecular Dynamics (CHEM 361) and its associated lab days. The independent projects at the end of CHEM 361 continue to spin off new ideas for the laboratory program. He also taught the lead lab section of Principles of Modern Chemistry (CHEM 155). During January 2018, summer 2018 and throughout the academic year, Thoman continued research projects with Professor Dave Richardson to probe the abundance and fate of organic pollutants in the regional environment. Working with *Tobias Muellers '18, Manami Diaz '18, Neena Patel '19, John Vélez '21, Alex Quizon '21, Fernando Villegas '21* and with huge help from technical assistants Jay Racela and Nate Cook, they refined methods for quantifying polychlorinated biphenyls (PCBs) and perfluorooctanoic acid (PFOA) in soil, vegetables, and crayfish. In the spring, Thoman co-taught Thermodynamics and Statistical Mechanics (CHEM 366) with visiting Professor *Steve Cramer '73*. With Sandra Burton, Thoman was co-sponsor of the dance contract major and thesis of *Nikki Pérez '18*.

In the spring semester, Thoman attended the national meeting of the American Chemical Society in New Orleans, LA. It was an opportunity to re-connect with colleagues including Helen Leung and Steve Cramer. He particularly appreciated a physical chemistry session on chirality, because it informed the thesis work of *Jonathan Meng '18*. Working with Professor Dave Richardson, Meng designed and synthesized a new molecule to probe the stereochemistry of a zinc-mediated deuteration reaction. *Katie Mahoney '20* and *Maria Heredia '20* continued Meng's project during summer 2018.

As College Marshal, Thoman spent time planning for the induction of Maud S. Mandel as the 18th President of Williams College. 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

John Ahn	Ph.D. in Biochemistry, University of Wisconsin
Daniel Brandes	Ph.D. in Chemistry, Yale
Elizabeth Gootkind	Medical School
Diego Guimaraes-Blandon	Consultant
Raisha Ismail	Medical School
Charles Jersey	Management Consultant
Eleanor Johnston	Math Teaching Apprentice, High Mountain Institute, Colorado
Esther Kim	Research Assistant, then medical school
Julianna Kostas	Research Assistant
Elizaveta Lavrova	Research Technician, Dana-Farber Cancer Institute, then medical school
Alexi McAdams	Research Assistant, Harvard University
Jonathan Meng	Dr. Herchel Smith Fellowship, Emmanuel College, Cambridge University
Cynthia Okoye	Ph.D. in Pharmacology, University of Cambridge (UK)
Robert Rowledge	Associate Consultant, Trinity Partners, Waltham, MA
Caroline Ryan	Fulbright Fellowship, Teaching, Poland
Carl Sangree	Teaching
Katie Spence	Ph.D. in Organic Chemistry, UCLA
Miranda Villanueva	Research Assistant, Children’s Hospital, Los Angeles, CA
Wilson Wang	M.Phil. in Biotechnology, University of Cambridge, then medical school
Allison Wong	Research Assistant, Pacific Northwest National Lab, then graduate school

Professor Chris Goh was manning the grill this year for the end-of-the-year picnic on the quad. Seen here taking Professor Gehring's order.

Chemistry Colloquia

Maren Buck, Smith College
"Poly(2-alkenyl azlactone)s: Versatile Polymers for the Synthesis of Multifunctional Gels and Drug Delivery Platforms"

Steven Cramer, University of California-Davis
"Synchrotron Radiation and a Hydrogen Economy - A Surprising Connection"

Mary Beth Daub '11, University of Wisconsin, Charles Compton Lectureship
"Strategic Synthesis of Natural Products"

Joel Freundlich, Rugers University
"The Intersection of Infectious Diseases with Chemical Biology"

Kathryn Geiger, Johns Hopkins University
"Transcription Activator-Like Effector (TALE)Folding Cooperativity is Fine-Tuned for Function"

Charles Jakobsche '04, Clark University
"From Organic Synthesis to Chemical Biology"

Sara Lincoln, Penn State
"New Insights from an Old Spill: Using the Sedimentary Record of the 1979 Ixtoc Blowout to Understand the Fate of Petroleum in the Deep Sea"

Kathryn Riley, Swarthmore College, Class of 1960 Scholars
"Probing Nanomaterial Transformations at the nano, Molecular, and Biomolecular Scale"

Jennifer Roizen '03, Duke University
"New Strategies to Control the Site of Atom-Transfer Processes"

Zuzana Tothova '01, Dana-Farber Cancer Institute, Charles Compton Lectureship
"Targeting Cohesin Mutations in Leukemia"

Dharni Vasudevan, Bowdoin College, Class of 1960 Scholars
"Pharmaceutical Interactions at the Solid-water Interface: Implications for Predicting Contaminant Fate"

Off-Campus Chemistry Colloquia

Amy Gehring
"Role of a Phosphodiesterase in the Secondary Metabolism of Streptomyces coelicolor"
Microbial Stress Response Gordon Research Conference, Mount Holyoke College, July 2018.

Cynthia Okoye '18 and Katie Hart
"What Drives Clinically-relevant Antibiotic Resistance Mutations?"
Protein Society 32nd Annual Symposium poster presentation, Boston, MA, July 9, 2018.

Miranda Villanueva '18 and Katie Hart
"Manipulating the Energy Landscapes of Beta-lactamases" Protein Society 32nd Annual Symposium poster presentation, Boston, MA, July 11, 2018.

Lawrence J. Kaplan
"Chemistry and Crime and the cCWCS Forensic Science Workshop for Introducing Chemical Concepts with a Forensic Science Theme"
Paper presented in the symposium entitled "Teaching Chemistry in the Context of Forensic Science" 25th Biennial Conference on Chemical Education at the University of Notre Dame, August 2018.

Enrique Peacock-López

“Simple Models of Chemical Self-replication in Open Systems”
University of Ben-Gurion, Department of Chemistry, Be’er Sheva, Israel, February 17, 2018.

“Competitive Self-replication: Differences Between First and Second Order Chemical Self-replication”
Gordon Conference, System Chemistry, Newry, Maine, August 2018.

Anne Skinner

“Por que nós estudiamos datação?”
University of São Fernando, São Raimundo Nonato, Piaui, Brazil, February 21, 2018.

“Procurando a primeira imigração para o Novo Mundo”
Federal University of Pernambuco, Physics Department, Recife, Brazil, March 16, 2018.

“Physical Methods in Archaeology”
Federal University of Pernambuco, Archaeology Department, Recife, Brazil, March 23, 2018.

“Quando o Homem chegou no Continente Americano? Um exemplo de datação de sítio arqueológico”
Federal University of São Paulo, Marine Sciences Department, Santos, Brazil, April 11, 2018.

“Physics: A Useful Tool in Archaeology”
University of São Paulo, Physics Department, Ribeiro Preto, Brazil, April 18, 2018.

“Dating Methods in the Service of Paleontology and Related Fields”
University of São Paulo, Biology Department, Ribeiro Preto, Brazil, May 2, 2018.

“Physics: A Useful Tool in Archaeology”
Autumn Meeting of the Brazilian Physics Society, Foz do Iguaçu, Brazil, May 9, 2018.

Computer Science Department

The 2017-2018 academic year was marked by extensive growth in both enrollments and faculty. Student interest in computer science soared with over 75 sophomore students declaring a major. Thankfully, the department grew in size last year, which helped us manage the increasing demand. Dan Barowy (PhD UMass), Iris Howley (PhD CMU), and *Bill Jannen '09* (PhD SUNY Stonybrook) all completed their first year as tenure-track faculty members in the Computer Science department.

In the spring, the department hosted *Chris Umans '96* as a Class of '60 speaker. Umans spoke about his work on computer algorithms, highlighting some of the ways in which algorithmic advances have been responsible for some of the most remarkable applications of computation today, from search engines to machine learning to error-correcting codes, cryptography and scientific computing. In the fall, the department also hosted *Elissa Shevinsky '01* as a Class of '60 speaker. Shevinsky spoke about her experiences in coping with the challenges associated with being a female entrepreneur in the male-dominated technology sector. Lastly, the department sponsored events and talks from Google, Facebook, and Microsoft that featured *Sarah Abramson '15, Dan Evangelakos '15, Josh Ain '03, Hilary Hutchinson '97, Josh Geller '14,* and *Rich Ward '89*.

Several members of the department attended the ACM Richard Tapia Celebration of Diversity this year, including *Matheus Cruz Correia de Carvalho Souza '18* and *Qianwen (Tiffany) Zheng '20*. In October, *Mary Imevbore '18, Joyce Wang '18, Stephanie Liu '18, Anya Michaelsen '19, Julia Goldman '18, Aria Kim '19, Alyssa Wang '20,* and *Susana Hawken '18* attended the Grace Hopper Celebration of Women in Computing. Also attending the conference in Orlando, FL were faculty members Jeannie Albrecht and Andrea Danyluk. All of the students enjoyed the opportunity to attend talks and panels and to explore the industry and national lab "Expo".

The department sponsored a turbo hackathon in February, 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 Under-Represented Identities in Computer Science (UnICS) group continued to expand its programming by organizing popular dinners with faculty once again.

Class of 1960's Scholars in Computer Science

Kiersten Campbell	Anya Michaelsen
Ryan Cox	Louisa Nyhus
Quan Do	Nathan Perry
Cole Erickson	Dzung Pham
John Ferguson	Nick Post
Emmie Hine	Tim Randolph
Lylia Li	Carl Rustad
Stephanie Liu	Leting (Lily) Shao
Wei Luo	

This year Prof. **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. So far the building has met 6 out of 7 LBC requirements. 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 when in use. If occupants do not make energy efficient decisions while using the kitchen, the building could go over its energy budget for the year.

To address these challenges, Albrecht continued working with several students, including *Jack Ferguson '18, Lylia Li '18, Casey Pelz '19, Abby Miller '19* and *Grace Murray '20* on a system for monitoring and visualizing energy usage in the Environmental Center, focusing specifically on the kitchen. They developed several prototype visualizations and an online simulator that display both power and energy usage for kitchen appliances in an intuitive and aesthetically pleasing way. They conducted user studies in the kitchen and online using Amazon's Mechanical Turk platform to measure the effectiveness of the visualization, and obtained very promising results. Albrecht plans to fully deploy the system in the building in the upcoming months, and hopefully publish the results.

Professor **Duane Bailey** continued a number of collaborations this year. This fall, Duane and four of his students from the spring's Computer Science 134C collaborated with Tina Olsen and Chad Weinard of WCMA, and Cheryl Handsacker of OIT in an exhibit entitled Pink. Duane and students, *Lily Lee '17, Jordan LeMothe '17, Haley Lescinsky '18,* and *Maria Mejia '20* developed five independent algorithms to classify the "pinkness" of each of WCMA's 14,000 works of art. The exhibit featured notable successes and failures of the algorithms. Duane and Chad Weinard gave a gallery talk in October to celebrate the opening. Duane also gave a talk to summer 2017 research students, The Story of One Pink Multiplication, a discussion of what happens during one of the multiplication from Haley Lescinsky's algorithm from Python down through C, assembly language, microcode, and digital logic.

Tony Liu '17 and Bailey presented a poster, Computational Robustness in Spatially Irregular Cellular Automata, at the International Conference on Complex Systems. The work summarizes Tony's thesis work which demonstrated the plausibility of irregularly structured networks (like the pores of a plant leaf) to establish decision-making computations. Tony will be heading to The University of Pennsylvania to work on his PhD this coming fall.

During Winter Study Bailey (again!) hosted Debora Coombs, a renowned stained glass artist, to teach a course on mathematically-motivated sculptural stained glass design. The result was a 3-dimensional mirrored surface that mimics the X-ray crystallography that lead to the discovery of quasicrystals, a relatively new form of condensed matter. The piece will be a nice addition to Bailey and Coombs's paper sculpture exhibit A.Periodic currently on long-term display in Schow Science Library.

Spring in even years finds Bailey at the Gathering for Gardner, a conference that brings together mathematicians, artists, puzzle designers, and magicians motivated by the intellectual curiosity of Martin Gardner. At G4G13 Bailey and Coombs discussed A.Periodic. He presented a paper A Grammatical Approach to the Curling Number Conjecture discussing surprising computational number theory work with *Derrick Bonafilia '17, Tony Liu '17, Riwaz Poudyal '18, Adly Templeton '20,* and *Diwas Timilsina '16*. Bailey and his programming partner at his puzzle design firm AnyBlue Idea, *Daniel Yu '20*, released their iPhone app, Sliding Puzzle Analyzer, as a puzzle exchange item at G4G13. The app is free and allows puzzlists to design and experiment with sliding-piece logic puzzles.

Professor Bailey also advised *Matheus Cruz Correia Carvalho Souza '18* on his honors work. Matheus investigated methods for making the programming of FPGA boards more accessible to the general public. The work was based on the Digilent/Xilinx Pynq hardware. Matheus is now at Microsoft.

Assistant Professor **Daniel Barowy** joined the CS department in the summer of 2017. In the fall, he developed and taught a new computer security course, CSCI 331: Introduction to Computer Security. In the spring, he taught CSCI 334: Principles of Programming Languages. During the spring, he advised *Cole Erickson's '18* CSCI 398 independent study, flarec: A Compilation Approach to Extracting Relational Data from Spreadsheets, which extended Barowy's research originally done at Microsoft. Cole made his work available to the public as an open source project at: https://github.com/coleerickson/flarec

In October, Barowy attended the Google CS Capacity Workshop in New York City to learn strategies for dealing with increased interest in CS as a major. In November, he attended the OOPSLA programming language conference in Vancouver, Canada. In December, he presented his work on programming languages for crowdsourcing at the IBM PL Day workshop held at the IBM TJ Watson Research Center. Barowy has continued working with researchers at UMass Amherst and Microsoft Research on tools to help novice users find and correct bugs in Microsoft Excel programs. His paper, ExceLint: Automatically Finding Spreadsheet Formula Errors was accepted at OOPSLA '18 during the spring and the source code for the research was independently verified by the SPLASH '18 Artifact Evaluation Committee.

This summer, Barowy will be working with Williams students *Kiersten Campbell '21, Emmie Hine '20,* and *Alex Taylor '20*. Swell (Swell Williams Entry-Level Language) is a new, web-based programming language environment that helps to teach 5th and 6th grade students how to program for the first time. Swell uses a technology called "direct manipulation" that allows students to manipulate—literally by clicking and dragging—program outputs so that they can see the effect on the program; these manipulations are hypothesized to facilitate learning abstract programming concepts.

Professor **Andrea Danyluk** continued her research in machine learning, specifically in the areas of classifier learning and their applications. She supervised the work of two honors students, *Wei Luo '18* and *Carl Rustad '18*. Wei extended the work of *Lauren Yu '16* on applying machine learning to induce models of expressivity for violin and viola. Carl's work was in the area of deep learning. Deep learning algorithms can be extremely effective, but they typically require large quantities of data for learning. Thus methods are being developed that take advantage of transfer learning, the idea that learning in one domain can improve learning in another. Carl investigated combining such "one-shot" learning methods (so called because they aim to learn a new concept from a single example) with another transfer learning technique called multitask learning.

Danyluk continues her work in the computer and data science education sphere. She is co-chair of the Association for Computing Machinery (ACM) Task Force on Data Science. This international effort will develop recommendations for the computing-based competencies that should be part of an undergraduate degree in Data Science. She is also on the Advisory Committee for the International Data Science in Schools Project, a collaboration of major statistical societies from around the globe. This effort is aimed at developing curriculum for students in their final two years of high school, as well as curriculum for teachers on how to teach Data Science to students.

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. She also speaks at mentoring programs for graduate students and early- as well as mid-career researchers. With the start of the new academic year, she is on leave from Williams and heading to Northeastern to work for a year as director of a Master's program that aims to increase diversity in computing fields.

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. This work was his primary focus while on sabbatical this past year.

As part of his research, Freund published a paper titled "BigFoot: Static Check Placement for Dynamic Race Detection" at the ACM Conference on Programming Language Design and Implementation in June 2017. The paper tackles a number of performance issues in dynamic data race detectors, which check for concurrency bugs in multi-core software. The resulting system, BigFoot, improves performance over the previously state-of-the-art detector, FastTrack, by 60%. He and his colleagues from UC Santa Cruz were awarded the ACM PLDI 2017 Distinguished Artifact Award for their implementation of the BigFoot checker. The Distinguished Artifact Award is given once a year to recognize the computer system presented at the conference that most clearly, robustly, and completely demonstrates the underlying research ideas and that facilitates further research on the topic.

Freund also revisited the design of FastTrack in order to improve the core analysis in various ways. He and colleagues then formally proved that its new implementation, VerifiedFT, is correct. This work was in collaboration with colleagues including Cormac Flanagan (UCSC), Shaz Qadeer (Microsoft Research), and *James Wilcox '13* (University of Washington), and it was presented at ACM Symposium on Principles and Practice of Parallel Programming.

In other work, Freund demonstrated that a particular program optimization can potentially lead to unexpected program errors in some cases. It goes on to show the conditions under which the optimization can be safely used without introducing errors. This is important, as those optimizations had been proposed for the types of software running on Android phones and common in web servers. This work was published in a paper titled "Correctness of Partial Escape Analysis for Multithreading Optimization" at the Workshop on Formal Techniques for Java-like Programs.

Professor **Brent Heeringa** is on an extended leave to focus on the startup Valt, which he co-founded with *Kaylee Prior '11*. More information is available at https://valt.io

Assistant Professor **Iris Howley** began research this summer on methods for explaining artificial intelligence algorithms to assist in fair and transparent decision-making. She worked with four students, *Young Cho '19, Grace Mazzarella '19, Kelvin Tejeda '20,* and *Tongyu Zhou '20*, to develop and evaluate interactive software tutors to teach Bayesian Knowledge Tracing, recruiting members of the Berkshire community to do so. Initial paper prototypes of the students' projects were presented by Howley at the Artificial Intelligence in Education conference workshop on Ethics in AIED: Who Cares? and the students' higher fidelity prototypes were accepted to the IEEE VIS Workshop on AI for Explainability. This research uses methods taught in her spring semester course on Human-Computer Interaction (CSCI 376) which Howley will be teaching again this autumn. Last fall, Howley taught Introduction to Computer Science (CSCI 134) with Andrea Danyluk, and she also taught a winter study course on Electronic Textiles (CSCI 11) where students learned to sew with conductive thread and program Arduinos.

Another ongoing research project explores the factors that influence when and how learners ask for help in technologically enhanced learning environments. Howley published and presented this work at the 2018 International Conference of the Learning Sciences and provides empirical evidence for understanding help seeking so designers and developers can create educational technologies that enhance the help seeking experience for learners.

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.

With the BetrFS team, Bill has continued to study file system aging—the degeneration of file system performance over time—in the article *How to Age Your File System*, coauthored by Ainesh Bakshi, Alexander Conway and Martin Farach-Colton (Rutgers), Donald Porter, Yizheng Jiao and Yang Zhan (UNC Chapel Hill), Michael A. Bender and Jun Yuan (Stony Brook), Rob Johnson (VMware), and Bradley Kuszmaul (Oracle). They have also contributed new data structure techniques to solve a long-standing problem in file system design: simultaneously achieving fast scans and fast renames; *The Full Path to Full Path Indexing*, with joint work by Zhan, Conway, Jiao, Eric Knorr (Rutgers), Bender, Farach-Colton, Johnson, Porter, and Yuan, was nominated for best paper at USENIX FAST.

In addition to defending his dissertation, Bill attended the USENIX Conference on File and Storage Technologies and the USENIX Workshop on Hot Topics in Storage and File Systems.

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. In September he presented results on joint work with co-authors Sylvain Lazard (INRIA, France) and Giuseppe Liotta (Università degli Studi di Perugia) at the 25th International Symposium on Graph Drawing & Network Visualization at Northeastern University, Boston, MA. The work establishes tight bounds on the planar edge-length ratio of outerplanar graphs. An expanded version of these results has just been submitted for publication in the journal Theoretical Computer Science under the title On the Edge-length Ratio of Outerplanar Graphs.

Another long-standing project, with co-authors Sylvain Lazard and Olivier Devillers (INRIA), in which we develop an efficient algorithm for approximating geometric objects with high-precision coordinates in 3 dimensions by topologically similar objects with much lower precision, was also completed and the results were presented as the paper 3D Snap Rounding at the 34th International Symposium on Computational Geometry, in Budapest, Hungary, this past June.

Finally, Bill supervised the summer research and senior thesis of *Timothy Randolph '18*. Tim's thesis, (k,p)-Planar Graphs: A Generalization of Hybrid Cluster Graph Representations, developed a framework for the visualization of complex networks and established a number of algorithmic results related to determining which graphs might admit visualizations within the framework. This work led to a collaboration with researchers, Giuseppe Liotta, Emilio, and Alessandra Tappini, (all at Università degli Studi di Perugia) that resulted in the paper (k,p)-Planarity: A Generalization of Hybrid Planarity, which will soon be submitted for publication.

Professor **Morgan McGuire** is on extended leave working 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 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 worked with *Phoebe Huang '20* and *Nicholas Weed '20* to develop debugging tools to support the completion of an experimental implementation of such a file system.

Post-Graduate Plans of Computer Science Majors

Nicholas (Cole) Erickson	Software Engineer, Facebook, Seattle, WA
Diego Gonzalez	Software Engineer, Google, Seattle, WA
J. Marcus Hughes	Computer Science PhD at the University of Colorado, Boulder
Mary Imevbore	Software Engineer, PillPack, Somerville, MA
Taylor Kennedy	Management Developer, Curriculum Associates, Boston, MA
Lylia Li	Technical Career Development Program, InterSystems, Boston, MA
Stephanie Liu	Software Engineer, Google, New York, NY
Tanner Love	Software Engineer, Tools and Infrastructure, Google, New York, NY
Wei Luo	MS in Computer Science, Columbia University, New York, NY
Cliff Makanda	Investment Analyst, Hudson Structured Capital, Stamford, CT
Dylan Martin	Investment Banking Analyst (Strategies/Data Science), Goldman Sachs, NY
Daishiro Nishida	Programmer, TeamLab, Tokyo, Japan
Chetan Patel	Associate, Parthenon-EY, Boston, MA
Ryan Patton	Software Engineer, Flatiron Health in New York, NY
Nick Post	Software Engineer, Google, Sunnyvale, CA
Riwaz Poudyal	Software Engineer, Microsoft, Seattle
Tim Randolph	PhD in Theory of Computer Science, Columbia University, New York, NY
Karan Tibrewal	Investment Banking Analyst (Strats), Goldman Sachs, New York, NY
Minh (Tuan) Tran	Software Engineer, Facebook, Menlo Park, CA
Joyce Wang	Software Engineer, JP Morgan, New York, NY
Yiheng Zhang	Software Engineer, Google NYC

Computer Science Colloquia

Stephen Van Wert '09, Penn State
"Treating the Brain with Electronics and Code: A Computational Neuroscience Perspective" October 5, 2017

Elissa Shevinsky '01
"Women in Silicon Valley: Success and Dodging Bullets" October 26, 2017

"Cryptography and Bug Bounties: Building a Secure Application" October 27, 2017

Gavin Andresen
"On Cryptocurrencies and Distributed Ledger Tech" November 3, 2017

Bruce Maxwell, Colby College
"Removing Illumination as a Confounding Signal Improves Machine Learning" December 1, 2017

Rich Ward, Microsoft
"Life at Microsoft" January 12, 2018

Ethan Gracer '14, Jet.com
"Distributed, Event-Drived Functional Programming And Other Software Buzzwords In Plain English" January 19, 2018

Michael Engling
"Secure Pairing of Smart Mobile Devices via (Shared) Environmental Sensing" February 23, 2018

Rodica Neamtu, Worcester Polytechnic Institute
"Interactive Exploration of Time Series Powered by Time Warped Distances" March 9, 2018

Cuong Pham, Microsoft
"Fast and Accurate Indoor Localization based on Spatially Hierarchical Classification" March 15, 2018

Rodric Rabbah, Apache OpenWhisk
"Serverless Computing with Functions" April 6, 2018

Jeff Epstein, Wesleyan
"An Introduction to Distributed Hash Tables" April 9, 2018

Chris Umans '96, Caltech
"Algorithmic Magic: Behind the Scenes of Modern Computer Science" April 26, 2018

"New Algorithms for Matrix Multiplication " April 27, 2018

Martin Farach- Colton, Rutgers
"What's PageRank and How do I Spam it?" May 4, 2018

Off-Campus Computer Science Colloquia

Jeannie Albrecht
"Sensor Driven Energy Management for Smart Buildings"
Williams in Montana Campaign Event, September 2017

"Sustainability: The Ultimate Liberal Art"
Williams in Montana Campaign Event, September 2017

Andrea Danyluk
"Priorities and Time Management"
SIGCSE 2018 New Educators Workshop, Baltimore, MD, February 2018

Stephen Freund
"BigFoot: Static Check Placement for Dynamic Race Detection"
ACM Conference on Programming Language Design and Implementation, Barcelona, Spain, June, 2017

"BigFoot: Static Check Placement for Dynamic Race Detection"
Microsoft Research, Redmond, WA, August 2017

Geosciences Department

This has been a year of many changes. Excitingly, we hired a new colleague: Alice Bradley, who comes to us from a post-doc position at Dartmouth, is an engineer who works on questions of modern climate change. She is interested in sea-ice dynamics, especially in those complex environments where ice cover is incomplete. Alice will move to Williamstown in mid-summer, and will begin teaching in the fall semester. David Dethier concluded his teaching career, retiring after 36 years in the department. His work will continue, however, as he grows and develops his research projects. David will still be an important part of our Geosciences community. With the closing of Bronfman, several Geos faculty have moved out of their long-time offices and labs into new spaces. Some of us are in the new South Building, others are in Clark. When the new North Building rises from the rubble of Bronfman in a few years, we will all reunite in the new Geosciences space.

Again this year we had several of our students attend national conferences. Attending the Geological Society of America's annual meeting in Seattle in November were *Emmett Blau '18, Andrew Bloniarz '18, Jacob Cytrynbaum '18, Daniel Donahue '19, Kyrien Edwards '17, Jordan Fields '17, Noah Williams '17, Caroline Hung '19, Ezekiel King Phillips '18,* and *Erikka Olson '19*. Poster presentations were given by Andrew, Jacob, Kyrien, Caroline, and Ezekiel. Oral presentations were given by Emmett, Daniel, Ezekiel, Jordan, Noah, and Erikka Olson. *Matthew Marcarelli '17* attended the NE Geological Society of America meeting in March where he also gave a poster presentation. *Natasha Baranow '18* and *Anna Black '19* gave poster presentations at the American Geophysical Union (AGU) fall meeting in New Orleans in December.

Berti Miller '19 was awarded the Lauren Interess Fellowship for a project on "Climate Change and Adventure in the Aleutian Islands." She spent two weeks in the summer exploring the island of Unalaska.

Three of our seniors completed thesis work over the course of their senior year and gave presentations of their work at our annual Senior Thesis Day on May 14. *Tim Nagle-McNaughton '18* was awarded the Freeman Foote Award, given to the student who gives the best presentation of his or her thesis. He received the American Mineralogist Undergraduate Award from the Mineralogical Society of America, which recognized the member of the senior class with the most outstanding record of scholarship and research in Mineralogy and Petrology. Andrew Bloniarz was awarded the David Major Prize, given to the outstanding senior Geosciences major for their invaluable contribution to the Geosciences Department.

Class of 1960 Scholars in Geosciences

Jonathan Ahsing	Christian Lockwood
Ally Alvarez	Germanie Louis
Isaiah Blake	Dayana Manrique
Franklin De La Cruz	Nohely Peraza
Nicole Fernandes	Daniel Russell
Joana Fernandez	Marco Vallejos
Nkem Iregbulem	

Assistant Professor **Alex Apotsos** was awarded a Fulbright fellowship to spend eleven months doing research in Cape Town, South Africa from August 2017 to June 2018. His project, "Mapping the Climate Change Vulnerability of Coastal Urban Areas in Southern Africa," has sought to increase our understanding of the climate vulnerability and informational needs of coastal urban areas in South Africa. As more and more people move to the urbanizing areas of the coast, it is essential that we begin to understand better the vulnerability of these growing populations.To achieve this objective, he developed localized socio-economic vulnerability maps that identify area more likely to be negatively affected by climate shocks and stresses. During the development of these maps, he has actively engaged with local and regional planners to understand better their perceptions of urban vulnerability, as well as the information they need to address these vulnerabilities. To translate the technical information into easily digestible formats, Alex developed simple 2 page documents that highlighted the key findings and provided them to relevant decision-makers in several South Africa cities.

Associate Professor **Phoebe Cohen** spent the summer and fall of 2017 on maternity leave. In December of 2017, Phoebe was awarded tenure and was promoted to Associate Professor in July of 2018. While on leave, Phoebe advised senior thesis student *Ezekiel King Phillips '18*, who spent the summer working with collaborators at Syracuse University. Zeke presented his research at the annual Geological Society of America meeting in the fall of 2017, and is currently working on writing up his thesis for publication. In the spring of 2018, Phoebe taught her Mass Extinctions tutorial, where students learn about past extinctions and think about the implications of current human-induced extinctions. In the spring Phoebe took on a new research student, Clare Booth Luce scholar *Kate Pippenger ’20*. Kate and *Lucas Estrada ’19* worked with Phoebe over the summer of 2018 on her research on the end-Devonian mass extinction. All three traveled to western New York State and Ohio to collect samples from this extinction interval, and then spent the summer processing and analyzing samples. Both Lucas and Kate will present their initial results at the fall 2018 Geological Society of America meeting. In addition to her research and teaching, Phoebe took on a new role on the Executive Committee of the Paleobiology Database, co-organized a workshop on using online databases in teaching paleontology, and is co-organizing and co-editing a short course and accompanying volume on teaching paleontology for the fall Geological Society of America meeting.

Assistant Professor **José Constantine** finished his second year at Williams. With *Daniel Donahue ’19* and *Samuel Gowen ’18*, José spent part of the year continuing a study on the impacts of engineering controls on the local Hoosic River, research that will inform restoration efforts being planned for the river. Daniel presented some of the early findings from this work as a talk at the annual meeting of the Geological Society of America (GSA) in Seattle. With *Emmett Blau ’18*, José continued his work on assessing the ability of river floodplains to sequester pollutants on the Housatonic River. Emmett presented some of the findings from the work as a talk at the annual GSA meeting and as a talk at a Williams alumni event in the spring. *Andrew Bloniarz ’18* continued his work on the environmental history of the Mississippi River as an independent study, presenting his findings as a poster at the GSA meeting. *Erikka Olson ’19* worked on a project assessing the impacts of climate variability on alpine glaciers throughout North and South America, presenting her work as a talk at the GSA meeting. José was invited to give a lecture at the annual meeting of the American Geophysical Union and presented at Middlebury College, Smith College, and the University of Massachusetts-Amherst. In addition to presenting his work on soil erosion at the GSA meeting, he co-organized a keynote symposium at the event on Landscapes in the Anthropocene. He submitted 3 papers of his work, each of which are currently in review.

During the summer, José will continue his work with Emmett Blau, finalizing their paper on the Housatonic. Daniel Donahue and *Monica Bousa ’19* will begin their thesis projects during this time. Daniel will be working on assessing the role of vegetation in controlling the evolution of a gravel bedded river in California. Monica will study the impacts of debris flows that hit the community of Montecito (CA) during January 2018, sorting out the subsequent role of the debris flows on flood hazards. *Summer-Solstice Thomas ’20* and *Molly Lohss ’21* will work in the new geomorphology lab, using remote sensing to understand the role of deforestation in affecting the evolution of meandering rivers throughout Borneo. José will use this time to develop an NSF proposal to study the rivers of Borneo, planning a field trip to Borneo with Summer-Solstice and Molly next summer.

Associate Professor **Mea Cook** had Five research assistants working on projects studying the influence of Pacific Ocean circulation on climate changes during ice age cycles. *Anna Black '19* and *Natasha Baranow ’18* studied how changes in ocean oxygen concentrations are recorded in the texture of deep-sea sediments, and their relationship to changes in the nutrients in the ocean over the last 500,000 years. They presented their results at the American Geophysical Union (AGU) fall meeting in New Orleans, LA. As part of a project funded by the National Science Foundation, *Wendy Hernandez '20* collected microfossils from a sediment core from the southeast Bering Sea which she analyzed for oxygen and carbon stable isotopes to study how the density and nutrient structure of the water column evolved through rapid climate changes that occurred during the last 20,000 years. *Fernando Villegas ’21* and *Roberta Miller ’18* studied the chemistry of volcanic ash layers from the same sediment cores in order to match the layers between land and sea to improve the precision of radiocarbon dating of these climate events. This work was included in an invited presentation that Cook gave at the AGU meeting. Cook reviewed manuscripts for the journals *Nature Geoscience, Environmental Pollution, Proceedings of the National Academy of Sciences,* and *Journal of Micropaleontology*. 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** concluded her sixth and final year as department chair. She will be on leave for 2018-19. She will continue to serve on the Editorial Board for the Geological Society of America’s journal *Geology*, and as a member of the society’s Publications and Ethics Advisory Committee, and will also start a four-year term as a member of the Annual Program Committee. Rónadh’s research on coastal geomorphology continues to expand. In January of this year, she—along with four Williams students—joined researchers from Notre Dame and University of Texas Corpus Christi to study wave-emplaced boulders along cliff tops on

Eleuthera, Bahamas, and over spring break she visited the Université de Bretagne Occidentale Brest for field work and to serve on the examination jury for PhD candidate Ronan Autret. Ronan is currently working on a proposal to come to Williams as a post-doc in 2019-20. During her leave, Cox will be a Visiting Professor in the School of Mathematics and Statistics at University College Dublin, where she will work with collaborators to merge data from off-shore wave-measuring devices with on-shore field measurements. In October 2018 she will co-convene an international meeting on coastal boulder deposits and extreme wave events, which will bring twenty researchers from nine different countries to the Fondation des Treilles in southern France for a week-long immersive workshop.

Student projects continue to be a backbone of Cox's research. *Tim Nagle-McNaughton '18* and *Jacob Cytrynbaum '18* will present their thesis results at the Geological Society of America's Annual Meeting this fall. Tim used UAV photogrammetry to quantify changes in coastal boulder deposits over time, and Jacob carried out wave-tank experiments in which he quantified relationships between incident waves and boulder movement. Their results are also being written up for publication. And taking the project in a multi-disciplinary new direction, Geosciences-Studio Art double major *Ava Palmo '18* will work with Cox this summer collecting footage for a documentary film on coastal processes, and the intersection between geosciences and society.

Professor Emeritus **David Dethier** continued his research based at Williams, focusing mainly on Hopkins Memorial Forest and the chemistry of springs, infiltration and groundwater flow on Niwot Ridge in the Colorado Front Range. *Jordan Fields '17* and *Noah Williams '17* presented papers from their Niwot Ridge thesis projects at the Geological Society of America National Meeting in Seattle, where Dethier received the Distinguished Career Award from the Quaternary Geology and Geomorphology Division. In cooperation with *Will Ouimet '01* (University of Connecticut) and colleagues from Germany, Dethier continued to work on a project that emphasizes the long-term geomorphic and geochemical impacts of historic charcoal production in western New England. 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 10Be and bomb-isotope (ex. 137Cs) techniques.

Working with **Jay Racela** (Environmental Studies), Dethier helps to coordinate ongoing collection of weather, streamflow, precipitation chemistry and other environmental data from Hopkins Memorial Forest and other nearby areas (www.wunderground.com/personal-weather-station/dashboard?ID=KMAWILLI14&cm_ven=localwx_pwsdash) and their analysis in the Environmental Science Lab in the Morley Science Center. Real-time weather and groundwater data and archived weather data from >30 years of monitoring are available at http://oit.williams.edu/weather/; archived watershed data (streamflow and temperature, stream chemistry and bulk precipitation chemistry) are at: http://web.williams.edu/weather/watershed/index.php. Dethier is now the Edward Brust Professor of Geology and Mineralogy Emeritus.

Associate Professor **Lisa Gilbert** was on sabbatical during 2017-18. For the fall semester, she was based at the University of California Santa Cruz in the Earth & Planetary Science Department. At UCSC she joined the hydrogeology group and also began wrapping up 6 years of work on the InTeGrate project, a major NSF-funded effort to innovate sustainability education in the US. While doing research full-time, she continued advising her four summer 2017 research students *Caroline Hung '19,* Meghan Suslovic (Williams-Mystic Fall 2016), Emma McCauley (Williams-Mystic Spring 2017), and Jason Swartz (Williams-Mystic Spring 2017). Two of the students made poster presentations of their summer research: McCauley participated in the American Geophysical Union's Fall 2017 Virtual Poster Showcase and Hung presented at the Annual Meeting of the Geological Society of America (GSA) in Seattle, WA. Gilbert also traveled to Lamont-Doherty Earth Observatory in NY to participate in an International Ocean Discovery Program workshop with 46 other scientists to discuss plans for future research at Axial Volcano.

For the next 6 months, Gilbert was based at the University of Otago in the Geology Department, where she joined the volcanology group. As part of her research, she conducted field work on ancient volcanoes in the Otago region of New Zealand. She collaborated with economic geologists, petrologists, and geophysicists, both at the university and at nearby GNS Science, as well as with a colleague at the University of Canterbury. She also supervised two students: research assistant *Erikka Olson '19*, who was studying abroad, assisted with laboratory and field work and thesis student Caroline Hung. Hung was awarded a grant by the Northeast Section of GSA to collect field data and samples from metabasalts on the southeastern coast of New Zealand and joined Gilbert in late May.

Professor Emeritus **Markes Johnson** attended the Conference of the Regional Committee on Neogene Atlantic Stratigraphy (July 10-13, 2017) at the University of the Azores in Ponta Delgada, São Miguel Island, which was followed directly by the Fourteenth International Workshop on "Palaeontology in Atlantic Islands" at Ville de Port on Santa Maria Island (July 14-21, 2017). Three invited lectures were presented in conjunction with these meetings. During much of August, Research Scientist Gudveig Baarli and Markes Johnson were in Norway for fieldwork on Upper Ordovician formations on islands in the Oslo region with access by ferry boat and (in some cases) by canoe. This was a follow-up study to the previous year's work with Fredrik Bockelie on the lithostratigraphy of those islands, now enlarged in scope to include evidence for hurricane activity. Office work during the fall term was devoted to preparation of a manuscript on the Ordovician-hurricane study, as well as a major review paper on the geology of oceanic islands stimulated by the pioneering work of Charles Darwin during the British mapping expedition of the H.M.S. Beagle (1831-1836) and related contributions of James Dwight Dana during the United States Exploring Expedition (1838-1842). Both papers were accepted for publication and released in 2018 (see faculty publications). February 11-18, Markes and his Mexican colleague Jorge Ledesma co-led an excursion for members of the San Diego Geologists' Association to the Loreto area of Baja California on Mexico's Gulf of California. The group helped collect data on a post-Holocene hurricane deposit from a 12-meter terrace on Isla del Carmen for a research paper under preparation. March 23 to April 4, Gudveig and Markes sailed from Natal, Brazil to La Palma (Grand Canary) in the Canary Islands as guests of The World, during which time Markes delivered several popular lectures on the Cape Verde Islands. Ending as it did in the Canary Islands, the trip was the perfect opportunity to independently visit Tenerife and the Spanish National Park devoted to the island's volcano Pico del Teida. Markes gave a formal lecture at the Tenerife Museum of Sciences (April 6, 2018), which was attended by colleagues interested in starting collaborative research on rocky-shore deposits in the Canary Islands. Office work during the Spring Term was focused on the launch of a book project under the preliminary title *Islands Deep in Time: Lost and Found* addressing the development, burial, and exhumation of islands of Cambrian to Pleistocene age. The book's first draft is anticipated to be ready by the end of 2018.

Professor **Paul Karabinos** continued research on his grant from the National Science Foundation to support an educational initiative: Google Earth for Onsite and Distance Education (GEODE). 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 also 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.

Karabinos attended the National meeting of the Geological Society of America in Seattle, Washington, in October, 2017, where he gave a presentation: "Stratigraphy of the Connecticut Valley-Gaspe Trough in Massachusetts and Vermont: Constraints from LA-ICPMS Dates from Detrital Zircon and CA-IDTIMS Dates from Volcanic Rocks."

Karabinos attended the Northeastern Section meeting of the Geological Society of America in Burlington, Vermont, in March, 2018, where he gave a presentation: "Stratigraphy and Provenance of the Connecticut Valley-Gaspe Basin in Western New England: Evidence for a Topographic Barrier Between the Acadian Hinterland and Foreland."

Professor **Bud Wobus** concluded his 52nd year of teaching at Williams, with his usual schedule of courses (GEOS 102, 202, 303) plus his Winter Study course, Geology of the National Parks. At GSA in Seattle he organized a reunion for 35-40 Williams alumni, current faculty, and students, concluding his several decades of hosting this event. In October he led a hike on Stone Hill for the Williamstown Rural Lands Foundation. In March he was co-author of a presentation about Proterozoic granite plutons in Colorado at the GSA Northeast Section Meeting in Burlington, VT, by one of his senior thesis students last year, *Matt Marcarelli '17*. He continues as a consultant for the Florissant Fossil Beds National Monument in Colorado (where one of his new thesis students, *Erikka Olson '19*, worked last summer) and for the High Trails Outdoor Education Center near Florissant (where *Nell Davis '15* is on the year-round staff and *Noah Williams '17* is on the summer staff). This summer Erikka will begin a study of boulder deposits on the Eocene erosion surface of Colorado's southern Front Range, co-advised by Prof. José Constantine. Bud will also be the on-campus co-advisor for *Caroline Hung '19* in her study with Prof. Lisa Gilbert at Mystic, of hydrothermally altered sea floor basalts in southern New Zealand. Last July he led the 24th iteration of the week-long Alumni College in the Rockies at The Nature Place Conference Center in Colorado, and will join an alumni group in the Canadian Rockies in July this summer.

Post-Graduate Plans of Geosciences Majors

Andrew Bloniarz	Intern at Haley House soup kitchen in Boston
Samuel Gowen	Nomura Securities, New York City
Madelyn Grant	FoodCorps, Mill City Grows, Lowell, MA (one year)
Ezekiel King Phillips	Taiwan, attending language program, graduate school after
Roberta Miller	Juneau Icefield Research Program, field research
Timothy Nagle-McNaughton	Univ. of New Mexico, PhD in Earth & Planetary Science

Caroline Hung '19, Lisa Gilbert and *Erikka Olson '19* atop Chrystalls Beach Formation metabasalts, in the Otago regions of the South Island, New Zealand doing research on the volcanic and hydrothermal origins of the metabasalts and epidote veins, counting and measuring the orientations of veins as part of Caroline's thesis field work.

Geosciences Student Colloquia

Jacob Cyntrynbaum ‘18
“How Can storm Waves Move Very Large Boulders? Investigations in a Wave Tank”

Ezekiel King Phillips ‘18
“A Palynological and Geochemical Approach to Understanding the Late Devonian Kellwasser Events in the Appalachian Basin”

Roberta Miller ‘18
Reckoning with Giants: Paleoclimate, Makushin Peak, and the Aleutian Island Arc”

Timothy Nagle-McNaughton ‘18
“The Beauty and Geomorphology of Death Valley National Park”

“Photogrammetric Monitoring of Coastal Boulder Deposits”

Geosciences Colloquia

Aisha Morris, UNAVCO, Class of 1960 Scholars
“Geoscience Workforce Development: Strategies and Opportunities”

Ted Steinberg, Case Western Reserve University
“Can New York City Survive the Sea?”

Mae Jemison, NASA Astronaut, Sperry Lecture
“STEM: The Importance of Science, Technology, Engineering & Math”

Aaron Strong, University of Maine, Orono
“Monitoring the Carbon Cycle, Measuring Resilience and Blaming Climate Change: Defining the Trajectory of the Anthropocene”

Hilary Palevsky, Woods Hole Oceanic Institute
“The Role of Biology in Ocean Carbon Uptake”

Alice Bradley, Dartmouth College
“Observational Approaches for Seasonal Sea Ice Environments”

Mea Cook, Williams College
“Carbon Dioxide and Ice Age Cycles”

Nathaniel Raymond, Harvard Humanitarian Initiative, Harvard University
“Big Disasters, Digital Invisibility and the Information Age”

Elizabeth Eide, The National Academies of Science, Engineering, and Medicine, Class of 1960 Scholars
“News, Policy, and Decision-Making: Why and How Geosciences Matters”

Cecilia McHugh, Queens College
“Can Continental Margin Sediments be Globally Correlated During Pleistocene Glacioeustatic Fluctuations?

Off-Campus Geosciences Colloquia

Phoebe Cohen
"Life in the Neoproterozoic: Hard Parts, Hard Dates, and Hard Questions"
Syracuse University, February 2, 2017
University of Wisconsin-Madison, March 31, 2017
Dartmouth College, April 14, 2017
Agouron Project Workshop: Unraveling the Record of Early Eukaryotic Evolution in Arctic Canada, May 18, 2017

"The Evolution of Life Before Animals: Gasping for Breath and Dodging Snowballs"
Cornell University and thee Paleontological Research Institution Darwin Days, February 2018

José Constantine
"Meandering Rivers: The Role of Sand Grains in Their Evolution and Demise"
Middlebury College, September 2017
Smith College, November 2017
University of Massachusetts-Amherst, November 2017

Rónadh Cox
"Gullies, Erosion and Landscape Evolution in Madagascar: Trying to Tease Apart Natural and Anthropogenic Effects"
University of Cincinnati, October 13, 2017

"Coastal Boulder Transport: New Results"
University College Dublin, November 15, 2017

Lisa Gilbert
"InTeGrate Student Learning Gains: Systems Thinking"
InTeGrate Advisory Board Meeting, Howard Hughes Medical Institute, Chevy Chase, MD, October 11, 2017

"InTeGrate 101: How to Incorporate InTeGrate Classroom Materials into Your Courses"
InTeGrate Webinar, December 8, 2017

"Modes of Seafloor Volcanic Breccia Formation at IODP Hole 1256D"
University of Otago, Department of Geology, Volcanology, Dunedin, NZ, March 14, 2018

"Volcanic origins of permeability in oceanic crust"
University of Otago, Department of Geology, Fluid Flow Series, Dunedin, NZ, June 15, 2018

Markes Johnson
"Overview of Neogene Rocky and Sandy Shores in the Macaronesian Realm (NE Atlantic Ocean)"
University of Azores, Ponta Eelgada, São Miguel Island, July 12, 2017

"Neogene and Present-day Hurricane Deposits from Islands of the Macarnonesian Realm (NE Atlantic Ocean)"
University of Azores, Ponta Delgada, São Miguel Island, July 13, 2017

"Pliocene Warm Period: A Comparison of Storm Evidence from Western Mexico and the Azores"
Ville de Port, Santa Maria Island Azores), July 20, 2017

"Rhodoliths Past and Present in the Macaronesian Islands: On the Genesis of Storm Beds and a Warning on Climate Change"
Tenerife Museo de Ciencias Naturales, Canary Islands, April 6, 2018

Bud Wobus
"Stone Hill Geological History"
Williamstown Rural Lands Foundation, October 14, 2017

Mathematics and Statistics Department

This year 18 seniors graduated with a major in statistics and 75 graduated with a major in mathematics, making it a record-breaking year for the number of math majors. We are currently located in Bascom House, our temporary home, and we are looking forward to moving into our new building in early 2021.

Two of our Math/Stat faculty members are leaving Williams. Brianna Heggeseth, assistant professor of statistics at Williams since 2013, accepted a position at Macalester College. Cory Colbert, a Gaius C. Bolin Fellow in Math/Stat for the last two years, accepted an assistant professor position at Washington and Lee University. We will miss both of them, and we wish them the best! We hired two new statisticians who will be joining us this fall: Xizhen Cai, a Postdoctoral Fellow Research Associate at Temple University for the last two years, and Anna Plantinga, who earned her Ph.D. in 2018 from the University of Washington.

Three faculty, Andrew Bydlon, *Haydee Lindo '08* and Chad Topaz all completed their first year as a professor at Williams. We were thrilled to have hired them last year! We celebrated many faculty accomplishments over the year, including: Steve Miller was promoted to full professor, Lori Pedersen's contract was renewed, Mihai Stoiciu won the Northeastern Section of the Mathematical Association of America's 2018 award for Distinguished College or University Teaching, and Dick De Veaux was elected Vice President of the American Statistical Association.

Professors Dick De Veaux, Leo Goldmakher (fall), and Allison Pacelli (spring) were on leave for 2017-18. Professors Bernhard Klingenberg, Allison Pacelli (fall), and Mihai Stoiciu will be on leave in 2018-19.

We are very proud of the accomplishments of our majors: Rosenberg prize for outstanding senior: *Sumun Iyer '18, Arjun Kakkar '18,* and *Daishiro Nishida '18*; Goldberg award for outstanding colloquium: *Chris D'Silva '18* for math and *Yolanda Zhao '18* for stat; Wyskiel award for teaching: *Ned Lauber '18*; Morgan prize in applied math: *Daniel Maes '18*; Kozelka award for outstanding student in statistics: *Anna Neufeld '18* and *Hallee Wong '18*; Beaver prize for service to the department and math/stat community: *Isabella Huang '18*; Benedict prize for outstanding sophomore: *Michael Curran '20* and *Alessandra Miranda '20* (first prize) and *Xiwei Yang '20* and *Teresa Yu '20* (second prize); Witte problem solving prize: *Minh Tuan Tran '19*; Colloquium attendance prize: *Isabella Huang '18* for math and *Daniel Maes '18* for stat.

Three of our seniors won Fulbright Scholarships: *Molly Knoedler '18, Nohemi Sepulveda '18,* and *Darla Torres '18*. *Sumun Iyer '18* was awarded a National Science Foundation Graduate Research Fellowship, and *Sarah Fleming '18* received an honorable mention for the national Alice T. Schafer award, given by the Association for Women in Mathematics. The 40th Green Chicken contest, a problem-solving exam between Williams and Middlebury students was held at Middlebury in October. The Williams team successfully defended their title. The top five scorers for Williams were *Ian Banta '19, Michael Curran '20, Markus Feng '21, Will Howie '20,* and *Richard Wu '21*. In December, fifteen Williams students took the notoriously difficult national Putnam exam. Williams' top scorers were *Daishiro Nishida '18, Minh Tuan Tran '19, Hunter Wieman '20* and *Richard Wu '21* who all placed in the top 500.

Finally, we thank the members of our student advisory board, SMASAB, who organized many Math/Stat events including ice cream socials, Math/Stat snacks, and dinners for job candidates: *Isabella Huang '18, Ned Lauber '18, Austin Vo '18, Yolanda Zhao '18, Anya Michaelsen '19, Grace Mabie '19, Izzy Ahn '19, Eli Cytrynbaum '20, Alessandra Miranda '20,* and *Sofie Netteberg '20*.

Class of 1960 Scholars in Mathematics and Statistics	
Federico Ardila	Thomas Halverson
Ciprian Crainiceanu	James Booth
David Jensen	Robert Lemke Oliver
Thomas Kindred	David Damanik
Andrew Bernoff	

In summer 2017, Professsor **Colin Adams** worked with six students as part of the SMALL Summer Research Project on hyperbolic knots. They traveled to Chicago in August for Mathfest, where the students gave talks and produced a paper on *Hyperbolicity of Knots and Links in Thickened Surfaces*. Over the academic year, he gave a variety of talks at conferences and schools, including research talks, expository talks and even a talk on knots and dance. He submitted a variety of papers, including research papers, expository papers and even a story imagining what would happen if Donald Trump was the president of the American Mathematical Society. Adams advised a thesis by *Daishiro Nishida '18*, who generalized classical braid theory to multi-crossing braids.

Over the past year, Assistant Professor **Julie Blackwood** has continued several ongoing projects in mathematical ecology. For example, she continues to work on mathematical models that describe the dynamics of periodical cicadas to better understand their synchronous behavior. She also continues to work on modeling the dynamics of infectious diseases, exploring questions related to identifying the drivers of spatiotemporal patterns of epidemics. Several Williams students have worked with her this past year, including thesis students *Molly Knoelder '18* and *Jackson Barber '18*. Several papers have also been published that have student co-authors including *A Neufeld '18, E Matt '18, A Meyer '16,* and *R Vargas Jr '16*.

Professor **Dick De Veaux** continued his work in data mining, writing textbooks and gave a variety of keynote addresses, talks and workshops on teaching and data mining throughout the world. He finished his term as Chair of the section on Statistical Learning and Data Science of the American Statistical Association, but was elected Vice President of the American Statistical Association for the term 2019-21. He served as tutorial chair for the IEEE Data Science conference (IEEE DSAA) in Turin Italy (Oct 2018) and was appointed program chair of the 2019 conference in Washington D.C. In June 2018 he was a Summer at Census fellow at the U.S. Census.

Professor **Tom Garrity** has continued his research in number theory. His paper *Generalizing the Minkowski Question Mark Function to a Family of Multidimensional Continued Fractions*, written with *Peter McDonald '16*, has been accepted for publication in *The International Journal of Number Theory*.

In June of 2017, he gave an invited talk at Project Dyna3S, Université Caen, titled "On Transfer Operators for Triangle Partition Maps." Also in June, he spoke "On a Thermodynamic Classification for Real Numbers," in the Automata Seminar at the Institut de Recherche en Informatique Fondamentale (IRIF), Université Paris-Diderot. In July of 2017, he gave a talk on Mathematical Maturity at the Park City Mathematics Institute. In September, 2017, he gave the Martha Davenport Heard Lecture at Wellesley College. In November, 2017, he gave the Keynote Lecture at the Mathematics Conference and Competition of Northern New York (MCCNNY), Clarkson University.

Assistant Professor **Leo Goldmakher** continued his research in number theory and additive combinatorics, spending the Fall semester on sabbatical and returning to teaching during the Spring. During the course of the year he had four papers accepted for publication (one written jointly with *Elijah Fromm '17*, (PhD program, Yale). In the Spring semester he taught a course on Galois theory and a tutorial on analytic number theory, and also gave the Spring 2018 Sigma Xi lectures.

Professor Goldmakher also gave invited talks at the Heilbronn Institute/University of Bristol (UK), TU Graz (Austria), Tufts (MA), University of Michigan-Ann Arbor (MI), Rice (TX), and Yale (CT). He also delivered a talk to the Yale Math Society, an undergraduate organization. Finally, he gave two invited talks at conferences: one at the Mathematical Congress of the Americas (in Montreal, QC, Canada) and the other at Canadian Math Society Summer Meeting (in Fredericton, NB, Canada).

Assistant Professor **Pamela Harris** developed two new courses for the Mathematics and Statistics Department: Combinatorics (MATH 328) and Undergraduate Research Topics in Graph Theory (MATH 392T). In honor of her continued mentoring activities at Williams College, Professor Harris was selected as the Outstanding Mentor of 2018 by the Davis Center.

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 Erik Insko and Mohammed Omar, which answers a very natural question regarding the number of ways to express the highest root of a classical Lie algebra as a sum of the positive roots. The article *The q-analog of Kostant's partition function and the highest root of the simple Lie algebras* appeared in the *Australasian Journal of Combinatorics*. This is one of 7 accepted papers this academic year.

Harris was awarded six grants or travel awards this year. This was also the second year of support under the National Science Foundation (award DMS-1620202). She also presented 23 lectures, 21 of which were invited lectures, including an international invitation to present her research in Quito, Ecuador. In addition, she attended 8 conferences, including trips to England, Ecuador, and Mexico.

Professor Harris is highly committed to fostering the success of underrepresented scientists and to improving diversity and retention rates among women and minorities in the mathematical sciences. To do so 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 secured grant funding to support 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 Latin(a)s and Hispanics in different areas of the Mathematical Sciences.

Lastly Professor Harris and her work has been featured in:

- Vanguard STEM feature for women of color in STEM, June 27, 2017.
- Association for Women in Mathematics ADVANCE website on Women do Math.
- London Mathematical Society Success Stories project celebrates the diversity of successful careers and mathematicians: https://www.lms.ac.uk/content/pamela-e-harris
- Featured mathematician in *Power in Numbers: The Rebel Women of Mathematics* by Talithia Williams

Assistant Professor **Brianna Heggeseth** enthusiastically returned from sabbatical to teach Introduction to Statistics and Data Analysis (STAT 101), the core upper level course Regression and Forecasting (STAT 346), and the senior seminar Data Mining and Computational Statistics (STAT 442T) that covered the methods, use, and ethics of modern statistical learning algorithms.

In her research, she submitted two methodological papers for review as well as co-authored collaborative papers. Additionally, she had two thesis students, *Hallee Wong '18* and *Anna Neufeld '18*. Hallee's work focused on methodological development for predicting 30-day hospital readmissions and Anna studied, implemented, and compared methods for fitting regression trees to longitudinal data. The review of the literature will be written as a review paper and her code will be developed into a publicly available R package with an accompanying paper. Dr. Heggeseth presented their work at an invited session at the ENAR Biometrics 2018 conference and will be presenting it at the Joint Statistical Meetings 2018.

Additionally, Dr. Heggeseth acted as a statistical consultant and then collaborator on a project of implicit and explicit bias with a colleague in the psychology department and a project of timing of cricket mating with a colleague in the biology department.

She left Williams at the end of the academic year to take a position at Macalester College in the Department of Mathematics, Statistics, and Computer Science.

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.

Prof. Johnson supervised a senior thesis by *Cody Cao '18*, where he studied the spatial implementation of the replicator equation from evolutionary dynamics, using highly parallel computation to establish the direction and properties of travelling waves, extending the ground-breaking work of Hudson, Vickers, and Cressman to higher dimensional models.

Professor **Bernhard Klingenberg** published a couple of papers in collaboration with scientists in medicine and biology and provided statistical consulting to faculty and students at Williams on a variety of projects. He also programmed new web apps published on his website ArtofStats.com that help students understand statistical concepts and carry out data analysis in the cloud. In March, he presented some of these at the Conference on Technology in Collegiate Mathematics. At the department, Prof. Klingenberg served as associate chair of statistics. He also continued as associate editor for the *Journal of Statistical Modelling*.

Professor **Susan Loepp** completed her second year of a three-year term as chair of Math/Stat. In addition to her chair duties, she enjoyed teaching and her research in commutative algebra. She helped organize the first commutative algebra seminar at Williams which met every two weeks. Four faculty and five students participated. She especially enjoyed her research collaborations with her three thesis students, **Sarah Fleming '18, Alex Semendinger '18,** and **Weitao Zhu '18**.

In summer 2017, Loepp advised the Commutative Algebra research group as part of the department's SMALL program. The group included the two Williams students *Timothy Kostolansky '18,* and *Alex Semendinger '18*. A paper based on the group's original results has been submitted to a refereed research journal to be considered for publication. Loepp gave a talk in April at an American Mathematical Society Sectional Meeting based on the results in the paper.

In January, Loepp attended the Joint Mathematics Meetings in San Diego. She is 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, and the Mathematical Association of America.

Professor **Steven Miller** is on year two of a three year individual NSF grant to continue his investigations in number theory and probability (he is also a co-PI on three grants to support the 32nd Automorphic Forms Workshop, which ran from March 18th to 22nd at Tufts), 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 20 papers and gave 38 talks (thesis students: *Hallee Wong '18* (health care), *Alyssa Epstein '18* (game theory; research students (academic year): Bryan Woolley, George Carroll, William Gearson, Charles Ide, J*ay Habib '18*; summer students (mentored with Ezra Waxman, visiting graduate student): Alexandre Gueganic, *Alina Shubina '19*, Eric Winsor, Granger Carty, Jared Lichtman, Jianing Yang, Ryan Chen, Shannon Sweitzer, Yujin Kim). 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 Operations Research, and to working with many math camps. With Mihai Stoiciu he ran math puzzle night and continued our streak of over 1% campus participation on the Putnam exam. He also expanded his involvement in using online resources in teaching; all of his course lectures are available online through YouTube, as are many of his talks. In addition to giving many math talks at Williamstown Elementary School, 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. He serves on many editorial boards (Managing Editor of the *Journal of Number Theory*, Editor of the *Notices of the American Mathematical Society*, Problem Editor of the *Pi Mu Epsilon Journal*, Member (and then chair) of the Arnold Ross Lecture Series Committee, Member of the Fibonacci Association Board, AMSTEXT Editorial Committee, and the Carus Editorial Committee). He is also a mentor for the Math Alliance, and a Senator-at-Large for Phi Beta Kappa (and faculty president of Williams Chapter).

Professor Emeritus **Frank Morgan** spent his second year of retirement as Editor-in-Chief of the *Notices of the American Mathematical Society*, the largest publication in higher mathematics. His travels included trekking in Nepal, with views of Mt. Everest.

Assistant Professor **Ralph Morrison** completed his second year at Williams College. He continued his research on tropical, algebraic, and discrete geometry. He was a guest at the Mittag-Leffler Institute for their program on Tropical Geometry, Amoebas, and Polytopes in January and February 2018, where he presented on his research. He attended and presented at the 2017 SIAM Conference on Applied Algebraic Geometry, the 2018 Joint Mathematics Meetings, and the 2018 AMS Spring Central Sectional Meeting. He led a research group in tropical geometry in the department's summer SMALL REU in both 2017 and 2018, working with nine undergraduates on embedded and abstract tropical geometry, including Williams students *Andrew Scharf '18, Franny Dean '19, Sammy Rosofsky '19,* and *Teresa Yu '20*. He took both groups to conferences to present on their work: in 2017, to the Young Mathematicians' Conference, and in 2018, to the MAA's Mathfest conference. He advised two senior honors theses in mathematics: Higher distance commuting matrices by *Madeleine Elyze '18* and Intersections of tropical surfaces by *Andrew Scharf '18*. He taught two sections of Discrete Mathematics (MATH 200) in the fall, and introduced two new upper level courses in the spring: a senior seminar on Tropical Geometry (MATH 474), and a tutorial on Discrete Geometry (MATH 329T).

Professor **Allison Pacelli** continued her work in algebraic number theory, including a project with a student about the geometry of modular arithmetic. She also supervised *Ned Lauber '18* on his thesis in math education about effective teaching methods. Pacelli is on sabbatical during 2018.

Professor **Cesar Silva** started the summer of 2017 by teaching in the Summer Science Program. In fall 2017, Silva taught Real Analysis (MATH 350) and Measure and Ergodic Theory (MATH 403). In spring 2018, he also taught Real Analysis (MATH 350) and then Chaos and Fractals (MATH 306). During the academic year, Silva had two thesis students, *Beatrix Haddock '18* and *Sumun Iyer '18*, who worked in ergodic theory. During January of 2018 he taught a travel Winter Study course in photography, in collaboration with Richard Washburne. He and his students travelled to the cities of Lima and Cuzco, and visited Machu Picchu, in Peru.

His professional activities included participating in a National Science Foundation panel, and being an associate editor for *Notices*, a monthly publication of the American Mathematical Society. He also published four papers, three of them with his former students. He attended a group research meeting at American Mathematics Institute, in San Jose, California, in November, 2017.

Together with his colleagues Colin Adams and Frank Morgan, Silva organized a Special Session at the annual meeting of the American Mathematical Society in San Diego, California, that took place on January 13, 2018. This was on the occasion of the 30th anniversary of the SMALL Undergraduate Research Program.

Professor **Mihai Stoiciu** taught Foundations in Quantitative Skills (MATH 102) and two sections of Applied Real Analysis (MATH 351) during the Fall Semester and Calculus II (MATH 140) during the Spring Semester of the Academic Year 2017-18. He also supervised the undergraduate thesis of *Eliza Matt '18* and an independent study course on Stochastic Calculus, taken by *William Chen '19*. During the year, Stoiciu continued his research on spectral properties of random and deterministic operators and was invited to present his work and at the conference "NEAM 2017: Second Northeastern Analysis Meeting", hosted by University at Albany in Albany, NY and at the AMS Special Session on "Spectral Theory", hosted by Portland State University in Portland, OR.

During June-July 2017, Stoiciu participated in IAS-PCMI Summer School on the topic "Random Matrices". There he taught a three-week course for advanced undergraduate students titled "Introduction to Random Matrix Theory". At Williams College Stoiciu advised four students in the SMALL Undergraduate Research Program, who worked on several projects in Random Matrix Theory. He gave a seminar at Williams College in August 2018, where he presented their summer research.

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. He represented Williams College at the 2018 LACOL Workshop, hosted by Carleton College, where he gave a presentation on the tutorial course on Numerical Analysis he developed at Williams.

Professor **Chad Topaz** greatly enjoyed his first year at Williams College! In the fall, he developed new courses in Computational Linear Algebra (MATH 307) and in Applied Partial Differential Equations (MATH 453), and in the spring, taught Discrete Mathematics (MATH 200). He was privileged to advise two students on research, namely *Daniel Maes '18* who built Markov chain models of the college admissions pipeline in order to assess "critical mass" in affirmative action, and *Arjun Kakkar '18* who used nonlocal energy balance models to study vegetation pattern formation.

Professor Topaz submitted and was awarded a three-year National Science Foundation research grant on "Variational and topological approaches to complex dynamical systems" to support his research. This past year, he worked on three manuscripts, including one he submitted that stems from a collaborative data science project he launched to measure the diversity of artists in major U.S. museums. Speaking of collaboration, he co-organized an American Mathematical Society Mathematics Research Community which facilitated research groups for Ph.D. students and postdocs, and he began co-organizing a workshop on topological data analysis to take place in 2019 at the ICERM math institute. Active within his professional organizations, he was appointed to the editorial board of the *SIAM Journal on Applied Dynamical Systems* and invited to be a plenary speaker at the 2019 SIAM Conference on Applications of Dynamical Systems.

Assistant Professor **Laurie Tupper** continued her research in classification, similarity, and clustering approaches to complex data, and the effects of using different structures (spatial, temporal, spatio-temporal, high-dimensional) to represent such data. She submitted an NIH Small Business Innovation Research grant application with academic and industry collaborators, for work on distinguishing mammalian cell types using electrical behavior. She also continues to work with wind and climate applications, including presenting an invited poster at the IMA Workshop on Frontiers in Forecasting and four current projects with summer research students *Youngsoo Baek '19, Alessandra Miranda '20, Eric Rosenthal '19,* and *Daniel Woldegiorgis '20*. She developed a new course on Design of Experiments (STAT 344) in the fall, incorporating both classical and modern optimal-design methods, and taught Regression and Forecasting (STAT 346) and two sections of Statistics and Data Analysis (STAT 201).

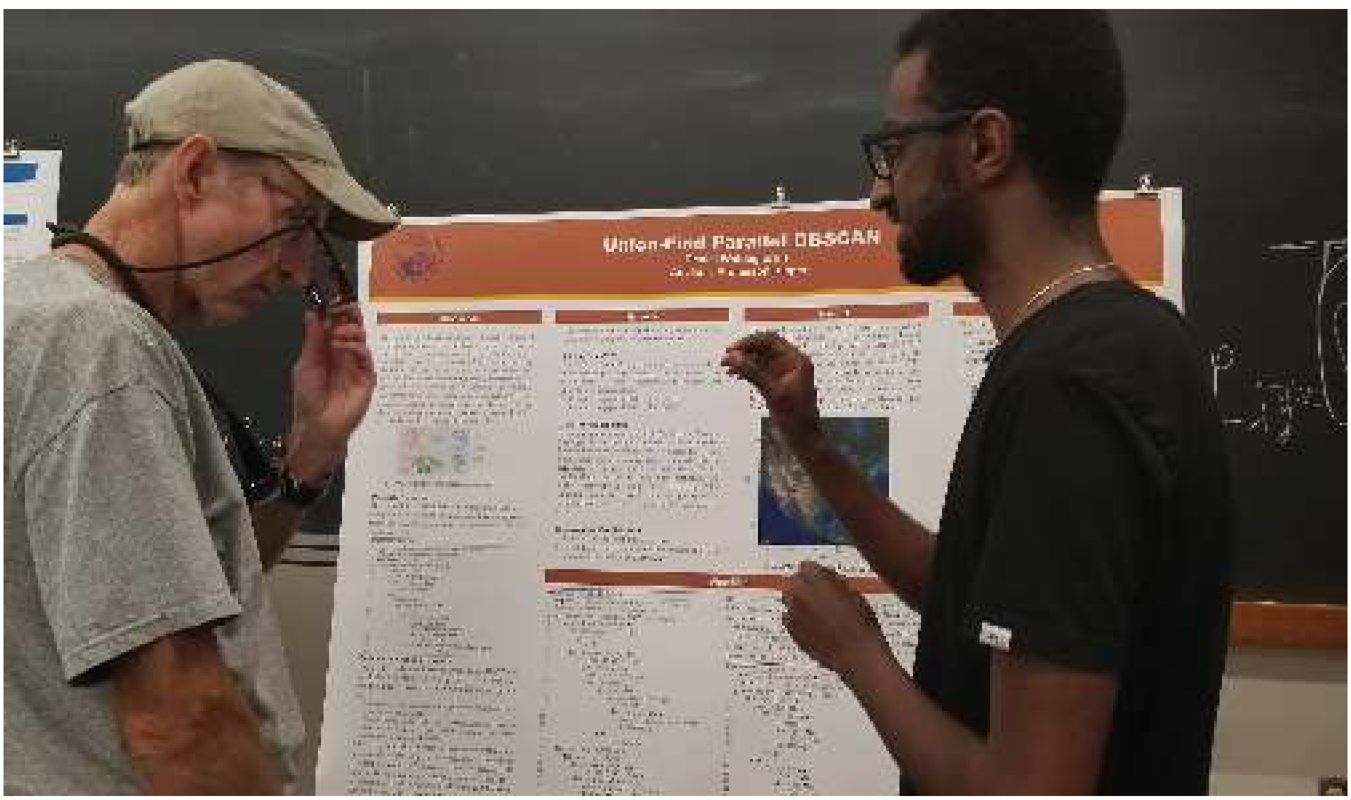
Assistant Professor **Daniel Turek** completed his second year at Williams. He continued his theoretical work in the area of computational statistical algorithms in which he developed highly efficient implementations of existing statistical methodology, or variations and hybrids of existing algorithms with the goal of improving computational performance. In addition, he continued his role as an active core developer of NIMBLE, an open-source statistical software project. The book *The Practice of Reproducible Research*, co-edited by Turek, was published by University of California Press in 2017.

Turek enjoyed advising the research of *Daniel Maes '18* during the summer of 2017. His research project analyzed statistical models for a variety of leveraged financial assets, and what properties of these assets led to profitable trading strategies.

Post-Graduate Plans of Mathematics and Statistics Majors

Stephen Ai	Pursuing a Masters of Philosophy in Music at Cambridge University
Nathan Andersen	Quantitative Developer at Akuna Capital
Jackson Barber	Fulbright English Teaching Assistant in Thailand
Marit Bjornlund	Working at the International Foundation for Electoral Systems (IFES) as a Program Associate for Asia-Pacific
Cody Cao	Master's program at Columbia University in Financial Engineering
Jack Cloud	Working for the data science company named Annalect, under the company, Omnicom
Kevin Deptula	Analyst at Cornerstone Research in New York City
Madeleine Elyze	Data Analyst at Minerva in Cambridge, MA
Alyssa Epstein	Attending Stanford Law School
Sarah Fleming	Pursuing an MDiv in Interfaith Chaplaincy at Harvard Divinity School
Jay Habib	Working as an Analytics Associate for the New York Mets
Beatrix Haddock	Pursuing positions at an NGO
Helene Hall	Working as a Research Assistant at the Federal Reserve Bank of New York
Caroline Hogan	Working as an Investment Analyst at the Williams College Investment Office
Isabella Huang	Pursuing a Ph.D. in Computer and Cognitive Sciences at the University of Colorado, Boulder
Sumun Iyer	Pursuing a Ph.D. in Math at Cornell University
Arjun Kakkar	Pursuing a Ph.D. in Applied Math at UCLA
Molly Knoedler	Awarded a Fullbright award to conduct math research in New Zealand, studying bird pollination and modelling bird navigation
Julianna Kostas	Working at the NIH with a Post-Baccalaureate CRTA Fellowship
Kiran Kumar	Working as an Associate Computational Biologist at the Broad Institute
Ryan Kwon	Working as a Software Engineer at Dropbox
Edward Lauber	Teaching secondary math in Connecticut for Teach for America while pursuing a Master's in Education through the Johns Hopkins School of Education
Haley Lescinsky	Public health research at the Institute for Health Metrics and Evaluation (HME), while taking classes in public health at the University of Washington in Seattle, WA
Stephanie Li	Working as a Research Associate in Finance at Dodge & Cox
Andrew Litvin	Analyst at BDT & Company in Chicago, IL
Tanner Love	Working for Google as a Software Engineer, Tools & Infrastructure
Ziqi Lu	Possibly pursuing a Ph.D. in Economics
Calvin Ludwig	Computational Bioinformatics as a Research Associate in the biomedical laboratory of Leonard Zon, MD at Harvard Medical School
Dalia Luque	Phoenix Program Manager at the non-profit, Student Expedition Program
Daniel Maes	M.S. Program in Applied & Interdisciplinary Mathematics at the University of Michigan
Jake Marrus	Working as a Consultant at Oliver Wyman
Ian Mook	Math Fellow for the Penn Boarding School Teaching Residency Program at the Lawrenceville School
Matt Morris	Private Equity Analyst at Landmark Partners
Anna Neufeld	Pursuing a Ph.D. in Statistics at the University of Washington
Daishiro Nishida	Working as a Programmer at an art/tech company in Toyko

Ashay Patel	Pursuing a Ph.D. in Physics at Caltech
Chetan Patel	Associate at Parthenon-EY in Boston, MA
Seth Perlman	Cybersecurity Consulting at Booz Allen Hamilton, Washington, DC
Timothy Randolph	Pursuing a Ph.D. in Computer Science at Columbia University
Miguel Samayoa	Operations Analyst at 20th Century Fox
Jake Savoca	Data Scientist at Booz Allen Hamilton, Washington, DC
Andrew Scharf	Planning to apply to graduate schools in the fall
Robert Schneiderman	Working in sales and trading for Société Générale in Manhattan
Alex Semendinger	Ph.D. program in Mathematics at UCONN
Nohemi Sepulveda	Awarded a Fulbright scholarship, will be in Spain as a Fulbright scholar teaching
Emily Sundquist	Entering the Master's Program in Epidemiology at Cambridge University in Cambridge, England
Gregory Szumel	Working as a Consultant at Oliver Wyman in Boston, MA
Sean Wang	Working as a Medical Scribe at the Pascack Valley Hospital in Westwood, NJ
Emilia Welch	Working at Guggenheim Partners in the Corporate Credit Group in New York City
Colin Williams	Economic Consulting at NERA in Washington, DC
Hallee Wong	Applied math research program at UCLA called Research in Industrial Projects for Students (RIPS) this summer, then working as an Analyst at an Analysis Group in Boston.
Ben Young	Software Development at Epic Systems in Madison, WI
Fangyuan Zhao	Working at NERA Economic Consulting in New York City
Weitao Zhu	Pursuing a Ph.D. in Mathematics at Columbia University



Daniel Woldegiorgis '20 shares his summer research work on parallel implementation of DBSCAN and its variations. DBSCAN is an algorithm that finds clusters in noisy data like weather measurements.

Mathematics and Statistics Student Colloquia

Stephen Ai ‘18
“Cardinality and Variety in Music: A Mathematical Investigation”

Spencer Alpaugh ‘18
“Intervention Analysis”

Nathan Andersen ‘18
“What Does it Really Mean to be Random?”

Prosper Atukwatse ‘18
“An Exposition of Fejer’s Theorem”

Jackson Barber ‘18
“The Spatial Dynamics of WNS”

Andrew Barry ‘18
“Violating the Parallel Postulate: A Crash Course in Hyperbolic Geometry”

John Beirne ‘18
“Properties of Multivariable Complex Functions”

Isaac Benioff ‘18
“Euclid’s A Liar! A Brief Introduction to Spherical Triangles”

Marit Bjornlund ‘18
“How Do We Know What’s Unfair?: Using Markov Chains to Evaluate Gerrymandered Political Districts”

Cody Cao ‘18
“A Numerical Investigation of the Traveling Wave in EGT”

Granger Carty ‘18
“Can a Monohedral Tiling be Aperiodic?”

Jacques Chaumont ‘18
“Exploring Random Draws”

Frankie Chen ‘18
“Developing an Essential Tool for Dealing With Polynomials and Their Roots: The Resultant”

Eugene Choe ‘18
“Intro to Regression Trees”

Jack Cloud ‘18
“Marketing Mix Models to Optimize Ad Spending”

Trevin Corsiglia ‘18
“A Proof for the Completeness of Propositional Logic”

Christopher D’Silva ‘18
“Quantum Computers, Mixed Drinks, and Friendship Bracelets: Searching for the Braid Index”

Kevin Deptula ‘18
“Kenneth Arrow’s Impossibility Theorem”

Benjamin Drews ‘18
“The ABC Conjecture and Fermat’s Last Theorem”

Agastya Easley ‘18
“Disease in Metapopulation Models”

Emily Eide ‘18
“Analysis of Spatial Data Using Kriging”

Mason Elizondo ‘18
“Evolutionary Dynamics and Rocks Paper Scissors Lizards”

Madeleine Elyze ‘18
“On Higher Distance Commuting Matrices”

Alyssa Epstein 1’8
“The Fibonacci Game”

Daniel Fisher ‘18
“Hyperreals and the Transfer Principle”

Ioannis Florokapis ‘18
“Local Network Effects in Stochastic Graph Structures”

Jahangir Habib ‘18
“Digit Bias in Data Sets”

Beatrix Haddock ‘18
“Weak Mixing in Infinite Measure”

Helene Hall ‘18
“Buffon’s Needle: How to Use a Random Experiment to Approximate Pi”

Caroline Hogan ‘18
“Architecture Frieze Patterns: The Seven One Directional Symmetry Groups”

Isabella Huang ‘18
“You’ve Peaked!: Combinatorial Problems on Peaks, Pinnacles, Descents, and Derangements”

Sumun Iyer ‘18
“Nonsingular Rank One Transformations”

Richard Jin ‘18
“Latent Semantic Analysis”

Arjun Kakkar ‘18
“Modeling and Analysis of Vegetation Patterns in Semi-Arid Regions”

Molly Knoedler ‘18
“Topology and Agent-based Modeling of Pollination Networks”

Julianna Kostas ‘18
“The Seasonal Influenza A Epidemic: SIRC Model and Bifurcation Analysis”

Timothy Kostolansky ‘18
“Hilbert’s Basis Theorem”

Kiran Kumar ‘18
“What is the Shape of Brexit?”

Ryan Kwon ‘18
“Axiom of Choice and Zorn’s Lemma”

Henry Lane ‘18
“Manipulation and Preferential Interaction in the Envelope Game, or How to Politely Dodge Favors”

Edward Lauber ‘18
“Pedagogical Approaches to Mathematics Instruction: Finding a Balance Between Lectures and Discovery”

Haley Lescinsky ‘18
“Population Dynamics of a Host Parasitoid System”

Stephanie Li ‘18
“Nim Games and the Sprague-Grundy Theorem”

Andrew Litvin ‘18

“Real-Time Win Probability in Texas Hold ‘em Poker”

Tanner Love ‘18
“Throwing Darts at the Real Line: A Probabilistic Intuition Against the Continuum Hypothesis”

Ziqi Lu ‘18
“The Game Theory of Social Norms”

Calvin Ludwig ‘18
“Mathematical Modeling of HIV Pathogenesis and Treatment”

Wei Luo ‘18
“Ramsey Numbers and Computational Methods”

Dalia Luque ‘18
“Juggling, Combinatorics, and Worpitzky’s Identity”

Eleanor Lustig ‘18
“Modeling the Impacts of Climate Change on Malaria Transmission”

Daniel Maes ‘18
“A Financial Statistical Approach for Leveraged Exchange-Traded Funds (LETFs)”

“Assessing Critical Mass at UC-Berkeley: Creating Predictive Models for Affirmative Action Policies in Undergraduate Admissions in the United States”

Jacob Marrus ‘18
“Can Pac-Man Ever Escape?”

Eliza Matt ‘18
“The Density of States of RNA”

Jonathan Meng ‘18
“The Mathematics Behind Heisenberg’s Uncertainty Principle”

James Millstone ‘18
“The Catalan Numbers and the Wigner Semicircle Distribution”

Ian Mook ‘18
“An Exploration of Turing Patterns and Their Presence in Nature”

Matthew Morris ‘18
“Modeling the Entire Distribution: An Introduction to Quantile Regression”

Anna Neufeld ‘18
“Longitudinal Regression Trees”

Daishiro Nishida ‘18
“Multi-Crossing Braids”

Francesca Paris ‘18
“Missing Data in Public Health and the EM Algorithm”

Ashay Patel ‘18
“Fundamental Solutions for PDEs and a Generalized Calculus”

Chetan Patel ‘18
“The P vs. NP Problem: A Short Exploration”

Sohum Patnaik ‘18
“Statistical Approaches for Automatic Text Summarization”

Seth Perlman ‘18
“Fun With Partition Numbers”

Timothy Randolph ‘18
“Proving the Existence of Monocolor Arithmetic Progressions (Van Der Waerden’s Theorem)”

Claudia Reyes ‘18
"Points of Visibility"

Andrew Robertson ‘18
"Boosting: Improving Learning Algorithm Performance"

Thomas Rosal ‘18
"The Gaussian Copula in Practice: Modeling Dependence and Where Assumptions Fail"

Jake Savoca ‘18
"Continued Fractions and Quadratic Irrationals"

Andrew Scharf ‘18
"Representing Tropical Intersection Curves"

Lev Schechter ‘18
"Optimal Strategies in a Basketball Shooting Contest"

Robert Schneiderman ‘18
"NFL Survival Analysis"

Alex Semendinger ‘18
"Noetherian UFDs with Weird Prime Spectra"

Nohemi Sepulveda ‘18
"Happy Numbers on a Happy Day"

Emily Sundquist ‘18
"Mapping Measles: Temporal and Spatial Epidemic Patterns"

Greg Szumel ‘18
"Gale and Stewart's Theorem on Games"

Spencer Thomas ‘18
"Is This the Real Deal?: Using Discrete Wavelet Transforms to Detect Forgeries in the Art World"

Karan Tibrewal ‘18
"The Twin Prime Conjecture and Brun's Sieve"

Darla Torres ‘18
"Quadratic Reciprocity"

Minh Tuan Tran ‘18
"Fast Fourier Transform and Applications"

Austin Vo ‘18
"Spatial Point Pattern Analysis"

Sean Wang ‘18
"The Ideal Number of Shuffles for a Deck of Cards"

Emilia Welch ‘18
"Modeling and Predicting Ocean Tides With Fourier Analysis"

Colin Williams ‘18
"Proving the Existence of a Nash Equilibrium"

Hallee Wong ‘18
"Using Data to Predict Hospital Readmissions at Berkshire Medical Center"

Zihan Ye ‘18
"Generalized Additive Models"

Benjamin Young ‘18
"Generating Functions and the Coin Problem of Frobenius"

Yiheng Zhang ‘18

“Liouville Numbers: Category vs. Measure”

Fangyuan Zhao ‘18
“A (Gentle) Introduction to Causal Inference – With a Focus on Propensity Score Methods”

Weitao Zhu ‘18
“A Local Ring With an Unusual Ideal Structure”

Michael Zuo ‘18
“Secure Secret Sharing for Strangers”

Mathematics and Statistics Colloquia

Colin Adams, Williams College
“The Hyperbolic Volume of Your Bathroom Tiling”

“Hyperbolic Knots and You”

Henry Adams, Colorado State University
“Evasion Paths in Mobile Sensor Networks”

Federico Ardila, San Francisco State University
“Using Geometry and Combinatorics to Move Robots Quickly”

Brittney Bailey, Ohio State University
“Missing Data in Cluster-Randomized Trials”

Andrew Bernoff, Harvey Mudd College
“Energy Driven Pattern Formation in Thin Fluid Layers: The Good, the Bad and the Beautiful”

Julie Blackwood, Williams College
“Spatial Synchrony of Periodical Cicadas in the Eastern United States”

James Booth, Cornell University
“Generalized Regression Estimation Via the Bootstrap”

Andrew Bydlon, Williams College
“Restriction of Test Ideals to Hypersurfaces”

Xizhen Cai, Temple University
“Variable Selection for the Proportional Odds Model”

Crain Crainiceanu, Johns Hopkins University
“Biostatistical Methods for Wearable and Implantable Technology”

David Damanik, Rice University
“Products of Random Matrices, Large Deviations, and Applications”

Thomas Garrity, Williams College
“On Some Wonders of Factoring and Its Many Choices”

Thomas Halvorson, Macalester College
“Signals on the Permutohedron”

Pamela Harris, Williams College
“Lattice Point Visibility of Generalized Lines of Sight”

Brianna Heggeseth, Williams College
“Many Data Views”

Sarah Iams, Harvard University
“Vegetarian Patterns in Earth’s Drylands”

David Jensen, University of Kentucky

“Chip Firing and Random Graphs”

Thomas Kindred, University of Iowa
“Checkerboard Plumbings”

Haydee Lindo, Williams College
“Counting Klein Bottles”

Susan Loepp, Williams College
“Chain Conditions on Noetherian Rings”

“Chain Conditions on Noetherian Integral Domains and Noetherian Unique Factorization Domains”

Steven Miller, Williams College
“Problems in Number Theory and Probability”

“From Random Matrix Theory to Number Theory”

Frank Morgan, Williams College
“The Isoperimetric Problem in Spaces With Density”

Ralph Morrison, Williams College
“Tropical Hyperelliptic Curves in the Plane”

Robert Lemke Oliver, Tufts University
“Prime Numbers, Randomness, and the Gambler’s Fallacy”

Mohamed Omar, Harvey Mudd College
“Convex Incidences Via Algebra”

Anna Plantinga, University of Washington
“High-Dimensional Regression Methods for Microbiome Association Analysis”

Alex Reinhart, Carnegie Mellon University
“A Spatio-Temporal Statistical Model of Crime Hotspots”

Cesar Silva, Williams College
“On the Moebius Random Law and Infinite Rank-One Maps”

“Mixing and Ergodic Transformations”

“Chaos in Kneading Dough”

Gwen Spencer, Smith College
“Influence Maximization in Networks: Spread Models and Optimization Methods”

Mihai Stoiciu, Williams College
“Spectral Properties of Various Ensembles of Random Matrices”

Chad Topaz, Williams College
“Gender Representation in Mathematics Through a Data Science Lens”

Laurie Tupper, Williams College
“The When and Where of Wind: Spatial Time Series Classification”

Stefanie Wang, Trinity College
“An Introduction to Quasigroups and Peri-Catalan Numbers”

Off-Campus Mathematics and Statistics Colloquia

Colin Adams

"Blown Away: What Knot to Do When Sailing"
Mathpath, Mt. Holyoke College, July 19, 2017
University of South Florida, Tampa, FL, April 12, 2018

"Open and Accessible Problems for Undergraduates in Knot Theory"
Special Session, JMM, San Diego, CA, January 11, 2018

"Mathematically Bent Theater"
Joint Mathematics Meetings, San Diego, CA, January 12, 2018
Topology in Dimensions 2,3, 3.5 and 4, Berkeley, CA, June 25-28, 2018
Park City Mathematics Institute, July 16, 2018

"A History of SMALL"
with F. Morgan and C. Silva, Special SMALL Session, San Diego, CA, January 13, 2018

"Knotted Dance"
Dance/Performance in Interdisciplinary Perspective, Williams College, March 10, 2018

"Multi-Crossing Number for Knots: Turning Knots into Flowers"
Kitao Lecture, Swarthmore College, Swarthmore, PA, March 27, 2018
University of South Florida, Tampa, FL, April 12, 2018
Pacific Northwest MAA Meeting, Seattle, WA, April 19 - 20, 2018
Plenary Lecture, SUMTOPO Conference, Western Kentucky University, Bowling Green, KY, July 18, 2018

"Constant Mean Curvature Surfaces in Hyperbolic 3-Manifolds"
Topology in Dimensions 2,3, 3.5 and 4, Berkeley, CA, June 28, 2018

"The Great Pi vs. e Debate"
with Tom Garrity, Park City Mathematics Institute, July 16, 2018

Julie Blackwood

"Uncovering the Drivers of Spatial Synchrony of Periodical Cicadas in the U.S."
Virginia Tech
Sixth International Conference on Mathematical Modeling and Analysis of Populations in Biological Systems
Society for Mathematical Biology Annual Meeting

Richard De Veaux

"The Seven Deadly Sins of Big Data"
Gordon Lecture, Denison University, OH, October 2017
4th International Researchers, Statisticians and Young Statisticians Congress (IRYSCS), U.S. Census Bureau, Washington, DC, June 2017
Fall Technical Conference, Philadelphia, PA, October 2017 (Finalist for Shewell Award for Best Presentation)

"Data Science For All? When, Where, How Much and Why?"
ECOTS e-conference on Teaching Statistics, May 2018

"Modeling Aging Effects in Human Sports Performance"
U.S. Census Bureau, Washington, D.C., June 2017
Denison University, OH, October 2017

"Building Better Models Through Predictive Analytics"
Paris, France, September 2017
New York, April 2018
Philadelphia, PA, April 2018

"Workshop on Presentation Skills"

Joint Statistical Meetings, Baltimore, MD, July 2017

"Short Course: Successful Data Mining in Practice"
Cleveland Chapter, American Statistical Association, April 2018
U.S. Army, Picatinny Arsenal, Wharton, NJ, April 2018

Thomas Garrity

"On Transfer Operators for Triangle Partition Maps"
Project Dyna3S, Université, June 2017

"On a Thermodynamic Classification for Real Numbers"
Automata Seminar, Institut de Recherche en Informatique Fondamentale (IRIF), Université Paris Diderot, June 2017

"Using Mathematical Maturity to Shape Our Teaching, Our Careers and Our Departments"
Cross-Section Talk, Park City Mathematics Institute, Park City, Utah, July 2017

"On Some Wonders of Factoring and Its Many Choices"
Martha Davenport Heard Lecture, Wellesley College, September 2017
Keynote Lecture, Mathematics Conference and Competition of Northern New York (MCCNNY), Clarkson University, Potsdam, NY, October 2017

Leo Goldmakher

"Why You Should Care About Polya-Vinogradov"
Mathematical Congress of the Americas, Montreal, QC, Canada, July 2017
Heilbronn/ESTIA Number Theory Seminar, University of Bristol, UK

"Why You Should Care About the Polya-Vinogradov Inequality"
Algebra, Geometry, and Number Theory Seminar, Tufts University, November 2017

"Improving Burgess Via Polya-Vinogradov"
Zahlentheoretisches Kolloquium, TU Graz, Graz, Austria, September 2017

"The Unreasonable Effectiveness of the Polya-Vinogradov Inequality"
Group, Lie and Number Theory Seminar, University of Michigan, Ann Arbor, November 2017
Algebraic Geometry and Number Theory Seminar, Rice University, November 2017

"Some Refinements of Artin's Conjecture"
Quebec-Vermont Number Theory Seminar, Montreal, QC, Canada, December 2017
Algebra and Number Theory Seminar, Yale University, January 2018
CMS Summer Meeting, Fredericton, NB, Canada, June 2018

"Insolvability of the Quintic Without Galois Theory"
Math Society, Yale University, January 2018

Pamela Harris

"Invisible Lattice Points"
Latinx in the Mathematical Sciences Conference, Institute for Pure and Applied Mathematics, March 2018
Mathematics Colloquium, United States Naval Academy, February 2018
Math Research Lecture, SUNY, Geneseo, January 2018
Mathematics and Statistics and Computer Science, Special Colloquium, Marquette University, January 2018
Youngstown State University, December 2017
Focus on Math Speaker Series, Brigham Young University, October 2017
Mathematics Colloquium, Colby College, October 2017
Union College BEAM Program, July 2017

"Computing Weight Multiplicities"
Special Colloquium, Wake Forest University, February 2018
AMS Special Session: Noncommutative Algebra and Representation Theory, JMM San Diego, CA, January 2018

"Partition Functions and Their Generalizations"
Mathematics Colloquium, Colby College, January 2018

"Konstant's Partition Function"
AMS Special Session: A Showcase of Number Theory at Liberal Arts Colleges,
JMM San Diego, CA, January 2018
California State University, Fresno, June 2017

"Lattice Point Visibility on Generalized Lines of Sight"
AMS Special Session: A Showcase of Number Theory at Liberal Arts Colleges,
JMM San Diego, CA, January 2018
Scientific Symposia Women Do Math, SACNAS National Conference, Salt Lake City, UT, October 2017

"Permutations, Peaks, Polynomials, and a Positivity Conjecture"
Wake Forest University, October 2017

"Representation Theory and Counting Partitions"
Scientific Symposia Latinxs Count! SACNAS National Conference, Salt Lake City, UT, October 2017

"From Undocumented Student to Mathematics Professor"
Colby College Runnals Dinner for Women in Mathematics, October 2017

"The q-Analog of Konstant's Partition Function and the Highest Root of the Simple Lie Algebras"
Special Session: Polynomials in Enumerative, Algebraic, and Geometric Combinatorics, AMS Sectional Meeting, SUNY Buffalo, NY, September 2017
Special Session on Algebraic Combinatorics, XXII Coloquio Latinoamericano de Algebra Quito, Ecuador, August 2017

Brianna Heggeseth

"Tree-Based Clustering of Longitudinal Childhood Growth"
Eastern North America Region (ENAR) of Biometrics Spring Meeting, March 2018

"Many Data Views"
Invited Talk, Macalester College, November 2017

"Estimating Complex Relationships With Nonlinear Longitudinal Growth Patterns"
Presentation at Joint Statistics Meetings, August 2017

Bernhard Klingenberg

"Intro Stats in the Cloud"
30th International Conference on Technology in Collegiate Mathematics, Washington, DC, January 2018
"Multivariate Binary Data: Analyzing Adverse Events in Influenza Vaccines"
Programin Data Science, New College Florida, Florida, January 2018

"A Confidence Interval for the Risk Difference in Meta Analysis"
New College Florida, Florida, April 2018

Susan Loepp

"Completions of Noncatenary Local Domains"
AMS Special Session on Homological Commutative Algebra, AMS Sectional Meeting
Northeastern University, April 2018

Steven Miller

"Pythagoras at the Bat: An Introduction to Stats and Modeling"
Developer Thursdays at ICloud85, Lever, North Adams, MA, June 8, 2017
University of Michigan, November 29, 2017
Greylock Talks, December 19, 2017

"Portable Lecture Capture, LACOL Teaching with Tech 2017 Lightning Round"
Vassar College, June 15, 2017

"Where's My Remote?"

Shared Upper Level Math Courses Across Schools, LACOL 2017, Session 7
Vassar College, June 16, 2017

"Egg Dropping Math: It's All It's Cracked Up To Be"
Math League Summer Program, July 17, 2017

"Extending Pythagoras"
Math League Summer Program, Williams SMALL REU, July 29, 2017

"From M&Ms to Mathematics, or, How I Learned to Answer Questions and Help My Kids Love Math"
Math League Summer Program, July 30, 2017
Prospective Days, Williams College, August 11, 2017

"Lower Order Biases in Fourier Coefficients of Elliptic Curve and Cuspidal Newform Families"
With Jared Lichtman, Eric Winsor and Jianing Yang, Maine-Quebec Number Theory Conference, October 14, 2017

"Variance of Gaussian Primes Across Sectors and The Hecke L-Function Ratios Conjecture"
With Yujin Kim and Shannon Sweitzer, Maine-Quebec Number Theory Conference, October 14, 2017

"From C to Shining Sea: Complex Dynamics from Combinatorics to Coastlines"
Williams in Mystic Program, October 20, 2017

"Cookie Monster Meets the Fibonacci Numbers. Mmmmmm – Theorems!"
Math Club, Michigan University, November 30, 2017

"Egg Drop Mathematics: It IS All It's Cracked Up To Be"
Math Circle, Ann Arbor, Michigan, November 30, 2017

"Continuing High School Math Education Lectures"
Wellesley High School, Part II, December 15, 2017
Wellesley High School, Part III, January 29, 2017

"Where's My Remote? Shared Upper Level Math Courses Across Schools"
AMS-MAA Special Session: Novel Methods of Enhancing Success in Mathematics Classes, Joint Mathematics Meeting, San Diego, CA, January 10, 2018

"Generalizations of Zeckendorf's Theorem to Two-Dimensional Sequences"
With Josh Siktar, AMS Special Session on Discrete Neural Networking and Applications, I, JMM, San Diego, CA, January 11, 2018

"Distributions in Generalized Zeckendorf Decompositions"
With Yujin Kim, Shannon Sweitzer, Eric Winsor and Jianing Yang, AMS Special Session on Discrete Neural Networking and Applications, I, JMM, San Diego, CA, January 11, 2018

"SNAP DECISIONS: Management Lessons Learned from Legos"
Lever, North Adams, MA, January 25, 2018

"Where's the Remote? Upper-Level Math/Stats Hybrid Course Sharing for the Liberal Arts"
With Jingchen (Monika) Hu, EDUCAUSE Learning Initiative (ELI) Annual Meeting, New Orleans, LA, January 30, 2018

"Results on GL(2) L-Functions: Biases in Coefficients and Gaps Between Zeroes"
Number Theory Seminar, Brown University, April 2, 2018

"From the Manhattan Project to Elliptic Curves"
Analysis Seminar, Virginia Tech, April 6, 2018

"Benford's Law and the 3x+1 Problem, or: Why the IRS Cares About Discrete Dynamical Systems"
AMS Northeastern Sectional, Discrete Dynamical Systems, April 22, 2018

"Solving the Rubik's Cube"
Pittsfield Public Library, May 19, 2018

"Within-Perfect & Near-Perfect Numbers"

With Kevin Kwan, Combinatorial and Additive Number Theory (CANT) 2018, May 22, 2018

"Finite Conductor Models for Zeros Near the Central Point of Elliptic Curve L-Functions"
Conference on Modular Forms and Related Topics, Beirut, May 28, 2018

"Exploration into a Framework for Digitally Shared Courses"
With Liz Evans, Lioba Gerhardi and Monika Hu, LACOL Workshop, Carlton College, June 1, 2018

Frank Morgan
"The Isoperimetric Problem With Density"
Fields Institute, July 2017
University of Delaware, Newark, September 2017
Baylor University, October 2017
Montclair State University, March 2018

"AMS Notices: Math and Diversity"
MathFest, August 2017

"The Most Efficient Tetrahedral Tile of Space"
State Dinner Talk, Wake Forest University, September 2017

"The Most Efficient Tile of Space"
EPaDel MAA meeting, Shippensburg University, November 2017

"Workshop on the Most Efficient Tiles of Space"
EPaDel MAA Meeting, Shippensburg University, November 2017

"What Every Student Should Know About JMM"
"Notices Editors-in-Chief"
"Mathematics from the SMALL Undergraduate Research Program"
Panel, San Diego Joint Math Meetings, January 2018

"Double Bubbles in Spaces With Density"
Lehigh University Geometry and Topology Conference, May 2018

Ralph Morrison
"Tropical Hyperelliptic Curves in the Plane"
SIAM Conference on Applied Algebraic Geometry, Atlanta, GA, August 2017
Number Theory Seminar, Cornell University, April 2018

"Tropical Graphs in the Plane"
alley Geometry Seminar, UMass, Amherst, December 2017
Institut Mittag-Leffler Seminar, Djursholm, Sweden, January 2018

"Hyperelliptic Tropical Curves in the Plane"
Joint Mathematics Meetings MAA Contributed paper session on Geometry, San Diego CA, January 2018

"Most Planar Graphs Aren't Tropical"
AMS Spring Sectional Meeting Special Session on Combinatorial Aspects of Tropical Geometry, Columbus OH, March 2018

"Tropical Curves and Bitangents"
Oliver Club Colloquium, Cornell University, April 2018

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
"Mobius Random Law and Infinite Rank-One Maps"
AMS Special Session on Ergodic Theory and Dynamical Systems to Celebrate the Work of Jane Hawkins, San

Diego, CA, January 2018

"On Rank-One Infinite Measure-Preserving Examples and Extensions of Properties of the Chacon Transformation"
AMS Special Session on Ergodic Theory and Dynamics in Combinatorial Number Theory, Boston, MA, April 2018

Mihai Stoiciu

"Introduction to Random Matrix Theory"
Three-week course in the Undergraduate Summer School at the 2017 IAS-PCMI Summer Session on "Random Matrices", Park City, UT, June - July 2017

"Bounds for the Pseudospectra of Various Classes of Matrices and Operators"
NEAM – Second Northeastern Analysis Meeting, University at Albany, Albany, NY, October 2017

"Numerical Investigations of the Eigenvalue Distribution of Random Hermitian and Unitary Operators"
AMS Special Session on "Spectral Theory", Portland State University, Portland, OR, April 2018

Chad Topaz

"Topological Data Analysis of Biological Aggregation Models"
Cornell University, October, 2017
Mt. Holyoke College, October, 2017
Brown University, April, 2018
Smith College, April, 2018
SIAM Annual Meeting, Portland, OR, July, 2018

"Topological Data Analysis of Collective Motion"
Applied Algebraic Topology Research Network, November, 2017
Boston University, March, 2018
Colorado State University, April, 2018

"What the Bleep are Agent-Based Models"
AMS Mathematics Research Community, West Greenwich, RI, June, 2018

"Re-envisioning Calculus"
Centre College, June, 2018

"Gender Representation through a Data Science Lens"
Colorado State University, April, 2018

"The Secret Life of Teaching"
Cornell University, October, 2017
Boston University, March, 2018
Brown University, April, 2018

Laurie Tupper

"Spatial Time Series Classification With Applications to Wind Energy"
Joint Statistical Meetings, Seattle, WA, August 2017

"Changes in the Wind: Similarity and Clustering for Spatial Time Series Data"
Advancing Women's Impact in Mathematics Symposium, Worcester, MA, April 2018

"Clustering and Similarity for Spatial Time Series Data"
IMA Workshop on Frontiers in Forecasting, St. Paul, MN, April 2018

"Depth-Based Clustering for Multivariate Time Series With Applications in Wind Energy"
Joint Statistical Meetings, Vancouver, BC Canada, August 2018

Neuroscience Program

The Neuroscience program continues to attract a talented set of concentrators with outstanding courses including both core requirements and a strong slate of electives. The faculty are drawn from the Biology and Psychology Departments, reflecting the range of topics under the Neuroscience umbrella. In 2017, Tim Lebestky and Lauren Williamson co-taught the core Neuroscience course. In addition, Lauren Williamson taught Brain, Behavior and the Immune System which included an advanced laboratory, and the Psychology senior seminar. The program supported two new writing-intensive tutorials, part of a division-wide effort to promote improved expression of scientific ideas. Tim Lebestky taught Biology of our Sexes: The Genetic and Epigenetic Regulation of Sex Determination and Heather Williams taught Cultural Evolution in Biological Systems, which explored the selection of behavioral traits that are transmitted by social learning rather than genetic inheritance. Matt Carter taught two electives: Neural Systems and Circuits, and the Neural and Hormonal Basis of Hunger. Amie Hane taught Early Experience and the Developing Infant, Developmental Psychology, and the senior seminar in Public Health. Noah Sandstrom taught the advanced laboratory elective Hormones and Behavior, and the capstone seminar in Neuroscience. Martha Marvin taught the core labs, and supported many aspects of the program.

Students conduct research with Neuroscience faculty, exploring topics such as the effect of gestational diabetes on behavior (with Lauren Williamson), and the effect of mild traumatic brain injury on learning and memory (with Noah Sandstrom). For details, see the faculty descriptions within Biology and Psychology. Fourteen graduating seniors completed the Neuroscience concentration. Six completed senior honors theses in Neuroscience; three concentrators completed honors theses in Biology. One student completed a senior independent study project.

Jacob Sperber was awarded the 2018 Patricia Goldman-Rakic prize for his demonstrated exceptional achievement in research within the field of neuroscience.

Fourteen students participated in the Neuroscience Class of 1960 Scholar program. Neuroscience concentrators also attended the Interdisciplinary Neurosciences Conference at the University of Massachusetts at which Dr. *Graeme Davis '89* was a featured speaker. The Neuroscience program sponsored fiction author Allegra Goodman, for a reading and conversation about her novel "Intuition", which illustrates the pressures of life in a research lab, as a joint project with the Biology and English departments.

For Brain Awareness week, five students joined Professors Sandstrom and Williamson and Dr. Marvin at Williamstown Elementary School for a presentation about brain health. The 6th graders followed up on what they learned by coloring swim caps with the lobes of the brain, and by looking at (and touching!) a plastinated human brain.

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

Daisy Banta	Anika Mitchell
Josselyn Barahona	Rachel Oren
Connor Dunn	Alexia Royal-Eatmon
Syed Hussain Ul Fareed Bukhari	Rebecca Smith
Marianna Frey	Jacob Sperber
Spencer Lee-Rey	Lauren Steele
Candy Lu	David Weathers

Lecturer **Martha Marvin** teaches the laboratories for Neuroscience (NSCI 201). She co-taught her Winter Study course, Project BioEyes, which for the past nine years has brought Williams students to teach genetics and development with live zebrafish to 3rd graders at local elementary schools. This year Project BioEyes served Williamstown, Lanesborough, and Brayton (North Adams) schools for one week each. Dr. Marvin mentored two honors students and six research assistants. Research in the Marvin lab investigates stress responses and the development of the cardiovascular system in zebrafish. Dr. Marvin coordinated a proposal from nine faculty members to obtain a Nikon A1 confocal microscope. This instrument supports advanced high resolution and rapid fluorescent imaging for faculty in physics, geosciences, biochemistry, biology and neuroscience.

The new imaging capabilities enabled *Miriam Semmar '18* to complete her work demonstrating that estrogen adversely affects heart valve morphogenesis in developing fish. Imaging of the valves in motion showed that leaflets were malformed, an abnormality that cannot be seen in static images. A major topic in the lab has been the role of the role of a family of proteins that protect animals from temperature stress, the small heat shock proteins. *Naomi Currimjee '18* followed up on the work of *Ashley Ngo '16, Maeve Serino '17,* and *Christie Black '15* by analyzing CRISPR/Cas9 mutations in hspb7, a member of this gene family. Although reducing transcription of hspb7 by another method caused defects in heart valves and left-right asymmetry, the genetic knockout had no obvious phenotype. Naomi demonstrated that there is no compensatory upregulation of similar genes that might have explained the difference; now we suspect that the mutants are temperature-sensitive. Expanding on our interest in genomic regulation, Currimjee also followed up on a project started by *Daniel Patrick Gainey '17* in collaboration with Ben Carone (Rowan University) by investigating the feasibility of epigenetically modifying a single gene using a Cas9-based fusion protein to place methyl groups at a specific DNA sequence to silence transcription. This work could provide evidence supporting a long-postulated role for DNA methylation in transcriptional regulation, in a whole-animal model.

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 which can be used to read out 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 and we plan to test this hypothesis in the coming year.

(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

Daisy K. Banta	Fulbright Teaching Fellowship in Brazil followed by Research Assistantship at Duke University
Josselyn D. Barahona	Fulbright Research Fellowship in Chile
Connor Dunn	Research Assistant at Dana-Farber Cancer Center, Boston
Syed Hussain Ul Fareed Bukhari	Research Assistant at University of California, San Francisco
Marianna B. Frey	Research Assistant, Hospital for Special Surgery, NYC
Spencer M. Lee-Rey	Clinical Research Assistant, Brigham and Women's Hospital, Boston
Candy Lu	Teacher and Coach at New Hampton School, New Hampshire
Anika A. Mitchell	Research Assistant, Columbia University Medical Center, New York
Rachel L. Oren	Research Assistant, Brigham and Women's Hospital, Boston
Alexia R. Royal-Eatmon	Master's program in Food Science, Kingston, Jamaica
Rebecca C. Smith	Master's program in Neuroscience, University of Cambridge
Jacob Sperber	Fulbright Research, Instituto Cajal, Madrid, Spain
Lauren B. Steele	Research Assistant, Boston Children's Hospital
David R. Weathers	Technical crew, "Hamilton" production, Chicago

Neuroscience Colloquia

Allegra Goodman, Author, "Intuition" April 26, 2018
"First Annual UMass Interdisciplinary Neurosciences Conference," UMass Amherst, May 2, 2018

Physics Department

This year we were delighted to welcome Assistant Professor Kate Jensen into the Physics Department. Jensen is an experimental materials scientist. She joins us from a postdoctoral research position at the ETH Zurich, where she used optical microscopy to study the properties of soft materials in which surface tension and elasticity are both important. We were also pleased to have Professor Tiku Majumder return from his important work as the Interim President of the College, and to welcome his postdoctoral researcher Dr. Dan Maser, who comes from the University of Colorado, Boulder.

Research with students is a central activity of physics department faculty. In the summer of 2017, 18 students did research with physics faculty, and 24 are currently involved in departmental research in the summer of 2018. Numerous other students did research during the academic year, some as part of a senior honors thesis. The research activities of our faculty and students focus on diverse topics in both experimental physics (atomic, hard, and soft condensed matter) and theoretical physics (biophysics, particle physics, and quantum information).

On the teaching front, we continued to offer a variety of elective courses in addition to our core curriculum. In the past academic year alone, these electives included a new materials science course along with courses on computational biophysics, particle physics, and general relativity, as well as an upper-level tutorial on electrodynamics. Adding further to this mix, we offered the non-majors courses Spacetime and Quanta and Sound, Light, and Perception. We also continued to run a dynamic colloquium series, which this year included a special co-sponsorship of Dr. Mae Jemison, the first woman of color to travel into space, who gave the 2017 Sperry Lecture in Geosciences.

Class of 1960 Scholars in Physics

Sam Alterman	Ashay Patel
Ellery Galvin	Emily Stump
Eliza Matt	Bingyi Wang

Professor **Daniel Aalberts** taught Electromagnetic Theory (PHYS 405T) and Computational Biology (PHYS 315T) tutorials and Math Methods for Scientists (PHYS/MATH 210). He has been optimizing gene sequences to increase protein yield. In his lab, *Ian Banta '19* and honors thesis student *Eliza Matt '18* studied the Density of States of RNA. Aalberts also did science outreach presentations for the Williamstown Elementary School.

Assistant Professor **Charlie Doret** spent the 2017-18 on research sabbatical, remaining in Williamstown to work in the lab. Doret's work is in the arena of quantum simulation; along with students he has been building a system to trap calcium ions. Such 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. A particular goal of Doret's group is to better understand thermal conductivity at the nanoscale, relevant both to quantum information processing with trapped ions and for understanding power dissipation in microelectronic devices.

Doret's work during the year was supported by a Cottrell Scholar Award from the Research Corporation for Science Advancement, and also a generous new grant from the National Science Foundation. During summer 2017 Doret was joined in the laboratory by thesis student *Ashay Patel '18* as well as rising sophomore *Kirby Gordon '20*. Ashay developed a four-channel frequency synthesizer for controlling the many lasers used to cool and manipulate the trapped ions. Kirby built a pair of additional lasers which enable the simultaneous trapping of ions of two different isotopes of calcium. Ashay continued his work throughout the academic year in his senior thesis. Working alongside Prof. Doret, Ashay used single trapped ions to optimize the performance of the ion trap, developed tools for trapping chains of ions, and began the lab's first measurements using chains of two co-trapped calcium isotopes. Ashay was joined by *Felix Knollman '19* during Winter Study; Felix developed a new athermal optical cavity to be used for laser frequency stabilization.

In addition to work in the lab, Doret authored Simple, low-noise piezo driver with feed-forward for broad tuning of external cavity diode lasers, published in *Review of Scientific Instruments*. He also attended a number of conferences, including the Cottrell Scholars Conference in Tucson, AZ, the North American Conference on

Trapped Ions in Boulder, CO, and the American Physical Society's Division of Atomic, Molecular, and Optical Physics Conference in Ft. Lauderdale, FL, where Doret met with an assortment of alumni ranging from the classes of '53 to '18. Doret also gave a colloquium at Bates College in November.

The Doret Lab began summer 2018 with a move from the Bronfman Science Center to a new home in the South Science Building. Rebuilding the laboratory in the new building was aided dramatically by the hard work of recently graduated thesis student Ashay Patel as well as returning students Felix Knollman and Kirby Gordon. Ashay left in late July, soon to start a PhD program at CalTech; however, he stayed long enough to join the lab in defeating Prof. Kate Jensen's lab at inter-lab wiffleball! Meanwhile, Felix, Kirby, and Prof. Doret finished reassembling the laboratory in early August. With the lab rebuilt, Felix will now kick-off work conducting a precision measurement of Ca+ structure as part of his formal thesis work during the '18-'19 academic year.

Assistant Professor **Kate Jensen** joined the Physics Department in Fall 2017. She taught Mechanics and Waves (PHYS 141) in the fall, and a new elective course Introduction to Materials Science (PHYS/GEOS 234) in the spring. Simultaneously, she began setting up her Materials Physics research lab with the help of four first-year students: *Justin Berman '21, Jamie Nichols '21, Joey Headley '21,* and *Nick Patino '21*. Professor Jensen's research focuses on understanding the mechanics of soft materials: What makes things soft and sticky? What happens when solids start acting like liquids, or liquids like solids? How does the underlying structure of soft materials give them the properties that make them useful or difficult to work with?

Throughout the first year of the lab, Professor Jensen and her students explored these and other questions as they set up new equipment, designed and built experimental apparatus, took 2D and 3D microscope images and high-speed videos, and wrote software to analyze their data. The first students mainly studied the dynamics of adhesive detachment. Two more students, *Minwoo (Josh) Kang '20* and *Abdullah Nasir '20*, joined the lab over Winter Study, focusing on 3D imaging of adhesive contact using the College's new confocal microscope. In the spring semester, *Hyeongjin Kim '21* and *Aidan Duncan (Mount Greylock Regional High School '19)* also joined the lab, focusing on the dynamics of making adhesive contact and on material synthesis and characterization.

At the start of the summer, the lab moved from the Bronfman Science Center to its home in the new South Science Building. Justin Berman, Joey Headley, Josh Kang, and Hyeongjin Kim stayed on campus for full-time summer research, joined by new group members *Heather Kurtz '20, Declan Daly '20, Anneliese Silveyra '21,* and *Jeremy Thaller '19*, who got started on his senior thesis. Over the summer, the group advanced ongoing research projects and launched a new set of projects related to wetting and flow of fluids. The group also attended two 1-day workshops, New England Complex Fluids and Soft Matter Day, at which some or all of the students presented short talks and/or posters on their research.

Professor Jensen also stayed active on and off campus by publishing three articles, giving several invited and contributed talks, reviewing manuscripts for *Scientific Reports and Soft Matter*, serving on a grant review panel for the National Science Foundation, co-organizing sessions at the APS March Meeting and at the ACS Colloid and Surface Science Symposium, co-organizing an outreach activity on the "Physics of Chocolate" for the Williams Science Blast, and competing (victoriously!) in the annual WCJA Latke vs. Hammentaschen Debate.

Kevin Jones, McElfresh Professor of Physics, continued his research collaboration with a group at the Joint Quantum Institute (JQI) on the campus of the University of Maryland. The institute is a joint operation between UMD and the National Institute of Science and Technology. The hosting research group is headed by Nobel Laureate William Phillips and his associate Dr. Paul Lett and the research is supported in part by a grant from the National Science Foundation. Three papers resulting from Jones' 2016-17 sabbatical at the JQI were published this year. During the summer of 2017 *Felix Knollman '19* joined Jones at the JQI and did an experiment on optical nano-fibers. The long term goal of that work was to explore the coupling of light and mechanical vibrations in these nano-fibers with an eye towards producing quantum states of light. Felix and his collaborators mastered making the delicate nano-fibers and were able to confirm the existence of coupling between mechanical vibrations of the fiber and the light going through the fiber.

During summer 2018 *Kwasi Fahie '20* is working with Jones at the JQI. A central experimental technique in the group is to use the non-linear interaction between laser beams crossed in Rubidium vapor cells as sources of exotic quantum states of light and as ultra-quiet quantum limited amplifiers for light. Typically, these laser beams (like most laser beams) have a non-uniform intensity profile across the beam – brightest in the center, fading out towards the edges. This non-uniform intensity profile leads to distortions in the output beams from the non-linear interaction region. There are optical devices available to convert a non-uniform intensity laser beam into one with a more nearly uniform intensity profile. Kwasi has been testing one such device to determine its suitability for use in the non-linear optics experiments. His measurements show that, although the optical device with proper adjustment can produce the desired uniform intensity beam, there are other unanticipated issues which complicate the use of the device in the non-linear optics experiments.

In the fall of 2017 Jones taught a course Energy Science and Technology (ENVI/PHYS 108) aimed principally at students majoring outside of physics. This contribution to the college's environmental studies offerings was pioneered by Professor Jefferson Strait. With Strait's recent retirement, Jones has taken up offering the course and will be teaching it again in fall 2018. In the spring of 2018 Jones taught Vibrations, Waves and Optics (PHYS 202), one of the required courses in the physics and astrophysics major, to an enthusiastic group of (mostly) sophomores.

Assistant professor **Catherine Kealhofer** taught the Introduction to Electricity and Magnetism (PHYS 201) in the Fall semester of the 2017-18 academic year. In the Spring, she taught a course for non-majors, Sound, Light, and Perception (PHYS 109). During Winter Study, along with Jason Mativi, she taught an introductory electronics course, where students met daily to build analog and Arduino-based electronics projects.

Kealhofer's research interest are the development of tools to generate, manipulate, and characterize ultrafast electron pulses. Ultrafast electron pulses are extraordinarily short pulses of electrons that could 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.

With several students, Kealhofer has been building the prerequisites for these experiments. *Emily Stump '18, Iona Binnie '19,* and *Ian Shen '19* aligned the ultrafast titanium sapphire laser in Summer 2017 and began work on ultrafast optics characterization. Emily continued this work during the academic year 2017-18, building an autocorrelator and writing code to numerically simulate nonlinear effects in ultrafast pulse propagation in optical fiber. Emily won the Physics department's Stabler Prize; next year, she will teach Physics at Tabor Academy, and she is currently planning to apply to graduate school.

At the start of Summer 2018, the lab moved from the basement of the Bronfman Science Center to a beautiful, spacious, and modern lab in the newly opened South Science Building. The lab benefited from the experience and built-up knowledge of Emily and Iona, who returned this summer and were joined by *Abdullah Nasir '20* and *Patrick Postec '21*. In addition to setting up the new lab; organizing tools, floating the optical tables, rebuilding and realigning the laser, students helped design the ultrahigh vacuum system, etched nanoemitters (which will be used as electron sources), and wrote simulations of electron pulse propagation in a low-energy ultrafast electron gun. Iona will continue as a thesis student in the 2018-19 school year, with the goal of finishing vacuum system construction and measuring electron emission from the nanoemitters.

In a year full of unique challenges and opportunities, Professor **Tiku Majumder** was responsible for teaching, overseeing the science center, running his atomic physics lab, then packing up that same lab for transport to the brand new science building, and, during the spring semester, for leading the College as its Interim President.

During the fall of 2017, Majumder continued his term as Director of the Science Center and Chair of the Science Executive committee. He also taught Seminar in Modern Physics (PHYS 151) to an enthusiastic group of first-year students. 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, design, and now completion of phase 1 of the science center building project. On the research side, he continued to pursue diode laser and atomic physics experiments in his research lab, teaming up with senior thesis student *Bingyi Wang '18*, as well as new postdoc Dr. Dan Maser. Bingyi won a prestigious graduate fellowship at Stanford (Knight-Hennessy fellowship) and will begin her Ph.D. this fall.

The group is supported by a generous grant from the National Science Foundation. 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). Bingyi and Dan completed work started by previous thesis student *Nathaniel Vilas '17* (beginning his Ph.D. at Harvard this fall). That work was published in *Physical Review A* in February, with these students as co-authors, along with current and former postdoc, and theory collaborators from the Safronova group at U. Delaware. Dan and Bingyi attended the 2018 DAMOP annual meeting in Fort Lauderdale, FL in June to present this work.

In this unusual academic year, an important part of 2017-18 consisted of packing up 20+ years of equipment in anticipation of the move to the new South Science Building, which opened in May. As of August, with the excellent work of postdoc Dan Maser, and first-year research assistants *Gabe Pattenote '21* and *Sameer Khanbhai '21*, the lead experiment is up and running and producing excellent new results in our brand new space. The physics experimentalists are pleased to all now be clustered in a group of offices and a suite of connected labs for the long-term future!

During the first half of 2018, Majumder took a hiatus from his physics/science center duties to serve as Interim President of Williams. This six-month position afforded him the chance to both lead and learn about the institution in new and deeply meaningful ways, serving as a bridge between presidents number 17 (Adam Falk) and number 18 (Maud Mandel). He looks forward to continuing to serve in an advisorial role during this transition period.

Assistant Professor **Swati Singh** taught Statistical Mechanics and Thermodynamics (PHYS 302) in spring 2018. Along with covering the traditional material, Singh introduced various examples from biology, mechanical engineering, astrophysics and condensed matter demonstrating how the techniques learned in this course are applied to various problems in the sciences. Since this year's class size was comparatively small, we decided to also explore current research topics such as entropy and information, and the greenhouse effect.

Singh uses theoretical techniques from quantum optics, AMO, and condensed matter to understand and exploit quantum effects in macroscopic systems. She 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. She uses both analytical and computational methods and work in close collaboration with experimentalists in atomic, optomechanical and solid-state qubit systems.

Singh worked with *Ellery Galvin '18* who chose to model the quantum mechanics of laser cooling of ultra-cold atoms as her thesis project. She took the initiative to teach herself several graduate level concepts so she understood the assertions and questions posed by recent experimental results we hope to model. She presented her work at several student conferences, even winning the best poster prize at CUWiP conference at RIT in Jan 2018.

Qiyuan Hu '20 used his newly acquired math skills to model the interaction of gravitational waves with elastic media. Qiyuan reproduced several key results from literature and Singh's earlier work, and even produced some new results.

Josh Reynolds `21 and Qiyuan Hu spent Winter Study 2018 developing analytical models of particle loss in levitated optomechanics experiments with Singh. Josh and Qiyuan collected relevant parameters from a range of papers, and analyzed the radiometric forces and various cooling and heating mechanisms for the sphere. Our simple model appears to explain the loss mechanism, along with intensity and size dependences observed by different experimental groups. They continued developing their model during Spring 2018.

Associate Professor **Frederick Strauch** taught Quantum Physics (PHYS 301) in the Fall of 2017, and Foundations of Modern Physics (PHYS 142) in the spring of 2018. He looks forward to continuing his exploration of the quantum world through an elective course, co-taught with Keith McPartland from Philosophy (previously with Bill Wootters, emeritus in Physics) called Philosophical Implications of Modern Physics (PHYS 312) in the coming year, and of the real world as Chair of the Department.

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, advanced coupling schemes for quantum circuits, as well as general topics in quantum information and dynamics. He published work in Quantum Information and Computing (with *Will Kirby '17*). During the academic year, he worked with thesis student *Sam Alterman '18* on environmentally-assistant quantum transport in networks, and during the summer 2018, he worked with *Nyein Soe '19* and *Qiyuan Hu '20* on the representation of quantum operations in the presence of noise.

In the fall semester, Professor **David Tucker-Smith** taught Introduction to Mechanics (PHYS 131). He also taught independent studies on quantum field theory and particle physics to six of our physics majors. In the spring, he taught Gravity (PHYS 418). Tucker-Smith also taught the winter-study course Light and Holography (PHYS 014).

Tucker-Smith continued his research in theoretical particle physics. His recent focus has been on developing and studying testable models of baryogenesis, which attempt to explain the matter-antimatter asymmetry in the universe. In March 2018 he participated in a workshop at UMass, CP-violation for baryogenesis. Tucker-Smith worked with summer students *Noah Cowit '20* and *Nye-in Chan Soe '19* during the summer of 2017 on aspects of baryogenesis, and he will continue this work with *Ian Banta '19* and *Mariam Ughrelidze '20* during the summer of 2017. Ian will work on a baryogenesis-related senior honors thesis during the upcoming academic year.

Professor Emeritus **Bill Wootters**, together with S*am Alterman '18, Jay Choi '17, Becky Durst '17,* and *Sarah Fleming '18*, finished a research project Becky and Sarah had started back in the summer of 2014. The project was based on the observation that, for at least a few simple physical systems such as a single particle in a box, the quantum mechanical thermal distribution of the particle's position is surprisingly similar to the corresponding classical mechanical distribution even at fairly low temperatures. It seems that the quantum mechanical Boltzmann probabilities—the probabilities that weight the energy eigenstates at a given temperature—are special in that they give these eigenstates precisely the weights they need to make the quantum and classical distribution match. Wootters and the four students were able to put this observation on a more solid mathematical footing by showing that the Boltzmann probabilities can, at least in some cases and in the limit of high temperature, be derived from an assumption of quantum-classical agreement.

In the summer of 2017, Wootters attended and gave a talk at the conference, Frontiers of Quantum and Mesoscopic Thermodynamics, in Prague. And in the spring semester of 2018, he took a break from retirement to teach Electromagnetism and the Physics of Matter (PHYS 132).

Post-Graduate Plans of Physics Majors

Alejandro Arechiga	Working for economics consulting firm in Bay Area
Ellery Galvin	Assistant Solution Consultant for DataArt
Ziqi Lu	PhD in economics at Harvard University
Ashay Patel	PhD in physics at CalTech
Jack Scaletta	NYC to study and work with theatrical director
Kieran Scannell	Summer job as line cook
Emily Stump	Teaching high school physics at Tabor Academy
Bingyi Wang	PhD program in physics at Stanford

Physics Colloquia

[Colloquia are held jointly with the Astronomy Department.]

Daniel Aalberts
"RNA's Strange Folding Landscape"
Summer Science Lunch, July 2017

Marty Baylor, Carleton College
"A Dynamical System Approach to the Cocktail Party Problem: Using Optics Instead of your Brain to Separate Signals"

Frederik Brasz '09, Boston University
"Interfacial Fluid Mechanics: Bubbles, Jets, and Drops"

Colin Bruzewicz '05, MIT Lincoln Labs
"Quantum-Logic-Assisted Readout in a Mixed-Species Ion Chain"

Susannah Dickerson
"Quantum simulation and inertial sensors: Variations on a theme"

Patrick Draper, UMass, Amherst
“Naturalness in the Higgs Era”

Melissa Eblen-Zayas, Carleton College
“Phase inhomogeneity in EuO1-x”

Darby Dyar, Mt. Holyoke
“Venus: Our Misunderstood Sister”

Shanhui Fan, Stanford University
“Electromagnetics for energy applications: harvesting the coldness of the universe”

Kate Follette, Amherst College
“How to Image Baby Planets”

Daniel Grin, Haverford College
“Axions and the Cosmological Dark Sector”

Jonathan Horner, University of Southern Queensland (Australia)
“Rocks from Space!”

Kate Jensen
“What makes things wet and sticky?”
Summer Science Lunch, July 2018

“How Sticky Stuff Sticks and Stays Stuck”
Physics Department Colloquium, October 2017

“Soft Sticky Stuff”
Faculty Lunch Series, September 2017

Nora Kling, University of Connecticut
“Ultrafast nuclear motion: Resolving hydrogen migration(s) in time”

Christina Knapp ’13, UC Santa Barbara
“Topological phases and topological quantum computing”

Tiku Majumder
“Are we there yet? Clocks, Navigation and (cold) Atoms”
Summer Science Lunch, July 2018

Olufolajimi “Jimi” Oke ’10, MIT
“Urban mobility simuation for scenario discovery in globally representative prototypes”

Steve Olmschenk, Denison University
“Quantum Information with Atoms and Light”

Seongjun Park and Alex Senko, MIT
“Optical, Electrical and Magnetic Neural Interfaces”

Gabriel Samach ’15, MIT Lincoln Lab
“So, you want to build a quantum computer…”

Li Zeng, Harvard
“Ocean Planets and Water Worlds”

Off-Campus Physics Colloquia

Charles Doret
"Quantum Simulations with Trapped Calcium Ions"
Physics Colloquium, Bates College, November 2017

Kate Jensen
"Sticking with Soft Solids"
Invited Talk, New England Workshop on Complex Fluids, Harvard University, December 2017

"How Sticky Stuff Sticks and Stays Stuck"
Physics and Astronomy Seminar, Amherst College, February 2018

"Dynamics of High-Speed Adhesive Detachment"
Contributed Talk, APS March Meeting, March 2018

"Soft Interface Mechanics"
Invited Talk, Northeastern Granular Materials Workshop, Yale University, June 2018

"Strain-dependent surface stress in soft adhesion"
Contributed Talk, ACS Colloid and Surface Science Symposium, June 2018

"Soft Interface Mechanics"
Invited Talk, Soft Matter Day, UMass Amherst, July 2018

Tiku Majumder
"Precise measurement of indium 7p polarizabilities using two-step excitation in an Atomic Beam"
APS Division of Atomic Molecular and Optical Physics meeting, Fort Lauderdale, May 2018

Swati Singh
"Using quantum systems as detectors"
Theory seminar, MPQ, Garching, Germany, June 2018

"Using quantum systems as detectors"
Special seminar, University of Vienna, Austria, July 2018

Fred Strauch
"From Superconducting Qubits to Microwave Photonics"
Invited talk at the American Physical Society March Meeting, March 2018

Bill Wootters
"The Boltzmann distribution and the quantum-classical correspondence"
Frontiers of Quantum and Mesoscopic Thermodynamics, Prague, July 2017

"A curious correspondence connecting quantum mechanics, classical mechanics, and statistical mechanics"
University of Maryland, Baltimore County, March 2018

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 several interdisciplinary programs, including Neuroscience, Cognitive Science, Program in Teaching, Justice and Law, Women's, Gender, and Sexuality Studies, and Public Health.

Psychology students have multiple opportunities to conduct research collaboratively with professors. Some of these are empirical projects conducted within required 300-level lab courses, some are in work-study or research assistant positions, and some as independent research projects and senior honors theses. Ten students completed yearlong senior honors thesis research under the direction of Psychology faculty during the 2017-18 school year. 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,” “Careers in Psychology,” and "Summer Internships 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 '60 Scholars Program brought accomplished researchers from universities to campus to give colloquia. The junior and senior '60 Scholars read the speaker’s work and then joined the speaker and faculty for a reception and dinner afterward. This year marked the ninth 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 *Kathryn Flaharty ’18* for her outstanding thesis and contributions to teaching and departmental life.

This year was Professor Paul Solomon's final year of teaching at Williams. He retired this year after a long tenure at Williams. Solomon was instrumental in helping to start the Neuroscience program at Williams, and scores of students benefitted from working in his lab and clinic studying important issues such as memory and dementia. This was also the final year for Assistant Professor Mariko Moher, who left for a position in Connecticut and will be missed by the faculty, staff, and students in the department.

The Psychology Department benefited greatly by having four visiting faculty this year; Nicole Harrington and Dan Norton (clinical psychology), *Lauren Philbrook ‘09* (developmental psychology), and *Lauren Williamson ’07* (neuroscience). Through all of these activities, we could not function without the invaluable help of Christine Russell (Administrative Assistant), C.J. Gillig (Technical Assistant), and Beth Stachelek (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. It was particularly bittersweet that this year marked the end of Beth Stachelek's 29 years working in the department. We are thrilled for Beth to begin her well-earned retirement, but we will all miss her extraordinary skills, poise, professionalism, and graciousness around the department.

We are excited to have hired a new assistant professor in the department, *Shivon Robinson ‘11* is back at Williams after completing her post-doc at the University of Pennsylvania. Dr. Robinson specializes in neuroscience and will begin at Williams in July of 2019.

Finally, these paragraphs are being typed as the longtime home of the psychology department at Williams, the Bronfman Science Center, is being reduced to rubble. 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. In our first year in the building on Stetson Court, we and our students have had to make some adjustments, but we have begun to be comfortable in our new, albeit temporary, home.

Class of 1960 Scholars in Psychology

Mollie Bernstein ‘18	Anna Leonard ‘19
Alexa Chumpitaz ‘18	Rachel Levin ‘19
Griffin Colaizzi ‘18	Arielle Rawlings ‘18
Kathryn Flaharty ‘18	Morgan Richman ’19
Haelynn Gim ‘19	Margaret Shilling ’18
Gabrielle Ilagan ‘18	Linda Zeng ‘19

Professor **Phebe Cramer** continued her research on defense mechanisms and narcissism, and published three new papers. In March, she presented a lecture and discussion to the Cooper Point Community in Olympia, WA, on the topic of Personality Change in Adulthood. 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. She was recently appointed to the Editorial Board of the *Ukrainian University Bulletin: Series Psychology*, and to the reviewer panel of the journal *Adolescent Psychiatry*.

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 supervised three senior honors students. *Gabrielle Illagan ’18* studied how people evaluate different types of evidence in “evidence-based” psychotherapy, using a discounting paradigm, and the role of racial and gender matching of client and therapist in discounting. *Bobby Rowledge ’18* studied possible mechanisms underlying different outcomes of rumination, co-rumination and expressive writing about one’s troubles. *Keiana West ‘18* studied the role of race and gender of high school students in teachers’ and students’ perceptions of misbehavior and psychological interventions. She travelled with Keiana to NYC in April, where Keiana presented a paper based on her work at the American Educational Research Association conference; Gabs’ research was accepted for presentation at the North American Society for Psychotherapy Research conference in Salt Lake City, Utah in November 2018.

Professor Heatherington served on the Editorial Boards of *Psychotherapy Research; Journal of Family Psychology; Psychotherapy: Theory, Research, Practice, and Applications;* and *Journal of Clinical Psychology: In Session* , and she was named Chair of the Publications Board of the Society for the Advancement of Psychotherapy/Division 29 of the American Psychological Association. For the Berkshire NAMI (National Alliance for the Mentally Ill) Chapter, she conducted an evaluation of the Crisis Intervention Training program, which helps police deal with emotionally disturbed persons. 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. She continued directing a long term study of treatment outcomes there, publishing a paper on the results with other members of the research team.

Associate Professor **Nate Kornell** continues his research on cognition, education, and self-regulated learning. He receives funding from a $600,000 grant from the James S. McDonnell Foundation to study self-regulated learning. He continues to write a blog for **Psychology Today**. He is an editor for *Journal of Experimental Psychology: Learning, Memory, and Cognition; Memory & Cognition*.

Professor **Noah Sandstrom** has continued his research examining environmental and biological factors that shape outcome following mild brain injuries. Working alongside Visiting Assistant Professor *Lauren Williamson ‘07*, he and thesis student *Daisy Banta ’18* developed a new paradigm for controlled head injury and generated intriguing behavioral and neuroimmune findings that are currently being further studied in the lab. During the summer, Sandstrom attended the Faculty for Undergraduate Neuroscience Education Workshop focusing on best practices for developing, assessing and sustaining inclusive curricula. In the fall, Sandstrom attended the annual meetings of the Society for Neuroscience as well as the Faculty for Undergraduate Neuroscience where he transitioned from Past-President to the Presidential Advisory Board.

Assistant Professor **Laura Smalarz** continued her research program on eyewitness identification and related topics at the Psychology-Law interface. *Hussein Ireri ’18* and *Alexandra Melishkevich ’19* conducted two intensive laboratory experiments that investigated the effects of social influence on eyewitness identification accuracy. *Jessica Munoz ’19* carried out a number of online studies examining contextual influences on eyewitness identification. Jessica also worked with Alexandra to design and conduct a series of experiments examining people’s perceptions of the wrongfully convicted.

Smalarz published two papers, including one on the biasing effects of criminal stereotypes on jurors’ evaluations of confession evidence (Smalarz, Madon, & Turosak, in press) and another on methods of analysis for eyewitness lineup data (Smith, Wells, Smalarz, & Lampinen, in press). She was an author on two conference presentations at the American Psychology-Law Society Conference in Memphis, Tennessee. In addition, Smalarz gave two on-campus talks—one as part of the Williams Reads program for the book *Just Mercy* by Bryan Stevenson and one to a group of alumni at the Post-50th reunion in the Fall. Smalarz also presented her research as part of Lenox Library's Distinguished Lecture Series and at the Williams College Alumni Associations in Vero Beach, West Palm Beach, and Naples, Florida. This year, Smalarz was appointed to the Editorial Board at *Law and Human Behavior*, the flagship journal of the American Psychology-Law Society.

Associate Professor **Catherine Stroud** began a longitudinal study examining biological, psychological, interpersonal, and environmental factors that affect risk for psychopathology among young adult women. *Julia Cheng '17* completed presented findings from her senior honor thesis (completed under Stroud's mentorship) at the Annual Meeting of the Association for Behavioral and Cognitive Therapies (ABCT). Cheng's work provided novel evidence that rumination is a mechanism through which serotonergic genetic risk interacts with early adversity to predict stress generation and depressive symptoms. At the same conference, Stroud and her colleagues presented their work showing that experiencing early adversity during childhood moderates the impact of proximal acute stress on the cortisol awakening response. In addition, at the annual meeting of the Society for Research on Adolescence, Stroud and her colleagues presented research demonstrating that trait-like individual differences in HPA axis activity (one of the body's main stress-responsive systems) is a mechanism through which serotonergic genetic variation interacts with early adversity to predict internalizing symptoms among early adolescent girls. Additionally, her collaborative work investigating the association between dopaminergic genetic variation and depressive symptoms was presented at the Society for Research in Psychopathology. Stroud also published a manuscript in *Development & Psychopathology* which provided the first evidence that early adversity influences risk for the development of internalizing symptoms via altering trait-like individual differences in one of the body's main stress-responsive systems. Along with her colleagues, Stroud co-authored a manuscript demonstrating that this effect was modified by variation in the serotonin transporter gene. Stroud also contributed an invited chapter on stress sensitization models in The Oxford Handbook of Stress and Mental Health.

Professor **Betty Zimmerberg** taught her laboratory-based tutorial "Nurture Via Nature" last fall, with students exploring the interactive effects of genetic inheritance and environmental stressors on behavioral development. She also continued her research with honors neuroscience student *Lauren Steele '18*, aided by research assistant *Andrea Orozco '21*. That research was presented at the annual Society for Neuroscience meeting in November 2017. 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.

Post Graduate Plans of Psychology Majors

Kendall Bazinet	Taking a gap year at home in Buffalo before applying to Social Psychology Ph.D. programs this fall
Mollie Bernstein	Working as a research technician in the Basbaum lab at UCSF
Stephanie Boulger	Working as an Analyst at Analysis Group (an economic consulting firm) in Boston
Alexa Chumpitaz	Working at St. Anne's-Belfield School in Charlottesville, VA, teaching French and Spanish to middle school-aged children through a 2-year fellowship offered by University of Pennsylvania's Day School Teaching Residency program (also getting a Master of Science in Education from UPenn)
Christina Cleroux	Studying at Schulich School of Law at Dalhousie University in Halifax, Nova Scotia
Griffin Colaizzi	Working as the lab manager for the Georgetown lab for Relational Cog-nition
Mikaela Cordasco	Working as a paralegal at Schreck, Rose, Dapello, Adams, Berlin & Dun-ham LLP (an entertainment law firm) in New York City
Elizabeth Cromack	Teaching elementary school at the Marymount School in New York City
Anna DeLoi	Pursuing a doctorate from Harvard's Graduate School of Education

Connor Dunn	Working as a research assistant at Dana-Farber Cancer Institute for the next two years; also working as a data analyst intern for the MGH/Harvard Center on Genomics, Vulnerable Populations, and Health Disparities gathering psychological, sociological, psychiatric, and medical variables to form hypotheses regarding health
Kristin Fechtelkotter	Hoping to find a position in marketing or advertising
Kathryn Flaharty	Hoping to teach and coach for a few years before going to medical school
Gabrielle Ilagan	Working as the Business Manager of McLean Hospital's Borderline Per-sonality Disor-der Training Institute doing research and administrative work
Hussein Ireri	Hoping to gain research experience in psychology before going to grad school
Adam Kroot	Working for Fortitude Systems (a staffing firm) in Chicago
Lara Lathrop	Working in NYC at Insider in luxury lifestyle management
Brenna Martinez	Working at Boston Children's Hospital in the Department of Psychiatry Research as a Clinical Research Assistant
Emily Orchant	Working in strategy consulting at Parthenon-EY
Hayley Parsons	Working at Citigroup in the Securities Services division
Arielle Rawlings	Participating in a Fulbright English Teaching Assistanceship (ETA) in India for one year; afterwards, working as a Policy Associate at the Abdul Latif Jameel Poverty Ac-tion Lab at MIT
Robert Rowledge	Working as an Associate Consultant at Trinity Partners in Waltham, MA
Carl Sangree	Teaching science and coaching wrestling at Philips Andover Academy in Andover, MA
Margaret Shilling	Working at HawkPartners (a market research and consulting firm) and later applying for Ph.D. programs and/or medical school
Abigail Soloway	Teaching K-9 music at The Fessenden School, a private elementary and middle school in the Boston area
Katie Spence	Enrolled in UCLA's Chemistry PhD program.
Jacob Sperber	Conducting neuroscience research in Madrid, Spain, with a Fulbright Scholarship
Lauren Steele	Working under Charles Nelson at the Boston Children's Hospital Labora-tories of Cog-nitive Science on The Emotion Project studying how 3- to 7-year-old children recognize and process their emotions
Elizabeth Sullivan	Working as a legal practice assistant/paralegal at Skadden, Arps, Slate, Meagher & Flom in New York City and preparing to apply to law school
Cole Teal	Planning to work in the field of professional or collegiate sports
Emilia Welch	Working in New York City at Guggenheim Partners (in the Corporate Credit group)
Keiana West	Serving as a one-year Princeton in Africa fellow at the Student Sponsor-ship Pro-gramme in Johannesburg (a non-profit organization that pro-vides financial resources and mentoring for low-income students to attend high school in South Africa where it is expensive to attend school)
Yinga Xia	Working in finance

Psychology Colloquia

Mina Cikara, Harvard University
"Their Pain, Our Pleasure"

Allegra Goodman, Author of Intuition
"A Reading and Discussion of Intuition"

Kristen Pleil, Department of Pharmacology, Weill Cornell Medical College
"Neuromodulation of Stress Circuits: Implication for Neuropsychiatric Disease"

Off-Campus Psychology Colloquia

Nate Kornell
"Productive struggle: using cognitive science to enhance learning"
SUNY: New Paltz, NY, March 2018

"Cognitive science in education"
Charlemont (MA) High School, August 2018

"Retrieval failures enhance memory as much as retrieval success in recognition memory"
Presented with Kalif Vaughn, K.
58th Annual Meeting of the Psychonomic Society, Vancouver, BC, Canada, November 2017

Laura Smalarz
"Evaluations of eyewitness accuracy based on witnesses' verbal and numeric confidence statements"
American Psychology-Law Society Conference, Memphis, TN, March 2018

"The Psychology of Eyewitness Misidentification"
Williams College Alumni Associations, Vero Beach, West Palm Beach, & Naples, FL, March 2018

"The Psychology of Criminal Injustice"
The Distinguished Lecture Series, Lenox Library, Lenox, MA, November 2017

Catherine Stroud
"The Mediation of Cortisol on the Association between Early Adversity and Internalizing Symptoms Varies by 5-HTTLPR"
Paper presented with F. R. Chen, S. Vrshek-Schallhorn, L. D. Doane, & D. A. Granger
Biennial meeting of the Society for Research on Adolescence, Minneapolis, MN., April 2018

"Interaction of Early Adversity and Additive Genetic Risk from Five Serotonin System Polymorphisms to Predict Stress Generation: Examining Rumination as a Mechanism"
Poster presented with J. Cheng '17, S. Vrshek-Schallhorn, & F. R. Chen
Annual meeting of the Association for Behavioral and Cognitive Therapies, San Diego, CA, November 2017

"Childhood Adversity Moderates the Influence of Proximal Episodic Stress on the Cortisol Awakening Response and Depressive Symptoms in Adolescents"
Paper presented with L. Starr, K. Dienes, Z.A. Shaw, Y.I. Li, *F. Mlawer '14* , & M. Huang
Annual meeting of the Association for Behavioral and Cognitive Therapies, San Diego, CA, November 2017

"Dopaminergic Genetic Variation and Depressive Risk Processes in Young Adolescents"
Poster presented with V. Sapuram, S. Vrshek-Schallhorn, L.M. Hilt
Annual meeting of the Society for Research in Psychopathology, Denver, CO, September 2017

Betty Zimmerberg
"Epigenetic Effects of Prenatal and Juvenile Stress in Rats
Paper presented with *L.B. Steele '18*
Annual meeting of the Society for Neuroscience, Washington, DC, November 2017

Abstracts from Student Theses

Biology

Characterization of genetic interactions between jus, Pfk, and ATPalpha

Seema Amin

Epilepsy is a neurological disorder marked by frequent seizures (Epilepsy Foundation). Several different organisms have been used as models to study the underlying causes of epileptogenesis, including drosophila and zebrafish. The gene responsible for seizure sensitivity in flies is Julius Seizure (jus), formally known as CG14509. The Jus protein is known to have two transmembrane domains and an extracellular loop. Through the RNA knockdown of jus, it is revealed that its function is essential in different neuronal types including in post-mitotic neurons (elav), GABAergic, and cholinergic neurons. The critical stage for jus expression is the early pupal stage since its knockdown during the early developmental stage causes strong bang-sensitivity (BS) in adult flies (Deitcher et al., 2017). The expression of functional GFP-tagged jus is mostly expressed in axons of thoracic abdominal ganglia. However, in the mutant, jusGFSTF, a MiMiC GFP-tag in the extracellular domain results in the mislocalization of Jus to cell bodies. We compare its function in both the mutant and the wild type, and investigate whether the mislocalization of jus expression in jus GFSTF has any influence on the gene's function.

We discovered that as the localization of jus expression is altered, it disrupts Jus function thus resulting in bang sensitivity. Exposure to cold shock and mechanical shock, the mutant flies showed enhanced seizure-paralysis-seizure response. Whereas, wild type flies were less bang-sensitive. This demonstrates that jus gene is able to function properly only when expressed in the axons.

In order to fully understand jus function, we explored the genetic interactions between jus, pfk and ATPalpha by characterizing the cold-sensitivity of flies double mutant for jus and either of the two proteins. We found that jus genetically interacts with pfk and ATPalpha, two genes that encode Jus protein binding partners.

Behavioral and Neuroinflammatory Consequences of Repetitive Mild Traumatic Brain Injury

Daisy Banta

The prevalence of concussion cases in the United States is immense and growing with an estimated 1.6 to 3.8 million cases annually [1]. While the scientific literature has principally focused on severe, single impact injuries, there is a growing understanding of the adverse effects of repeated mild injuries such as those occurring during sports participation [1, 2, 3]. This study characterized the behavioral and neuroinflammatory consequences of repeated mild traumatic brain injury (rmTBI) induced through the use of a controlled head impact (CHI) model. Because clinical data suggest that females are at greater risk for concussion and require longer recovery periods [4, 5], we also included sex as an independent variable. This CHI protocol caused a delay in righting which may be associated with a loss of consciousness. Within hours, however, mice showed no deficits in motor coordination. In addition, rmTBI mice demonstrated impairments in spatial learning as well as decreases in social interactions. They did, however, exhibit normal social habituation and dishabituation suggesting that social learning was unaffected. Contrary to our predictions, rmTBI mice exhibited increases in activity during tail suspension testing. Together, these findings reveal selective changes in learning and memory and suggest a particular vulnerability to hippocampally-mediated spatial learning. Finally, rmTBI was associated with an increased immune response as evident by increased density of microglial staining in the cortex, indicating a lasting adverse consequence of this injury protocol. The overlap between behavioral and neuroimmunological changes in response to rmTBI in mice and common clinical symptoms in humans make this CHI model a potentially useful means to study the repetitive concussions that impress a public health threat. Potential future directions include using this model to further elucidate neuroimmunological progression following rmTBI, investigate therapeutic intervention measures, and explore the relationship between behavioral or environment risk factors, such as sleep deprivation, on the consequences of repeated concussions

1. Centers for Disease Control and Prevention, Report to congress on traumatic brain injury in the United States: epidemiology and rehabilitation. Atlanta, GA: National Center for Injury Prevention and Control, 2014: p. 1-72.

2. McCrory, P., et al., Consensus statement on concussion in sport—the 4th International Conference on Concus-

sion in Sport held in Zurich, November 2012. PM&R, 2013. 5(4): p. 255-279.

3. Graham, R., et al., Treatment and management of prolonged symptoms and post-concussion syndrome. Sports-related concussions in youth: Improving the science, changing the culture. Institute of Medicine of the National Academies, The National Academies Press, Washington, DC, 2013.

4. Broshek, D.K., et al., Sex differences in outcome following sports-related concussion. Journal of neurosurgery, 2005. 102(5): p. 856-863.

5. Preiss-Farzanegan, S.J., et al., The relationship between gender and postconcussion symptoms after sport-related mild traumatic brain injury. PM&R, 2009. 1(3): p. 245-253.

The role of regulatory T-cells in the inflammatory response of allergic asthma

Josselyn Barahona

Allergic asthma is a chronic inflammatory disease of the airway that is mediated by a subset of allergen-specific CD4+ T-cells that persist in the lung as tissue-resident memory T-cells (TRMs) and promote a rapid immune response upon allergen re-exposure. Sublingual immunotherapy (SLIT), has emerged as an effective treatment for allergic asthma that induces immunological tolerance to a specific allergen through the repeated exposure of small, controlled doses of the allergen under the tongue. Based on previous literature demonstrating the induction of a regulatory T-cell population following SLIT, SLIT was hypothesized to prompt regulatory T-cells to take up residence in the lung to better suppress the inflammatory response initiated lung TRMs10,97. To dissect the effects of sublingual immunotherapy on the dynamics of the regulatory T-cell population in both the lungs and the spleen, sublingual immunotherapy was administered to a murine model of chronic lung inflammation induced using ovalbumin (OVA) and lipopolysaccharide (LPS). Mice sensitized with OVA and LPS demonstrated an increased frequency and absolute number of lung TRMSs that was significantly reduced following SLIT. Unexpectedly, sublingual immunotherapy did not establish a definite change in the frequency of regulatory T-cells or tissue-resident regulatory T-cells in the lungs or the spleen. Although this study did not show any significant changes in the regulatory T-cell population in the lung tissue of asthmatic mice following SLIT, our results suggest the possibility that SLIT may reduce the TRM population in the lungs of asthmatic mice through its effects on the regulatory T-cells.

Effect of Stevia on Glucose Tolerance and the Gut Microbiome

Sarah Becker

Non-caloric artificial sweeteners have been correlated with reduced glucose tolerance and obesity in both mice and humans, however the effect of the non-caloric natural sweetener stevia has shown mixed results, with some indication it may act as an anti-hyperglycemic agent. Furthermore, the effect of stevia on the gut microbiota has yet to be characterized. Other non-caloric sweeteners are known to induce dysbiosis, which is correlated with changes in glucose tolerance, most pronouncedly saccharin [1]. We tested the hypothesis that stevia would reduce high fat diet-induced glucose intolerance which would be correlated with a significant change in the microbiome. We evaluated physiologic markers including caloric intake, liquid consumption, and body weight as well as glucose tolerance tests at the initiation and end of treatment. Fecal samples were collected at start of treatment, at the midpoint, and at the end of treatment. Male and female C57BL/6J mice (n=40) were randomly assigned (unblinded) to one of four treatment groups: low fat diet and water (LF), high fat diet and water (HF), high fat diet and saccharin (saccharin), or high fat diet and stevia (stevia). Over 10 weeks of sweetener treatment, stevia mice ate an average of 1,244±44 kcalories per animal, however this was not significantly less than other animals on a HF diet, with HF animals eating on average 1,312±140 kcalories and saccharin eating 1,309±203. Liquid consumption was similar between groups on a HF diet, while the LF diet group consumed significantly more water (males $p=0.017$, females $p=0.002$). Stevia supplementation also did not prevent weight gain, though mice on LF diet weighed significantly less than HF, saccharin, and stevia (males $p=0.017$, females $p=0.003$). Sweetener treatment did not affect glucose tolerance, with no difference between HF, saccharin, and stevia in area under the glucose response curve (AUC) (81,300 ±3300 mg/dL, 76,200 ±2800 mg/dL, and 85,800 ±3400 mg/dL, respectively).

While all groups on HF diet had similar changes in operational taxonomic unit (OTU) counts over the course of treatment, stevia showed a significant increase in genera Lactobacillus ($p=0.029$), Lactoccoccus ($p=0.034$) compared to saccharin. Saccharin showed a significant increase in genus Streptococcus ($p=0.034$) which was not observed in HF or stevia. Saccharin did not display the changes observed in several Ruminoccoccae and Clostridiales families observed in both stevia and HF, suggesting there are distinct microbiome profiles for each sweetener beyond changes due simply to a HF diet.

Stevia had a significant effect on alpha diversity as measured by the Shannon index which was significantly different than both saccharin and HF groups (p=0.002 HF, 0.008 saccharin). Two measures of beta-diversity did not show a significant effect of treatment (weighted UniFrac and Bray-Curtis). These data position stevia as a potentially beneficial non-caloric sweetener as it does not appear to alter the microbiome beyond the effects exerted by the stress of a HF diet though more research is needed to evaluate the extent of its functional consequences on the metabolome.

The Effects of Hyperglycemia and Neonatal Immune Activation on Rodent Offspring Anxiety-Like Behavior and Inflammation

Syed Hussain Fareed Bukhari

This study sought to examine the potential of using streptozotocin (STZ) to induce gestational diabetes (GD). Gestational diabetes is a chronic state of hyperglycemia experienced by pregnant mothers for the course of pregnancy, which disproportionately affects offspring born to mothers in low-income settings that have low-access to healthcare. These offspring face another developmental immunological threat through the inflammation caused by early-life sickness. We sought to investigate the interaction between gestational diabetes and neonatal inflammation in rodent offspring across their lifespan to understand how different measures of anxiety-like behavior and immune responses were affected. Sprague-Dawley dams were injected with STZ or saline in the mid-gestational period to replicate GD, and litters were treated with either saline or lipopolysaccharide in the neonatal period to induce neonatal immune activation. Anxiety-like behavior was tested using ultrasonic vocalizations after maternal separation on P7, and ELISA was used to assess molecular changes in the offspring brain. The lowered survivability of pups in response to STZ administration prevented behavioral and biological testing in the juvenile and adult phases of the offsprings' life. STZ's toxicity, in combination with its inability to induce similar levels of hyperglycemia in injected dams, draws attention to its ineffectiveness in modeling gestational diabetes.

Evolution of Niche Differentiation in the Open Ocean: Light and Iron as Selective Pressures

Michael Chen

Prochlorococcus is a globally important marine picocyanobacterium that dominates open ocean, oligotrophic ecosystems and plays a critical role in primary production and biogeochemical cycling. Physiological studies and genomic sequencing of cultured isolates show that Prochlorococcus strains have evolved diverse physiological properties and environmental responses. This strain diversity is reflected by the existence of multiple Prochlorococcus ecotypes within open ocean ecosystems, which have evolved divergent niches to occupy different environmental gradients. Prochlorococcus is thus a valuable model system to link molecular, cellular, and genomic studies to broader ecological consequences. Here, I investigate the effects of light and iron on the evolution of niche differentiation in Prochlorococcus. To investigate the effects of light, I compared the growth physiologies of deeply-branched strains MIT9313 and NATL2A at 10 and 20 μmol photons m-2 s-1 of photon flux density, and assessed NATL2A's response to light stress at higher light levels. MIT9313 and NATL2A displayed similar growth rates at 10 μmol photons m-2 s-1, but NATL2A displayed consistently lower Chlorophyll a fluorescence per cell, suggesting that the strains have distinct photosynthetic strategies. NATL2A grew significantly faster at a higher irradiance of 20 μmol photons m-2 s-1. NATL2A also grew faster than MIT9313 at 20 μmol photons m-2 s-1. In response to light stress, NATL2A rapidly adopts a lower Chlorophyll a fluorescence state but continues division, suggesting that it can rapidly acclimate to increased irradiance. In order to investigate the effects of iron on Prochlorococcus evolution, I used computational genomics approaches to investigate ferritin proteins (which facilitate iron storage) in sequenced strains. Prochlorococcus possesses two distinct ferritin genes: ferritin 1, which is found in all Prochlorococcus strains, and ferritin 2, which is only found in deeply-branched strains MIT9313 and MIT9303. These sequences are poorly conserved and possess unique sequence features that may reflect functional differences. These proteins also evolved separately, and ferritin sequences in some strains may be evolving at unequal rates, suggesting that they may be experiencing different selection pressures and contributing to diversification in Prochlorococcus iron physiologies. These physiological and computational studies advance our understanding about the bases of Prochlorococcus niche differentiation in response to the environmental factors of light and iron.

CRISPR/Cas9 mediated knockout and methylation of hspb7

Naomi Currimjee

DNA methylation is the process by which a methyl group is added to cytosines adjacent to a guanine (CpG) in a 5' to 3' orientation. This process is mediated by DNA methylase enzymes (DNMTs). Many studies have shown that there is a strong correlation between DNA methylation of clusters of CpGs called CpG islands, and gene silencing. Dysregulation of DNA methylation has been observed in various diseases including cancer, and neurological and cardiovascular diseases. Additionally, developmental genes that get downregulated with aging show increased levels of DNA methylation as development progresses. While various studies have reported correlations between methylation and gene silencing, causation has not been confirmed. In this project, we were interested in inducing methylation at a specific region of exon 1 of small heat shock protein, beta 7 (hspb7) in zebrafish embryos in order to better understand the developmental importance of this epigenetic process. We built a construct in which a mutant form of Cas9, dCas9, was fused to the zebrafish methyltransferase, DNMT6, and EGFP. Transcription with the T7 Polymerase resulted in early transcription termination, suggesting that dCas9 could potentially contain a region homologous to the T7 terminator sequence. While we successfully incorporated the SP6 promoter in our plasmid, SP6 transcription was also unsuccessful. Concerning the importance of the hspb7 for proper embryogenesis, hspb7-morpholino knockdown in zebrafish embryos disrupted cardiac morphogenesis, but this effect was not observed in CRISPR/cas9 hspb7 knockout embryos. In addition, while the loss of hspb7 expression was shown to stimulate the expression of hspb5b in cardiac tissues of 5 days old zebrafish, our preliminary results obtained in 21hpf embryos do not suggest that the complete loss of hspb7 expression has an effect on the expression of hspb5b, hspb8 and hspb12.

Characterization of ZNF367 and SRY-like Transcripts in Stem Cell Development in Helobdella robusta

Connor Dunn

Embryonic stem cells (ESCs) have a founding role in myriad developmental processes. Although understanding these types of stem cells is critical to elucidating embryogenesis and organ homeostasis, the underlying molecular mechanisms behind their formation and regulation is poorly understood. To this end, this thesis studied the leech (Helobdella robusta) to elucidate the two phases of the formation of stem cell fate, namely, specification and maintenance. Specification refers to the initiation of the stem cell fate usually controlled by one set of factors. On the other hand, the maintenance phase usually involves a second set of factors that maintain the stem cell fate for the life of the cell. Previously, the Savage Lab conducted an unbiased screen that identified factors that are enriched during stages of stem cell formation. The goal of this thesis was to characterize two of these potential gene products that may be involved in stem cell processes: zinc finger 367 (ZNF367) and SRY. This thesis determined that ZNF367 mRNA expression is highly expressed early in leech embryogenesis. ZNF367 mRNA expression is also observed in many of the teloblasts, although it appears to be enriched at higher levels in the M teloblast. Importantly, this expression is maintained only in the m bandlets up towards the germinal band in later stage embryos. SRY-like mRNA is also expressed in many of the teloblasts, although expression is only retained in the m bandlet. Taken together, these gene expression patterns suggest that ZNF367 may be involved in stem cell specification. In addition, both ZNF367 and SRY-like may be involved in maintenance of the mesodermal lineage. Future work will complete the characterizations of these proteins toward the goal of using functional studies to test for their specific roles.

Neuroinflammatory model of Alzheimer's disease elucidates neural and cognitive effects of systemic inflammation throughout adulthood

Marianna Frey

Alzheimer's disease (AD) research has stalled in recent decades. Although enormous resources are being poured into AD laboratories, no successful treatments have yet been discovered. Animal models, which provide the most direct means of study in AD research, have been largely based on the amyloid beta cascade hypothesis, which was originally proposed in 1991. This hypothesis was primarily based on work with heritable, early-onset AD patients and has not led to any effective treatments since its proposal. Neuroinflammation, a state in which the brain's immune system is activated, seems to play an important role in AD, especially in late-onset patients, who make up 90% of those affected by AD. A mouse model, by Lee et al. (1), used inexpensive C57J/B6 mice and 5 days of lipopolysaccharide (LPS)-induced, chronic, systemic inflammation, to successfully display several hallmarks of human AD. Our study investigated whether Lee et al.'s neuroinflammatory model, which was originally created in young adult, 3-month old mice, could be reproduced in Sprague-Dawley rats across 3 age groups, and whether aging would affect disease-like presentation. We found inconsistent effects of short-term chronic inflammation across 3-month-old, 6-month-old, and 12-month-old rats in contextual learning and memory, as well as IL-1β and phosphorylated tau concentrations in the hippocampus. Because age is the single strongest risk factor for the development of late-onset Alzheimer's disease, it is imperative that modern models encompass aging as a significant pathogenic component. In keeping with previous work (2), it is unclear in our findings whether or not aging drives pathogenesis, but aging clearly has a significant impact on the brain's response to identical inflammatory insults. By investigating the validity of a neuroinflammatory model used in today's AD research, we hope to improve the translatability of animal models to human pathology and investigate neuroinflammation's role in the aging mammalian brain. Given the distinct reactions of each age group in both our behavioral and molecular studies, this study reveals the importance of rodent models' ages, a finding which is widely applicable across research fields.

Characterizing the Role of Abscisic Acid in Agrobacterium tumefaciens Virulence

Rebecca Gorelov

Agrobacterium tumefaciens is a soil bacterium that infects many plants, causing crown gall disease. The infection process is mediated by the insertion of a single-stranded portion of the bacterial Tumor-inducing (Ti) plasmid into the plant's genome. A transmembrane complex of bacterial proteins, the Type VI Secretion System (T6SS), is also known to influence the infection process. Previous research in our lab showed that this complex enhances A. tumefaciens virulence, while also eliciting plant defenses. We proposed that directly or indirectly, the T6SS may dampen levels of the phytohormone abscisic acid in the plant, and by doing so it both promotes bacterial virulence and induces plant defenses. To test this hypothesis, we used RT-qPCR, transient transformation assays and callose deposition assays to investigate the effect of the T6SS on ABA-mediated signaling pathways.

ABA appears to play an important role in modulating A. tumefaciens virulence. Seedlings with altered ABA sensitivity or exposure to exogenous ABA exhibited variable susceptibility to transient transformation, compared to wildtype seedlings. Moreover, ABA homeostasis seems to be especially important in seedlings infected with T6SS-bearing bacteria, since these bacteria induce a hypersensitive response in seedlings with altered ABA sensitivity. These and other data suggest that the A. tumefaciens T6SS may regulate ABA signaling in order to maximize infection.

Our RT-qPCR data indicate that T6SS does not directly alter ABA synthesis at the transcriptional level. However, preliminary gene expression analysis revealed an apparent reduction in ABA signaling at both early and late time points after infection with T6SS-bearing bacteria. One byproduct of the T6SS-dependent alterations in ABA signaling was the up-regulation of the defense gene PAD3. We found that seedlings deficient in PAD3 are significantly more susceptible to transient transformation, suggesting that by elevating levels of PAD3, the T6SS may be eliciting plant defenses that limit transient transformation. However, the full extent of theT6SS-ABA pathway interaction has yet to be completely explored and remains an area of ongoing investigation.

This project also sought to characterize the effects of a previously uncharacterized lon mutation in what we had originally considered a wildtype A. tumefaciens strain. Transient transformation assays confirmed that this lon mutation was associated with poor transient transformation, and was likely responsible for aberrantly low virulence in a strain sent to us by a collaborating lab.

Floral Traits Determine Structure of a Highly Nested, Dominantly Dipteran Flower visitation Network on Isle Royale, Michigan

Alexandra Griffin

Most plant-pollinator networks are considered to be generalized, nested, and temporally and spatially dynamic, a structure which facilitates robustness to species extinction and declines

(Bascompte et al. 2003). However, the functional explanations underlying these trends in pollination network structure remain unclear. Morphological traits of both flowers and

pollinators may determine network structure and interaction strength, facilitating how effective a flower visitor is at pollination and how readily it can access resources from the plant (Junker et al. 2013). We studied the flower visitation on Isle Royale, Michigan, an island ecosystem with extraordinary floral diversity and solely native plant and insect species. I address the following questions: 1) What is the structure of the network? 2) What is the impact of floral functional traits (plant heights, stamen counts, nectar tube depth, and accessibility of nectar and pollen) and plant phylogeny on insect visitation? 3) What is effect of ant visitation on visitation by other pollinators? 4) Is there spatial and temporal heterogeneity in insect visitation? Studies of pollination networks have been limited by decreased sampling effort and the presence of observers which disrupts insect visitation. To obtain a more complete record of insect visitors, we filmed patches of flowers of 21 plant species at 2 sites from sunrise until sunset and recorded a total of 12,191 interactions.

The Isle Royale flower visitation network is highly nested, with a network core that is predominantly composed of intensively-interacting open flowers visited primarily by Dipterans and Hymenopterans. Overall, the accessibility of pollen and nectar resources— defined by an "open" or "closed" flower structure—was the most significant determinant of the composition and abundance of insect visitors, and created niches within the network, indicating that diversity in floral structure is critical to the maintenance of pollinator biodiversity. Stamen counts and nectar tube depth were also important determinants of visitation. Visitation by ants, who consume resources but are likely not pollinators in this system, was inversely correlated with visits by other insects, suggesting that ants deter pollinators and may exert a doubly deleterious impact on the plant. Although the network structure and overall visitor composition was similar at both sites on the island, there was temporal and spatial heterogeneity in insect visitation to individual plant species, including a rare Vanessa cardui migration. Taken together, these findings suggest that the nested structure and generalist flower visitation network contribute to a network that has species-level flexibility both spatially and temporally which, in turn, should increase resilience to disruption and rare events.

Hypothalamic Neurons that Regulate Food Intake and Energy Homeostasis are Active During Torpor

Heidi Halvorsen

Topor is a depressed metabolic state that allows small animals to conserve energy to meet homeostatic needs. During a substantial caloric energy deficit, mice lower their metabolism heart rate, blood pressure, and body temperature to reduce their energy expenditure. The neural mechanisms behind torpor are unknown. We hypothesize that neural populations in the hypothalamus are likely involved, as this brain region is involved in coordinating body temperature, food intake, and energy expenditure. More specifically, neurons that receive both interoceptive and environmental signals and mediate complex behaviors are of primary interest. Neurons that express agouti-related peptide (AgRP) and neurons that express proopiomelanocortin (POMC) are well known regulators of energy homeostasis and food intake. Located in the arcuate nucleus, AgRP and POMC neurons play opposing roles in the regulation of food intake. AgRP neurons mediate many behaviors that collectively orchestrate feeding and decrease energy expenditure, while POMC neurons orchestrate satiety. We hypothesize that AgRP neuron activity is increased during torpor, compared to non-torpor caloric restriction, due to their responsiveness to metabolic and environmental signals and their role in coordinating homeostatic feeding and energy expenditure. Due to the increased AgRP activity, we hypothesize that POMC neurons will be less active in torpor. Additionally, due to the involvement of many hypothalamic circuits in mediating these behaviors, we hypothesize there would be increased neuronal activity in several distinct subpopulations within the hypothalamus during torpor. To measure neural activity during torpid and non-torpid conditions, we stained for Fos, an indirect marker of neuronal activation. The results from our Fos studies support our hypotheses that there is increased activity in AgRP neurons and other hypothalamic brain regions during torpor. Our study of POMC neuronal activity, however, was inconclusive.

When Two Does Not Equal Two: Understanding Gene Expression in Tandem Gene Duplicates via CRISPR-Cas9 Mediated Gene Deletion

Ye Rem Kim

Tandem gene duplicates are useful models to understand the expressional effects of the local gene environment. There is no current consensus on the expected expression of a tandem duplicate, and at least three models attempt to explain the expressional phenomena. The gene dosage model proposes that expression is proportional to copy number, and predicts two-fold expression relative to single copy. The regulatory ceiling model proposes that duplicate expression is under negative feedback in trans, and predicts less than two-fold expression. The local synergy model proposes that tandem arrangement results in positive interaction in cis, and predicts greater than two-fold expression.

In this study, we use CRISPR-Cas9 to selectively delete individual gene copies to compare the expression between tandem and single copy counterparts, and propose a potential model for tandem gene regulation. We identified tandem duplicates in the D. melanogaster genome, chose a promising candidate in CG11659 and CG6300, and designed reagents for gene deletion. As of this writing, we have not yet isolated flies with the desired modifications. However, once this is accomplished, future students can quantify levels of gene expression to identify the expression patterns, and use this information to better determine whether cis or trans or both mechanisms are at play.

Lagged Effects of Herbivory Unchanged by Mutualism Impact Host-Choice but not Survivorship in the Treehopper Publilia concava.

Daniel Kirsch

Mutualisms are reciprocally beneficial interactions between species. The treehopper Publilia concava is a mutualist with various ant species that protect the treehopper and facilitate its feeding on its typical host plant, tall goldenrod (Solidago altissima). Because this mutualism reduces top down control on treehoppers, it is possible that the relationship causes treehoppers to overexploit host plants. This thesis describes a study testing the hypothesis that treehoppers avoid previous sites of herbivory and mutualism because of reductions in quality. Specifically, I tested whether the presence of either ants or treehoppers on a plant in one year affects treehopper host choice and performance the subsequent year. While treehoppers avoided choosing plants that previously experienced herbivory as hosts, the presence of ants did not amplify this effect. Evidence of herbivory or mutualism reducing plant quality is ambiguous, and neither mutualism nor herbivory affected nymphal survival. This avoidance in response to herbivory may mediate the destabilizing effects of this mutualism. These findings suggest the need to further investigate why herbivory impacts only host choice but not ultimate performance, and how plant quality may influence dispersal.

Genetic Basis of Reproductive Isolation in Drosophila Athabasca

Haley Lescinsky

Speciation is the process by which the Earth's biodiversity is generated; it occurs when one species splits into two as a result of limitations on gene flow and/or free recombination throughout the genome. Because of their inherent ability to prevent recombination, inversions are possible facilitators of speciation. They are most likely implicated in systems where reproductive isolation occurs because distinct combinations of prezygotic isolation traits are favored within the population. The Drosophila athabasca species complex is a fascinating case of recent speciation caused by the pre- zygotic isolation traits female preference and male courtship song. In this thesis I studied SNP introgression rates to determine candidate genes and worked to develop a fluorescent in situ hybridization (FISH) protocol to determine if the candidate genes were contained within an inversion. My results suggest further investigation into the role of X- linked genes nonA and nlk in the pre-zygotic isolation barrier in D. athabasca. My project failed to get fluorescent in situ hybridization to work, leaving the inversion hypothesis untouched, but the D. athabasca system warrants continued investigations to determine the reason and genetic basis of speciation event and is an ideal candidate system to test the inversion recombination suppression hypothesis.

Individual Performance and Cultural Evolution in Savannah Sparrow Song

Jonah Levy

I examined the interactions between cultural evolution and individual performance in the learned songs of the Savannah sparrow (Passerculus sandwichensis). I focused on "interstitial notes," which are sung between highly-conserved introductory notes, to determine: 1) the spatial patterns of note abundance in an island archipelago, 2) the potential constraints on note performance and the incorporation of different note types into song, and 3) the cultural specificity of note types that require vocal virtuosity. Note abundance varied geographically: "X" note abundance was strongly associated with the geographic distance between subpopulations, while "Click" note abundance may have been affected by stochastic dispersal and subpopulation size. Performance varied with note type. X notes were sung with shorter note periods than Click notes. Presence of interstitial notes (particularly Click notes) was associated with shorter interval durations, and with some acoustic characteristics of adjacent introductory notes. Performance also varied geographically. For birds singing both Click and X notes, note periods were not correlated on Kent Island, but were inversely correlated on Grand Manan. This suggests that the cultural dominance of Click notes on Kent Island may limit the establishment of novel note types, while Grand Manan birds may use X notes to improve perceived song performance through increased note rate. Playback experiments aligned with this interpretation: Grand Manan birds did not discriminate between stimuli of varying Click note number. Because interstitial notes are influenced by geography, performance value, and cultural specificity, the

Savannah sparrow's learned song provides a useful link between the fields of cultural evolution and individual performance.

ASAP1 reduces cancer chemotherapy susceptibility and promotes the Hippo pathway in ovarian cancer

Calvin Ludwig

An Arf-GAP-family protein with known functions in the organization of cytoskeletal cell motility apparatuses, oncogene ASAP1 is upregulated in 40% of clinical ovarian cancers. Previous experiments in this laboratory suggested that in conditions of high cell-cell contact ASAP1 reduces ovarian cancer proliferation. This finding contrasts the actions of many other oncogenes, which typically increase cell division—a hallmark of cancer. In search of reasons why ovarian cancer would decrease its proliferation, we proposed that cells employ ASAP1 to mitigate proliferation to reduce sensitivity to cancer drugs that target rapidly-dividing cells. Because ASAP1 knockdown caused increased ovarian cancer cell proliferation only in conditions of high cell-cell contact, we hypothesized that ASAP1 acts through the cell contact growth inhibitory pathway, Hippo. We show through immunostaining studies that ASAP1 knockdown in ovarian cancer Ovcar5 cells causes (1) significantly increased nuclear localization of pro-proliferation Hippo transcriptional regulator YAP and (2) decreased phosphorylation of YAP and of upstream negative YAP regulator Hippo pathway member LATS1/2. These findings, taken together, suggest ASAP1 acts through the Hippo pathway to impart its effect on ovarian cancer proliferation. Critically, we show that ASAP1 knockdown in Ovcar5 cells causes greater cell death compared to wildtype cells in the presence of the rapid-division cancer drug paclitaxel (Taxol®), suggesting that ASAP1 reduces sensitivity to cancer rapid-division chemotherapies, likely through its Hippo-mediated proliferation mitigation. We propose a novel dual-drug ovarian cancer therapeutic approach whereby cancer cells are subjected to both an ASAP1 antagonist and a rapid-division cancer drug.

Effects of Mowing Frequency on Native Goldenrod Pollinator Community Composition Across Space and Time

Natalia Miller

We test the effects of mowing frequency (annually or biennially) and patch size (large or small) on the diversity and abundance of insect visitors to four species of native goldenrods in an open field environment established in 2013, using a randomized block designed experiment. We filmed all floral species at two sites: a field in a residential area of Hopper Road and a field in a forested area of Hopkins Memorial Forest (HMF). Previous studies found that mowing plots in October increased both the number of flowering stems and the clonal patch size of several goldenrod species, and that these patches grew at a faster rate. For the first time since this investigation's inception, this study will analyze data for two consecutive years of a biennially-mowed plot, which will deepen our knowledge of the long-lasting effects of human-mediated disturbance on patch size and pollinator abundance. We found evidence of both small-scale and large-scale spatial and temporal heterogeneity in insect visitors. Flower visitor abundance and diversity was significantly higher at HMF compared to Hopper Road, suggesting the presence of fewer insects at residential sites. Nevertheless, unique insect taxa appeared at the Hopper Road site, suggesting that the preservation of multiple sites is important for pollinator conservation. Comparisons of visitors to S. altissima and S. rugosa in 2016 and 2017 also showed shifts in pollinator community composition, indicating temporal variation. Comparisons of two patches at a single site (24 m by 24 m plot) showed differences in pollinator communities, indicating fine-scale heterogeneity. Comparisons between late annual and late biennially-mown plots showed no significant differences, indicating that both treatments support pollinator communities to a comparable extent.

Estrogen and Heart Development in Zebrafish

Miram Semmar

Estrogen is both a naturally occurring and synthetically processed compound that is found in the body, foods, drugs, cosmetic products and environmental waters. Multiple studies have yielded results that suggest an overexposure to estrogen can lead to a host of problems related to cancers, cardiovascular diseases and reproductive issues, among others. Using the transgenic Tg(5xERE:GFP) line, which uses five estrogen receptor elements to drive GFP expression, estrogen receptors have been detected in the heart valves (Gorelick and Halpern 2011). Receptor expression was observed in the heart at environmentally relevant concentrations of 17-β estradiol (E2) as low as 100 ng/mL (0.367 μM), but their function remains a mystery (Gorelick and Halpern 2011). In zebrafish, research has also shown that overexposure to high doses of 17-β estradiol can result in many defects in various parts of the body or in relation to gene expression. This project explored the effects of estrogen on zebrafish heart development as well as a potential interaction between estrogen and the Notch pathway.

Given the presence of estrogen receptors in the heart, we anticipated an interaction between these receptors and other pathways known to be involved in heart development and have other interactions with estrogen. The Notch pathway is of particular interest because of its known role in heart valve development and connection to estrogen via the VEGF pathway. Estrogen acts as an inhibitor of VEGF while VEGF normally up regulates the Notch pathway (Carroll et al. 2014; Kanz et al. 2016). In our work, dual exposure treatments to threshold doses of estradiol and DAPT, a Notch inhibitor, suggested a potential synergistic interaction. This was based on the prevalence of pericardial effusion in treatment samples, stereoscope microscopy and confocal microscopy. However, these results were difficult to reproduce and our single exposure experiments with estradiol suggest a higher dose will be necessary to instill greater confidence in these results.

In the heart, exposure to high doses of 17-β estradiol has led to pericardial edema and structural abnormalities (Diamante et al. 2017). To our knowledge, the specific cause of these defects following estradiol exposure have not previously been explored. Following exposure to estradiol at various concentrations and points in time during development, confocal microscopy revealed that in some cases, particularly at the highest doses, overexposure to estradiol led to enlargement of the valves as well as a failure for the valve leaflet to form. These results strongly suggest a role for estrogen in the development of the heart valve.

Influence of female cuticular hydrocarbon (CHC) profile on male courtship behavior in two hybridizing cricket species Gryllus firmus and Gryllus pennsylvanicus.

Danielle Sim

Pre-zygotic barriers prevent members of different species from mating and can influence speciation. Behavioral isolation, an early pre-zygotic barrier, is important in limiting hybridization and thus gene flow between two species. In this thesis, I studied the behavioral isolation between two hybridizing cricket species Gryllus firmus and Gryllus pennsylvanicus. Given that male mate choice acts as a pre-zygotic barrier in this hybridizing system, I sought to examine the influence of female cuticular hydrocarbon (CHC) profile on male courtship behavior. I determined that while males of both species exhibit the same CHC profile, females exhibited one of four distinct CHC profiles: G. firmus-like (F), G. pennsylvanicus-like (P), intermediate (Int), and male-like (ML). Gryllus firmus males courted females independent of species type more quickly and successfully than G. pennsylvanicus, indicating that these males were less selective towards potential mates. With respect to female CHC profile, G. firmus males courted the F, Int, and ML profiles types more quickly than the P type. Conversely, G. pennsylvanicus males courted the P profile more quickly than the F, Int, and ML profiles. Overall, the results suggest that male mate choice is partially mediated by female CHC profile.

Expression of GATA in Helobdella robusta Embryonic Stem Cell Patterning

Justin Sim

The gene products that specify stem cell identity in the leech Helobdella robusta are currently unknown. It was previously found that the GATA gene coded for a transcription factor in leech development. My goal was to test this gene's role in the process of stem cell genesis and fate differentiation in the leech embryo. Through amino acid sequence alignment and analysis, it was determined that the leech GATA factor shares the conserved dual zinc finger region found in many other GATA transcription factors across other plant and animal species. Sequence comparisons suggest that the leech GATA sequence being studied is more similar to the GATA4/5/6 class than the GATA1/2/3 class. To investigate its putative function, the spatiotemporal expression of GATA mRNA transcript expression was observed through in situ hybridization. It was found that the GATA transcript is restricted to the mesodermal lineage. This is consistent with the GATA4/5/6 subfamily's role in mesoendodermal layer development in other annelid species, such as Capitella sp. I and Platyneries dumerilli, whereas GATA1/2/3 factors are associated with ectodermal development. Given these data, I suggest that the candidate gene that I have characterized in Helobdella robusta is a homologue of GATA4/5/6.

Developing a fluorescence-based assay to quantify in vitro myosin filament assembly and investigate its modulators

Timmy Suh

Motility on the cellular level is critical for maintaining the integrity of living organisms, as it forms the organism's foundation for being able to respond and interact with its surrounding environment. For this reason, the molecular mechanisms that an organism uses to manipulate its form in relation to its environment must be tightly and dynamically regulated. One of the primary family of proteins that is responsible for this cellular motility is class II myosins, motor proteins that must homo-oligomerize into bipolar filaments to produce contractile force. Because this reversible process of filament assembly and disassembly is directly linked to the functional capability of class II myosins, there is a complex network of regulatory mechanisms that dictates the spatiotemporal dynamics of class II myosin filament assembly.

In order to efficiently and accurately track the process of myosin filament assembly, we labeled rabbit skeletal myosin II with the fluorophore Alexa Fluor 647 and developed a novel fluorescence-based microscopy assay that provides a rapid read-out of filament assembly and disassembly. Based on the concept that co-localized, overlapping fluorescent signal indicates the homo-oligomerization that occurs during myosin filament assembly, we acquired images of in vitro reaction mixtures of myosin and various potential regulatory molecules, then used image processing to locate clusters of fluorescence and quantitatively analyze them for size and fluorescence intensity. In doing so, we confirmed the sensitivity and accuracy of myosin cluster detection through a salt dependence assay and collected preliminary data suggesting that the Arf-GAP ASAP1, a known binding partner of class II myosins, is a positive regulator of filament assembly.

Linking Modes of Sexual Selection in House Finches (Haemorhous mexicanus)

Rebecca Smith

Auditory and visual signals use two distinct modalities to carry information related to an organism's fitness, communication, mate choice, and territory. When given by a single individual, these two forms of signals can reinforce or contradict the other. Both song and coloration are under sexual selection in house finches (Haemorhous mexicanus). In this study, I investigate if fitness signaled by coloration reinforces or contradicts fitness signaled by song. My results suggest that the two signals are largely independent, with two important tradeoffs. Song stereotypy and transition type both decreased with the proportion of red coloration elaborated in a male's plumage.

Characterization of the Parasubthalamic Nucleus as an Appetite Suppression Center

Jacob Sperber

Feeding behavior is controlled by an array of orexigenic (appetite-stimulating) and anorexigenic (appetite-suppressing) neural circuits within the brain. Recent work from the Carter lab identified the parasubthalamic nucleus (PSTN), a relatively unexplored population of neurons in the lateral hypothalamus, as a potential anorexigenic brain region. Neural activity of the PSTN has been correlated with anorexia and activation of the PSTN is associated with reduced food intake in mice, however, the role of the PSTN in regulating food intake remains relatively uncharacterized1,2. This study tested the hypotheses that PSTN neurons expressing corticotropin releasing hormone (CRH) increase neural activity following a meal (during conditions of appetite suppression) and that stimulation of these neurons is sufficient to reduce food consumption during ad libitum feeding conditions. We found that optogenetic and chemogenetic stimulation of CRH-expressing neurons in the PSTN did not affect food consumption. Fos was upregulated in the PSTN following refeeding, however, there was minimal colocalization of refeeding-induced Fos and CRH. Thus, the PSTN is activated by refeeding but the majority of PSTN neurons involved in appetite regulation do not express CRH.

Developing a Lipopolysaccharide and Ovalbumin Murine Model of Allergic Asthma for Gene Expression Studies of CD4+ Lung Resident Memory Cells

Nicole Tanna

Allergic asthma is a chronic disease causing inflammation of the lung in response to a harmless environmental antigen, and affects millions of patients worldwide. Prior research suggests that allergic asthma may be driven by tissue-resident memory CD4+ T lymphocytes, a subset of memory helper T cells that resides in peripheral tissues over the long term. Though murine models of allergic asthma often use house dust mite (HDM) extract, this process requires many sensitization doses over a relatively long period of time. This study found that a sensitization model using ovalbumin and lipopolysaccharide together generates a population of CD4+ tissue-resident memory T lymphocytes that acts in an antigen-specific manner independent of CD4+ circulating memory T lymphocytes. These CD4+ tissue-resident memory cells recruit both innate and adaptive immune cells to the airways, with an emphasis on eosinophils, the prevalence of which is a hallmark of asthma in humans. Early gene expression studies aimed at better understanding the key cytokines and chemokines used by tissue-resident memory T cells to rapidly recruit immune cells to the airways were inconclusive. However, the ovalbumin and lipopolysaccharide model will allow for future, more thorough gene expression studies to illuminate the mechanisms by which CD4+ tissue-resident memory cells may be driving allergic asthma.

The Bang Sensitive Locus jus: Cold Sensitivity, Abnormal Neural Activity, and Genetic Interactions in Drosophila melanogaster

Hannah Weinstein

Seizures, typically defined as the involuntary movement of part or all of the body, are a result of abnormal or excessive neural activity. Drosophila melanogaster are a model system used to explore the genetic basis of epilepsy because there are many mutants that exhibit a seizure-like phenotype termed “bang sensitivity”. Recently, the bang-sensitive mutant, julius seizure (jus), was determined to encode a novel transmembrane protein. jus function is required in cholinergic and GABAergic neurons during the pupal stages, but the mechanism by which it functions is unclear. We began our investigation by determining that cold shock allows further differentiation and investigation of the three jus alleles. RNAi of jus in the central nervous system increases calcium signaling in cell bodies in the thoracic ganglia and we characterized the expression of two candidate jus-GAL4 drivers, 78T-UAS mCherry and 17T-UAS mCherry. To help expand our analysis, we investigated hormone receptor-like in 38 isoform D (HR38), a transcription factor that modifies neural activity. HR38 is also the homolog of NR4A1, a human gene implicated in epilepsy, and may play a role in epileptogenesis. We found RNAi of HR38 in cholinergic or pan-neuronal neurons does not cause bang-sensitivity, but the loss of gene expression ubiquitously is lethal. Finally, we show jus and HR38 seem to genetically interact. This was shown because extra copies of HR38 in jus mutants suppresses bang-sensitivity and cold-sensitivity, and loss of endogenous HR38 expression in jus mutants enhances bang-sensitivity. Taken together, these results expand our understanding of jus mutants and the seizure-like phenotype in Drosophila.

Chemistry

Characterizing the Function of Phosphodiesterase SCO6672 in the Biosynthesis of Secondary Metabolites in Streptomyces coelicolor A3(2)

John Ahn

The Streptomyces are a genus of soil dwelling, Gram-positive bacteria, known for being prolific producers of bioactive secondary metabolites. Streptomyces coelicolor A(3) produces five antibiotics: linear tripyrrole undecylprodigiosin (RED), polyketide actinorhodin (ACT), cyclic lipopeptide calcium dependent antibiotic (CDA), cyclopentane methylenomycin, and polyketide coelimycin P1. The production of these compounds relies on the activation of carrier protein domains within non-ribosomal peptide synthetase (NRPS) and polyketide synthase (PKS) enzymes through the addition of a 4'-phosphopantetheine (Ppant) cofactor. Phosphopantetheinyl transferases (PPTases) catalyze the addition of Ppant groups, converting apo, inactive carrier proteins to holo, active carrier proteins. Phosphodiesterases catalyze the opposing reaction. Previous work has found that the SCO6672 gene encodes a phosphodiesterase. Substrate specificity studies of SCO6672 have found that the phosphodiesterase can hydrolyze Ppant groups from holo-CPs in Type I PKS, NRPS, FAS, and oligopyyrole systems. However, CPs involved with producing siderophores and grey spore pigment have not yet been tested. The in vivo role of SCO6672 in antibiotic production has also been explored with RED and ACT spectrophotometric assays, as well as CDA zone of inhibition assays. Two hypotheses have been proposed for the regulatory role of SCO6672: SCO6672 activity as a negative regulator of secondary metabolite production or rather that the phosphodiesterase acts as a rescue enzyme to remove damaged intermediates stalling NRPS or PKS biosynthesis.

The substrate specificity of SCO6672 was explored here against holo-WhiE ACP and CchH PCP3 substrates, which are involved with grey spore pigment and siderophore coelichelin biosynthesis, respectively. Both holo carrier proteins were experimentally shown to be hydrolyzed to the apo form by SCO6672 as detected by MALDI-TOF mass spectrometry. The physiological role of the phosphodiesterase was also investigated through RED and ACT antibiotic assays. Although mutant ΔSCO6672 S. coelicolor and wildtype strains grew at roughly the same rates, the mutant ΔSCO6672 strain demonstrated increased RED production, lending evidence towards the negative regulator hypothesis. However, taken with previous results suggesting decreased CDA production in mutant ΔSCO6672 strains, it is possible that SCO6672 may act as both a negative regulator and a rescue enzyme.

Synthesis of Novel 1,4-diaryl-1,2,3-triazoles as Histidine Kinase Inhibitors for Antibiotic Drug Discovery

Daniel Brandes

Owing to the rapid rise of antibiotic resistance in bacteria, the development of new classes of therapeutics is necessary. Histidine kinases (HKs) represent an ideal target for antibiotic development, because they are integral elements of bacterial two-component systems (TCS), which promote transcriptional responses to extracellular stimuli, potentially leading to virulence. Bacteria rely on these responses for survival, so disrupting the TCS via HK inhibition may lead to antibiotic activity. HKs are ubiquitous among bacteria, and contain highly conserved structural motifs, such as the ATP binding domain. We hypothesize that inhibition of this widely conserved ATP binding domain might lead to the development of a broad-spectrum antibiotic. I report the synthesis of seven 1,4-diaryl-1,2,3-triazole inhibitors. To assess these inhibitors, I examined binding affinity to CckA, an HK isolated from Caulobacter crescentus. I performed ThermoFluor assays to assess binding affinity, and observed promising thermal shifts greater than 2 °C for six inhibitors. Systematic substitution of para-electron withdrawing groups on the "solubility ring" component confirmed the importance of electron withdrawing character for enhanced binding affinity. Finally, assessment of structure activity relationships between my 1,4-diaryl-1,2,3-triazole inhibitors and previously synthesized inhibitors via ThermoFluor assays confirmed the importance of the 5-chloro-2,4-dihydroxy motif on the "resorcinol ring" component. Ultimately, these results are promising indications that the 1,4-diaryl-1,2,3-triazole inhibitor motif has potential for binding to bacterial HKs, and that the presence of electron withdrawing groups leads to enhanced biological activity.

Investigating the Phosphopantetheinylation of the RedO and RedQ Carrier Proteins of Streptomyces coelicolor A3(2)

Esther Kim

The Streptomyces genus is comprised of Gram-positive, soil-dwelling bacteria that produce secondary metabolites, many of which demonstrate antimicrobial, anticancer, antifungal, and immunosuppressive properties. The biosynthesis of many of these secondary metabolites involves polyketide synthases (PKS) and/or nonribosomal polypeptide synthetases (NRPS) and hinges on the post-translational attachment of a 4'-phosphopantetheine (Ppant) group onto their carrier protein domains. Phosphopantetheinylation is catalyzed by phosphopantetheinyl transferases (PPTases), and the model streptomycete Streptomyces coelicolor A3(2) has three PPTases: Acps, SCO6673, and RedU. While the first two have been studied extensively and characterized as "promiscuous" PPTases with broad carrier protein specificity, the substrate specificity of RedU PPTase has yet to be elucidated. The present investigation aimed to isolate and purify this PPTase for in vitro assays with the RedQ and RedO carrier proteins and employed heterologous gene expression in Vibrio natriegens as well as redU codon optimization to achieve increased gene expression in Escherichia coli. While codon optimization led to high levels of redU_29G gene expression, the resulting protein was largely insoluble. Nonetheless, preliminary results indicated the phosphopantetheinylation of the RedQ and RedO carrier proteins by crude lysates of both the E. coli and V. natriegens overexpression strains, which contained native PPTases in addition to RedU. Disentanglement of the substrate specificities by isolating soluble RedU will be necessary for further studies with the goal to fully understand the scope of the specificity of the RedU PPTase for carrier proteins encoded by the S. coelicolor genome.

Investigation of promoter specificity of the SCO4409 sigma factor in Streptomyces coelicolor

Elizaveta Lavrova

The SCO4409 ECF sigma factor of Streptomyces coelicolor has previously been implicated in regulation of antibiotic biosynthesis in this bacterium. Particularly, in knockout mutants of the gene encoding the ZAS anti-sigma factor SCO4408, where SCO4409 activity is presumed to be unregulated, both actinorhodin and undecylprodigiosin production appear to be reduced. In this study, we sought to identify the promoter recognized by the SCO4409 sigma factor as a means to discover the genes under its transcriptional control. We used two complementary approaches to attempt to define the SCO4409 regulon. First, we sought to investigate, with eGFP reporter plasmid experiments, the promoter sequence to which SCO4409 binds and from which it directs transcription. Second, we compared cytoplasmic proteins produced by the SCO4408::apr anti-sigma factor knockout mutant to those produced by the M145 wild type strain in order to find and identify any differentially abundant proteins, which might suggest SCO4409-controlled genes.

SCO4409 does not appear to bind and direct transcription from its own promoter, and we were not able to definitively assign a functional promoter sequence within the upstream region of the SCO4409 gene. Two proteins that are more abundant in the SCO4408::apr mutant, fructose-biphosphate aldolase and superoxide dismutase, are implicated in primary metabolism and in mediation of oxidative stress, respectively. Our results invite further investigation of the spatio-temporal transcription pattern from the SCO4409 promoter(s), as well as further investigation into the regulon of SCO4409, since it may be involved in mediating stress and/or regulating S. coelicolor metabolism.

Synthesis and Characterization of Amphiphilic Diblock Copolymers from Lignin Derivatives Alexi McAdams

Crosslinked polymeric micelles promise improved delivery of chemotherapeutics. In this study, we synthesized five novel amphiphilic copolymers using RAFT polymerization. Bio- based vanillin and syringaldehyde acrylate monomers were polymerized to form the hydrophobic block, and polymerized N,N-dimethylacrylamide was used as the hydrophilic block. The polymers self-assemble in water into monodisperse spherical micelles of 50-200 nm at 10-8 M CMCs. The micelle cores were reversibly crosslinked with redox-sensitive cystamine through formation of pH-sensitive imine bonds for dual-sensitivity. According to TEM studies, crosslinking prevented disassembly upon dilution.

Stereochemical Outcomes of Zinc-Mediated Deuteration of Iodotetralins

Jonathan Xianglong Meng

The selective incorporation of deuterium into an organic molecule has broad application ranging from mechanistic studies to drug design. Zinc-mediated deuteration, previously optimized in the Richardson/Thoman lab, represents a promising synthetic method for the installation of deuterium in place of an iodine substituent. In the first half of this work, an attempt was made to investigate our previous deuteration trials for the presence of hydroxyl-products. Varying experimental parameters, such as temperature, reaction atmosphere (N2/air), D2O/H2O, and substrate structure, allowed us to explore how our optimized reaction conditions diverged from the deuteration reaction to result in elimination and hydroxylation. Our preliminary results suggested that the presence of air/oxygen seemed to introduce the possibility of hydroxylation. In the second half of this work, an attempt was made to investigate the stereochemical outcome of the deuteration reaction via deuteration of a substrate featuring a stereochemically well defined trans-relationship between methyl- and iodo-substituents on a cyclohexyl framework. A tetralin-based substrate was synthesized and then subsequently brought to high purity on a milligram scale. This substrate successfully addressed the structural deficiency observed in Goss '17's bicyclic iodoether: it was deuterated with minimal competing elimination reaction. The presence of air/oxygen again seemed to introduce the possibility of hydroxylation for this cyclohexyl-based system, but only at a very low level. More importantly, the stereochemical outcome, successfully deciphered by 1H- and 13C-NMR spectral analysis demonstrated the zinc-mediated deuteration of this tetralin substrate was highly stereoselective (~73% retention), which suggested that zinc-mediated deuteration occurs as a surface-bound process.

Comparing clinical and synthetic mutations in antibiotic resistance genes

Cynthia Okoye

Resistance has been observed for almost every kind of antibiotic in clinical use and antibiotic resistance has now been labeled as a global threat to health. In order to maintain an upper hand in the drug resistance arms race, it is important to understand the factors that drive clinically relevant resistance. We conducted a comparative study of mutations in TEM β-lactamase that underlie broad-spectrum resistance phenotypes in bacteria: M182T occurs naturally in many strains found clinically, whereas M182S is a synthetic variant that we have identified and studied in our lab but has not been documented clinically. M182T is known to increase the thermodynamic stability of TEM β-lactamase but does not have a large effect on activity measured in vitro. The activity and stability parameters of M182S alone and in combination with other clinically relevant mutations were determined using UV-vis spectroscopy, circular dichroism, and intrinsic fluorescence measurements. We found that neither kcat /Km nor thermodynamic stability was significantly different between the enzymes bearing M182S or M182T, regardless of the background mutations. Additionally, through quantitative fitness competition assays, we found that bacterial strains bearing the clinical or synthetic β-lactamase variants were comparable in fitness in the presence of up to 1500 nM cefotaxime. The M182S amino acid mutation requires the occurrence of at least two consecutive mutations within the DNA codon. However, DNA sequence alignments of 34 TEM variants relative to wild type TEM reveal that there is a very low probability of achieving consecutive DNA mutations within a codon. We believe that this provides a significant explanation as to why the M182S mutation is not naturally found in the TEM gene despite the ability of this mutation to confer a similar increase in stability as M182T.

Combatting Antibiotic Resistance: A Search for Inhibitors of the Bacterial SOS System

John Roberts

The acquisition of antibiotic resistance in bacteria is an alarming phenomenon that has grown into a significant health concern worldwide. Spurred on by the considerable use of antibiotics, infectious strains of bacteria have evolved to survive the drugs originally designed to eradicate them. A critical bacterial response for the acquisition of antibiotic resistance is the bacterial SOS system, which is regulated by the LexA and RecA proteins. Activation of the bacterial SOS system is due to autocleavage of the LexA protein, which is mediated by the RecA protein. Once turned on, the SOS system leads to enhanced mutagenesis and horizontal gene transfer, the two mechanisms by which bacteria can acquire antibiotic resistance. Because the interaction between LexA and RecA is highly conserved among bacteria, and given the role of RecA-mediated LexA autocleavage in the activation of the SOS system, the Lovett Lab has been working to identify bioactive compounds capable of inhibiting LexA self-cleavage in two distantly related species of bacteria, E. coli and B. subtilis. Over the past few years, members of the Lovett Lab have screened more than 11,000 compounds from the Maybridge HitFinder™ chemical library for inhibitors of RecA-mediated LexA cleavage in vitro using purified LexA and RecA proteins from E. coli. Compounds found to inhibit E. coli LexA cleavage in vitro have then been examined in vivo for their inhibitory efficacy in E. coli and B. subtilis cells. Through combined efforts from a number of members of the Lovett Lab, over the course of this particular research period, roughly 1,800 Maybridge Library compounds have been screened and fifteen new inhibitors of RecA-mediated LexA self-cleavage have been identified and characterized.

The Role of Functional Group Identity on the Formation of Atmospheric Organic Aerosol

Katie Spence

Atmospheric aerosol particles, condensed phase droplets suspended in the air, have key implications for human health, climate and visibility. Current models, however, tend to underpredict aerosol loadings by up to an order of magnitude. The highest uncertainty is associated with organic aerosol, which can be primary or secondary in nature. While primary organic aerosol is emitted to the atmosphere as a particle, secondary organic aerosol forms when a volatile organic compound (VOC) undergoes oxidation reactions in the atmosphere, ultimately condensing to form aerosol. Many of the VOCs present in the atmosphere are extremely complicated with multiple functionalities, and to understand more about the reactions of these complex compounds in the atmosphere, we first need to understand how simple compounds react. This thesis investigates the oxidation reactions of unfunctionalized and simple monofunctional C10 molecules to probe how functional group identity impact aerosol yields. Gasphase oxidation reactions of this type are generally conducted in atmospheric environmental chambers. To run these experiments, we used a 1 m3 Teflon environmental chamber. Because this chamber was new, we first needed to characterize and optimize it. Our process for doing so is outlined and included, among others, conducting residence time calculations, optimizing generation of radical precursor and seed particles, and developing methods for SMPS and GC analysis. Ultimately, our preliminary results suggest that while C10 aldehydes form larger oxidation products that ultimately partition into aerosol, C10 ketones follow a fragmentation pathway that leads to the formation of gasphase products.

Manipulating the energy landscapes of β-lactamases TEM-1 and CTX-M-9

Miranda Villanueva

Proteins spontaneously fold into their most thermodynamically stable state; but for many proteins, alternative or partially folded states also exist at equilibrium. A protein's sequence determines its entire energy landscape, which describes all the accessible conformations and their relative populations. To understand how a protein's energy landscape is encoded by its sequence, we surveyed the effects of a disulfide bridge on two homologous enzymes involved in antibiotic resistance, TEM-1 and CTX-M-9. The homologs have high structural similarity and consist of two structural domains, α and β. However, they differ in stability and in the number of states populated at equilibrium: CTX-M-9 exhibits a two-state denaturation curve, whereas TEM-1 has an additional intermediate state (I). We hypothesized that a disulfide bond in the α domain was a major underlying determinant for these differences. To test this hypothesis, we removed the disulfide bridge from TEM-1 and introduced a disulfide bridge at the same location in CTX-M-9 and then determined the variants' stabilities by monitoring denaturation through fluorescence and circular dichroism (CD). As predicted, removing the disulfide from TEM-1 decreased the intermediate's stability, and thus population, and adding a disulfide bridge to CTX-M-9 introduced an intermediate state. Unexpectedly, however, the TEM-1 and CTX-M-9 intermediates appear structurally distinct. The TEM-1 intermediate contains 60% of the native state's secondary structure, whereas the CTX-M-9 intermediate has all the secondary structure of the native state but 20 % of its tertiary structure. Our data support a structural model of the TEM-1 intermediate in which the α domain is mostly folded and the β domain is unfolded. Additionally, our working model for the CTX-M-9 intermediate is one in which the secondary structure of both domains is preserved but tertiary interactions, particularly in the β domain, are not well formed.

Singlet Oxygen Photolysis of Tannic Acid as a Proxy for Atmospheric Humic-Like Substances

Allison Wong

Atmospheric aerosol has numerous impacts on visibility, health and climate that depend on its chemical composition, reactivity, size, and lifetime. While humic-like substances (HULIS) are a major component of aqueous aerosol, HULIS is a complex mixture of organic compounds that is challenging to study directly. In this thesis, tannic acid (TA), which is a component of HULIS, was used a proxy for HULIS to study changes to its chemical composition due to exposure to singlet oxygen (1O2), a potentially important atmospheric photooxidant. Characterization of the TA used in these experiments resulted in the identification of 32 distinct molecular formulas that differ in the number of gallic acid (GA) units polymerized around one of four core structures. 1O2 was first generated using molybdate (MoO4-2) and hydrogen peroxide (H2O2), but it was determined that TA complexes with MoO4- 2 and its use was discontinued. The photosensitizer Rose Bengal (RB) was instead used to generate approximately 5 days of daytime environmental exposure to 1O2. Control photolysis experiments to account for other light dependent photochemical processes resulted in minimal changes to TA, primarily the growth of secondary alcohol peaks in the IR spectrum. Although 1O2 is a known oxidant, exposure to 1O2 decreased the degree of oxidation of TA. Further characterization of degradation products and the development of a mechanism for 1O2 photolysis of TA is ongoing.

Computer Science

Sharing Silicon: Improving FPGA Accessibility

Matheus Cruz Correia Carvalho Souza

With the end of Moore's Law, reconfigurable computation fabric will be part of the solution to avoiding Dark Silicon—the need to turn off transistors to reduce computational power consumption. In this work, we improve field programmable gate array accessibility and we offer motivation for a more widespread adoption of this paradigm. We illustrate the development of hardware configurations, show the potential of hardware acceleration, and explain methods for time- and space-sharing of FPGA devices.

Solar Thematic Map Generation via Machine Learning

J. Marcus Hughes

The new Solar Ultraviolet Imager (SUVI) instruments aboard NOAAs GOES-R series satellites collect continuous, high-quality imagery of the Sun in six wavelengths. SUVI imagers produce at least one image every 10 seconds, or 8,640 images per day, considerably more data than observers can digest in real time. Over the projected 20-year lifetime of the four GOES-R series spacecraft, SUVI will provide critical imagery for space weather forecasters and produce an extensive but unwieldy archive. In order to condense the database into a dynamic and searchable form I have developed solar thematic maps, maps of the Sun with key structures, such as coronal holes, flares, bright regions, quiet corona, and filaments, identified. Thematic maps will be used in NOAAs Space Weather Prediction Center to improve forecaster response time to solar events and generate several derivative products. Likewise, scientists use thematic maps to find observations of interest more easily and guide experiments.

This thesis presents machine learning approaches to automatically generate thematic maps in real-time. In order to train these classifiers, I created software to collect expert classifications of solar structures based on SUVI images. Using this software, I compiled a database of expert classifications, which will be made available for future use. These are used to establish experimental limits on human performance. Here, I describe the software to collect expert training and the successes and limitations of the classifier. These results are promising and encourage future research into an ensemble classification approach and solar weather prediction with similar methods.

Predicting Bow Controls and Audio Features for Expressive Computational Music Generation

Wei Luo

Music is different from ordinary sound, in that it captures our emotion and is expressive. Just as how poetry allows for various vocalizations, music allows for different interpretations. One effect of having an expressive musical interpretation is that the performance deviates from the written music, possibly by modifying the speed and loudness. While we can speculate that these are two of the aspects that are influenced, the exact computational representation of a function that maps from a score to an expressive performance is not well-understood.

An important goal in the field of computational music is to make a machine perform music, just as a human might. However, one challenge encountered is that a machine cannot translate a written piece of music into an expressive performance directly. The written music contains only the fundamental information, but the nuances are left for an individual's interpretation. If such expressive information is not taken into account, a machine's performance will sound mechanical. In this thesis, we use machine learning techniques to construct models that predict bow controls and audio features for expressive computational music generation.

(k,p)-Planar Graphs: A Generalization of Hybrid Cluster Graph Representations

Timothy Randolph

A cluster graph consists of a graph G = (V, E) and a partition of the vertex set V into clusters V1, V2, ...VC . We refer to an edge (u, v) ∈ E as intracluster if it connects two vertices in the same cluster and intercluster otherwise. A port drawing of a cluster graph Gis a planar representation of G in which every cluster Vi is associated with a distinct cluster region Ri, each vertex v ∈ Vi is associated with one or more ports on the perimeter of Ri, and each intercluster edge (u, v) ∈ E is associated with a simple curve connecting a port of u to a port of v. A port drawing is planar if no edge curves cross or enter cluster regions.

Previous cluster graph representations highlight structural features, minimize edge crossings, or attempt to do both. We introduce the (k,p)-planar drawing, a planar representation for cluster graphs that generalizes established cluster graph representations and allows for the flexible representation of cluster subgraphs within cluster regions. We say that a cluster graph G is (k,p)-planar if Gadmits a planar port drawing in which every vertex is associated with at most p ports and no cluster contains more than k vertices. This thesis relates the (k, p)-planar graphs to established graph classes, bounds the edge density of the (k,p)-planar graphs, provides hardness results for the problem of deciding whether or not a graph is (k, p)-planar, and considers extensions to the (k, p)-planar drawing schema that introduce intracluster representations.

Multitasking Model-Agnostic Meta-Learning

Carl Rustad

Deep learning has allowed for advances in many fields from image classification to text prediction. Despite these successes, deep learning remains difficult to apply to many tasks. It requires large amounts of data to be effective; in domains where collecting data is expensive, deep learning is impractical. Few-shot learning is a deep learning paradigm focused on reducing the amount of data necessary to perform well on tasks. MAML is a state-of-the-art few-shot learning algorithm that is lightweight and general. This thesis investigates the efficacy of integrating multitask learning into MAML. The objective is to increase MAML's performance on common few-shot tests while minimizing increases in computational complexity and space requirements.

Geosciences

Can Storm Waves Move Very Large Boulders? Investigations in a Wave Tank

Jacob Cytrynbaum

Coastal boulder deposits accumulate above the high tide line, emplaced by high-energy wave events. They can include boulders >600t close to sea level, 100t boulders up to about 12m small (<1t) boulders up to 51m above high water mark. Among researchers studying coastal boulder deposits, there is controversy over whether storm waves or tsunamis are a more likely boulder emplacement mechanism. We used a Froude-scaled laboratory wave tank model of the Aran Islands, Ireland with simulated storm wave spectra to examine how individual waves interact with large boulders (441-1075t scaled equivalent) on cliff tops and to evaluate existing wave-transport equations. We also attempted to constrain initiation-of-motion criteria. We recorded water surface elevation data and video footage to extract wave parameters and wave-boulder interactions that are difficult to measure at full scale.

We found that storm waves, when they overtop a cliff and develop into high velocity bores, can move very large boulders, with masses in excess of those predicted by existing wave-transport equations. This demonstrates that hydrodynamic equations often used coastal boulder deposits are not effective. We were not able to establish specific criteria for initiation of motion, but we show that it likely relates to a combination of incoming wave shape, resulting bore velocity, and boulder shape and size. This study adds to the discussion of boulder emplacement mechanisms, demonstrating the significant potential to transport large boulders storm waves have. Further it contributes to overtopping studies by demonstrating that overtopping flows can displace massive objects.

A Palynological and Geochemical Approach to Understanding the Late Devonian Kellwasser Events in the Appalachian Basin

Ezekiel King Phillips

The Late Devonian is characterized by declining ρCO2, global climatic cooling, increased deposition of organic matter, widespread anoxia, and marine extinctions, specifically prevalent in shallow low latitude seas. The biggest pulses of extinction are linked to widespread laminated black shales, known as the Kellwasser horizons, which are correlated with two positive excursions in $\delta^{13}C$ of both carbonates and organic matter. In order to better understand the origin of these excursions, we extracted kerogens from black shales of the Kellwasser horizons at Cameron Creek and Eighteenmile Creek in upstate New York. Resulting macerates contained organic material that was predominantly of marine origin (with significant terrestrial input), and include abundant and diverse organic-walled microfossils (i.e. acritarchs). We analyzed the $\delta^{13}C$ of organic matter from bulk kerogens, as well as individual organic walled microfossils found in these strata to learn more about the driver of the $\delta^{13}C$ excursions and to help resolve unknowns about the paleoecology of the organic microfossils.

We measured the $\delta^{13}C$ of 150 microfossils and kerogen grains using a cryotrapping, capillary-focusing 'nanoEA' for trace $\delta^{13}C$ measurements. The $\delta^{13}C$ values of individual microfossils were variable between fossils and significantly different from coeval kerogens. The difference between the microfossil and kerogen values, $\Delta_{acritarch}$ or Δ_a, varies between sections, with the largest Δ_a values occurring in the bed below the Lower Kellwasser horizon and the bed containing the Upper Kellwasser Horizon. While the paleoecology and taxonomic affinity of these fossils is uncertain, the $\delta^{13}C$ values suggest that they are consistent with an algal origin. We speculate that the isotopic difference between bulk organic matter and the organic-walled microfossils may be the result of a surface water ecology where DIC is 13C-enriched because of a strong biological pump. This work sets the stage for more nuanced analyses of carbon cycle dynamics across the end-Devonian extinction event and for a better understanding of Paleozoic organic-walled microfossil paleoecology.

We photographed and measured microfossils from each sample to calculate relative abundance and morphology through each section. We found significant shifts in the relative abundances of each fossil type through time, while the shifts in morphology within each fossil type were not as drastic.

Quantitative Structure-from-Motion Modeling for Monitoring Change in Coastal Boulder Deposits

Timothy Nagle-McNaughton

Coastal boulder deposits (CBD) are supratidal accumulations of wave-deposited boulders that can individually weigh hundreds of tonnes. These deposits can be isolated clasts or imbricated boulder ridges. The movement of these boulders have been the subject of numerous studies, but these studies largely have focused on the largest clasts and relied on GPS points and hand-collected photographs to assess change. This study developed and tested a methodology for monitoring CBD by building centimeter-resolution structure-from-motion (SfM) models in Agisoft PhotoScan and comparing these models using CloudCompare. This method was applied to three islands: Inishmaan, Inishmore, Valentia Island. 2015 SfM models of Inishmaan were compared to 2012 Bing imagery and detected large-scale boulder movement in two areas along the coast. This change was likely due to intense winter storms during this period. A time-series comparison of SfM models from Inishmore between 2015 and 2017 detected smaller-scale boulder movement during these two much calmer years. A time-series comparison of SfM models of Valentia Island from July 2017 and November 2017 served as a control sample for CloudCompare's change detection algorithms. This methodology for building and comparing three-dimensional models proved to be a reliable and useful tool for measuring CBD movement, and will help facilitate more frequent and detailed observations of CBD evolution.

Mathematics and Statistics

Modelling the Spatial Dynamics of White Nose Syndrome Under Various Intervention Scenarios

Jackson David Barber

Since its recent introduction, White Nose Syndrome has infected bats throughout the North American continent, resulting in mass mortality across a wide geographic range. Because of the relative recency of the disease, the conservation community is largely uncertain about how to best address this chiropteran crisis. Insufficient research has been conducted to confidently inform ecologists how to prevent further bat mortality. This thesis implements a S-I-R type dynamical systems model to investigate and predict the efficacy of three proposed interventions: fungicidal treatment of hibernacula, microclimate engineering inside hibernacula, and implementation of a theoretical vaccine, under a number of epidemiological scenarios. My model indicates that, singularly among the three tested interventions, the theoretical vaccine promises to significantly reduce mortality among WNS-infected hibernacula in both single-hibernaculum and multi-hibernaculum scenarios; the fungicide and microclimate interventions, save in highly optimal conditions, fail to significantly reduce WNS-induced mortality, and in some cases actually exacerbate mortality.

A Numerical Investigation of the Traveling Wave in the Replicator-Diffusion Equation

Cody Cao

The replicator equation fails to capture the population dynamics in which individuals are distributed throughout a space. One solution to this shortcoming is to incorporate a diffusion term, thereby providing a spatial structure and allowing individuals to move. We call the resulting equation the replicator-diffusion equation. In this thesis, we study these evolutionary game dynamics with a spatial component through two different reaction - diffusion systems, both in 1D and 2D, based on previous works by Hutson, Vickers, and Cressman via computational simulation. We numerically investigate the behavior of the traveling wave in both dimensions and give criteria for the direction of the traveling wave in 2D. We also explore other nuances in the 2D case, namely turning points and wave shapes.

On Higher Distance Commuting Matrices

Madeleine Constantina Elyze

In general, matrix multiplication is not commutative. However, sometimes pairs of matrices do commute. We say that two matrices A and B commute, denoted A←→B, if AB-BA=0. The collection of pairs of non-scalar matrices that commute forms an algebraic affine variety in C2(n x n), where C denotes the complex numbers. In the case that A and B do not commute, A ←→ B, it is still possible that A and B commute with some common, non-scalar matrix X. Then we say A←→X←→B. In this way, we can construct chains of matrices of arbitrary lengths, A←→X-1←→...←→Xk←→B. We say that A is distance k+1 away from B if our chain is the shortest such path between A and B. This thesis is concerned with understanding the algebraic properties of these chains in C2(n x n) space. We show that the collection of distance less than or equal to 2 matrices forms an algebraic variety and offer intuition for proving that the collection of distance less than or equal to 3 matrices also forms a variety.

The Zeckendorf Game

Alyssa Epstein

A brilliant theorem of Zeckendorf proves that every positive integer n can be written as the sum of unique, non-adjacent Fibonacci numbers. This theorem generalizes: Miller and Wang showed that every positive linear recurrence relation defines a unique legal decomposition, where legal means the recurrence relation cannot be applied again and the summands are appropriately bounded. This thesis examines the Zeckendorf game, a two player game on a specific recurrence relation. This game is defined on the Fibonacci numbers and can be meaningfully extended to all positive linear recurrence relations of the form F_n = c F_{n-1} + ... + c F_{n-k}. We prove that the game always terminates at the appropriate (generalized) Zeckendorf decomposition, but that there are always games of multiple lengths. We also find upper and lower bounds on the number of moves taken in a game. For the Fibonacci Zeckendorf game, we show upper bounds on the order of *nlog(n)*; for all other Zeckendorf games, we show an upper bound on moves that grows linearly with n. The thesis centrally contains an analysis of winning strategies, including a proof of the main theorem: for the Fibonacci Zeckendorf game, Player 2 has the winning strategy for all $n > 2$.

Almost Excellent Unique Factorization Domains

Sarah M. Fleming

Let (T,m) be an equidimensional complete local (Noetherian) ring such that no integer of T is a zero divisor and depth $T > 1$. In addition, suppose T contains the rationals, $|T|=|T/m|$, and the set of all principal height one prime ideals of T has the same cardinality as T. We construct a universally catenary unique factorization domain A such that the completion of A is T and such that uncountably many height one prime ideals of T have nonzero intersection with A and have geometrically regular formal fibers. If T is assumed to be normal, then we can ensure that the generic formal fiber is also geometrically regular. Furthermore, in the case where T is a normal domain, we can make A “close” to excellent in the following sense: we can show that the formal fibers at the prime ideals of height not equal to one are geometrically regular.

Multiplier Properties in Infinite Measure

Beatrix Haddock

We offer an alternative proof of Maharam’s recurrence theorem. We then consider various formulations of weak mixing for infinite measure-preserving transformations, and define a new one: locally compact ergodic with isometric coefficients, and study three such conditions for infinite subinvariant transformations. We study joint weakly doubly ergodic transformations and show that 2-JWDE implies k-JWDE.

Combinatorial Problems Related to Peaks, Pinnacles, Descents, and Derangements

Isabella Huang

We say a permutation $\pi = \pi_1\pi_2 \ldots \pi n \in Sn$ has a peak at index i if $\pi_{i-1} < \pi_i > \pi_{i+1}$, has a pinnacle at value π_i if $\pi i\text{-}1 < \pi_i > \pi_{i+1}$, has a descent at index i if $\pi_i > \pi_{i+1}$, and is a derangement if for all $i \in [n]$, $\pi_i \neq i$. In this thesis, we provide formulas for the number of derangements with no peaks, one descent, and special cases of two descents, the last of which connects this work to counting diagonal staircase paths. In 2017, the work of Davis, Nelson, Petersen, and Tenner studied pinnacles of a permutation and asked whether there was a particular group action that preserves pinnacles. We consider the proposed group action introduced by Foata and Strehl and find that while it does preserve pinnacles of a permutation, the orbits do not encompass all elements having the same set of pinnacles. Thereby, we establish and measure the insufficiency of this particular group action. We end the thesis with future directions of research in combinatorial problems related to peaks, pinnacles, descents, and derangements with a focus on permutahedra.

Combinatorial Conditions for Nonsingular Rank-One Transformations

Sumun Sitalakshmi Iyer

An invertible measurable transformation T of a measure space is nonsingular if for any measurable set C, its image under T has measure zero if and only if C has measure zero. We study rank-one transformations in the nonsingular setting. We provide necessary combinatorial conditions for a transformation to be nonsingular rank-one. We also develop a class of nonsingular Morse sequences that we conjecture to have rank two.

Network Topology, Pollen Movement and Models of Insect Behavior in Neighboring Flower Communities

Molly Riley Knoedler

The dynamics and structure of networks of ecological interaction offer insight into stability, resilience, co-evolution, and diversification of ecosystems. Visitation networks, which represent the interaction of plants and their potential pollinators, are of particular interest due to the world-wide decline of insect populations and the importance of pollination to agriculture. In Chapter 1, I examine topological properties and pairwise visitor partitioning at two sites on a small island to better understand fine-scale variation between neighboring flower communities. These results are evidence of the possibility of multiple structures of stable organization in similar natural ecosystems. In Chapter 2, I discuss the results of an agent-based model I developed that investigates how the rules of insect behavior in a heterogeneous floral landscape dictate to pollen movement. I find that even with significantly different visitor partitioning between conspecific flowers, pollen can move over large areas and keep neighboring flower communities genetically connected. While agent-based modeling of pollen movement is not yet widely used, this tool has great potential to improve understanding of pollination in agricultural contexts and aid efforts to protect declining insect populations.

Pedagogical Approaches to Mathematics Instruction: Finding a Balance Between Lectures and Discovery

Edward Lachance Lauber

Math education is an issue of critical importance in the United States and around the world, yet there is still no scientific consensus on the best ways to teach math. One of the central debates concerns the use of discovery-based learning in comparison to more standard lecture techniques. Some theorists argue that students cannot learn without discovering material for themselves, while others contend that more structured lectures enable students to learn much more. In this study, we set up multiple classrooms with three different teaching paradigms: a lecture condition, a discovery condition, and a mixed condition. Over the course of three days, participants studied the same material on cake-cutting and fair division. Our findings revealed no significant differences between conditions, indicating that perhaps there is no single best way to teach this material.

Assessing Critical Mass at UC-Berkeley: Creating Predictive Models for Affirmative Action Policies in Undergraduate Admissions in the United States

Daniel Paul Maes

Affirmative action refers to hiring and recruiting practices designed to combat discrimination against members of certain demographic groups. These policies are used in settings ranging from federal contractors to local employment to public education, and can focus on race, ethnicity, or gender. Due to the broad applicability and direct social impact of affirmative action, substantial effort has gone into monitoring the necessity and effectiveness of these policies. This effort has manifested itself in frequent legal and state action over the past forty years. In this thesis, we focus on the application of race-based affirmative action policies in public undergraduate college admissions in the United States, specifically through a case study of admissions to the University of California, Berkeley. We make three primary contributions. First, we introduce a quantitative framework through which to interpret a key concept used in contemporary affirmative action litigation: "critical mass." Historically, policies have been assessed using retroactive data studies. However, using predictive models would reduce the monetary and temporal costliness of such studies. Thus, second, we construct a predictive model of college admissions demographics using Markov Chains. Third, we bring together the two previous contributions, using our quantified version of the critical mass criterion as a benchmark for assessing the outcomes of the predictive model. The type of mathematical model we construct can be modified for use at other universities or for affirmative action applied to other axes, including gender.

Finding a Model for the Density of States of RNA

Eliza Woolworth Matt

RNA molecules can adopt a multitude of fold configurations of varying free energy G. The Boltzmann probability suggests the average energy should be near the minimum free energy, but surprisingly we find the difference between the average energy and minimum free energy to be much larger than the product of the Boltzmann constant and the temperature. In this thesis, we show this is because the density of high-energy states grows more quickly than the Boltzmann factor suppresses. We observe this for RNAs across sequence lengths and types, both randomly generated and natural, coding and non-coding. We find that both a flattened exponential and a hyperbolic function are able to approximate well the observed density of states better than either a power law function or a standard exponential function.

Longitudinal Regression Trees and Their Application to Body Mass Index Growth Trajectories

Anna Neufeld

A growing body of scientific literature suggests that exposure to environmental pollutants during key periods of development can cause lasting changes in an individual's metabolism. These changes can impact an individual's body mass index (BMI) trajectory and risk of obesity later in life. Given the complex ways in which environmental pollutants interact with one another and the challenges of studying trajectories over time, nontraditional statistical models are needed to truly understand the relationship between environmental pollutants and an individual's BMI trajectory. Our goal is to cluster individuals with similar BMI trajectories and similar chemical exposures so as to understand which environmental pollutants may cause heightened risk of obesity. We propose longitudinal regression trees as a promising approach to accomplishing this goal. While a few algorithms for longitudinal regression trees have been previously developed, they have never been applied with the goal of clustering growth trajectories. We compare several existing longitudinal regression tree algorithms in a simulation study setting, and evaluate the potential of these algorithms for tackling the BMI growth trajectory problem. Along the way, we propose modifications to existing algorithm so that we can group individuals by the change in their BMI over time, rather than by the level of their BMI. We then demonstrate the potential of the existing algorithms and the modified algorithm on real BMI trajectories from the National Longitudinal Survey of Youth (NLSY).

Multi-Crossing Braids

Daishiro Nishida

Traditionally, knot theorists have considered projections of knots where there are two strands meeting at every crossing. A multi-crossing is a crossing where more than two strands meet at a single point, such that each strand bisects the crossing. In this thesis we generalize ideas in traditional braid theory to multi-crossing braids. Our main result is an extension of Alexander's Theorem. We prove that every link can be put into an n-crossing braid form for any even n, and that every link with two or more components can be put into an n-crossing braid form for any n. We find bounds on the number of strings or crossings necessary to represent a link in an n-crossing braid. We explore different ways to obtain multi-crossing braids, and use these techniques to find new multi-crossing numbers.

Representing Tropical Intersection Curves

Andrew Louis Scharf

Many studies of tropical curves (one-dimensional tropical varieties) in the plane have been made possible due to the existence of an associated polygon from which combinatorial properties of the curve can be derived. More concretely, if a curve C is the vanishing locus of a tropical bivariate polynomial f, then C is dual to the induced subdivision of the Newton polygon Newt(f). Here we study an analogous situation with tropical curves that arise as the intersections of tropical surfaces in 3 dimensions, for which there exists an associated 4-dimensional Cayley polytope. We explore combinatorial properties of intersection curves that can be derived from this correspondence, ways of representing the Cayley polytope in lower dimensions, and computational methods used to assess the types of curves associated with a given polytope.

Finite Subsets of the Prime Spectra of Local UFDs

Alex Paul Semendinger

In a 2017 paper, Avery et al. characterized the completions of noncatenary local (Noetherian) UFDs. This was accomplished using a construction similar to one used by Heitmann in a 1993 paper. However, we know very little about the prime ideal structures of the UFDs obtained with this construction. We adjust Avery et al.'s techniques, allowing for greater control over the prime ideal structure of the constructed UFDs. This expands our collection of examples of noncatenary local (Noetherian) UFDs and gives insight into the question of which partially ordered sets can arise as the prime spectrum of a Noetherian UFD.

Using Data to Predict Hospital Readmissions at Berkshire Medical Center

Hallee Erica Wong

Hospital readmission -- whether a patient returns to the hospital within 30 days of discharge -- is a popular metric in healthcare policy because frequent hospitalizations are a negative outcome for both hospitals and patients' health. A model to identify patients with high risk of readmission would enable hospitals to optimize the allocation of resources. Analyzing a dataset of hospitalizations from Berkshire Medical Center, we fit models to predict readmission using logistic regression, decision trees, ensembles of models, and integer programming-based methods. To strategically utilize high dimensional medical code data, we consider ensemble models in which patients are stratified by primary diagnosis and separate models are fit for each group. We show that an ensemble model stratified on the existing hierarchy in the International Classification of Diseases (ICD-10) performs significantly worse than a single global model. We propose a new method, Categorical Co-Frequency Analysis (CCoFA), that uses random forests to identify relationships between categorical labels. Applying CCoFA to identify three disparate clusters of patients defined by diagnosis, we show the performance of an ensemble model stratified on CCoFA clusters is not statistically significantly different from that of a single global model. Additionally, we compare the performance of RiskSLIM (Ustun and Rudin, 2017), an integer programming-based method, to logistic regression and decision trees. Using RiskSLIM to generate a risk scoring system with integer coefficients leads to a model with lower accuracy than logistic regression with real-valued coefficients.

An Unacountable Dimension-Two Ring With a Countable Spectrum

Weitao Zhu

In this paper, we construct a quasi-semi-local ring with two maximal ideals M and N, where M contains only countably many prime ideals but N contains uncountably many. When we localize this ring at its maximal ideal M, we produce an uncountable dimension-two Noetherian local ring with a countable spectrum, reproducing a result of Colbert for dimension-two rings.

Neuroscience

Honors theses written under the supervision of Biology and Psychology faculty are listed in the appropriate department section.

Physics

Environment-Assisted Quantum Transport in Fully Connected Networks

Sam Baudon Alterman

The quantum nature of energy transport in photosynthetic light-harvesting complexes has for several years been an area of active research in the study of quantum systems, with the Fenna-Matthews-Olson (FMO) complex of the green sulfur bacteria Chlorobium limicola frequently used as a test case. An area of particular interest has been the numerically observed phenomenon of environment-assisted quantum transport (ENAQT), where normally destructive environmental noise in fact increases the efficacy of energy transport. A proposed mechanism for ENAQT is the Goldilocks principle, which posits that efficiency is increased in a quantum system when the various time scales of the system are of the same order of magnitude.

In my thesis, we develop an analytic model for network-based excitonic energy transfer in a noisy environment, accounting for exciton dissipation, trapping, and dephasing. We additionally allow the trapping site to have a different energy from the other sites, a configuration which has not been considered in previous analytic works but which has intriguing connections to analog quantum search algorithms. We then use a quantum Master equation to derive the long-range efficiency and transfer rate of energy transport.

From our equations for efficiency and transfer rate, we are able to replicate the ENAQT behavior previously observed in the literature, and also provide evidence for the Goldilocks principle. Additionally, we find that an energy offset is indeed beneficial to transport, and observe that correctly matching the offset to the system's preferred time scale appears to be an extremely significant factor in the efficacy of transport. This suggest that quantum search algorithms may play a role in photosynthetic energy transport, and raises the question of whether the Goldilocks principle could be used to increase the efficiency of analog quantum search algorithms at experimentally relevant temperatures.

Numerical Simulations of Bichromatic Laser Cooling

Ellery Galvin

Optical control and manipulation of atoms at the quantum level is at the heart of several atomic physics experiments. In this work, we model the evolution of electronic and motional states of an atom interacting with laser fields. We use a numerical approach known as Monte Carlo Wave Function simulations to model the driving and dissipative interactions of the atom with the reservoir made of electromagnetic vacuum modes. This approach is applied to the cases of Doppler laser cooling and bichromatic laser cooling and culminates with results comparable to recent experimental [1] and theoretical [2] work.

[1] C. Corder, B. Arnold, and H. Metcalf, Physical Review Letters 114 (2015).

[2] C. Corder, B. Arnold, X. Hua, and H. Metcalf, Journal of the Optical Society of America B (2015).

Finding a Model for the Density of States of RNA

Eliza Matt

RNA molecules can adopt a multitude of fold configurations of varying free energy G. The Boltzmann probability suggests the average energy should be near the minimum free energy, but surprisingly we find the difference between the average energy and minimum free energy to be much larger than the product of the Boltzmann constant and the temperature. In this thesis, we show this is because the density of high-energy states grows more quickly than the Boltzmann factor suppresses. We observe this for RNAs across sequence lengths and types, both randomly generated and natural, coding and non-coding. We find that both a flattened exponential and a hyperbolic function are able to approximate well the observed density of states better than either a power law function or a standard exponential function.

Towards an Analog Quantum Simulation of Heat Transport in a Dual-Species Ion Chain

Ashay Patel

We have begun a precision measurement of the 729 nm 4S1/2-3D5/2 E2 transition isotope shift in the even isotopes of Ca+, a step towards our longer-term goal of performing a quantum simulation of nanoscale heat transfer with ions in a surface-electrode RF Paul trap.

In support of this goal, we first completed the construction of our experimental apparatus and implemented automated experimental control. We then used our trapped ions as a probe to characterize the performance of our ion trap. We demonstrated global compensation of stray electric fields in the trap, thus creating a field-free zone over which one can assemble ion chains. We then designed trap electrode voltages to merge and split potential wells. This set of potentials allowed us to deterministically trap up to six ions in a chain. Using the merge/split voltages and a modified set of laser frequencies, we co-loaded a dual-species ion chain. Finally, having locked our 729 nm laser, we probed the ion E2 transition spectrum using electron shelving, collecting preliminary isotope shift data for 40Ca+ -44Ca+ by using an EOM to span the isotope shift and an AOM to scan over the transition in each ion.

Development of Laser Systems toward Ultrafast Electron Diffraction Experiments

Emily Stump

This thesis describes two pulsed laser systems that will be used in ultrafast electron diffraction experiments. A titanium:sapphire (Ti:sapph) laser was assembled and aligned as a source of femtosecond pulses. In order to characterize these pulses, the wavelength power spectrum of the pulses was measured and its full width at half maximum was determined to be 20.8 nm. An autocorrelator was designed and built in order to measure the temporal width of the output pulses. This width was determined to be 100 fs, with an error of 30 fs. These measurements will guide the future assembly of a prism compressor to decrease the width of the Ti:sapph pulses. Progress has also been made in developing tools to simulate a pulsed fiber laser, which will be useful in the future construction of such a laser.

High-precision polarizability and transition amplitude measurements in In and Pb using vapor cell and atomic beam spectroscopy

Bingyi Wang

This thesis includes recent work in two precision measurements using laser spectroscopy in indium and lead. First, I present the completed high-precision measurements of the Stark shift polarizabilities in the $7P_{1/2}$ and $7P_{3/2}$ excited states of ^{115}In in an atomic beam. Our final result for the scalar polarizabilities are $1.811(4)\times10^5\ a_0^3$ and $2.876(6)10^5\ a_0^3$ for the $7P_{1/2}$ and $7P_{3/2}$ states respectively (in atomic units). These are a factor of 30 to 50 times greater than the previously measured indium polarizabilities in our lab. For the tensor polarizability component of the $7P_{3/2}$ state, we estimate its value to be $-1.43(18)10^4\ a_0^3$. These measurements represent the first high-precision benchmarks of transition proprieties of such high excited states of trivalent atomic systems. The precision of our experiment is sufficient to differentiate between the *ab initio* calculations of indium polarizabilities using two distinct theoretical models, as well as to allow precise determination of the indium $7P$ - $6D$ matrix elements. Second, I present our progress towards measuring the $6s^26p^2\ {}^3P_0 \rightarrow {}^3P_2$ electric quadrupole (E2) transition amplitude in relation to the known $6s^26p^2\ {}^3P_0 \rightarrow {}^3P_1$ magnetic dipole (M1) transition amplitude, using Faraday rotation spectroscopy in a lead vapor cell. We employ the Faraday rotation technique to detect induced optical rotations with sensitivity at the few μrad level, revealing the previously unobserved E2 transition. We have improved the apparatus and developed a new data acquisition and analysis method, as necessary preparatory work to a precise measurement of the E2 transition amplitude. Both precise measurements serve as tests to recent theoretical predictions of these quantities and provide much-needed guidance for the future refinement of theoretical approaches to complicated atomic systems.

Psychology

Egocentric Biases and Emotion Expression: The Existence of an Illusion of Transparency when Conveying Information Using Emotion Expressions of Varied Types

Kendall Bazinet

The psychological literature on emotion expression has long focused on facial expressions almost exclusively as the modality of expression that gets researched. Recent studies have looked into vocal bursts, another one of countless different methods of expressing emotion, while some authors cite a need for more research into the multimodal nature of emotion expression. Meanwhile, research on egocentric biases in the past two decades, especially on the illusion of transparency, has gradually expanded from applying to the concealment of emotion, to the conveyance of information, and then to the intentional expression of emotion. One study by Savitsky and MacIntosh (2002) went so far as to provide some evidence for an illusion of transparency in that we overestimate how identifiable the specific emotions we express in facial expressions are to other people. The current research aims to extend on the finding that there is an illusion of transparency in facial expressions by finding similar effects for both the expression of emotions via vocal bursts and the expression of emotions multimodally. The findings in Study 3 highly suggest that an illusion of transparency exists for both vocal bursts and multimodal emotion expressions as it does for facial expressions, and additionally by measuring the intensity of the emotion being expressed this study was able to find data that corroborated the anchoring and adjustment mechanism behind the illusion of transparency. Insight into the mechanism often lying underneath the mismatch between the emotions we think we convey and the emotions other people perceive coming out of us may simply lead to better communication in general, aided by the idea that this mismatch can likely be overcome with deliberate thought like other cognitive biases. Future research could extend upon the modalities in which emotions are expressed, very possibly looking at things like body language.

Steadying the Scales of Justice: How Citizens Morally Weight the Different Outcomes of a Justice System

Griffin Colaizzi

Determining the effectiveness of a criminal justice system requires making moral judgments. There have been no scientific attempts at measuring and making quantifiable moral judgment about a justice system. In this study we ascertained how citizens morally weight the different outcomes of a justice system. We found that reminding participants that a guilty criminal is still on the loose in a False Alarm, Correct Rejection, and No-Arrest scenario led participants to weight these outcomes more negatively. We also found that participants generally weight Hits as very good and False Alarms as very bad. Misses and Correct Rejections were weighted as equal negative outcomes. We added No-Arrest as a possible outcome and participants considered it to be a negative outcome and weighted as worse than both Misses and Correct Rejections. Finally, we utilized the weights provided in the studies to create a utility model which can be used to measure the effectiveness of a criminal justice system. Implications of these findings on eyewitness accuracy measurements are also discussed.

Storytellers and Philosophers: How Children Learn to Think About Ideas

Anna DeLoi

Engaging with abstract ideas is a vital part of leading a meaningful and successful life. However, educational systems have placed very little emphasis on children's ideas; therefore, there is no consensus about how young children begin working with them or whether we can help them to do so more easily. Through a series of four studies with kindergarten through 2nd grade students, we investigated the relationship between narrative thinking and children's ability to discuss, learn, and generate ideas. In Study 1, we compared participants' willingness to engage with an idea when it was introduced through a story they could easily relate to, a story that was less relatable, or a simple, abstract definition of the idea. In Study 2, we assessed participants' understanding of an idea that was unfamiliar to them, when that idea was introduced earlier through a story or a simple, abstract definition. In Study 3, we measured participants' ability to generate original ideas after being primed with either a story that was rich in abstract ideas or a story that did not contain ideas. In Study 4, we gave students the opportunity to choose what topic they most wanted to talk about and elicited their ideas about that topic. Participants who heard the narrative materials in Studies 1 and 2 were more engaged in idea-based discussions and more able to successfully learn new ideas. Study 4 showed that children prefer discussing ideas about animals and the natural world than those about humans. Studies 3 and 4 suggested that children generate ideas using specific narrative thinking strategies, a model that invites testing in future research. Overall, our findings indicate that narrative thinking is deeply tied to children's interest in and ability to engage with abstract ideas.

Face it, Actions Matter: The Role of Visual Cues and Behavioral Information on Visual Representations

Kathryn Flaharty

Our ability to call to mind visual depictions of other people's faces helps to orient us to our social environment. However, data from eyewitness misidentification tells us that our mental recall of faces is not always accurate. What are the factors that can lead to these inaccuracies? The main goal of this project is to examine two factors that may contribute to bias in our memory of others' faces: visual information communicated by the face, such as cues to trustworthiness or dominance, and behavioral information about the target individual. In three studies, I manipulate features of a person's facial characteristics as well as information provided to participants about their actions and observe how these two factors influence the visual representations they develop of their facial characteristics. In Study 1a and 1b, I manipulate visual cues of trustworthiness. Study 1a made use of an extremely untrustworthy behavior whereas Study 1b made use of an extremely trustworthy behavior. In Study 2, I manipulate a cue that is orthogonal to the behavior by manipulating dominance and submissiveness, but expose participants to an extremely untrustworthy behavior. All three studies support the idea that behavioral information can bias people's visual impressions. However, there was also evidence for a valence asymmetry in formation and updating, as well as evidence for interactions between the visual cue and the behavior. These findings provide insight into the formation and alteration of visual representations by way of visual cues and diagnostic behavioral information.

Who Cares?: Discounting Different Types of Evidence for a Racial/Gender Match in Psychotherapy

Gabrielle Ilagan

Experts have taken sides in the "great debate" about empirically supported treatments (EST) versus evidence-based practice (EBP), with one contentious point being the generalizability of randomized control trial results to minorities underrepresented in these studies. Although client preferences for racial and gender matching have previously been studied, whether clients have preferences about the types of evidence supporting their treatments is unknown. We examined these variables in tandem, by examining how much effectiveness people are willing to discount to guarantee a racial or gender match, and whether that preference is affected by the purported nature of the evidence supporting the therapy. Participants (53% male, 35.8% racial minority) were 172 college students and 96 adults recruited through Amazon Mechanical Turk (MTurk). They were randomly assigned to read one description of evidence-based practice that defined "evidence" as based on (a) the EST approach; (b) the EBP approach; or (c) a fabricated "No Research" (NR) approach that counted therapist experience as the sole source of evidence. Using a discounting method (Swift et al., 2015), participants were asked to indicate their preference strength for a racial match and a gender match with a therapist. Most were unwilling to discount effectiveness in exchange for a match, and there were no main effects of condition. Female participants had stronger preferences for gender matching compared to male participants. Significant differences between the samples emerged: college students were much less willing, and MTurk workers much more willing, to discount effectiveness in the EBP condition. Also, racial minorities from the college sample had the strongest preferences for a racial match, whereas minority MTurk workers the weakest preference. Our results suggest clients may not have preferences regarding the type of evidence supporting treatments, and results from studies involving only one kind of population may have limited generalizability.

Equity Restoration: An Experimental Test of Self-Sabotage Following Unfair Advantage

Brenna Martinez

Participants were told that they were competing in an online trivia competition against a classmate (Study 1) or a stranger (Study 2). Halfway through this competition, participants in the manipulation conduction in

Study 1 received an unfair advantage when their competitor was marked wrong for a correct answer. In Study 2 there was an added condition where participants were unfairly advantaged by being marked correct for their own wrong answer. Then participants were given the opportunity to sabotage their subsequent performance to restore equity by choosing how difficult their following task would be (Study 1 and 2), or by actually performing a task that required clicking (Study 1). There were no significant effects of the manipulation in either study, despite evidence that the participants did view what happened to their competitor as an injustice.

Family Nurture Intervention and Maternal Physiology

Anika Mitchell

The neonatal intensive care unit (NICU) is a particularly stressful environment for the development of a healthy mother-infant dyadic attachment—what many would consider the foundation of development (Bowlby, 2008; Weinfield, Sroufe, Egeland, & Carlson, 1999). It is within this particular ecology that preterm and both physically and physiologically fragile infants are faced with their first jarring extrauterine experience characterized by 15-20 daily skin puncturing procedures, bright lights, loud noises, and artificial regulatory technologies. Perhaps more impactful than the exposure to new stimuli in this physiologically demanding environment is the maternal-infant separation in the NICU. While much research has focused on the physiological implications of NICU admission for preterm and very low birth weight infants, little has examined the physiological dysregulation of mothers as they care for their infants in the NICU. Just as the stressful NICU sets the stage for an infant's transition from intrauterine to extrauterine life, the NICU serves as the stage for mothers of preterm infants to transition from pregnancy to motherhood. Expectations for motherhood include caring for one's infant and feeling efficacious in doing so. This study seeks to elucidate patterns of physiological regulation and/or dysregulation in mothers as they care for their preterm infants in the NICU within the context of an intervention called the Family Nurture Intervention (FNI). This intervention aims to increase maternal-infant connection within the NICU and is based in Dr. Martha Welch's calming cycle theory (M. G. Welch, 2016). In a randomized control trial (RCT) subjects were assigned to either an FNI condition or a Standard Care (SC, control) condition and asked to complete three caregiving tasks in the NICU; diaper change, hold, and feed. As mothers completed these caregiving tasks physiological data (ECG) were recorded. For the present study heart rate variability and vagal tone (RSA) were calculated, and analyzed across both groups. As hypothesized, diaper change was the most physiologically challenging task across the three caregiving tasks, evident by increased heart rate and low vagal tone across the sample. Additionally, relative to mothers in the SC condition, FNI mothers showed increased physiological regulation (higher RSA, vagal augmentation) during holding. This study provides preliminary evidence for the efficacy of the Family Nurture Intervention in improving maternal stress responding as they care for their preterm infants in the NICU. This study of mother's physiology in the NICU during caregiving tasks is novel and future studies should continue to investigate patterns of physiological reactivity and regulation in this ongoing study of the FNI.

Examining the Mechanisms Behind the Outcomes of Different Methods of Induced Rumination

Robert Rowledge

Why and how do different methods of reflecting on one's troubles have different effects? This study examined mechanisms underlying the different mental health outcomes of rumination, expressive writing, and co-rumination that have been demonstrated in the research literature. Participants (N = 88) were induced to ruminate via one of three methods and were tested at baseline, during the intervention phase of the study, and at two and four weeks following the interventions on several rumination behavior, internalizing symptom, and mood related measures. In the short term, there was significant decrease in participants' sadness from the first to the second intervention and those in the co-rumination condition felt happier immediately after the intervention. In the longer term, the expressive writing interventions did not lead to decreases in stress, anxiety, or depressive symptoms, and contrary to previous findings; those in the expressive writing condition saw increased anxiety at the last follow-up from their baseline scores. There was a significant interaction between time and condition on rumination and co- rumination, such that those in the co-rumination condition maintained rumination habits over time, while participants in the other conditions, either reported decreases in the habits. These results provide evidence for a model in which co-ruminating with a friend is positively reinforcing, but may also serve to maintain levels of rumination on one's own, which is associated with increased internalizing symptoms, depression, and anxiety.

The Influence of Neonatal Maternal Care on Juvenile Behavior in Rats Selectively Bred for an Infantile Affective Trait

Lauren Steele

Human temperament is shaped by genetic inheritance and maternal care, which in turn influences how we interact with others. Temperament is relatively stable over the lifespan, but quality of maternal care is a factor that can play a role in longitudinal temperament change. This thesis developed a new paradigm to quantify maternal care in an animal model of temperament: two lines of rats selected for their rate of distress calls after a brief maternal separation (Low and High lines). It then determined if differences in prior maternal care could account for variations in juvenile Low and High offspring's behavioral phenotypes. Dams from both lines were observed when their pups were five days old in a four-part maternal behavior paradigm. At 32 days of age, offspring of these dams were observed in pairs for their social behavior and activity in an animal model of childhood internalizing and externalizing behavioral profiles. We found that maternal self-attention mediated Line's effect on passive juvenile contact and that maternal rearing during a forced separation mediated Line's effect on juvenile social approach. However, active social play was not mediated by maternal care. The High's reliance on passive social contact with a conspecific and the Low's tendency towards active play respectively map onto juvenile internalizing and externalizing behaviors. These results indicate that maternal care and genetics work together to predict juvenile social behaviors in rats.

Perceptions of Student Misbehavior and Psychological Intervention: Three Empirical Studies

Keiana West

This project comprised studies, two of which examined the effects of student race and gender on causal attributions and intervention recommendations regarding student misbehavior. In a 2x3 between-groups design, 409 middle and high school teachers (Study 1) and 160 high school students (Study 2) read a scenario of a hypothetical misbehaving student in which the race (Black, Latinx, White) and gender (female, male) of the student were manipulated, then responded to a questionnaire regarding their perceptions of the misbehavior. Teacher characteristics (gender and years of teaching experience) and student participant characteristics (race, gender, and academic and behavioral characteristics) were also assessed. The hypothetical student's race and gender affected some, but not all, causal attributions for misbehavior and perceptions of interventions. For instance, teachers were less likely to attribute misbehavior to mental health issues if they were told the student was Black vs. White and had stronger teacher-related attributions for Black boys vs. White and Latino boys. Both teacher gender and hypothetical student gender influenced perceptions of psychological intervention; in general, counseling was expected to be more useful for boys and by female teachers. Study 3 assessed the influence of student race, gender, and academic/behavioral characteristics on their willingness to seek psychological help. Students with fewer behavioral issues were more willing to seek psychological help for emotional or behavioral crisis. Implications of the findings with regard to gender biases, educational policy and practice are discussed.

Abstracts from Faculty and Student Publications

Astronomy

Resource Letter OSE-1 on Observing Solar Eclipses
Pasachoff, Jay M., and Andrew Fraknoi

American Journal of Physics 85(7), 485-494, July 2017

This Resource Letter provides a guide to the available literature, listing selected books, articles, and online resources about scientific, cultural, and practical issues related to observing solar eclipses. It is timely, given that a total solar eclipse will cross the continental United States on August 21, 2017. The next total solar eclipse path crossing the U.S. and Canada will be on April 8, 2024. In 2023, the path of annularity of an annular eclipse will cross Mexico, the United States, and Canada, with partial phases throughout those countries.

The Great Solar Eclipse of 2017
Pasachoff, Jay M.

Scientific American, 317, #2, 54-61, August 2017

On August 21, Americans in a narrow path from Oregon to South Carolina will be treated to a total eclipse of the sun. The eclipse offers a rare and precious opportunity to study the sun under conditions impossible at any other time. Scientists will be seeking answers to lingering mysteries such as ho the sun's magnetic field shapes the solar corona, why the corona is so hot, and more.

Heliophysics at Total Solar Eclipses
Pasachoff, Jay M.

Nature Astronomy 1, article number 0190, August 2017

Observations during total solar eclipses have revealed many former secrets about the solar corona, from its discovery in the 17th century to its million-kelvin temperature in the 19th and 20th centuries to more about its dynamics and role in the solar-activity cycle in the 21st century. Today's heliophysicists benefit from continued instrumental and theoretical advances. The coast-to-coast totality that will be visible uniquely from the United States for the first time ever, crossing coast-to-coast for the first time in 99 years, on 21 August 2017, will provide an opportunity not only for massive expeditions with the latest equipment in totality on the ground but also for observations from aloft in airplanes and balloons, all of which will be matched with observations from spacecraft old and new to provide the complete picture of the solar atmosphere that is available only on the days of total solar eclipses. This review explores the most recent decade of solar-eclipse studies, including advances in our understanding of the corona and its coronal mass ejections as well as terrestrial effects. We mention side effects of the eclipse observations, including recreating the original verification of the general theory of relativity.

Predicting the Corona for the 21 August 2017 Total Solar Eclipse
Mikic, Zoran, Cooper Downs, Jon A. Linker, Ronald M. Caplan, Duncan Mackay, Lisa Upton, Pete Riley, Roberto Lionello, Tibor Török, Viacheslav Titov, Janvier Wijaya, Miloslav Druckmüller, Jay M. Pasachoff, and Wendy Carlos

Nature Astronomy, 2017

Eclipses have long been a source of wonder and fascination, but they also have a unique place in the scientific discovery process. The total solar eclipse that occurred on 21 August 2017 across the United States provided an opportunity to test scientific theories of the solar corona. We used a magnetohydrodynamic model, driven by measured magnetic fields in the photosphere, to predict what the corona would look like, one week before the eclipse. Here we describe how this prediction was accomplished, and how it compared with observations of the eclipse in white light and extreme ultraviolet. We show that the prediction was successful, and that it gave us significant insight into the physics of the coronal magnetic field. The discrepancies that arise when observations are compared with models in this way are an opportunity to improve the models, forging the path to improved space weather prediction.

Science at the Great American Eclipse
Pasachoff, Jay M.

Astronomy & Geophysics (A&G), 59 (August 2017), 4.1-4.5

Jay Pasachoff rounds up the observations made across the continental US during the 2017 eclipse, by citizen scientists, individuals and groups of observers on the ground and by an array of spacecraft.

Education and Outreach about Science at the 2017 Eclipse
Pasachoff, Jay M.

The 2017 Total Solar Eclipse, Astronomical Society of the Pacific Conference Series, Sanlyn Buxner, Linda Shore, and Joe Jensen, eds., submitted., 2018

When a solar eclipse is visible from a country, especially a total solar eclipse, we astronomers have the attention of the general public in addition to that of scientists and students. At the time of the 2017 solar eclipse whose totality crossed the Continental United States, with a partial eclipse visible from all states, we were able to provide students and the general public, as well as scientists a wide range of substantial scientific information about eclipses, about the Sun, and about the rest of the Universe. For the Working Group on Solar Eclipses of the International Astronomical Union, we also acted as a liaison providing letters of invitation that were useful for foreign colleagues obtaining U.S. visas and helping to arrange observing locations.

Eclipse Megamovie 2017 Successes and Potential Future Work
Peticolas, Laura, Hugh Hudson, Calvin Johnson, Dan Zevin, Vivian White, Juan Carlos Martínez Oliveros, Igor-Ruderman, Justin Koh, David Konerding, Mark Bender, Christopher Cable, Brian Kruse, Darlene Yan, Larisza Krista, Braxton Collier, Andrew Fraknoi, Jay M. Pasachoff, Bryan Mendez, Alex Filippenko, Scott McIntosh, and Noelle Filippenko

The 2017 Total Solar Eclipse, Astronomical Society of the Pacific Conference Series, Sanlyn Buxner, Linda Shore, and Joe Jensen, eds., submitted.

In 2011, an "Eclipse Megamovie" was envisioned for the 2017 total solar eclipse that would be created using the public's photographs of the Sun's corona as frames in a movie illuminating dynamic changes in the chromosphere and corona. On August 21st, 2017 during and shortly after the total solar eclipse, our team collected photographs from thousands of volunteers with telescopes, DSLR (Digital Single Lens Reflex) cameras, and mobile device cameras setup across the path of totality. Our efforts resulted in 1,190 photographers contributing 50,016 DSLR photographs in a final open-source, public archive that is 766 GB in size. All photographs in this archive are creative commons zero, CC0, making them freely available for public use. From mobile devices, we obtained an archive of 60,000 images, 211 GBs in size. The first Eclipse Megamovie video was compiled and made available to the public a few hours after the moon's shadow left the U.S. East Coast. For two weeks, additional images were added to this video, as volunteers uploaded them to the project server. The project also resulted in a comprehensive website with profiles created by 12,749 users, several short documentaries, 190 articles and press releases, open-source code for use in future related efforts, and hundreds of public presentations across the country prior to the eclipse. Information on how to access these resources is included in the paper.

On the production of He, C, and N by low- and intermediate-mass stars: a comparison of observed and model-predicted planetary nebula abundances
R.B.C. Henry, B. G. Stephenson, M.M. Miller Bertolami, K.B. Kwitter, and B. Balick

Monthly Notices of the Royal Astronomical Society, 473, 241, 2018

The primary goal of this paper is to make a direct comparison between the measured and model-predicted abundances of He, C, and N in a sample of 35 well-observed Galactic planetary nebulae (PNe). All observations, data reductions, and abundance determinations were performed in house to ensure maximum homogeneity. Progenitor star masses ($M \leq 4\,M_{\odot}$) were inferred using two published sets of post-asymptotic giant branch model tracks and L and T(eff) values. We conclude the following: (1) the mean values of N/O across the progenitor mass range exceeds the solar value, indicating significant N enrichment in the majority of our objects; (2) the onset of hot bottom burning appears to begin around 2 $M_{\odot}$ i.e. lower than ~5 $M_{\odot}$ implied by theory; (3) most of our objects show a clear

He enrichment, as expected from dredge-up episodes; (4) the average sample C/O value is 1.23, consistent with the effects of third dredge up; and (5) model grids used to compare to observations successfully span the distribution over metallicity space of all C/O and many He/H data points but mostly fail to do so in the case of N/O. The evident enrichment of N in PN and the general discrepancy between the observed and model-predicted N/O abundance ratios signal the need for extra mixing as an effect of rotation and/or thermohaline mixing in the models. The unexpectedly high N enrichment that is implied here for low-mass stars, if confirmed, will likely impact our conclusions about the source of N in the Universe.

Turbulence in the TW Hya Disk

Flaherty, K.M., Hughes, A.M., Teague, R., Simon, J.B., Andrews, S.M., Wilner, D.J.

The Astrophysical Journal, 856, 117, 2018

Turbulence is a fundamental parameter in models of grain growth during the early stages of planet formation. As such, observational constraints on its magnitude are crucial. Here we self-consistently analyze ALMA CO(2–1), SMA CO(3–2), and SMA CO(6–5) observations of the disk around TW Hya and find an upper limit on the turbulent broadening of <0.08c s (α < 0.007 for α defined only within 2–3 pressure scale heights above the midplane), lower than the tentative detection previously found from an analysis of the CO(2–1) data. We examine in detail the challenges of image plane fitting versus directly fitting the visibilities, while also considering the role of the vertical temperature gradient, systematic uncertainty in the amplitude calibration, and assumptions about the CO abundance, as potential sources of the discrepancy in the turbulence measurements. These tests result in variations of the turbulence limit between <0.04c s and <0.13c s, consistently lower than the 0.2–0.4c s found previously. Having ruled out numerous factors, we restrict the source of the discrepancy to our assumed coupling between temperature and density through hydrostatic equilibrium in the presence of a vertical temperature gradient and/or the confinement of CO to a thin molecular layer above the midplane, although further work is needed to quantify the influence of these prescriptions. Assumptions about hydrostatic equilibrium and the CO distribution are physically motivated, and may have a small influence on measuring the kinematics of the gas, but they become important when constraining small effects such as the strength of the turbulence within a protoplanetary disk.

ALMA 1.3mm Map of the HD 95086 System

Su, K.Y.L., MacGregor, M.A., Booth, M., Wilner, D.J., Flaherty, K., Hughes, A.M., Phillips, N.M., Malhotra, R., Hales, A.S., Morrison, S., Ertel, S., Matthews, B.C., Dent, W.R.F., Casassus, S.

The Astronomical Journal, 154, 225, 2017

Planets and minor bodies such as asteroids, Kuiper-Belt objects, and comets are integral components of a planetary system. Interactions among them leave clues about the formation process of a planetary system. The signature of such interactions is most prominent through observations of its debris disk at millimeter wavelengths where emission is dominated by the population of large grains that stay close to their parent bodies. Here we present ALMA 1.3 mm observations of HD 95086, a young early-type star that hosts a directly imaged giant planet b and a massive debris disk with both asteroid- and Kuiper-Belt analogs. The location of the Kuiper-Belt analog is resolved for the first time. The system can be depicted as a broad (ΔR/R ˜ 0.84), inclined (30° ± 3°) ring with millimeter emission peaked at 200 ± 6 au from the star. The 1.3 mm disk emission is consistent with a broad disk with sharp boundaries from 106 ± 6 to 320 ± 20 au with a surface density distribution described by a power law with an index of -0.5 ± 0.2. Our deep ALMA map also reveals a bright source located near the edge of the ring, whose brightness at 1.3 mm and potential spectral energy distribution are consistent with it being a luminous star-forming galaxy at high redshift. We set constraints on the orbital properties of planet b assuming coplanarity with the observed disk.

IN-SYNC. V. Stellar Kinematics and Dynamics in the Orion A Molecular Cloud

Da Rio, N., Tan, J.C., Covey, K.R., Cottaar, M., Foster, J.B., Cullen, N.C., Tobin, J., Kim, J.S., Meyer, M.R., Nidever, D.L., Stassun, K.G., Chojnowski, S.D., Flaherty, K.M., Majewski, S.R., Skrutskie, M.F., Zasowski, G., Pan, K.

The Astrophysical Journal, 845, 105, 2017

The kinematics and dynamics of young stellar populations enable us to test theories of star formation. With this aim, we continue our analysis of the SDSS-III/APOGEE IN-SYNC survey, a high-resolution near-infrared spectroscopic survey of young clusters. We focus on the Orion A star-forming region, for which IN-SYNC obtained spectra of ˜2700 stars. In Paper IV we used these data to study the young stellar population. Here we study the kinematic properties through radial velocities (vr). The young stellar population remains kinematically associated with the molecular gas, following a ˜ 10 km/s gradient along the filament. However, near the center of the region, the v r distribution is slightly blueshifted and asymmetric; we suggest that this population, which is older, is slightly in the foreground. We find evidence for kinematic subclustering, detecting statistically significant groupings of colocated stars with coherent motions. These are mostly in the lower-density regions of the cloud, while the ONC radial velocities are smoothly distributed, consistent with it being an older, more dynamically evolved cluster. The velocity dispersion {σ }v varies along the filament. The ONC appears virialized, or just slightly supervirial, consistent with an old dynamical age. Here there is also some evidence for ongoing expansion, from a v r -extinction correlation. In the southern filament, σv is ˜2-3 times larger than virial in the L1641N region, where we infer a superposition along the line of sight of stellar subpopulations, detached from the gas. In contrast, σv decreases toward L1641S, where the population is again in agreement with a virial state.

A Three-Dimensional View of Turbulence: Constraints on Turbulent Motion in the HD 163296 Protoplanetary Disk Using DCO^+

Flaherty, K.M., Hughes, A.M, Rose, S.C., Simon, J.B., Qi, C., Andrews, S.M., Kospal, S., Wilner, D.J., Chiang, E., Aritage, P.J., Bai, X.

The Astrophysical Journal, 843, 150, 2017

Gas kinematics are an important part of the planet formation process. Turbulence influences planetesimal growth and migration from the scale of submicron dust grains through gas-giant planets. Radio observations of resolved molecular line emission can directly measure this non-thermal motion and, taking advantage of the layered chemical structure of disks, different molecular lines can be combined to map the turbulence throughout the vertical extent of a protoplanetary disk. Here we present ALMA observations of three molecules (DCO^+(3-2), $C^{18}O$(2-1) and CO(2-1)) from the disk around HD 163296. We are able to place stringent upper limits ($v_{turb} < 0.06c_s$, $<0.05c_s$, and $<0.04c_s$ for CO(2-1), $C^{18}O$(2-1), and DCO^+(3-2) respectively), corresponding to $\alpha \lesssim 3\times10^{-3}$, similar to our prior limit derived from CO(3-2). This indicates that there is little turbulence throughout the vertical extent of the disk, contrary to theoretical predictions based on the magnetorotational instability and gravitoturbulence. In modeling the DCO^+ emission, we also find that it is confined to three concentric rings at 65.7±0.9 au, $149.9_{-0.7}^{+0.5}$ {au}, and 259±1 au, indicative of a complex chemical environment.

Biology

Moving forward on individual heterogeneity

Sandra Hamel, Jean-Michel Gaillard, Nigel G. Yoccoz, Ron D. Bassar, Sandra Bouwhuis, Hal Caswell, Mathieu Douhard, Eric J. Gangloff, Olivier Gimenez, Phylis C. Lee, Isabel M. Smallegange, Ulrich K. Steiner, Oscar Vedder and Yngvild Vindenes

Oikos, 127: 750-756, 2018

The aim of this Oikos special issue entitled ’Individual heterogeneity: the causes and consequences of a fundamental biological process’ was to provide a balanced view of individual heterogeneity as a biological process relevant for a broad range of ecologists and not simply as a noisy process that needs to be accounted for to get reliable estimates of biological parameters. The methodological and empirical contributions included in this special issue provide a synthesis of the recent advances in measuring and quantifying individual heterogeneity. These contributions also provide a broad range of perspectives on the ecological and evolutionary causes and consequences of individual heterogeneity. The works compiled in this special issue emphasize the relevance of individual heterogeneity as a biological process that shapes a substantial proportion of observed variation in traits, which can drive population demography and eco-evolutionary dynamics. Following discussions held during the workshop (‘Ontogeny, adaptation, and chance in life-history trajectories: do individual differences matter?’ UiT The Arctic University of Norway, 13–15 October 2015) dedicated to this special issue, we propose a way forward in the study of individual heterogeneity in ecology and evolution, by identifying research gaps that still need to be filled and challenges that remain to be solved, both from a methodological and an empirical viewpoint.

Nutrients from salmon parents alter selection pressures on their offspring

Sonya K. Auer, Graeme J. Anderson, Simon McKelvey, Ronald D. Bassar, Darryl McLennan, John D. Armstrong, Keith H. Nislow, Helen K. Downie, Lynn McKelvey, Thomas A.J. Morgan, Karine Salin, Danielle L. Orrell, Alice Gauthey, Thomas C. Reid and Neil B. Metcalfe

Ecology Letters (2018) 21: 287–295

Organisms can modify their surrounding environment, but whether these changes are large enough to feed back and alter their evolutionary trajectories is not well understood, particularly in wild populations. Here we show that nutrient pulses from decomposing Atlantic salmon (Salmo salar) parents alter selection pressures on their offspring with important consequences for their phenotypic and genetic diversity. We found a strong survival advantage to larger eggs and faster juvenile metabolic rates in streams lacking carcasses but not in streams containing this parental nutrient input. Differences in selection intensities led to significant phenotypic divergence in these two traits among stream types. Stronger selection in streams with low parental nutrient input also decreased the number of surviving families compared to streams with high parental nutrient levels. Observed effects of parent-derived nutrients on selection pressures provide experimental evidence for key components of eco-evolutionary feedbacks in wild populations.

Predicting coexistence in species with continuous ontogenetic niche shifts and competitive asymmetry

Ronald D. Bassar, Joseph Travis, and Tim Coulson

Ecology, 98(11), 2017, pp. 2823–2836

A longstanding problem in ecology is whether structured life cycles impede or facilitate coexistence between species. Theory based on populations with only two discrete stages in the life-cycle indicates that for two species to coexist, at least one must shift its niche between stages and each species must be a better competitor in one of the niches. However, in many cases, niche shifts are associated with changes in an underlying continuous trait like body size and we have few predictions concerning conditions for coexistence for such a widespread form of ontogenetic development. We develop a framework for analyzing species coexistence based on Integral Projection Models (IPMs) that incorporates continuous ontogenetic changes in both the resource niche and competitive ability. We parameterize the model using experimental data from Trinidadian guppies and show how niche shifts and competitive symmetries impact species coexistence. Overall, our results show that the effects of competition on fitness depend upon trait-mediated niche-separation, trait-mediated competitive asymmetry in the part of the niche that is shared across body sizes, and the sensitivity of fitness to body size. Interactions among these processes generate multiple routes to coexistence. We discuss how our modeling framework expands results from two-stage models to mutli-stage or continuous stage models and allows for deriving predictions that can be tested in populations displaying continuous changes in niche use and competitive ability.

Local Adaptation in Trinidadian Guppies Alters Stream Ecosystem Structure at Landscape Scales despite High Environmental Variability

Troy N. Simon, Ronald D. Bassar, Andrew J. Binderup, Alex S. Flecker, Mary C. Freeman, James F. Gilliam, Michael C. Marshall, Steven A. Thomas, Joseph Travis, David N. Reznick, and Catherine M. Pringle

Copeia 105, No. 3, 2017, 504–513

While previous studies have shown that evolutionary divergence alters ecological processes in small-scale experiments, a major challenge is to assess whether such evolutionary effects are important in natural ecosystems at larger spatial scales. At the landscape scale, across eight streams in the Caroni drainage, we found that the presence of locally adapted populations of guppies (Poecilia reticulata) is associated with reduced algal biomass and increased invertebrate biomass, while the opposite trends were true in streams with experimentally introduced populations of non-locally adapted guppies. Exclusion experiments conducted in two separate reaches of a single stream showed that guppies with locally adapted phenotypes significantly reduced algae with no effect on invertebrates, while non-adapted guppies had no effect on algae but significantly reduced invertebrates. These divergent effects of phenotype on stream ecosystems are comparable in strength to the effects of abiotic factors (e.g., light) known to be important drivers of ecosystem condition. They also corroborate the results of previous experiments conducted in artificial streams. Our results demonstrate that local adaptation can produce phenotypes with significantly different effects in natural ecosystems at a landscape scale, within a tropical watershed, despite high variability in abiotic factors: five of the seven physical and chemical parameters measured across the eight study streams varied by more than one order of magnitude. Our findings suggest that ecosystem structure is, in part, an evolutionary product and not simply an ecological pattern.

Identification of discrete, intermingled hypocretin neuronal populations

Iyer M, Essner RA, Klingenberg B, Carter ME.

In press at *Journal of Comparative Neurology*

Neurons in the lateral hypothalamic area that express hypocretin (Hcrt) neuropeptides help regulate many behaviors including wakefulness and reward seeking. These neurons project throughout the brain, including to neural populations that regulate wakefulness, such as the locus coeruleus (LC) and tuberomammilary nucleus (TMN), as well as to populations that regulate reward, such as the nucleus accumbens (NAc) and ventral tegmental area (VTA). To address the roles of Hcrt neurons in seemingly disparate behaviors, it has been proposed that Hcrt neurons can be anatomically subdivided into at least two distinct subpopulations: a "medial group" that projects to the LC and TMN, and a "lateral group" that projects to the NAc and VTA. Here, we use a dual retrograde tracer strategy to test the hypotheses that Hcrt neurons can be classified based on their downstream projections and medial/lateral location within the hypothalamus. We found that individual Hcrt neurons were significantly more likely to project to both the LC and TMN or to both the VTA and NAc than would be predicted by chance. In contrast, we found that Hcrt neurons that projected to the LC or TMN were mostly distinct from Hcrt neurons that projected to the VTA or NAc. Interestingly, these two populations of Hcrt neurons are intermingled within the hypothalamus and cannot be classified into medial or lateral groups. These results suggest that Hcrt neurons can be distinguished based on their downstream projections but are intermingled within the hypothalamus.

AgRP neurons can increase food intake during conditions of appetite suppression and inhibit anorexigenic parabrachial neurons

Essner RA, Smith AG, Jamnik AA, Ryba AR, Trutner ZD, Carter ME

Journal of Neuroscience 37(36):8678-8687.

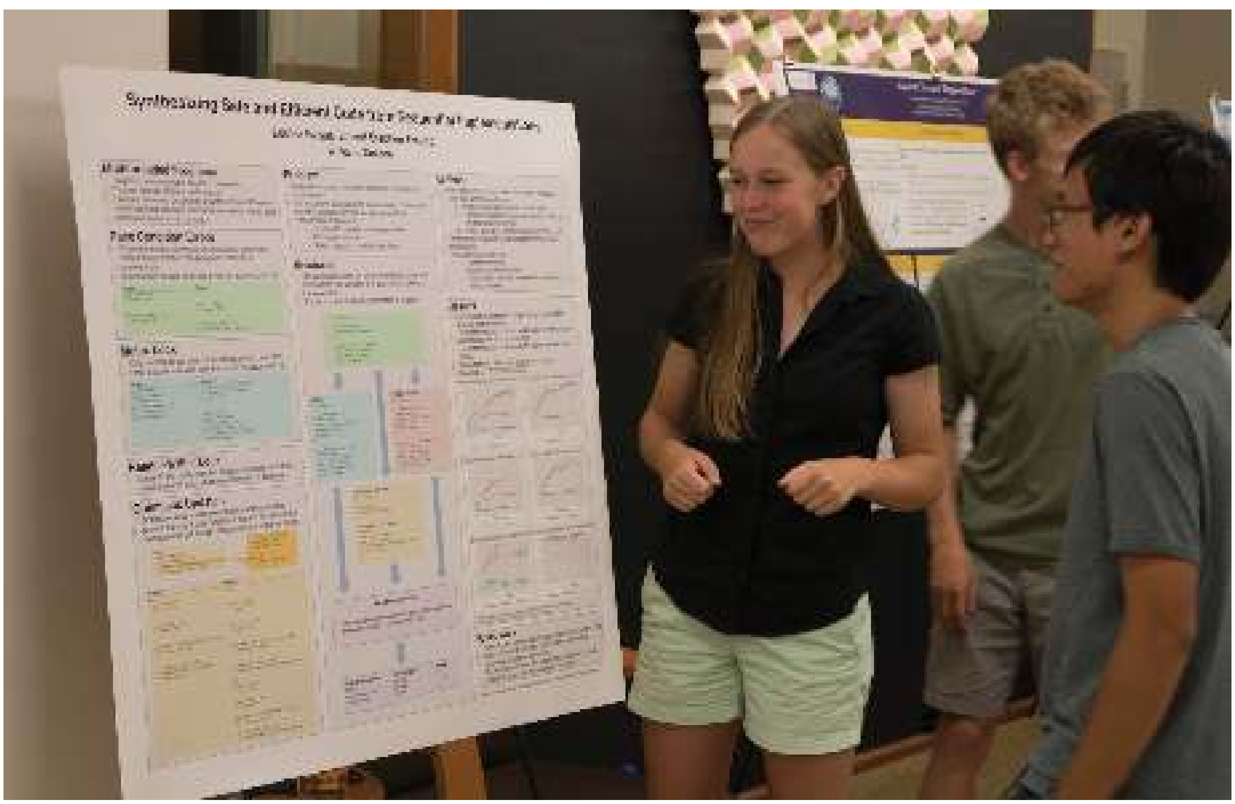
To maintain energy homeostasis, orexigenic (appetite-inducing) and anorexigenic (appetite suppressing) brain systems functionally interact to regulate food intake. Within the hypothalamus, neurons that express agouti-related protein (AgRP) sense orexigenic factors and orchestrate an increase in food-seeking behavior. In contrast, calcitonin gene-related peptide (CGRP)-expressing neurons in the parabrachial nucleus (PBN) suppress feeding. PBN CGRP neurons become active in response to anorexigenic hormones released following a meal, including amylin, secreted by the pancreas, and cholecystokinin (CCK), secreted by the small intestine. Additionally, exogenous compounds, such as lithium chloride (LiCl), a salt that creates gastric discomfort, and lipopolysaccharide (LPS), a bacterial cell wall component that induces inflammation, exert appetite-suppressing effects and activate PBN CGRP neurons. The effects of increasing the homeostatic drive to eat on feeding behavior during appetite suppressing conditions are unknown. Here, we show in mice that food deprivation or optogenetic activation of AgRP neurons induces feeding to overcome the appetite suppressing effects of amylin, CCK, and LiCl, but not LPS. AgRP neuron photostimulation can also increase feeding during chemogenetic-mediated stimulation of PBN CGRP neurons. AgRP neuron stimulation reduces Fos expression in PBN CGRP neurons across all conditions. Finally, stimulation of projections from AgRP neurons to the PBN increases feeding following administration of amylin, CCK, and LiCl, but not LPS. These results demonstrate that AgRP neurons are sufficient to increase feeding during noninflammatory-based appetite suppression and to decrease activity in anorexigenic PBN CGRP neurons, thereby increasing food intake during homeostatic need.

POMC neurons in heat: A link between warm temperatures and appetite suppression

Vicent MA, Mook CL, Carter ME

PLoS Biol. 16(5):e2006188.

When core body temperature increases, appetite and food consumption decline. A higher core body temperature can occur during exercise, during exposure to warm environmental temperatures, or during a fever, yet the mechanisms that link relatively warm temperatures to appetite suppression are unknown. A recent study in PLOS Biology demonstrates that neurons in the mouse hypothalamus that express pro-opiomelanocortin (POMC), a neural population well known to suppress food intake, also express a temperature-sensitive ion channel, transient receptor potential vanilloid 1 (TRPV1). Slight increases in body temperature cause a TRPV1-dependent increase in activity in POMC neurons, which suppresses feeding in mice. Taken together, this study suggests a novel mechanism linking body temperature and food-seeking behavior.



Louisa Nyhus '20 explains the work that she conducted with Professor Freund (Computer Science) during the summer science poster session in August 2018.

Chemistry

Comprehensive Characterization of Atmospheric Organic Carbon at a Forested Site

J. F. Hunter, D. A. Day, R. L. N. Yatavelli, B. B. Palm, A. W. H. Chan, L. Kaser, L. Cappellin, P. L. Hayes, E. S. Cross, Anthony. J. Carrasquillo, P. Campuzano-Jost, H. Stark, Y. Zhao, T. Hohaus, J. N. Smith, A. Hansel, T. Karl, A. H. Goldstein, A. Guenther, D. R. Worsnop, J. A. Thornton, C. L. Heald, J. L. Jimenez, and J. H. Kroll

Nature Geoscience, 10, 748-753, 2017.

Atmospheric organic compounds are central to key chemical processes that influence air quality, ecological health, and climate. However, longstanding difficulties in predicting important quantities such as organic aerosol formation and oxidant lifetimes indicate that our understanding of atmospheric organic chemistry is fundamentally incomplete, probably due in part to the presence of organic species that are unmeasured using standard analytical techniques. Here we present measurements of a wide range of atmospheric organic compounds—including previously unmeasured species—taken concurrently at a single site (a ponderosa pine forest during summertime) by five state-of-the-art mass spectrometric instruments. The combined data set provides a comprehensive characterization of atmospheric organic carbon, covering a wide range in chemical properties (volatility, oxidation state, and molecular size), and exhibiting no obvious measurement gaps. This enables the first construction of a measurement-based local organic budget, highlighting the high emission, deposition, and oxidation fluxes in this environment. Moreover, previously unmeasured species, including semivolatile and intermediate-volatility organic species (S/IVOCs), account for one-third of the total organic carbon, and (within error) provide closure on both OH reactivity and potential secondary organic aerosol formation.

Prediction of New Stabilizing Mutations Based on Mechanistic Insights from Markov State Model

M. I. Zimmerman, Katie M. Hart, C. A. Sibbald, T. E. Frederick, J. R. Jimah,
C. R. Knoverek, N. H. Tolia, G. R. Bowman

ACS Central Science, 3, 1131-1321, 2017.

Protein stabilization is fundamental to enzyme function and evolution, yet understanding the determinants of a protein's stability remains a challenge. This is largely due to a shortage of atomically detailed models for the ensemble of relevant protein conformations and their relative populations. For example, the M182T substitution in TEM β-lactamase, an enzyme that confers antibiotic resistance to bacteria, is stabilizing but the precise mechanism remains unclear. Here, we employ Markov state models (MSMs) to uncover how M182T shifts the distribution of different structures that TEM adopts. We find that M182T stabilizes a helix that is a key component of a domain interface. We then predict the effects of other mutations, including a novel stabilizing mutation, and experimentally test our predictions using a combination of stability measurements, crystallography, NMR, and in vivo measurements of bacterial fitness. We expect our insights and methodology to provide a valuable foundation for protein design.

Paleoenvironments of the last Neanderthals in SW Europe (MIS 3): Cova del Coll Verdaguer (Barcelona, NE of Iberian Peninsula)

J. Daura, M. Sanz, E. Allué, M. Vaquero, J. López-García, A. Sanchez-Marco, R. Domènech, J. Martinell, J. S. Carrión, J. Ortiz, T. Torres, L. J. Arnold, A. Benson, D. L. Hoffmann, Anne R. Skinner, R. Julià

Quaternary Science Reviews, 177, 34-56, 2017.

Marine isotope stage 3 (MIS 3) was characterised by marked oscillations of extreme cold episodes with very short warm events during the stadial, and several regional differences have been recorded in the ice cores and marine deposits. The aim of this study is to reconstruct this period by evaluating both terrestrial and regional responses. Cova del Coll Verdaguer, a site located on the Iberian Peninsula, preserves a sedimentary deposit dated to between 34 and 56 ka BP and provides an opportunity for evaluating the impact of climate changes on the regional landmass during a period that coincided with the last Neanderthal population on the Iberian Peninsula. Several dating methods, including U-series, electron spin resonance, amino acid racemization and radiocarbon (14C), were applied to the site and the ages obtained show good agreement. The biotic evidence obtained is substantial, comprising floristic data from palynology and charcoal analysis, and faunal data from large and small mammals, birds and gastropods. Environmental reconstruction points to an initially open meadow landscape at the base of the sequence (~56 ka) that

progressively changes to a woodland environment dominated by conifers (~34 ka). The presence of few *thermophilous* taxa, in contrast with lower latitudes of the Iberian Peninsula, is also detected. The environmental conditions of mid-altitude, Mediterranean, limestone mountains for the last Neanderthal populations appear to have been dominated by a forested landscape comprising boreal or mixed coniferous forest, characterised by a low usable biomass with poor comestible plant resources and dispersed herbivore populations.

ESR analyses for herbivore teeth and molluscs from Kharga, Dakhleh and Bir Tarfawi oases: Constraining water availability ad hominin Paleolithic activity in the Western Desert, Egypt

B. A. B. Blackwell, Anne.R. Skinner, J. R. Smith, C. L. Hill, C. S. Churcher, J. M. Kieniewicz, K. A. Adelsberger, J. I. B. Blickstein, J. A. Florentin, A. E. Deely, *Kassandra V. Spiller '16*

Journal of African Earth Sciences, 136, 216-238, 2017.

Today, Bir Tarfawi, Kharga and Dakhleh Oases all sit in Egypt's hyperarid Western Desert. A dearth of naturally occurring surface water coupled with _ 0.1 mm/y of precipitation, and evaporation rates >2 m/y make Bir Tarfawi uninhabitable today, while Dakhleh and Kharga depend on borehole water to support human inhabitation. Yet in scattered locations dotting the Quaternary surfaces and deposits near each oasis, Paleolithic artefacts, fossil ungulate teeth, and snails record times when surface water did exist in wetlands, small ponds, and even large lakes. At Bir Tarfawi in Marine Isotope Stages (MIS) 5, 7, and 13, wetlands or small lakes supported freshwater snails, large herbivores, and hominins. Dakhleh Oasis hosted a large lake in MIS 6 that provided a deep reliable water supply for many millennia subsequently.

ESR dates on fossils and tufa dates show thriving lacustrine and terrestrial ecosystems at Dakhleh during MIS 5, 7, 9, 11, and 17, and in shorter episodes in MIS 1, 2, 3, 6, and 12. At Kharga Oasis, springs discharged along the Libyan Escarpment edge, but the water was ponded in small basins dammed within tufa deposits. These dated deposits and fossils attest that water existed there in MIS 2e11, and one spot dating to ~ 2.3 Ma. This proxy evidence suggest that, thanks to higher rainfall and/or groundwater tables, sufficient water persisted for much of the Pleistocene, supporting food resources, like large herbivores and molluscs, to thrive and enabling hominin habitation and activity in the Western Desert.

Middle Stone Age human teeth from Magubike rockshelter, Iringa Region, Tanzania

P. R. Willoughby, T. Compton, S. M. Bello, K. M. Biittner, P. M. Bushozi, Anne R. Skinner, C. B. Stringer

PLoS One, 13(7): e0200530, July 2018.

In 2006, six isolated hominin teeth were excavated from Middle Stone Age (MSA) deposits at the Magubike rockshelter in southern Tanzania. They comprise two central incisors, one lateral incisor, one canine, one third premolar, and one fourth premolar. All are fully developed and come from the maxilla. None of the teeth are duplicated, so they may represent a single individual. While there is some evidence of post-depositional alteration, the morphology of these teeth clearly shares features with anatomically modern Homo sapiens. Both metric and non-metric traits are compared to those from other African and non-African dental remains. The degree of biological relatedness between eastern and southern African Stone Age hunter-gatherers has long been a subject of interest, and several characteristics of the Magubike teeth resemble those of the San of southern Africa. Another notable feature is that the three incisors are marked on the labial crown by scratches that are much coarser than microwear striations. These non-masticatory scratches on the Magubike teeth suggest that the use of the front teeth as tools included regularly repeated activities undertaken throughout the life of the individual. The exact age of these teeth is not clear as ESR and radiocarbon dates on associated snail shells give varying results, but a conservative estimate of their minimum age is 45,000 years.

Computer Science

Smart Homes: Undeniable Reality or Always Just around the Corner?

A. J. Brush '96, M. Hazas and J. Albrecht

IEEE Pervasive Computing, vol. 17, no. 1, Jan.-Mar. 2018.

With this issue, we're excited to launch the Smart Homes department of IEEE Pervasive Computing. Research on smart homes isn't new. Academics and practitioners have been envisioning smart homes for at least 50 years (some were presented at the International Conference on Computers in Architecture in 1972), and commercial home automation technology such as X10 (www.x10.com) was invented in the 1970s. However, recently there has been an explosion in connected devices for the home, in conjunction with declining prices and easier installation given the prevalence of home wireless networks. For example, traveling through the Seattle airport last year, we were surprised to spot video doorbell systems for sale alongside sunglasses (see Figure 1). With inexpensive wireless devices that don't require a home remodel, maturing standards, mobile devices for remote access, and the emergence of speech appliances as a user interface for in-home interaction, it's an exciting time for smart homes around the world. In this article, we'll highlight trends and research related to smart homes, focusing on different topics, inviting researchers in the area to share their personal perspective, and surveying recent conference and journal papers.

Smart Homes: Inhabited

A. J. Brush '96, M. Hazas and J. Albrecht

IEEE Pervasive Computing, vol. 17, no. 3, Jul.-Sep. 2018.

Although academics and researchers have been developing smart home technologies for about 50 years, for a long time the work was experimental at best—large numbers of people were not incorporating the technologies into their own homes. One of the biggest hurdles to the widespread adoption of smart home technologies was making devices work together. Several different networking

protocols were used for communication, and the configuration was challenging. In 1999, Kevin Ashton introduced the concept of the Internet of Things, and one of most exciting developments that grew from this was home automation technologies. By connecting devices to the Internet, it became more tractable to integrate smart home technologies into real homes. At the same time, sensors and gadgets themselves have been improving at a rapid rate. For example, technologies that use voice as a computing interface are gaining significant traction, and as the accuracy of voice recognition approaches 99%, experts predict that people will rely on them even more. As smart home devices continue to improve and more people adopt them, it is also becoming easier to study how people live with these technologies. In this article, we highlight recent research on the experiences of people living in smart homes.

VerifiedFT: A Verified, High-Performance Precise Dynamic Race Detector

James R. Wilcox '13, Cormac Flanagan, Stephen N. Freund

ACM Symposium on Principles and Practice of Parallel Programming, pages 354 - 367, 2018.

Dynamic data race detectors are valuable tools for testing and validating concurrent software, but to achieve good performance they are typically implemented using sophisticated concurrent algorithms. Thus, they are ironically prone to the exact same kind of concurrency bugs they are designed to detect. To address these problems, we have developed VerifiedFT, a clean slate redesign of the FastTrack race detector. The VerifiedFT analysis provides the same precision guarantee as FastTrack, but is simpler to implement correctly and efficiently, enabling us to mechanically verify an implementation of its core algorithm using CIVL. Moreover, VerifiedFT provides these correctness guarantees without sacrificing any performance over current state-of-the-art (but complex and unverified) FastTrack implementations for Java.

BigFoot: Static Check Placement for Dynamic Race Detection

Dustin Rhodes, Cormac Flanagan, Stephen N. Freund

ACM Conference on Programming Language Design and Implementation, pages 141-156, 2017

Precise dynamic data race detectors provide strong correctness guarantees but have high overheads because they generally keep analysis state in a separate shadow location for each heap memory location, and they check (and potentially update) the corresponding shadow location on each heap access. The BigFoot dynamic data race detector uses a combination of static and dynamic analysis techniques to coalesce checks and compress shadow locations.

With BigFoot, multiple accesses to an object or array often induce a single coalesced check that manipulates a single compressed shadow location, resulting in a performance improvement over FastTrack of 61%.

Correctness of Partial Escape Analysis for Multithreading Optimization

Dustin Rhodes, Cormac Flanagan, Stephen N. Freund

Workshop on Formal Techniques for Java-like Programs, pages 9:1-9:6, 2017

Compilers often use escape analysis to elide locking operations on thread-local data. Similarly, dynamic race detectors may use escape analysis to elide race checks on thread-local data. In this paper, we study the correctness of these two related optimizations when using a partial escape analysis, which identifies objects that are currently thread-local but that may later become thread-shared. We show that lock elision based on partial escape analysis is unsound for the Java memory model. We also show that race check elision based on a partial escape analysis weakens the precision of dynamic race detectors. Finally, we prove that race check elision based on a partial escape analysis is sound with respect to this weakened, but still useful, notion of precision.

The Full Path to Full Path Indexing

Yang Zhan, Alexander Conway, Yizheng Jiao, Eric Knorr, Michael A. Bender, Martin Farach-Colton, William Jannen, Rob Johnson, Donald E. Porter, and Jun Yuan

Proceedings of the 16th USENIX Conference on File and Storage Technologies (FAST '18), 123–138, 2018.

Full-path indexing can improve I/O efficiency for workloads that operate on data organized using traditional, hierarchical directories, because data is placed on persistent storage in scan order. Prior results indicate, however, that renames in a local file system with fullpath indexing are prohibitively expensive.

This paper shows how to use full-path indexing in a file system to realize fast directory scans, writes, and renames. The paper introduces a range-rename mechanism for efficient key-space changes in a write-optimized dictionary. This mechanism is encapsulated in the key-value API and simplifies the overall file system design.

We implemented this mechanism in BetrFS, an inkernel, local file system for Linux. This new version, BetrFS 0.4, performs recursive greps 1.5x faster and random writes 1.2x faster than BetrFS 0.3, but renames are competitive with indirection-based file systems for a range of sizes. BetrFS 0.4 outperforms BetrFS 0.3, as well as traditional file systems, such as ext4, XFS, and ZFS, across a variety of workloads.

How to Fragment Your File System

Alex Conway, Ainesh Bakshi, Yizheng Jiao, Yang Zhan, Michael A. Bender, William Jannen, Rob Johnson, Bradley C. Kuszmaul, Donald E. Porter, Jun Yuan, and Martin Farach-Colton

;login: magazine, Vol 42, No. 2, 6–11, Summer 2017.

File systems attempt to avoid aging, or fragmentation over time, by strategically allocating space for files. System implementers and users alike treat aging as a solved problem. Here, we present a realistic workload, based on Git, that can cause these best-guess file-block placement heuristics to fail, inducing large performance declines due to aging. This performance decline cannot be prevented with more caching or larger disks, and SSDs reduce but do not eliminate the aging effects. Our Git-based aging scheme can simulate a year of aging in under an hour. To make it easy for practitioners to incorporate aging into benchmarks, we have open-sourced our aging scripts at betrfs.org.

OARS: Exploring Instructor Analytics for Online Learning

Jon Bassen, Iris Howley, Ethan Fast, John Mitchell & CandaceThille

Proceedings of the 5th ACM Conference on Learning at Scale (L@S 2018)

Learning analytics systems have the potential to bring enormous value to online education. Unfortunately, many instructors and platforms do not adequately leverage learning analytics in their courses today. In this paper, we report on the value of these systems from the perspective of course instructors. We study these ideas through OARS, a modular and real-time learning analytics system that we deployed across more than ten online courses with tens of thousands of learners. We leverage this system as a starting point for semi-structured interviews with a diverse set of instructors. Our study suggests new design goals for learning analytics systems, the importance of real-time analytics to many instructors, and the value of flexibility in data selection and aggregation for an instructor when working with an analytics system.

Empirical Evidence for Evaluation Anxiety and Expectancy Value Theory for Help Sources

Iris Howley & Carolyn Rosé

Proceedings of the 13th International Conference of the Learning Sciences (ICLS 2018)

Expectancy-Value Theory for Help Sources (EVT-HS) states that whether or not students seek help from a particular source is determined by their perceived expectation that there will be help available, and the perceived value for the help from that source. This paper provides initial empirical validation for EVT-HS, while also introducing and providing support for costs of seeking help from a particular help source impacting intention to seek help. Our survey experiment shows that raising perceived expectancies and values for a help source significantly predicts a student's intention to seek help. Our results also show that evaluation anxiety, as a potential negative value, inversely predicts intentions to seek help from a particular source.

If an Algorithm is Open Accessible, and No One Can Understand it, is it Actually Open?

Iris Howley

Artificial Intelligence in Education Workshop on Ethics in AIED 2018

As blackbox algorithms play an increasing role in classroom decision-making, calls to "open" these algorithms and explain the inputs and latent variables that determine the decision outcomes grow increasingly louder. However, even systems using open algorithms face similar concerns. Using open algorithms does not mean that stakeholders (e.g., instructors, students, parents, etc.) of the system understand the connection between features in the underlying machine learning model and the outcomes displayed to them. Some algorithms (i.e., multilevel neural networks) are too complex to easily interrogate the decision-making process, but other algorithms (e.g., Bayesian Knowledge Tracing (BKT), classification, etc.) are considerably more comprehendible, but teachers and students still do not understand them. This work asks, what are the ethical implications of providing students and teachers with algorithmic decision-making software they could interrogate, but due to lack of knowledge, cannot interrogate and how might researchers help bridge that gap?

Geosciences

Examining the Marine Isotopic Gradient Through the Late Devonian Using Microfossils from the Kellwasser Horizons

Ezekiel King Phillips '18, Phoebe Cohen, Christopher Junium, and Benajim Uveges

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-307035, 2017

The Late Devonian is characterized by declining ρCO_2, increased deposition of organic matter, widespread anoxia, and marine extinctions, specifically prevalent in shallow low latitude seas. The biggest pulses of extinction are linked to widespread laminated black shales, known as the Kellwasser horizons, which are correlated with two positive excursions in $\delta^{13}C$ values of both carbonates and organic matter. In order to better understand the origin of these excursions, we extracted kerogens from black shales of the Kellwasser horizons at Cameron Creek and Eighteenmile Creek in upstate New York. Resulting macerates contained organic material that was predominantly of marine origin and include abundant and diverse organic-walled microfossils (i.e. acritarchs). To learn more about the driver of the $\delta^{13}C$ excursions and to help resolve unknowns about the paleoecology of the organic microfossils, we measured the $\delta^{13}C$ of 150 microfossils and kerogen grains using a cryotrapping, capillary-focusing 'nanoEA' for trace $\delta^{13}C$ measurements.

The $\delta^{13}C$ values of individual kerogen grains were isotopically similar between grains, as well as similar to bulk $\delta^{13}C_{org}$within each section. The $\delta^{13}C$ values of individual microfossils were variable between fossils and significantly different from coeval kerogens. The difference between the microfossil and kerogen values, Δacritarch or Δa, varies between sections, with the largest Δa values occurring in the bed below the Lower Kellwasser horizon and the bed containing the Upper Kellwasser Horizon. While the paleoecology and taxonomic affinity of these fossils is uncertain, the $\delta^{13}C$ values suggest that they are consistent with an algal origin. We speculate that the isotopic difference between bulk organic matter and the organic-walled microfossils may be the result of a surface water ecology where DIC is ^{13}C-enriched because of a strong biological pump. This work sets the stage for more nuanced analyses of carbon cycle dynamics across the end-Devonian extinction event and for a better understanding of Paleozoic organic-walled microfossil paleoecology.

New Approaches to Accessing High-Resolution Biogeochemical Signals from Ancient Organic Materials

Christopher K. Junium, Benjamin Uveges, Linda C. Ivany, Rowan C. Martinale, Phoebe A. Cohen, Shibajyoti Das, Alaina Hickey, *Ezekiel J. King Phillips '18*

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-305791, 2017

When assessing the geological record, the dynamics of the sedimentary environment blur our analytical resolution and limit our ability to understand processes that occur over decadal to subannual scales. Even with mm-scale sampling in marine rocks, the resulting organic material may comprise hundreds if not thousands of years. Yet within the geologic record, there are materials that reveal information about paleoecology, ontogeny, and environmental dynamics at extraordinary temporal resolution. Skeletal carbonates such as bivalves and corals grow over the course of years to decades, and contain trace quantities of organic matter within their shells that can be accessed and utilized for carbon and nitrogen isotope analyses. With nanoEA, which is a cryo-trapping, capillary focusing technique for nitrogen and carbon isotopes, we can begin to analyze recalcitrant organic material preserved in ancient skeletal carbonates as well as extractable organic materials such as individual organic microfossils.

We will highlight a suite of new organic nitrogen and carbon isotope data from Middle Devonian rugose corals and modern bivalves as well as carbon isotope measurements from individual Devonian organic microfossils and Eocene fossil wood. For example, the nitrogen isotopic composition of organic matter extracted from rugose corals is, on average, enriched by 2-3‰ relative to the bulk rock nitrogen in the host rock. Assuming that the bulk nitrogen is largely representative of the long-term primary production background, the modest enrichment is consistent with a trophic effect, and that rugose corals are planktivores. The organic content of the corals is extremely low, but nanoEA allows for serial sampling of 5-10 samples per coral. In an individual coral, δ15N ranges by 3-4‰ over the length of an individual coral, and when adjusted for trophic enrichment varies around the average δ15N of bulk sedimentary organic matter (2.0‰). The variability in the δ15N of the coral organic matter likely reflects short-term variability in basinal conditions or changes in coral food supply.

New Re-Os and U-Pb Age Constraints for the Biological Innovations and Geochemical and Climatic Perturbations of the Neoproterozoic

Alan D. Rooney, Justin V. Strauss, Phoebe A. Cohen, Daniel Condon, and Mark D. Schmitz

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-302273, 2017

Over the past two decades a renewed interest in the Neoproterozoic Era (1000-541 Ma) has led to the recognition of globally synchronous and long-lived (multi Myr) glacial episodes, large-scale shifts in many geochemical cycles, and biological innovations that ushered in increased ecological niche complexity. All of these biogeochemical and climatic upheavals took place during the final assembly and subsequent rifting of the Rodinia supercontinent. Unraveling the tempo of interactions between tectonics, oscillating marine redox cycles and biology is essential in order to better understand the drivers of evolutionary developments during this critical period of Earth history. Of particular interest is the paleoenvironmental context and timing of eukaryotic diversification in the lead up to the Sturtian glaciation. A paucity of radiometric age constraints has hindered our efforts to refine the temporal framework of these environmental and evolutionary events and global correlation schemes for Neoproterozoic sedimentary successions. Here we present new U-Pb zircon and Re-Os sedimentary rock and sulfide geochronological data from multiple locations. Coupled with mineralogical, geochemical, and paleontological datasets, these new age constraints enable us to more fully understand the role of tectonic and/or environmentally driven change that triggered the biological and geochemical transformations of the Neoproterozoic Era.

It's a Protist-Eat-Protist World: Recalcitrance, Predation, and Evolution in the Tonian–Cryogenian Ocean

Phoebe A. Cohen and L. A. Riedman

Emerging Topics in Life Sciences 5, ETLS20170145–8, 2018

Predation, and how organisms respond to it, is an important ecological interaction across the tree of life. Much of our understanding of predation focuses on modern metazoa. However, predation is equally important in single-celled eukaryotes (commonly referred to as protists). In the fossil record, we see evidence of protists preying on other protists beginning in the Tonian Period (1000–720 Ma). In addition, the first evidence of eukaryotic biomineralization and the appearance of multiple unmineralized but recalcitrant forms are also seen in the Tonian and Cryogenian (720–635 Ma), potentially indirect evidence of predation. This fossil evidence, coupled with molecular clock analyses, is coincident with multiple metrics that show an increase in the diversity of eukaryotic clades and fossil assemblages. Predation, thus, may have played a critical role in the diversification of eukaryotes and the evolution of protistan armor in the Neoproterozoic Era. Here, we review the current understanding of predation in the Tonian and Cryogenian oceans as viewed through the fossil record, and discuss how the rise of eukaryotic predation upon other eukaryotes (eukaryovory) may have played a role in major evolutionary transitions including the origins of biomineralization.

Biogeochemical Controls on Black Shale Deposition During the Frasnian-Famennian Biotic Crisis in the Illinois and Appalachian Basins, USA, Inferred from Stable Isotopes of Nitrogen and Carbon

B.T. Uveges, C.K. Junium, D.L. Boyer, Phoebe A. Cohen, J.E. Day

Palaeogeography, Palaeoclimatology, Palaeoecology, 2018

The Frasnian-Famennian biotic crisis is marked by two distinct intervals known as the Lower and Upper Kellwasser Events (KWEs) that in many locations are associated with deposition of organic-rich shales. Sedimentary nitrogen and carbon isotopes offer insight into the biogeochemical processing of nutrients, production of organic matter, and palaeoceanographic conditions during the KWEs. Here we present new bulk nitrogen (δ15Nbulk) and organic carbon (δ13Corg) isotope data from the Late Devonian Appalachian and Illinois Basins (AB and IB), with a focus on intervals encompassing the KWEs. Black shales from the IB and AB, including the KWEs, are 15N-depleted (−1.0–+2.0‰) and have significantly lower δ15Nbulk than interbedded grey shales (+0.5–+4.0‰), a trend consistent with many instances of black shale deposition in the Phanerozoic. Organic carbon isotopes exhibit the broad, positive excursions (~+3.5‰ from background) that are typical of the KWEs globally. Superimposed over these positive excursions in δ13Corg are sharp decreases of up to ~3.0‰ within the black shale beds, to as low as −30.5‰. The pattern of δ15Nbulk and δ13Corg values suggests that the depth of the chemocline and the degree of water-column stratification exert a primary control on both δ15Nbulk and δ13Corg during black shale deposition. In the context of the Frasnian-Famennian biotic crisis, the oscillating redox state and changing temperatures would have likely placed extreme stress on organisms within the marine environment of the AB and IB and may potentially have been a contributing factor to diversity loss over this time period.

Surface Ocean Radiocarbon Reservoir Ages from Land-Sea Tephra Correlation Constrains Deglacial Chronology and Ocean Circulation in the Southeast Bering Sea

Mea S. Cook, *Roberta Miller '18*, *Caroline White-Nockleby '17*, *Alice Chapman '15*, and A.C. Mix

Abstract PP44A-07 presented at 2017 AGU Fall Meeting, New Orleans, LA, 11-15 Dec, 2017

Radiocarbon estimates of the past ocean are valuable because unlike passive tracers, radiocarbon has the potential to trace both the distribution and rate of transport of water masses. Most studies using paired radiocarbon measurements on planktonic and benthic foraminifera assume that the surface reservoir age was constant at the preindustrial value, which if incorrect, can strongly bias radiocarbon reconstructions. The subarctic Pacific is ringed by volcanic arcs, and there is great potential to use tephrochronology as a stratigraphic tool in sediments from the last glacial and deglaciation, and assign calendar ages to the marine sediment without relying on calibrated planktonic radiocarbon ages. In this study, we use major and trace element analysis of volcanic glass to match tephras between radiocarbon-dated lake cores from Sanak Island in the eastern Aleutians to marine cores from Umnak Plateau in the southeast Bering Sea. There are numerous thin tephras preserved in laminated sediments from the Bolling-Allerod and early Holocene in marine cores from depths (1000-1500 m) within the modern oxygen minimum zone. We find that trace elements are crucial in distinguishing tephras from individual eruptions. Our preliminary radiocarbon measurements suggest that the benthic-atmosphere radiocarbon differences and marine surface reservoir ages in the Bolling-Allerod are similar to pre-industrial values, supporting previously published radiocarbon reconstructions from the region.

Testing the Fidelity of Laminations as a Proxy for Oxygen Concentration in the Bering Sea Over Millennial to Orbital Timescales

Anna Black '19, Natasha Baranow '18, Samuel Amdur '15, and Mea Cook

Abstract PP41C-1321 presented at 2017 AGU Fall Meeting, New Orleans, LA, 11-15 Dec, 2017

Ocean circulation and biological productivity play an important role in the climate system through their contribution to global heat transport and air-sea exchange of CO¬2. Oceanic oxygen concentration provides insight to ocean circulation and biological productivity. Sediment laminations provide a valuable proxy for local oceanic oxygen concentration. Many sediment cores from the Pacific Ocean are laminated from the last deglaciation, but previous studies have not provided an in-depth examination of laminations over many glacial and interglacial (G/IG) cycles. Typically, studies to date that consider bioturbation as a proxy for oxygen concentration have only considered one sediment core from a site, leaving ambiguity as to whether laminations faithfully record local oxygen levels. With sediment cores from three different holes (A, C, D) on the northern Bering Slope from IODP site U1345 (1008 m), we investigate how faithfully laminations record oxygen concentration. We assign a bioturbation index from 1 to 4 for 1-cm intervals for the cores from each of the three holes and align the holes based on physical properties data. We find that the bioturbation is relatively consistent (within one bioturbation unit) between holes, suggesting that laminations may be a faithful, if not perfect, proxy for local oxygen concentration. After examining laminations from a complete hole, representing over 500,000 years, there seems to be no consistent pattern of laminations during the past five glacial cycles, suggesting there is no consistent pattern to oxygen concentration during glacial periods in the northern Bering Slope. Thus, hypotheses on ocean circulation and productivity in the northern Bering Sea from the last deglaciation may not apply to previous G/IG cycles.

The Environmental Legacy of Channelisation on Aquatic Habitats of a Gravel-Bed Wandering River

Daniel Donahue ’19 and José Constantine

Geological Society of America Abstracts with Programs, 49, (6) doi: 10.1130/abs/2017am-301186, 2017

As one of the last remaining cold-water fisheries in Massachusetts, efforts are underway to restore the natural functioning of the gravel-bed, wandering Hoosic River. Channelisation of kilometres of stream peaked into the mid-20th century, resulting in narrowed stretches of channel absent of any alluvial cover. The environmental impacts of this extensive engineering have not been thoroughly evaluated, but are motivating several plans for enhancing ecological flows and channel connectivity. In order to better assess the environmental legacy of channelisation and to inform restoration strategies being developed, we document the historical changes to the river’s planform and aquatic habitats and assess the conditions needed to support stable bed-material supplies. Using maps and historical aerial imagery, we highlight the historical importance of mid-channel bars and point bars to the previously unaltered stream. We quantify the rate of loss of these in-channel features as a result of channelisation and supplement the historical analysis with modern surveys of the channel. We conclude that the sinuous, meandering planform that is the focus of many of the restoration plans may be inappropriate for the Hoosic River, as its flashy discharge and unsteady bed-material supply has tended to force the formation of large mid-channel bar habitat that creates temporally stable bifurcations.

Snapshots of a Changing Landscape: The Historical Geomorphology of the Lower Mississippi River

Andrew Bloniarz ’18 and José Constantine

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-299851, 2017

The Mississippi River system has undergone a dramatic transformation since the early days of European exploration throughout the North American heartland in the 16th and 17th centuries. The alteration of the river channel by levees and dams, the near-total deforestation of the river bank, and the dredging of the channel to promote/protect high volume river traffic are just a few examples of how the way the Mississippi operates has been fundamentally changed. Scientific observations of the river and its processes prior to human intervention are scarce and far less comprehensive than what would be made today. This results in a significant lack of trustworthy scientific information about the behavior of the river before the addition of dams, the clearing of debris, and the dredging of the channel. A better understanding of how the Mississippi and its tributaries operated prior to human intervention could provide insight as to how rivers around the world operate/operated before human intervention and how ecosystems and landscapes surrounding these rivers might change as a result of engineering of the rivers. The observations cataloged in this study could influence future research pertaining to the relationship between vegetation and bank stability, changes in land use and sinuosity of the river, and effects of sediment trapping by dams. Using historical descriptions of forms and processes, we describe the conditions of a natural river system just prior to the moment of profound change. These observations seem to parallel conditions in modern river systems at the cusp of extensive land cover classification.

The Role of the Floodplain in the Storage of Contaminants along Meandering Rivers

Emmett Blau '18 and José Constantine

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-299850, 2017

The Housatonic River, a meandering channel that drains 1950 square miles and flows from just north of Pittsfield, MA, through Connecticut and directly into the Long Island Sound, was heavily polluted with polychlorinated biphenyls by General Electric over much of the 20th century. Since the 1980s, GE, the USGS, and the EPA have collected over 9,600 sediment samples from the river and its floodplain, testing for PCB concentrations at a range of depths. Although this comprehensive dataset has been publicly available since 2003, there have been no investigations into how PCB concentrations might reflect the fluvial geomorphology of the floodplain. In this project, we will combine the pre-existing data with our own supplementary sediment cores to explore spatial trends in PCB concentrations across the floodplain. We intend to answer questions about how sediment is distributed and reworked within the floodplain during flooding events, focusing specifically on the role floodplain depressions such as oxbow lakes play in sequestering sediment-adsorbed legacy contaminants, as well as how grain-size heterogeneity within point bars is reflected by PCB concentrations. We will also calculate an approximate sediment budget for the river and examine the implications that budget has on the fate of currently stored contaminants.

Mid Latitude Glacial Responses to ENSO in the Eastern Pacific: a Tale of Two Hemispheres

Erikka Olson '19 and José Constantine

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-300416, 2017

Changes in average temperatures and precipitation associated with ENSO conditions can have significant impacts on glacial ablation and accumulation patterns. Despite the large role ENSO plays in Pacific weather variations, a comparison of its effects on coastal glaciers in both the Northern and Southern Hemispheres has not been quantified in previous research. We present here evidence of variable ENSO effects across mid-latitude glaciers along the Pacific Coast of Canada and Chile. Our findings indicate significant changes in glacial area and rates of accumulation during times of strong ENSO variations, with significant differences observed in the Northern and Southern hemispheres. Two comparable glaciers were chosen to study-- Homathko Icefield in British Columbia, Canada,and the Northern Patagonian Icefield in Chile. Both glaciers are located at similar latitudes (Homathko Icefield at 51°05′N and Northern Patagonian Icefield at 47°00′S) and elevations (ranging from approximately 5000-8000ft). GIS analysis of Landsat satellite images was conducted to measure glacial areas through annual and seasonal (Dec-Feb and Jun-Aug) intervals. We saw a stronger correlation between ENSO conditions and glacial area in the Southern Hemisphere than in the Northern Hemisphere, particularly during heightened El Niño conditions as measured by the Multivariate ENSO Index (MEI). During El Niño conditions in the Southern Hemisphere, we observed greater than average glacial areas and rates of winter accumulation. Climate anomaly data for these times show cooler to moderately warmer temperatures and significantly increased levels of precipitation. Understanding how glaciers respond regionally to large-scale circulation patterns such as ENSO gives context to seasonal changes we see currently. As more information is gathered on how ENSO patterns will be impacted by climate change, our findings have the potential to gain greater significance in predicting glacial responses to a changing climate.

Unravelling the Drivers of Chute Cutoff and the Universality of Oxbow ProductionC

José Constantine, D. Edmonds, and D. Scott

Abstract presented at 2017 Fall Meeting, AGU, New Orleans, LA, 11-15 Dec, 2017

Chute cutoff is the principal means of channel shortening along steep, sparsely vegetated, or perturbed meandering river floodplains, often requiring the intervention of river engineering to prevent its completion. Although flood waters are capable of unravelling the floodplain in a variety of ways, only a small number of mechanisms of chute cutoff have been observed in nature, each with seemingly different controls on their occurrence. The complexity of these controls partly explains the difficulty of incorporating physically based strategies for predicting chute cutoff into channel evolution models. Despite the challenges, recent field observations have allowed us not only to identify particular mechanisms but also to highlight first-order controls. We provide a summary of these findings and describe the processes that drive the various mechanisms of cutoff and their resulting oxbow lakes. For example, many agricultural floodplains show evidence of pervasive gully incision as a precursor to chute cutoff. And perhaps surprising given the diversity of cutoff mechanisms, oxbows globally share characteristic dimensions that are a function of the sinuosity and width of the rivers from which they are derived. Our results suggest that, in spite of the many processes involved, aspects of the mechanisms of chute cutoff can be generalised, providing a means for improving cutoff prediction and for assessing the impacts of cutoffs on the meandering river floodplain.

Climate Change and the Role of Vegetation in the Reduction of Soil Erosion

José Constantine, R. Ciampalini, K.W. Walker-Springett, T.C. Hales, S.J. Ormerod, E. Gabet, and I.R. Hall

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-299839, 2017

Simulations of 21st century climate change predict increased seasonal precipitation that may lead to widespread soil loss and reduced soil carbon stores by increasing surface runoff. Vegetation may counteract this increase through its response to climate change, possibly mitigating any impact on soil erosion. Here, we document for the first time the potential for vegetation to prevent widespread soil loss by surface-runoff mechanisms by applying a process-based soil erosion model to British catchments with varying land-cover, topography, and soil characteristics. Our model results reveal that, even under a significantly wetter climate, warmer air temperatures can limit soil erosion across areas with permanent vegetation cover by enhancing primary productivity and in turn improving leaf interception, soil infiltration-capacity, and the erosive resistance of soil. Consequently, any increase in air temperature associated with climate change will increase the rainfall thresholds required to accelerate soil loss, and rates of soil erosion could decline by up to 50% from 2070-2099 compared to baseline values under the IPCC-defined medium-emissions scenario SRES A1B. We conclude that enhanced primary productivity due to climate change can introduce a negative-feedback mechanism that limits soil loss by surface runoff as vegetation-induced impacts on soil hydrology and erodibility offset the effects of increased precipitation. The expansion of permanent vegetation cover over exposed ground could provide an adaptation strategy to reduce climate-driven soil loss.

Widespread Land Cover Transformation and the Management Impacts for Tropical Meandering River Systems

Alexander Horton, José Constantine, and T. C. Hales

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017am-300507, 2017

Tropical meandering rivers and their floodplains provide habitats to many of the planet's critically endangered species, but they are now being threatened by recently intensified rates of deforestation driven by global demands for food and biofuels. This has been especially true for the Kinabatangan River of northern Borneo, where palm oil plantations have replaced the majority of natural forest during the past 30 years. Using the Kinabatangan as a natural laboratory, we report that tropical deforestation not only increases the rate by which meandering rivers migrate across their floodplains, but widespread forest clearing appears to affect the nature of river meandering itself. In the absence of trees protecting and stabilising riverbanks, river flows can more efficiently access and mobilise riverbank materials, the result being that agricultural practices become increasingly costly for cases of complete riverbank deforestation. Our results are based on an analysis of Landsat imagery spanning the duration of active deforestation, which then informed a numerical model that allowed us to assess the economic impacts of widespread land clearing. The findings should inform management practices to better support the sustainability and ecological functioning of tropical river floodplain habitats.

Making Tsunami in a Wave Tank: Experiments on Boulder Transport

Kyrien Edwards '18, Rónadh Cox, and K. Goto

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-301251, 2017

Coastal Boulder Deposits (CBD) occur worldwide. They include impressively large clasts emplaced above high tide and sometimes at long distances inland. In many instances it can be difficult to determine whether CBD were emplaced by storm waves or tsunami. In the past it was thought that very large clasts were a signature of tsunami events, but recent work has shown that storm waves are capable of creating and moving megagravel, so it is necessary to look more closely at CBD sedimentology to determine the dynamics of tsunami versus storm deposition. Boulder ridges, i.e. CBD where clasts are arranged in long linear coast-parallel accumulations, are a case in point. Boulder ridges are highly organized. They have a steep ocean-facing side made up of imbricated clasts, piled up to a few metres high. The boulders are closely packed on top of one another, several clasts deep. The landward side is more gently sloping, usually tailing off into a scattered boulder field. Some workers argue that boulder ridges can be created only by storm waves, whereas others propose that they are formed by tsunami.

To address this issue, we carried out experiments at Tohoku University to test whether a tsunami-like bore can build organised clast ridges. Within a wave tank, we built a cliffed topography with a flat subaerial platform, similar to the setting of CBD in the eastern Atlantic region. We distributed clasts at different locations in the tank. We used a dam-break set up to create the bores, and ran a series of experiments with differing water depths and topographic configurations. We used Froude scaling parameters, with clasts and topography scaled at 1:100. Experiments were recorded using high-speed video. We found that the final disposition of clasts was not a simple function of bore velocity or depth, and that topographic variations strongly affect the bore-clast interaction. In particular, inland topographic barriers cause strong backwash that can affect clast deposition. Although clasts showed a tendency towards clustering under some conditions, there were never more than a few contiguous clasts, and at most one or two stacked clasts. Generally the deposits were dominated by isolated clasts spread widely over the surface. Where clusters occurred, they were randomly interspersed. No linear deposits or ridges were formed.

Global Signatures of Extreme Wave Events: Investigating the Mass-Topography Relationships of Coastal Boulder Deposits

Jacob Cytrynbaum '18 and Rónadh Cox

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-300951, 2017

Coastal boulder deposits (CBD) are emplaced above high water (AHW) during extreme wave events, and occur worldwide on high-energy rocky coasts. In many cases it is unclear whether storms or tsunami were responsible for boulder dislodgement and transport. CBD are sometimes interpreted as tsunami-related based mainly on the large size of included boulders, the argument being that storm waves may be incapable of entraining such masses, but recent observations show that storms can move megagravel >600t near sea level, and even at distances >100m inland and 15m AHW, boulders >10t have been created and moved by storm waves.

Can data patterns from verified storm deposits help us understand depositional mechanics in locations where CBD emplacement mechanisms are unclear? To address this question, we compiled a database of CBD measurements, using published studies in which authors reported not only boulder masses but also the elevation and distance inland at which the boulders lie. By amalgamating data from many locations, we achieve a broad spread relating boulder masses to the widest possible range of elevations, distances inland, and coastal steepnesses.

Our reference set includes recent observations from western Ireland and the Philippines, which show that storm waves shifted megagravel in the 200-600t range at near-sea-level locations, that boulders in the 10-50t range were created and transported at distances up to 200 m inland, and that clasts of order 1t can be moved at elevations more than 40 m AHW. These amalgamated data define a parameter space for storm-wave deposition of boulders.

Many CBD interpreted as tsunamigenic fall within this space, indicating that their masses and topographic locations may in fact be consistent with storm-wave transport, even in cases where application of wave-transport equations suggested that was unlikely. These results reinforce the growing consensus that large coastal boulders are not necessarily a priori tsunami signatures, and that storm waves interacting with coasts are more powerful than hydrodynamic equations predict. Defining a mass-topography parameter space for storm-wave clast transport provides a tool that can be applied in any location as a first-order test of whether a storm origin for CBD should be considered as a realistic interpretation.

Rising Waters and Sinking Lands: The Plight of Native American Groups in Southern Louisiana

Shirell Parfait-Dardar and Rónadh Cox

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-295019, 2017

As the Mississippi River delta subsides and sea level rises to engulf it, Louisiana land is lost at increasing rates. Large swaths of terra firma turn first to marsh and then to open water, leaving a filigree in which narrow green strands—generally the locations of distributary levees—remain barely elevated above the surrounding muddy water. The effects extend far inland.

Members of the Grand Caillou/Dulac Band of Biloxi-Chitimacha-Choctaw Indians live in Dulac, 17 miles from the coast. The community, strung out along the Grand Caillou levee, lost land at an average of 1% per year between 1974 and 1990 (Britsch and Dunbar 1993). Recent analysis (Zou et al., 2016) shows that subsidence rates—averaging 12.5 mm/yr— are among the highest in southern Louisiana. Fields and woodlands in which Tribe members wandered as children have sunk below sea level and are now traversed in boats. Only the highest ground remains dry—but dry is a relative term. In this inland community, areas that never flooded from the sea now regularly do. Hurricanes are always trouble, but now there are “south wind floods” that inundate the area regularly during spring tides when the wind is from the south. Mitigation programs exist to elevate houses above the floodwaters, but progress is slow. People suffer. Another dilemma is taking care of departed loved ones and ancestors, because graves cannot be protected. Coffins work loose during floods and float away. Some are not recovered.

The people’s identity is one with the land and with the ancestors. As environmental conditions deteriorate, so does their quality of life. Lack of education and lack of opportunity makes it difficult to relocate, but ties to traditional ways of life are also strong and hard to sever. Other Native American groups are similarly threatened and marginalized. Examples include the Grand Bayou Atakapa tribe, whose homes are accessible only by boat, and the nearby Isle de Jean Charles band of Biloxi-Chitimacha-Choctaw—currently undergoing federal resettlement as the first American “climate refugees”. The people feel disenfranchised. Lacking the financial basis to engineer their own survival, they find that their future is controlled by outsiders wielding power. Narratives of this sort are becoming common in communities at the frontiers of Anthropocene landscape change.

Boulders as Bellwethers: Studying the Effects of Storm Waves on Boulder Deposits can Improve our Understanding of Coastal Storm Wave Forces

Rónadh Cox, Frederic Dias, Björn Elßäßer, Louise O’Boyle, and Fabio Sacchetti

European Meteorological Society Annual Meeting Abstracts 14, EMS2017-801, 2017

As sea level rises, so does the threat to coastlines, populations, and infrastructure. Rocky coasts are especially understudied, in part because of difficulties in modeling wave-energy attenuation in such environments. But recent studies show they are surprisingly sensitive to high-energy events, and need to be better integrated into coastal management and environmental response planning. Predicting the forces likely to act on infrastructure requires understanding extreme wave behavior in the coastal zone. Surprisingly, we lack data on how big coastal waves can get and exactly how much work they can do, as illustrated by debates about whether storm waves can move coastal boulders weighing 100s of tonnes. Some use hydrodynamic equations to argue that only tsunami can exert the required forces, but others contend that existing equations are not fully descriptive, and cite evidence for boulders moving during storms. Because there is no consensus about how big waves can be at the coast, and the masses they can move, it has not been possible to fully model or predict effects of storm waves on coasts.

Work in progress will change that situation. Using a baseline dataset documenting >1000 boulders in western Ireland that moved during the 2013-2014 storms—including nineteen in the range 50-500t—our research group is working toward a unified model, integrating field, numerical, and experimental methods, directly linking waves of known magnitude to specific physical work.

First, we are working with the Marine Institute to produce three-dimensional terrestrial-to-marine topography for the Aran Islands. This allows us to link boulders (and their movements) to coastal geometry and offshore geomorphology. Second, numerical modeling of non-linear wave dynamics over variable bathymetry shows how waves are amplified in the coastal zone. Spectra generated by these codes will be tied to measured bathymetry so that results can be ground-truthed. Third, wave-tank experiments link fieldwork and numerical models, showing in a scaled environment—constructed to model the Aran Islands—relationships between wave amplification, pressures generated, and boulder masses moved. The result will be a quantified, multivariable model combining wave forces, geomorphology, and work done onshore (represented by boulder movements).

Our analysis will be valuable for considering storm effects on walls, roads, and other coastal infrastructure. The numerical models of wave power, grounded in physical reality, will provide robust estimates of dynamics in the shallow offshore environment. This will enhance our understanding of rocky coasts, and will inform coastal engineers, civil planners, and groups developing renewable marine energy installations.

How Does Wave Impact Generate Large Boulders? Modelling Hydraulic Fracture of Cliffs and Shore Platforms

J. Herterich, Rónadh Cox and F. Dias

Marine Geology 399, 34-46, 2018

Boulder quarrying by large waves along steep, high-energy coastlines contributes to erosion both by causing inland migration of cliff faces and by vertical lowering of coastal platform surfaces. It also leads to the formation of coastal boulder deposits (CBD) above and inland of the high water mark. We describe mechanisms by which hydraulic fracture creates boulders from cliffs and bedrock platforms. Intense fluid pressures are induced by wave impact on the base of overhanging ledges, and also along interior surfaces as cracks fill with water during wave runup and overtopping. These processes impose large loads on the overlying rock, and bending stresses thus induced can create or propagate microcracks in the rock. Repeated loading leads to complete fracture and detachment of bedrock slabs, which are liberated as boulders. We consider these processes using the Aran Islands (Ireland) as a type locality, both because CBD there are well documented and because flat-lying strata and orthogonal joint patterns yield tabular bedrock geometry, which lends itself to modelling. The loaded rock is modelled as a beam with a microcrack that is fractured by a bending stress from an applied hydrodynamic load. This simple approach allows us to examine general scalings and dependencies. We determine a condition for fracture, relating the fluid pressure, loaded area, fracture stress, microcrack position and geometry. In some situations, the fluid pressure need only be a fraction of the fracture stress. Fracture is most likely to occur during extreme wave conditions and when the exposed rock has a large eroded area for loading. The balance of forces suggests that larger beams break more easily, facilitating the creation of large boulders.

Semi-automatic Digital Clast Sizing of a Cobble Beach, Nantian, Taiwan

N. Bujan, Rónadh Cox, L-C Lin, C. Ducrocq, and H.-H Hwung

Journal of Coastal Research,10.2112/JCOASTRES-D-17-00165.1, in press

Surface sediment data is scarce for beaches that are made of material close to the cobble size range, partly because of the difficulty of direct sampling for sediment size analysis. An object-detection tool for semiautomatic analysis of clast geometry, originally developed for riverbeds, was applied to the coarse-clastic beach of Nantian, Taiwan. Comparison of the software with digital point counts for the common size percentiles D5, D16, D30, D50, D70, D84, and D95 indicated an average coefficient of determination of 0.990 over 10 test pictures. The surface sediment was digitally sampled at three cross-shore locations along the beach: near the shoreline, on the steep part of the beach face, and on the beach crest. Clast-size distributions, including clast area and elongation ratio, were computed from the geometry of 1000 clasts for each location and the cross-shore variance was captured. The combination of sediment characteristics with topographic measurements showed significant relations between bidimensional size and elongation of the sediments and morphology of the beach. The method can only access the clast geometry that is visible on pictures and cannot describe the full tridimensional shape. Despite this limitation, semiautomatic digital sizing is well suited to coarse-clastic beaches and has the potential to increase the understanding of coastal sedimentology over a wide range of sediment sizes.

Extraordinary Boulder Transport by Storm Waves (West of Ireland, Winter 2013–2014), and Criteria for Analysing Coastal Boulder Deposits

Rónadh Cox, *Kalle Jahn '14, Oona Watkins ' 15*, and Peter Cox

Earth-Science Reviews 177, 623-636, 2018

Before-and-after photos of supratidal coastal boulder deposits (CBD) in the west of Ireland show that storms in the winter of 2013–2014 transported boulders at elevations up to 29 m above high water, and at inland distances up to 222 m. Among the clasts transported are eighteen weighing more than 50 t, six of which exceed 100 t. The largest boulder moved during those storms weighs a fairly astonishing 620 t. The boulders moved in these recent storms provide pinning points for mapping storm-wave energies on coasts: their topographic positions mark elevations and distances inland reached by wave energies sufficient to dislocate those specific masses. Taken together, the CBD data reveal general relationships that shed light on storm-wave hydrodynamics. These include a robust correlation (inverse exponential) between maximum boulder mass transported and emplacement height above high water: the greater the elevation, the smaller the maximum boulder size, with a dependency exponent of about -0.2 times the elevation (in metres). There is a similar relationship, although with a much smaller rate-of-change (exponent -0.02), between boulder mass and distance inland, which holds from the shoreline in to about 120 m. Coastal steepness (calculated as the ratio of elevation to inland distance) seems to exert the strongest control, with an inverse power-law relationship between maximum boulder mass and slope ratio: the more gentle the topography, the larger the moved boulders. Quantifying CBD dynamics helps us understand the transmission of wave energies inshore during high-energy storm events. The transported boulders documented here are larger than many of those interpreted to have been moved by tsunami in other locations, which means that boulder size alone cannot be used as a criterion for distinguishing between tsunami and storm emplacement of CBD. The biggest blocks—up to 620 t—are new maxima for boulder mass transported by storm waves. We predict, however, that this record will not last long: the 2013–2014 storms were strong but not extreme, and there are larger boulders in these deposits that didn't move on this occasion. Bigger storms will surely move larger clasts, and clasts at greater distances from the shoreline. These measurements and relationships emphasise the extreme power of storm waves impacting exposed coastlines, and require us to rethink the upper limits of storm wave energy at coasts.

Analysis of the Pressure at a Vertical Barrier Due to Extreme Wave Run-up Over Variable Bathymetry

J. Brennan, C. Clancy, *Joshua Harrington '16*, Rónadh Cox, and F. Dias

Theoretical and Applied Mechanics Letters, 7(5), 269-275, 2017

The pressure load at a vertical barrier caused by extreme wave run-up is analysed numerically, using the conformal mapping method to solve the two-dimensional free surface Euler equations in a pseudo-spectral model. Previously this problem has been examined in the case of a flat-bottomed geometry. Here, the model is extended to consider a varying bathymetry. Numerical experiments show that an increasing step-like bottom profile may enhance the extreme run-up of long waves but result in a reduced pressure load.

Asymmetric Hillslope Erosion Following Wildfire in Fourmile Canyon, Colorado

Edward R. Abrahams, James M. Kaste, *William Ouimet '01*, and David P. Dethier

Earth Surface Processes and Landforms 43(9), 2009-2021, DOI: 10.1002/esp.4348, 2018

Infrequent, high-magnitude events cause a disproportionate amount of sediment transport on steep hillslopes, but few quantitative data are available that capture these processes. Here we study the influence of wildfire and hillslope aspect on soil erosion in Fourmile Canyon, Colorado. This region experienced the Fourmile Fire of 2010, strong summer convective storms in 2011 and 2012, and extreme flooding in September 2013. We sampled soils shortly after these events and use fallout radionuclides to trace erosion on polar- and equatorial-facing burned slopes and on a polar-facing unburned slope. Because these radionuclides are concentrated in the upper decimeter of soil, soil inventories are sensitive to erosion by surface runoff. The polar-facing burned slope had significantly lower cesium-137 (137Cs) and lead-210 (210Pb) inventories ($p < 0.05$) than either the polar-facing unburned slope or equatorial-facing burned slope. Local slope magnitude does not appear to control the erosional response to wildfire, as relatively gently sloping (~20%) polar-facing positions were severely eroded in the most intensively burned area. Field evidence and soil profile analyses indicate up to 4 cm of local soil erosion on the polar-facing burned slope, but radionuclide mass balance indicates that much of this was trapped nearby. Using a 137Cs-based erosion model, we find that the burned polar-facing slope had a net mean sediment loss of 2 mm (~1 kg m2) over a one to three year period, which is one to two orders of magnitude higher than longer-term erosion rates reported for this region. In this part of the Colorado Front Range, strong hillslope asymmetry controls soil moisture and vegetation; polar-facing slopes support significantly denser pine and fir stands, which fuels more intense wildfires. We conclude that polar-facing slopes experience the most severe surface erosion following wildfires in this region, indicating that landscape-scale aridity can control the geomorphic response of hillslopes to wildfires.

Anthropocene Landscape Change and the Legacy of 19th and 20th Century Mining in the Colorado Front Range

David P.Dethier, *William B. Ouimet '01*, Sheila F. Murphy, Maneh Kotikian,
Will Wicherski '15, and R. M. Samuels

Annals of the American Association of Geographers 108(4), 917-937, 2018

Human impacts on earth surface processes and materials are fundamental to understanding the proposed Anthropocene epoch. This study examines the magnitude, distribution, and long-term context of nineteenth- and twentieth-century mining in the Fourmile Creek catchment, Colorado, coupling airborne LiDAR topographic analysis with historical documents and field studies of river banks exposed by 2013 flooding. Mining impacts represent the dominant Anthropocene landscape change for this basin. Mining activity, particularly placer operations, controls floodplain stratigraphy and waste rock piles related to mining cover >5% of hill-slopes in the catchment. Total rates of surface disturbance on slopes from mining activities (prospecting, mining, and road building) exceed pre-nineteenth-century rates by at least fifty times. Recent flooding and the overprint of human impacts obscure the record of Holocene floodplain evolution. Stratigraphic relations indicate that the Fourmile valley floor was as much as two meters higher in the past 2,000 years and that placer reworking, lateral erosion, or minor downcutting dominated from the late Holocene to present. Concentrations of As and Au in the fine fraction of hillslope soil, mining-related deposits, and fluvial deposits serve as a geo-chemical marker of mining activity in the catchment; reducing As and Au values in floodplain sediment will take hundreds of years to millennia. Overall, the Fourmile Creek catchment provides a valuable example of Anthropocene landscape change for mountainous regions of the Western United States, where hillslope and floodplain markers of human activity vary, high rates of geomorphic processes affect mixing and preservation of marker deposits, and long-term impact varies by landscape location.

Thirty-year Trends in Acid Deposition and Neutralization in Two Headwater Catchments, Northwestern Massachusetts, USA

Jason Racela, Scott Wieman, and David Dethier

Geological Society of America Abstracts with Programs 50(2), doi: 10.1130/abs/2018NE-310419, 2018

Long-term decreases in acidic precursors have changed the chemistry of precipitation and streamflow in two moderately to well-buffered, forested headwater catchments in the Taconic Range of western New England, USA. Using Hopkins Memorial Forest (HMF) as our primary research site, we report 30-yr geochemical trends from the Birch Brook catchment and annual and seasonal variations from Birch Brook and the adjacent Ford Glen, which drain phyllitic and carbonate bedrock. Median pH of bulk precipitation and throughfall in HMF has increased irregularly since 1983 and 1986 respectively, whereas SO4 concentrations have decreased, consistent with regional trends. Increases in precipitation pH and decreases in SO4 concentration mirror increasing stream pH and decreasing stream SO4 concentration and flux over at least the past 30 years. Birch Brook median Ca concentrations and acid-neutralizing capacity (ANC) decreased from 1984 to 2005, then began to increase, whereas Mg concentrations began to decrease in 2005. Birch Brook and Ford Glen display contrasting chemistries that likely reflect the influence of rock materials and flow pathways. Sampled at a point and over a range of flows, Birch Brook chemistry is a mixture of upstream source waters (throughfall; soil water; ground water) with different flow characteristics. Acidic precipitation and shallow soil water affect stream chemistry only in the upper reaches of Birch Brook and during periods of extremely high flow, such as snowmelt. Ford Glen has high ANC and is near saturation with magnesian calcite at most flows. Long-term trends measured at Birch Brook and other streams in western New England show that stream geochemistry mirrors decreases in acidic deposition in upland catchments, even where ecosystem chemistry is buffered by bedrock composition.

Soils on Historic Charcoal Hearths – Terminology and Chemical Properties

Florian Hirsch, Thomas Raab, *William Ouimet '01*, David Dethier, Anna Schneider, and Alexandra Raab

Soil Science Society of America Journal 81(6), 1427-1435, 2017

Historic charcoal hearth remains provide a unique archive of the long-term interaction between biochar, soil development, and plant growth. Charcoal as raw material was crucial for production of iron in iron works, and hence numerous charcoal hearths can be found in the forests near historic iron works in Europe and in the eastern United States. Charcoal hearths are round to elliptical forms often around 10 m in diameter and consist of several-decimeter-thick layers that contain charcoal fragments, ash, and burnt soil. We studied the soil chemistry of 24 charcoal hearths and compared them with the surrounding "natural" soils in the northern Appalachians of northwestern Connecticut. The thickness of the topsoils on the charcoal hearths and their carbon content are remarkably higher than in the surrounding topsoils. The presence of residual products from charcoal production classifies the soils as Anthropic Udorthents (US Soil Taxonomy) or Spolic Technosols (Humic) according to the World Reference Base for Soil Resources. The widespread occurrence of charcoal hearth remains, and their high spatial density in different ecosystems underlines their importance for further pedological research.

Eroding the Southern Rocky Mountains—Weathering and Fluid Flow in Slow Motion in the Critical Zone

David P. Dethier and *William B.Ouimet '01*

GSA Quaternary Geology and Geomorphology Division Distinguished Career Award

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-301215, 2017

Diverse lines of evidence demonstrate slow denudation rates in the cool, dry landscape of the southern Rocky Mountains despite pervasive fracturing that dates from Laramide time and local hydrothermal alteration of mainly granitic materials. Denudation rates near 2 cm kyr-1 result from the long-term balance between slow rock uplift and chemical weathering of silicates at cool temperatures in environments where fluid contact times are relatively short. Moisture from snowmelt dominates upland to alpine hydrology and fluid transit is rapid through sandy soils and regolith, and in channels. Soil infiltration rates are relatively high and ephemeral streams lose substantial volumes to the shallow subsurface. Groundwater velocities are slow from meters to tens of meters beneath the rocky regolith, but reactive surface area is limited and solution chemistry is relatively dilute. In the past ~two decades, new dating tools based on cosmogenic nuclides, new measurement tools, particularly those involving lidar, and integrative approaches such as critical-zone research and hydrologic connectivity offer new ways of quantifying geomorphic processes. Undergraduate field-based studies, particularly where they build upon ongoing research, offer substantial scientific and educational opportunities for studying geomorphic and hydrochemical processes in the critical zone. Research examples include analysis of: fracture spacing, rock strength and regolith thickness within and beyond the glacial limit; solution chemistry and inferred weathering pathways; chemistry of weathering profiles; long-term erosion rates inferred from 10Be in alluvium, and short-term erosion rates after fire and flooding events. Intense rainfall from infrequent to millennial events drives erosion rates that exceed long-term values by at least 10-100 X. Despite active freeze-thaw regimes at higher elevations, erosion rates are lowest above the late Pleistocene glacial limit. Landscape relief is increasing from episodic glacial stripping of alpine valleys and from canyon-downcutting into the slowly weathering, rolling upland beyond the glacial limit.

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

Jordan Fields '17, David P. Dethier, and *Noah N. Williams '17*

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-299793, 2017

Snowmelt-fed springs and small (0.5 km2) upland catchments in alpine areas of the western USA contribute significantly to the quantity and chemistry of water delivered to downstream basins. Understanding these springs is important as warming global temperatures cause more precipitation to fall as rain at high elevations, affecting long-term runoff and storage patterns. In years of low snowpack, shallow groundwater from alpine and subalpine zones is an additional water source. We report the geochemistry of snowmelt springs that drain the alpine zone of Niwot Ridge, Colorado Front Range and examine how rock type, contact time and hydrologic mixing control their chemistry and that of surface and groundwater from this area. Dilute calcium bicarbonate waters (mean total dissolved load of 450 ± 170 μmol L-1) are typical of springs and small streams draining Niwot Ridge and adjacent areas in the granitic core of the southern Rocky Mountains and are a mixture of soil water, deep groundwater, and snowmelt runoff. The water in 48 sampled springs takes generally short flow paths (~0.3 km) through shallow regolith, resulting in short contact time with rock materials. However, rock type is an important control on spring chemistry. Chemical weathering of feldspars is the primary contributor of solutes; oligoclase is the major source of Na and SiO2. Concentrations of Ca in the springs and shallow groundwater exceed stoichiometric predictions of oligoclase weathering by ~3.5x, indicating that Ca has other sources, such as eolian material, interstitial calcite, or trace minerals. Solute concentrations in springs and shallow groundwater increase with contact time; silica provides the best measure of transit time for waters draining from Niwot Ridge. Using silica concentrations and estimated groundwater flow paths, we estimate an average residence of 0.6 yr for Niwot spring waters, and ~3 yr for shallow groundwater sampled by wells. Alpine waters acquire solutes rapidly despite cold temperatures, and concentrations change slowly downstream. Over 50% of the dissolved load of waters exiting the Boulder Creek watershed >20 km downstream accumulated before the waters emerged from alpine springs. Understanding how alpine waters acquire solutes thus has implications beyond small upland catchments.

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

Noah N. Williams '17, David P. Dethier, and *Jordan Fields '17*

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-294823, 2017

Interactions between surface and groundwater are a critical component of the water budget for snowmelt-dominated headwater catchments of the western United States. Flow into alpine and subalpine subsurfaces in the Colorado Front Range is changing as climate warms, precipitation patterns evolve at the same time as downstream demands for water increase. This study reports and analyzes hydraulic conductivity (K) values derived from 130 soil infiltration measurements on 13 transects and 14 falling head slug tests conducted on 10 closely spaced piezometers at the Niwot Ridge LTER site. K-values at the atmosphere-soil interface are similar to those measured in the shallow aquifer. Infiltration values vary spatially (transect medians range from 2.09x10-7 to 7.74x10-5 ms-1) and increase with elevation. Modified Hvorslev K values range from 4.86x10-7 to 1.77x10-4 ms-1 in the subalpine unconfined aquifer, which is developed in late-Pleistocene glacial till. Measured rates overlap with infiltration K-values from lower elevations. The apparent increase in infiltration capacity with elevation suggests that the unglaciated alpine area acts as a "leaky roof " that allows the shallow subsurface to absorb and transport the maximum rate of snowmelt. Analysis of groundwater flow during the 2016 snowmelt season in the glaciated subalpine suggests that channel infiltration from Como Creek, a snowmelt-fed, seasonally connected stream, contributes more to groundwater recharge than direct infiltration through the unsaturated zone. However, direct infiltration likely wets the vadose zone and initiates groundwater recharge before the pulse of channel infiltration takes over. These findings, combined with infiltration results, suggest an elevational gradient from (alpine) high infiltration capacity where infiltration feeds surface water into periglacial deposits and snowmelt streams to lower elevations where surface and channel infiltration feed water into forested glacial deposits and evapotranspiration is significant. This study illustrates how interactions between surface and groundwater differ in alpine and subalpine environments based on elevation because of rocks materials, snowpack distribution and vegetation.

Facilitating Development of Effective Interdisciplinary Curricular Materials

Anne E. Egger, Monica Z. Bruckner, Stuart J. Birnbaum, and Lisa A. Gilbert

In: *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*, Association of Environmental Sciences and Studies Book Series, Springer, forthcoming August 2018

Development of strong interdisciplinary curricular materials requires bringing together teams of instructors with diverse disciplinary expertise around complex and compelling topics. Many faculty lack the experience and support needed to effectively develop curricula as part of a team. To address these needs and to meet its own goal of engaging students in learning about Earth in the context of societal issues, the InTeGrate project designed a process that (1) constructed diverse and interdisciplinary materials development teams, (2) structured the materials development around a detailed rubric that included grand challenges and interdisciplinary problem solving, (3) supported materials development teams through a semi-flexible, scaffolded development timeline with several checkpoints, and (4) developed an extensive website to support both development teams and adopting instructors. Through this process, 32 interdisciplinary teams of 113 unique authors from around the country and many institution types produced 26 modules and 6 courses that are published on the InTeGrate website. The materials address a wide range of Earth-related grand challenges and contain explicitly interdisciplinary components. Authors and project leadership used the website heavily to support the development process. The rubric, timeline, and web-based tools that supported team-based curriculum development encode research-based practices in curriculum design and teaching and learning, and all components can be adapted for use by other projects.

Measuring Literacy, Attitudes, and Capacities to Solve Societal Problems

Ellen Iverson, Lisa A. Gilbert, Kim Kastens, Kristin O'Connell, and David Steer

In: *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*, Association of Environmental Sciences and Studies Book Series, Springer, forthcoming August 2018

Effective assessments offer more than just a measurement of learning. When sequenced and aligned to evidence-based curriculum, assessments can facilitate learning and inform instruction. The Interdisciplinary Teaching of Earth for a Sustainable Future (InTeGrate) project viewed assessment as a core strategy of the curriculum being developed.

InTeGrate used a community-based approach to assessment. An assessment team engaged with materials development teams to facilitate module and course assessment design. In addition, the assessment team developed common instruments. They analyzed student data from pilot tests to inform curriculum revisions. They used the findings to fine-tune assessment instruments and to shed light on opportunities for faculty development within the geoscience education community. The community approach ensured high quality curricula and instruments and strategies to investigate learning at the module, course, and project level. Perhaps more importantly, the approach increased the capacity of the geoscience education community by harnessing the expertise from within the community to promote a culture of evaluative thinking.

InTeGrate: Interdisciplinary Teaching about the Earth for a Sustainable Future

Cathryn A. Manduca '81, David Blockstein, Timothy Bralower, Felicia Davis, Diane Doser, Anne Egger, Sean Fox, Lisa Gilbert, David Gosselin, Richard Gragg, Ellen Iverson, Kim Kastens, David McConnell, Elizabeth Nagy-Shadman, Cailin Orr, David Steer, and John Taber

European Geophysical Union, 2018: EOS16/HS1.14, EGU2018-11029

The InTeGrate project supports integrated interdisciplinary learning about resource and environmental issues across the undergraduate curriculum. The project has developed teaching materials and examples of their use in US programs and is currently engaged in a suite of activities that support use of these resources in improving undergraduate Earth education. Thirty-three sets of teaching materials supporting instruction over time periods of 2 weeks to a full semester have been developed by interdisciplinary teams of faculty. The materials are peer-reviewed to ensure strong research-based pedagogic design and attention to five design principles: 1) address one or more grand challenges involving the Earth and society, 2) develop student ability to address interdisciplinary problems, 3) improve student understanding of the nature and methods of science and developing geoscientific habits of mind, 4) make use of authentic and credible science data to learn central concepts in the context of scientific methods of inquiry, and, 5) incorporate systems thinking. They have been tested in a wide variety of institutional and disciplinary settings and are documented with instructor notes describing adaptation for specific settings. All published materials passed a review for scientific accuracy. Student assessment data demonstrates improvements in systems thinking relative to a control population. Over 1000 faculty from 701 unique institutions have reported teaching courses that adapted, adopted or were inspired by InTeGrate materials enrolling in total more than 70,000 students. Sixteen program models demonstrate strategies for strengthening learning about Earth and sustainability at scales ranging from a department to an interinstitutional collaboration. These examples document the use of InTeGrate resources in the development and evaluation of these programs. A synthesis of lessons learned by these projects addresses strategies for teaching about the Earth across the curriculum. InTeGrate is currently supporting use of ideas and resources developed over the past six years of project work through a webinar series and other activities.

An Integrated Approach to Erosional Processes at a New England Salt Marsh

Caroline Hung '19, Lisa A. Gilbert, Emma Q. McCauley, Meghan R. Suslovic, Jason L. Swartz, and Molly E. Weiner

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-306285, 2017

Increased rates of sea-level rise (SLR) due to anthropogenic climate change threaten many coastal environments. At Barn Island Wildlife Management Area, a coastal salt marsh in Stonington, CT, USA, we examined the interaction between the physical and ecological factors that shape the marsh-bay edge. Marsh stability is influenced by marsh grasses and mussels. Over the four years of this study, we observed shifts in marsh grass diversity and density. With reduced root stabilization, the edge progressed from a normal slope to a vertical cliff. Roughly, 1/2 of ~200 m of measured shoreline has changed profile at least once in our four years of observation. Although the byssal threads of mussels are thought of as a stabilizing force, mussels may also contribute to erosion. During this study, Barn Island's marsh edge has exhibited decreases in mussel population. On slumped edges that have experienced significant erosion due to wave undercutting; however, mussel populations have increased. As sea level rises and inundation time increases, the weight of mussels on slumped edges may further exacerbate erosion and cause the marsh edge to migrate inland. We found marsh edge erosion proceeds as a cycle in which single-event breakage of marsh edges is preceded by months or years of gradual change. The cyclic mechanisms of marsh edge erosion are likely controlled by the rate of SLR, elevation, location and human disturbance at each site. One or more of these factors may override the physical and ecological defenses that slow down erosion.

Facilitating Three-Dimensional Learning with Adaptable, Searchable, NGSS-Aligned Curricular Materials from InTeGrate

Anne E. Egger, Sean P. Fox, John R. McDaris, and Lisa A. Gilbert

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-306673, 2017

The InTeGrate project developed and tested curricular materials with goals to address societal grand challenges, use rigorous science and research-based practices in learning, and be adaptable by instructors in many types of institutions and environments. These goals, developed prior to the Next Generation Science Standards (NGSS), are encoded in a detailed rubric that materials had to pass in order to be tested in the classroom, peer-reviewed, and published online as freely available modules and courses. The rubric consists of six sections: guiding principles, learning objectives and outcomes, assessment and measurement, resources and materials, instructional strategies, and alignment. The guiding principles are well-aligned with disciplinary core ideas (DCIs) in Earth science as well as with the science and engineering practices (SEPs) and cross-cutting concepts (CCCs) within the NGSS, while the rest of the rubric encodes research-based practices in curriculum development.

In July of 2017, a team of experienced educators independently assessed the InTeGrate materials for alignment with the NGSS and coded each component of the materials with the relevant CCCs, DCIs, SEPs, as well as, where possible, performance expectations. Within this extensive collection, virtually all materials address elements from all three dimensions. As a result of the coding process, instructors interested in adopting InTeGrate materials can: (1) search and browse the InTeGrate materials by NGSS elements, such as a particular cross-cutting concept; (2) find activities that "bundle" elements from the three dimensions to create new performance expectations; and (3) see how to adapt the materials to fit their own classroom needs.

These curricular materials have already been tested and utilized in courses designed for pre-service teachers, including elementary and secondary methods courses, as well as introductory geoscience courses that fulfill General Education requirements. Assessment results from these implementations show greater learning gains in systems thinking with use of the InTeGrate materials over traditional materials. The new coding and search/browse functionality allow instructors to more purposefully select activities to align with the NGSS in their own classroom in a way that suits their needs.

Explicit Focus on Systems Thinking in InTeGrate Materials Yields Improved Student Performance

Lisa A. Gilbert, Ellen R. Iverson, Kim A. Kastens, Aida Awad, Emma Q. McCauley, Joshua L. Caulkins, David N Steer, C. Douglas Czajka, David A. McConnell, and *Cathryn A. Manduca '81*

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-304783, 2017

Solving complex problems often requires complex approaches, especially systems thinking, a skill increasingly desired by employers. Despite the importance of systems thinking, undergraduate instructors struggle with effectively teaching systems thinking. As part of an NSF-funded Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) center, the InTeGrate project developed course materials that sought to incorporate systems thinking resources in materials created for a range of courses involving geoscience themes. These materials, published after internal and external review and evaluated for systems approaches, have been adopted across the U.S. Materials that most strongly addressed systems thinking were explicit about teaching both the terminology and skills of systems thinking, including using and making systems diagrams and models.

We sought to determine if the InTeGrate materials were successfully applied to teach systems approaches using a common essay prompt. Participating students were asked to define a system, explain how the system works, and address the impact of multiple causal factors on one part of the system. We scored essays written by 533 students in 57 undergraduate classes, to assess students' systems thinking ability. The students also completed a second essay on an interdisciplinary topic, a geoscience literacy exam (GLE), and responded to a demographic and attitudinal survey. The sample population were selected from among the larger InTeGrate student data (n>6,000). We compared our treatment population who were enrolled in courses using InTeGrate materials to a similar group of students taking a course that did not use InTeGrate materials. Both treatment and control groups had equivalent GLE and interdisciplinary essay scores and similar demographic characteristics. However, students in the treatment group scored significantly higher than the students in control group on the systems thinking essay question.

Preparing for an Academic Career in the Geosciences Workshop: A Success of the On-the-Cutting-Edge Program

Lynsey E. LeMay, Robyn W. Dunbar, Sue C. Ebanks, Lisa A. Gilbert, R. Heather Macdonald, Carol J. Ormand, *Catherine Riihimaki '98*, and Gary S. Weissmann

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-303080, 2017

The annual Preparing for an Academic Career in the Geosciences workshop has been offered through the NAGT/On the Cutting Edge program since 2003. The main goals are for participants to become more effective teachers, stronger candidates for academic jobs, and better prepared future faculty who will be able to make a quick and effective start in teaching and research. Over 900 graduate students and post-docs have participated in these workshops. Participants engage with workshop leaders and peers from different educational settings and backgrounds, allowing participants to learn about various academic career settings (two-year colleges, primarily undergraduate institutions, research-focused universities, and a range of minority-serving institutions) and varied career pathways. All participants work to improve application and interview skills for academic jobs, plan for their first academic job through goal-setting, and broaden their network of colleagues and resources.

Participant reviews of the workshop have been consistently positive, with many referring peers to future workshops, and many noting that the workshop had a positive influence on their career path. Participants appreciate the opportunity to learn more about faculty positions at different types of institutions and the academic job search, to get feedback on their teaching and/or research statements, and to meet others in a similar career stage.

Since 2016, the once stand-alone workshop has been integrated into the week-long Earth Educators' Rendezvous (EER) as a 3-day morning workshop. With a format change from 2.5 days to 9 hours, the focus of the workshop has shifted towards goal-setting and the job search, enabling customized participation in other parts of the EER that focus on aspects of teaching practices and pedagogy as well as geoscience education research. Optional lunch discussion sessions provide insights on other topics. Embedding the Preparing for an Academic Career workshop within the week-long EER both supports long-term sustainability of this workshop and introduces future faculty members into a community of practice in geoscience education. The workshop and associated website (https://serc.carleton.edu/NAGTWorkshops/careerprep/index.html) continue to help to prepare future faculty and ultimately improve student learning.

Hirnantian (latest Ordovician) Glaciations and Their Consequences for the Oslo Region, Norway, with a Revised Lithostratigraphy for the Langøyene Formation in the Inner Oslofjorden Area

J.F. Bockelie, B.G. Baarli, and Markes E. Johnson

Norwegian Journal of Geology 97, 119-201, doi: org/10.17850/njg97-201, 2017

During the Hirnantian Age (Late Ordovician) the Oslo Region was located in a subtropical setting with siliciclastic input and carbonate production. At that time, the sea level fluctuated in the Oslo Region during three regressive-transgressive episodes, some of which involved subaerial exposure and coastal valley erosion. The last major sea-level drop resulted in the formation of a conspicuous network of incised valleys that were subsequently filled with sediment during the transgression in the latest part of the Hirnantian. The continuing transgressive event rapidly flooded the exposed land areas in the central Oslo–Asker district. The areas towards the west in mainland Asker and Sylling in the adjacent Modum district were first transgressed in the late Rhuddanian (Early Silurian). Primarily eustatic processes affected the area, but synsedimentary faulting may also have been in play. There are two distinct palaeovalley trends: one at Hovedøya in Oslo more or less NW–SE, with narrow valley sides, the other at Kalvøya and surrounding areas trending approximately NE–SW, with one valley more than 10 km long. There may have been more than one filling phase. Sediment fill of the last-formed incised valleys were mapped and correlated across a large area of the Oslo–Asker district. Four new members of the Langøyene Formation are proposed: the Skaueren, Høyerholmen, Pilodden and Kalvøya members. Strata of the lateral Langåra Formation began deposition during the Katian. The rest of the formation as well as the Skaueren and Høyerholmen members contain fossils belonging to the cold-water Kosov fauna of early to mid Hirnantian age. The Pilodden and fossiliferous parts of the Kalvøya members include a mix of cold-water Kosov and warm-water Edgewood faunas of late Hirnantian age. Detailed descriptions of many incised valley fill sections in Oslo and Asker are included to show the spectrum of the sediment fill composition.

Storm Tracks Predict Land-to-Sea Sediment Transfer: Erosional Patterns from the Upper Ordovician (Hirnantian) in the Oslo Region, Norway

Markes E. Johnson and B.G. Baarli

Journal of Geology 126, 325-342, doi: 10.1086/697038, 2018

Recent refinements in nomenclature with an emphasis on member-level organization of Hirnantian strata from Norway's Oslo region provide a useful way to grasp depositional processes recorded in the last stage of the Ordovician system. Found in outcrops throughout the many small islands of the Oslofjord and the adjacent Bunnefjord, the multifaceted Langøyene Formation is differentiated into older, mostly stratiform deposits of sandstone and oolitic limestone in the Skauern, Høyerholmen, and Pilodden Members and younger cut-and-fill breccias and conglomerates in the Kalvøya Member. Combinations of sandy and calcareous conglomerates derived from erosion of the foregoing Høyerholmen, Pilodden, or older lithologies make up the preponderance of pebble- to boulder-size materials in the basal parts of the Kalvøya Member. As many as three generations of overlapping incisions into fully hardened strata resulted from cyclic changes in sea level during late Hirnantian time. Conditions under which channels were eroded and filled were variable, dependent on position along a preexisting gradient from land to sea. From 50 to 100 m in cross section, proximal streambeds accumulated fill characterized by chaotic debris-flow deposits as well as more normal riverine deposits with imbricated clasts. In a middle-slope position, channels exhibit a more mature organization, with clast-supported deposits that formed as flood jets off river mouths. Most distal in position, true tidal channels are eroded into strata with trace fossils diagnostic of normal marine conditions. Evidence from additional parts of the paleocontinent of Baltica in Norway, Sweden, and Estonia supports the argument that land-to-sea sediment transfer was induced by hurricane-related tropical storms bringing catastrophic rainfall to the Fennoscandian Shield. Similar evidence from other Late Ordovician continents is reviewed in the context of hurricane landfall patterns based on predictable storm tracks.

On the Rise and Fall of Oceanic Islands: Towards a Global Theory Following from the Pioneering Studies of Charles Darwin and James Dwight Dana

Markes E. Johnson, B.G. Baarli, M. Cachão, E. Mayoral, R.S. Ramalho, A. Santos, and C.M. Silva

Earth-Sciences Review 180, 17-36, doi.org/10.1016/j.earscirev.2018.03.008, 2018

The careers of Charles Darwin (1809–1882) and James Dwight Dana (1813–1895) are intimately linked to circumnavigations of the globe with the British mapping expedition on the H.M.S. Beagle (1831–1836) under Captain Robert FitzRoy and the United States Exploring Expedition (1838–1842) under Lieutenant Charles Wilkes. The former expedition mainly surveyed coastal South America, but also visited many volcanic islands in the Atlantic, Pacific, and Indian oceans. The latter expedition followed a similar path through the Atlantic, but devoted more time to Pacific Ocean islands. Remembered more today for his visit to the Galapagos Islands and its subsequent impact on understanding the mechanisms of biological evolution, Darwin was motivated early on during his stopover in the Cape Verde Islands to compile studies on the geology of volcanic islands. Better known for his theory of atoll development from the subsidence of volcanic islands stimulated by his visit to the Keeling Islands and published in 1842, Darwin also wrote a related volume published in 1844 with an equally strong emphasis on island uplift. Dana was influenced by Darwin's theory of atoll development, and published his own independent observations on coral reefs and island subsidence in 1843, 1849, and 1853. The work of both geologists matured from primary observations using inductive logic during fieldwork (i.g. unconformable position of limestone on and between basalt flows as an indicator of paleo-sea level) to the advancement of broader theories regarding the behavior of the Earth's oceanic crust. Notably, Dana recognized age differences among islands in Pacific archipelagos and was strongly influenced by the orientations of those island groups. The classic Hawaiian model that features a linear string of progressively older and subsiding islands does not apply easily to many other island groups such as the Galapagos, Azores, Canary, and Cape Verde islands. Geologists and coastal geomorphologists increasingly find that the original observations on island uplift covered in Darwin's 1844 treatment provide an alternative pathway to understanding the complexities of island histories in oceanic settings. Original work by Darwin and Dana also led to ongoing studies on the trans-oceanic migrations of marine organisms, such as barnacles, corals and non-attached coralline red algae represented by rhodoliths. This work gives added importance to oceanic islands as way stations in the dispersal of biotas over time.

Microbial Diversity of a Closed Salt Lagoon in the Puertecitos Area in the Upper Gulf of California

J.A. Kozlowski, Markes E. Johnson, J. Ledesma-Vázquez, D. Birgel, J. Peckmann, and C. Schleper

Ciencias Marinas 44(2), 71-90, 2018

Located 20 km south of Puertecitos on the Baja California Peninsula, Mexico, is a salt-crusted lagoon with a surface area of approximately 265,000 m^2 that is isolated from the adjacent Upper Gulf of California by a 50-m wide berm. The berm rises 2 m above mean sea level extending for 530 m across the lagoon's seaward front to bar replenishment by normal seawater except possibly by seepage. On another side of the lagoon an extinct Pliocene volcano Volcán Prieto, marks an equally abrupt boundary delineated by basalt flows. The lagoon's well-constrained physical geography represents a high-salinity environment under conditions of extreme aridity, flooded only during rare events associated with subtropical storms. The Volcán Prieto Lagoon (so named herein) formed through distinct stages in developmental geomorphology outlined in this study. A duplicate set of cores (17-cm in length) were retrieved from the lagoon and sampled for biological associations that record high-diversity colonization and stratification of microbial mats dominated by bacteria. Small subunit ribosomal RNA gene sequencing of different horizons revealed at least 25 major-named bacterial phyula and 89 major named archaeal phyla, as well as several un-named candidate taxa from miscellaneous groups. Lipid biomarker analyses of the same horizons revealed that cyanobacteria contributed significantly to biomass production only at shallow depth, whereas the lipids of anoxygenic phototrophic bacteria persisted to a depth of 15 cm, although with decreasing contents. The lipid patterns also showed that sulfate-reducing bacteria became more abundant with depth, whereas the contests of archaeal lipids increased from 1 to 5 cm depth, but remained relatively constant below. Closed lagoons on the Gulf of California are widely distributed over the length of the Baja California Peninsula, but detailed taxonomic studies regarding the diverse microbial communities that colonized thee extreme habitats have only begun to shed light on complex colonization patterns.

Modern Rhodoliths from the Insular Shelf of Pico in the Azores (Northeast Atlantic Ocean)

A.C. Rebelo, Markes E. Johnson, R. Quartau, M.W. Rasser, C.S. Melo, A.I. Neto, F. Tempera, P. Madeira, and S.P.´Avila

Estuarine, Coastal and Shelf Science 210, 7-17, doi.org/10.1016/j.ecss.2018.05.029, 2018

A seabed sediment-sampling survey conducted on the Pico insular shelf found abundant rhodoliths between −64 and −73 m off the south coast of the island. These were small and mainly ellipsoidal in shape with a maximum diameter of 3.75 cm. Granules and small pebbles of eroded basalt were also a typical component of these samples. Thin algal crusts were secreted on basalt pebbles by the coralline red algae Phymatolithon calcareum which, in turn, were covered by Lithophyllum incrustans. Additional samples were collected by snorkelling at Maré (Lajes do Pico), a shallow lagoon (2–4m in depth) on the south coast. Here, rhodoliths are mostly spheroidal and bigger (maximum diameter of 4.75 cm), formed by thin thalli of P. calcareum. Based on these results (distribution of shapes and species) and previous work on the characteristics of fossil specimens from Neogene deposits on Santa Maria Island (Azores) and other North Atlantic Archipelagos, an empirical depositional model is proposed for the development of rhodoliths on the Pico Island shelf: (1) Nearshore rhodoliths, formed solely by P. calcareum, are subjected to a wide range of currents and waves resulting in their spheroidal shapes. However, those of Maré lagoon are protected from offshore transport and tend to grow larger than deep- water rhodoliths; (2) Although not sampled, there must be middle shelf rhodoliths formed solely by P. calcareum that tend to form more ellipsoidal shapes due to seafloor oscillatory movements caused by waves crossing the shelf; (3) During storms, these middle shelf rhodoliths are then transported to the outer shelf, where L. incrustans overgrows the initial cover of P. calcareum. Shallow associations are normally larger, reflecting therefore, a longer life span than the deeper associations. Transport by storms appears to be an important factor in the formation of some deep-water rhodoliths around volcanic oceanic islands subjected to high-wave energy. However, their exposure to an energetic environment and likely frequent offshore transport does not allow them to grow as large as those from shallow-water.

Seasonal Wind Patterns Influence the Configuration and Geomorphology of Insular Reef Systems: Yongxing Island, Xisha Islands, China

Jian-Wei Shen, Markes E. Johnson, Feixue Fu, Yue Wang, and Yongbin Jin

Geological Journal 53(2), 754-766, DOI: 10.1002/gi.2925, 2018

Yongxing Island is a coral reef island formed by the growth and accumulation of corals and other skeletal fragments on a reef platform. The reef flat is developed around the entire island. The southeast reef flat and the north and northwest reef flat are asymmetrical in proportions, showing significant differences in reef-flat width, patterns of sedimentary and ecological zonation, forereef slope gradients, and submarine geomorphic features. Through application of an underwater survey, measurements and statistics were recorded on the extensional pattern of the Yongxing reef platform, the reef pool, and the spur–groove systems incised on the reef crests and forereefs. It is demonstrated that the Yongxing reef platform is an irregular ovoid in form with a distinct NW-SE elongation that includes gently and steeply sloping forereefs and fore-reef slopes. A gradual transition to the deep-sea basin occurs in the southeast part of the Yongxing reef platform, whereas a steep forereef and fore-reef slope that rapidly transition to the deep-water basin are more characteristic of the north and northwest sectors of the Yongxing reef platform. The width of the reef platform in the southeast direction is much greater than that in the northwest direction. Correspondingly, the developmental pattern of the north and northwest reef crest and forereef is different from that of the southeast reef crests and forereefs. The southeast reef crest and forereef are characterized by reef pools with various shapes, different water depths, and dis- continuous tidal channels on the outer reef flat. In contrast, the north and northwest reef crest and forereef developed a typical spur-and-groove system. The former is related to coral reef growth and construction, whereas the latter is shaped by wave or tide flow scouring that contributes to substrate erosion. Similar geomorphic features are known from examples of Indian-Pacific and Caribbean-Atlantic reef crests and forereefs, but the occurrence of such features in different parts of the same reef platform provides a new example of reef crest and forereef development. The differences in slope gradient of forereef and forereef slopes (gentle vs. steep in transition), the development of contrasting submarine platform widths in different directions, as well as other submarine geomorphic features on reef crests and forereefs around the reef flats of Yongxing Island may be related to the confluence of several factors. These include the tectonic uplift of reef platform, the island's initial underwater topography, the windward and leeward positions, the direction and strength of winter and summer monsoon, the sea-water dynamics, and the substrate characteristics related to coral reef growth.

Stratigraphy of the Connecticut Valley-Gaspe Trough in Massachusetts and Vermont: Constraints from LA-ICPMS Dates from Detrital Zircon and CA-IDTIMS Dates from Volcanic Rocks

Paul Karabinos, J.L. Crowley, *Laura K. Stamp '16, Jean-Michel Didier '17, Henry C. Barker '18*, and F.A. Macdonald

Geological Society of America Abstracts with Program 49(6), doi: 10.1130/abs/2017AM-305977, 2017

The Connecticut Valley-Gaspe trough (CVGT) extends from CT to QC, and is one of several post-Taconic basins in the northern Appalachians filled by Silurian and Devonian rocks. In VT and MA, the western contact between CVGT and Ordovician rocks of the Shelburne Falls arc is mapped as an unconformity or a fault zone. The Silurian Shaw Mountain (VT) and Russell Mountain (MA) Fms (SM/RM) form discontinuous lenses of quartzite at the contact. The Northfield (VT) and Goshen (MA) (N/G) Fms structurally overlie the quartzite lenses or arc rocks. The Waits River and Gile Mountain Fms are exposed east of the N/G Fms. Poorly preserved fossil evidence suggests an Early Devonian age for the Waits River and Gile Mountain Fms (Hueber et al., 1990), but does not resolve the relative ages of the units. Recent absolute age constraints include dates from metarhyolites in the Meetinghouse Slate Mbr of the Gile Mountain Fm (407 ± 3 Ma; Rankin and Tucker, 2009) and the Goshen Fm. (405 ± 4 Ma; Karabinos and Aleinikoff, 2011).

New U-Pb LA-ICPMS and CA-IDTIMS zircon dates constrain the provenance and age of these units. Detrital zircon age spectra from the RM/SM Fms have significant Silurian, Ordovician, Neoproterozoic and Mesoproterozoic peaks, and show a mixed Laurentian and Gondwanan provenance. Detrital zircon age spectra from the Waits River, Gile Mountain, and N/G Fms have significant Early Devonian, Silurian and Ordovician, and Proterozoic peaks, and show a mixed Laurentian and Gondwanan provenance. Airfall tephras are preserved in the Goshen Fm and one newly identified felsic bed gave a CA-IDTIMS date of 408.6 ± 0.1 Ma. The youngest grain dated from dark gray schist of the Goshen FM in MA, just south of the VT border and on strike with the Northfield Fm is 414.1 ± 0.3 Ma.

We suggest that 1) some rocks mapped as SM/RM Fm are highly sheared Ordovian arc rocks, 2) there is a significant age gap between SM/RM Fm rocks and other CVGT units, which are Early Devonian, 3) the Waits River Fm is older than the N/G and Gile Mountain Fms, which are facies equivalents of each other, and 4) a significant topographic or drainage barrier separated the CVGT trough from the Silurian-Devonian Catskill basin, which did not receive abundant Ordovician and Silurian zircon grains until the Middle Devonian and did not receive Gondwanan detritus until the Upper Devonian (Selleck et al., 2016).

Stratigraphy and Provenance of the Connecticut Valley-Gaspe Basin in Western New England: Evidence for a Topographic Barrier Between the Acadian Hinterland and Foreland

Paul Karabinos, J.L. Crowley, and *Laura K. Stamp'16*

Geological Society of America Abstracts with Programs 50(2), doi: 10.1130/abs/2018NE-310880, 2018

The Connecticut Valley-Gaspe basin (CVGB) is one of several basins in the northern Appalachians filled by Silurian and Devonian rocks. The Shaw Mtn (VT) and Russell Mtn (MA) Fms form discontinuous lenses of quartzite along the western contact of the basin. The Northfield (VT) and Goshen (MA) Fms structurally overlie the quartzite lenses. The Waits River and Gile Mtn Fms are exposed east of the Northfield and Goshen Fms. Fossil evidence suggested a Devonian age for the Waits River and Gile Mtn Fms (Hueber et al., 1990). Recent absolute age constraints include dates from meta-rhyolites in the Meetinghouse Slate Mbr of the Gile Mtn Fm (407 ± 3 Ma; Rankin and Tucker, 2009) and the Goshen Fm. (405 ± 4 Ma; Karabinos and Aleinikoff, 2011).

New U-Pb LA-ICPMS and CA-IDTIMS zircon dates constrain the age and provenance of these units. Two detrital zircon age spectra from the Russell Mtn Fm have significant Silurian, Ordovician, Neoproterozoic, and Mesoproterozoic peaks, and show a mixed Laurentian and Gondwanan provenance. One sample of the Shaw Mtn Fm from northern VT contains abundant Ordovician zircon grains and shows a mixed Laurentian and Gondwanan provenance. In contrast, two samples of the Shaw Mtn Fm from southern VT contain exclusively Laurentian grains and no grains younger than Neoproterozoic. Detrital zircon age spectra from the Waits River, Gile Mtn, and Northfield/Goshen Fms have significant Early Devonian, Ordovician, and Proterozoic peaks, and show a mixed Laurentian and Gondwanan provenance. Airfall tephras are preserved in the Goshen Fm and one newly identified felsic bed gave a CA-IDTIMS date of 408.6 ± 0.1 Ma. The youngest grain dated from the Goshen Fm in MA, just south of the VT border and on strike with the Northfield Fm is 414.1 ± 0.3 Ma.

We suggest that 1) the western contact of the CVGB is a fault along its entire length, 2) there is a significant age gap between Russell Mtn and Shaw Mtn Fms and other CVGB units, 3) the Waits River Fm is older than the Gile Mtn and Northfield/Goshen Fms, which may be facies equivalents of each other, and 4) a significant topographic barrier separated the CVGB from the Silurian-Devonian Catskill basin, which did not receive abundant Ordovician and Silurian zircon grains until the Middle Devonian and did not receive Gondwanan detritus until the Upper Devonian (Selleck et al., 2016).

Developing New Geologic Trail Exhibits at Florissant Fossil Beds National Monument: A Collaborative Project by Gips

Erikka R. Olson '19, Herbert W. Meyer, Mariah Slovacek, Emily D. Thorpe, Ricardo Daniel Escobar- Burciaga, Sarah E. Allen, Alexander J. Lowe, and Conni J. O'Connor

Geological Society of America Abstracts with Programs 49(6), doi: 10.1130/abs/2017AM-300140, 2017

A testament to the power of strong GIP intern involvement at Florissant Fossils Beds National Monument has been the ongoing development of a geologic trail. Though the monument is best known for its petrified redwood stumps and abundant fossil insects and plants, it also showcases a wide-ranging, dynamic geologic history. First initiated in 2015, the project has since evolved through collaborative efforts from many Geoscientists-in-the-Parks /Mosaics-In- Science/ Geocorps interns and park staff. Today, visitors can walk a short, easily accessible trail and learn about the broader geology of the area. It started with an idea of adding one geology-themed trailside exhibit to a pre-existing trail. From there, it quickly expanded with the addition of two more panels and ideas for many more. Six interns have contributed, each responsible for a particular wayside topic. Each intern came from a different background- bringing new ideas, talents, and perspectives to the project. In designing the waysides, we aimed to convey complex scientific concepts without oversimplification, while also considering public interpretation. Research specialists and park interpretive staff were involved in the review process, providing interns with valuable experience in peer review and critical evaluation. Nine panels have been developed overall, with topics ranging from the formation of Precambrian granites to modern erosional processes. This fills a gap in scientific education at the monument, which had previously focused primarily on the Florissant Formation of the late Eocene. Overall, the addition of this trail supports objectives of expanding the scope and depth of geoscience education for the public at the monument. Just as each GIP intern contributed a part to the greater project, various disciplines within geoscience were integrated to advance the park's goals of increased visitor curiosity, understanding, and scientific engagement.

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 '17 and Reinhard A. Wobus

Geological Society of America Abstracts with Programs 50(2), doi: 10.1130/abs/2018NE-309618, 2018

Granitic plutons of ca. 1.4 Ga age occur across much of North America, from the southwestern United States to Labrador. This study focuses on a group of these plutons in the southern Front Range of Colorado which have gone largely unstudied in terms of petrology and geochemistry. Major and trace elements were determined for 20 samples from the Elevenmile and Cripple Creek plutons and two other informally named pluton groups, the Firefly and Tarryall-Elkhorn. Textures and mineralogical features were first analyzed at hand specimen and thin section scale.

Petrographic and normative analyses show that most samples cluster in the monzogranite field near the minimum-melt-temperature composition for the granite system. Geochemical analysis shows that the samples are predominantly calc-alkaline or alkali–calcic, ferroan, and peraluminous, the latter predicted by modal muscovite and garnet. Two micas and myrmekitic intergrowths indicate hydrous magmas, as confirmed in the field by abundant pegmatites and hydrothermal alteration of sillimanitic schist in the wall rock.

The hydrous and peraluminous character of these plutons is consistent with S-type granites derived from the partial melting of metasedimentary rocks in thickened continental crust of collisional orogens. Concentrations of Nb, Y, Ta, Yb, Rb, Zr and Ga plotted on tectonic discrimination diagrams also suggest an orogenic, S-type petrogenesis. This contrasts strongly with plutons of similar age in northern and southern Colorado, which indicate the A-type features of anorogenic plutons produced in extensional tectonic regimes.

At 1.4 Ga these plutons were emplaced far inboard of the active southern margin of Laurentia, which had been expanded and thickened by arc accretion during the Yavapai and Mazatzal orogenies (1.71-1.60 Ga). Decompression melting during erosion of crust thickened by these previous contractional events may have been a factor in their genesis.

Mathematics and Statistics

Densities of Hyperbolic Cusp Invariants
Colin Adams, Rose Kaplan-Kelly*, Michael Moore*, Brandon Shapiro*, Shruthi Sridhar*, Joshua Wakefield*
Proceedings of American Mathematical Society, Vol. 146, No. 9, 4073-4089, September 2018
This is an investigation into two new invariants associated to hyperbolic 3-manifolds.

Presidential Address
Colin C. Adams
Mathematical Intelligencer, Volume 39, Issue 2, 3-5, 2017
What if Donald Trump was the President of the American Mathematical Society?

Referee's Report
Colin C. Adams
Mathematical Intelligencer, Volume 39, Issue 3, 24-26, 2017
The worst case scenario of a referee's report.

The Seven Labors of Hercules
Colin C. Adams
Mathematical Intelligencer, Volume 39, Issue 4, 27-29, 2017
A mathematical take on the labors of Hercules.

Turning Knots into Flowers and Related Undergraduate Research
Colin C. Adams
American Mathematical Monthly, Vol. 124, No. 9, 791-806, 2017
An introduction to multi-crossing number and petal number, highlighting student research.

To the Fields Medal Committee
Colin C. Adams
Mathematical Intelligencer, Volume 40, Issue 1, 24-25 (Also appeared on *Scientific American* on-line), 2018
A self-nomination for the Fields medal.

What is the Greatest Number of all Time?
C. Adams and T. Garrity
Mother Jones on-line https://www.motherjones.com/media/2018/03/pi-day-is-a-great-day-for-a-math-argument/, March 2018
A debate on which is the greatest number of all time.

What is…a Hyperbolic 3-Manifold?
Colin C. Adams
AMS Notices, Vol. 65, No. 5, 544-546, May 2018
A brief introduction to hyperbolic 3-manifld theory

On Writing Math Fiction
Colin C. Adams
MAA Focus, Vol. 38, No. 3, 17-18, June/July 2018
A brief introduction to mathematical fiction and the writing thereof.

Zika Virus Dynamics: When Does Sexual Transmission Matter?
JC Blackwood, O. Maxian, *A. Neufeld '18*, EJ Talis and LM Childs

Epidemics, 21 48-55, 2017

The Zika virus (ZIKV) has captured worldwide attention with the ongoing epidemic in South America and its link to severe birth defects, most notably microcephaly. ZIKV is spread to humans through a combination of vector and sexual transmission, but the relative contribution of these transmission routes to the overall epidemic remains largely unknown. Furthermore, a disparity in the reported number of infections between males and females has been observed. We develop a mathematical model that describes the transmission dynamics of ZIKV to determine the processes driving the observed epidemic patterns. Our model reveals a 4.8% contribution of sexual transmission to the basic reproductive number, R0. This contribution is too minor to independently sustain an outbreak but suggests that vector transmission is the main driver of the ongoing epidemic. We also find a minor, yet statistically significant, difference in the mean number of cases in males and females, both at the peak of the epidemic and at equilibrium. While this suggests an intrinsic disparity between males and females, the differences do not account for the vastly greater number of reported cases for females, indicative of a large reporting bias. In addition, we identify conditions under which sexual transmission may play a key role in sparking an epidemic, including temperate areas where ZIKV mosquito vectors are less prevalent.

Unraveling Within-Host Signatures of Dengue Infection at the Population Level

R. Nikin-Beers, JC Blackwood, LM Childs, and SM Ciupe

Journal of Theoretical Biology, 446, 79-86, 2018

Dengue virus causes worldwide concern with nearly 100 million infected cases reported annually. The within-host dynamics differ between primary and secondary infections, where secondary infections with a different virus serotype typically last longer, produce higher viral loads, and induce more severe disease. We build upon the variable within-host virus dynamics during infections resulting in mild dengue fever and severe dengue hemorrhagic fever. We couple these within-host virus dynamics to a population-level model through a system of partial differential equations creating an immuno-epidemiological model. The resulting multiscale model examines the dynamics of between-host infections in the presence of two circulating virus strains that involves feedback from the within-host and between-hosts interactions, encompassing multiple scales. We analytically determine the relationship between the model parameters and the characteristics of the model's solutions, and find an analytical threshold under which infections persist in the population. Furthermore, we develop and implement a full numerical scheme for our immuno-epidemiological model, allowing the simulation of population dynamics under variable parameter conditions.

A Cascade of Destabilizations: Combining Wolbachia and Allee Effects to Eradicate Insect Pests

JC Blackwood, *R. Vargas, Jr. '16*. and X Fauvergue

Journal of Animal Ecology, 87, 59-72, 2018

The management of insect pests has long been dominated by the use of chemical insecticides, with the aim of instantaneously killing enough individuals to limit their damage. To minimize unwanted consequences, environmentally-friendly approaches have been proposed that utilize biological control and take advantage of intrinsic demographic processes to reduce pest populations. We address the feasibility of a novel pest management strategy based on the release of insects infected with Wolbachia, which causes cytoplasmic incompatibilities in its host population, into a population with a pre-existing Allee effect. We hypothesize that the transient decline in population size caused by a successful invasion of Wolbachia can bring the population below its Allee threshold and, consequently, trigger extinction. We develop a stochastic population model that accounts for Wolbachia-induced cytoplasmic incompatibilities in addition to an Allee effect arising from mating failures at low population densities. Using our model, we identify conditions under which cytoplasmic incompatibilities and Allee effects successfully interact to drive insect pest populations toward extinction. Based on our results, we delineate control strategies based on introductions of Wolbachia-infected insects. We extend this analysis to evaluate control strategies that implement successive introductions of two incompatible Wolbachia strains. Additionally, we consider methods that combine Wolbachia invasion with mating disruption tactics to enhance the pre-existing Allee effect. We demonstrate that Wolbachia-induced cytoplasmic incompatibility and the Allee effect act independently from one another: the Allee effect does not modify the Wolbachia-invasion threshold, and cytoplasmic incompatibilities only have a marginal effect on the Allee threshold. However, the interaction of these two processes can drive even large populations to extinction. The success of this method can be amplified by the introduction of multiple Wolbachia cytotypes as well as the addition of mating disruption. Our study extends the existing literature by proposing the use of Wolbachia introductions to capitalize on pre-existing Allee effects and consequently eradicate insect pests. More generally, it highlights the importance of transient dynamics, and the relevance of manipulating a cascade of destabilizations for pest management.

Modeling Alternative Stable States in Caribbean Coral Reefs

JC Blackwood, C. Okasaki, A. Archer, *EW Matt '18*, E. Sherman, K. Montovan, *R. Vargas, Jr. '16*

Natural Resource Modeling, 31, e12157, 2018

The resilience of Caribbean coral reefs, which are an important source of biodiversity and provide essential ecosystem services, is constantly challenged by many reef stressors including ocean acidification, hurricane damage, and overharvesting of herbivorous reef fish. The presence of two alternative stable states—a desirable state with high levels of coral cover and its coral-depleted counterpart—has been widely documented in the literature. Increasing coral resilience to prevent phase shifts to the undesirable state is a critical research priority, and mathematical models can serve as an important tool to not only better understand the underlying dynamics of observed coral communities, but also to evaluate the potential impacts of stressors and the outcome of management strategies designed to promote coral persistence. Here, we review the existing literature of mathematical models designed to understand the processes that generate alternative stable states. We focus on models that are comprised of ordinary differential equations and, at their core, capture algal–coral dynamics.

Intro Stats, 5th Edition

Richard De Veaux with Paul Velleman and David Bock

Pearson, 2017

Stats: Data and Modeling the World, 5th Edition

Richard De Veaux with David Bock, Floyd Bullard and Paul Velleman

Pearson, 2017

The Distribution of the Maximum of Character Sums

Leo Goldmakher with J. Bober, A. Granville, D. Koukoulopoulos

Journal of the European Mathematical Society 20, no 7, 1759-1818, 2018

Refinements of Lagrange's Four-Square Theorem

Leo Goldmakher with P. Pollack

American Mathematical Monthly, 125, no. 3, 258-262, 2018

The q-Analog of Kostant's Partition Function and the Highest Root of the Simple Lie Algebras

Pamela E. Harris, Erik Insko, and Mohamed Omar

Australasian Journal of Combinatorics, Volume 71, no. 1, 68-91, 2018

For a given weight of a complex simple Lie algebra the q-analog of Kostant's partition function is a polynomial valued function in the variable q where the coefficient of q^k is the number of ways the weight can be written as a nonnegative integral sum of exactly k positive roots. In this paper we determine generating functions for the q-analog of Kostant's partition function when the weight in question is the highest root of the classical Lie algebras of types B, C, and D, and the exceptional Lie algebras of type G_2, F_4, E_6, E_7, and E_8.

A Minimal-Preserving Crystal on Ordered Multiset Partitions

Georgia Benkart, Laura Colmenarejo, Pamela E. Harris, Rosa Orellana, Greta Panova, Anne Schilling, and Martha Yip

Advances in Applied Mathematics, 95, 96-115, 2018

We provide a crystal structure on the set of ordered multiset partitions, which recently arose in the pursuit of the Delta Conjecture. This conjecture was stated by Haglund, Remmel and Wilson as a generalization of the Shuffle Conjecture. Various statistics on ordered multiset partitions arise in the combinatorial analysis of the Delta Conjecture, one of them being the minimaj statistic, which is a variant of the major index statistic on words. Our crystal has the property that the minimaj statistic is constant on connected components of the crystal. In particular, this yields another proof of the Schur positivity of the graded Frobenius series of the generalization $R_{n,k}$ due to Haglund, Rhoades and Shimozono of the coinvariant algebra R_n. The crystal structure also enables us to demonstrate the equidistributivity of the minimaj statistic with the major index statistic on ordered multiset partitions.

Computing Weight q-Multiplicities for the Representations of the Simple Lie Algebras

Pamela E. Harris, Erik Insko, and *Anthony Simpson '19*

Applicable Algebra in Engineering, Communication and Computing, 2017

The multiplicity of a weight μ in an irreducible representation of a simple Lie algebra g with highest weight λ can be computed via the use of Kostant's weight multiplicity formula. This formula is an alternating sum over the Weyl group and involves the computation of a partition function. In this paper we consider a *q*- analog of Kostant's weight multiplicity and present a SageMath program to compute *q*-multiplicities for the simple Lie algebras.

Computing Weight Multiplicities

Pamela E. Harris

A Primer for Undergraduate Research, Wootton A., Peterson V., Lee C. (editors)
Foundations for Undergraduate Research in Mathematics, Birkhauser, Cham, 193-222, 2017

Central to the study of the representation theory of Lie algebras is the computation of weight multiplicities, which are the dimensions of vector subspaces called weight spaces. The multiplicity of a weight can be computed using a well- known formula of Kostant that consists of an alternating sum over a finite group and involves a partition function. In this paper, we specialize to the Lie algebra sl_r+1(C) and focus on questions regarding the number of terms contributing non- trivially to Kostant's weight multiplicity formula. Through this study, we show that these contributing sets, called *Weyl alternation sets*, show interesting combinatorial and geometric properties. We dedicate a section to detailed examples that illustrate accessible techniques students may use to begin investigating the open problems we present in this area.

How Gaussian Mixture Models Might Miss Detecting Factors That Impact Growth Patterns

Heggeseth, BC and Jewell NP

Annals of Applied Statistics, 12 (1) 222-245, 2018

Review of Handbook of Cluster Analysis by Christian Hennig, Marina Meila, Fionn Murtagh, and Roberto Rocci, editors

Heggeseth, BC and Jewell NP

Journal of American Statistical Association, 112 (518) 878-882, 2017

Let's Join the conversation. Blog post about best practices for supporting inclusion and diversity in the field for the ASA Statistical Education Section

Heggeseth, BC and Jewell NP

Published at https://statisticseducatio.wixsite.com/mysite/single-post/2018/03/11/Lets-Join-the-Conversation.

Ovarian Cancer Survivors' Acceptance of Treatment Side Effects Evolves as Goals of Care Change Over the Cancer Continuum

Fry, Ellis, Koontz, Shyne, Klingenberg, Fields, Chern and Blank

Gynecologic Oncology, Vol. 146 (2) 386–391, 2017

Women with ovarian cancer can have long overall survival and goals of treatment change over time from cure to remission to stable disease. We sought to determine whether survivors' acceptance of treatment side effects also changes over the disease continuum.

Decreasing Recurrent Bowel Obstructions, Improving Quality of Life With Physiotherapy: Controlled Study

Rice, Patterson, Reed, Wurn, Robles, Klingenberg, Weinstock, Pratt, King and Wurn

World Journal of Gastroenterology, 24(19): 2108-2119, 2018

This paper compares over 30 quality of life measurements and rates of recurrent small bowel obstructions for patients treated with a novel manual physiotherapy versus no treatment.

Identification of Discrete, Intermingled Hypocretin Neuronal Populations

Iyer, Essner, Klingenberg and Carter

Journal of Comparative Neurology, doi: 10.1002/cne.24490, 2018

Neurons in the lateral hypothalamic area that express hypocretin (Hcrt) neuropeptides help regulate many behaviors including wakefulness and reward seeking. In the paper we test the hypotheses that Hcrt neurons can be classified based on their downstream projections and medial/lateral location within the hypothalamus.

The M & M Game: From Morsels to Modern Mathematics

Steven Miller (with Ivan Badinski, Christopher Huffaker, *Nathan McCue '15*, Cameron N. Miller, Kayla S. Miller and Michael Stone)

Mathematics Magazine, 90, no. 3, 197-207, 2017

To an adult, it's obvious that the day of someone's death is not precisely determined by the day of birth, but it's a very different story for a child. When the third named author was four years old he asked his father, the fifth named author: If two people are born on the same day, do they die on the same day? While this could easily be demonstrated through murder, such a proof would greatly diminish the possibility of teaching additional lessons, and thus a different approach was taken. With the help of the fourth named author they invented what we'll call the M&M Game: Given k people, each simultaneously flips a fair coin, with each eating an M&M on a head and not eating on a tail. The process then continues until all M&M'S are consumed, and two people are deemed to die at the same time if they run out of M&M'S together. This led to a great concrete demonstration of randomness appropriate for little kids; it also led to a host of math problems which have been used in probability classes and math competitions. There are many ways to determine the probability of a tie, which allow us in this article to use this problem as a springboard to a lot of great mathematics, including memoryless process, combinatorics, statistical inference, graph theory, and hypergeometric functions.

Constructing Families of Moderate-Rank Elliptic Curves Over Number Fields

Steven Miller (with David Mehrle, Tomer Reiter, Joseph Stahl and Dylan Yott)

Minnesota Journal of Undergraduate Mathematics, 2, 11 pages, 2016-2017

We generalize a construction of families of moderate rank elliptic curves over Q to number fields K/Q. The construction, originally due to Steven J. Miller, Alvaro Lozano-Robledo ´ and Scott Arms, invokes a theorem of Rosen and Silverman to show that computing the rank of these curves can be done by controlling the average of the traces of Frobenius; the construction for number fields proceeds in essentially the same way. One novelty of this method is that we can construct families of moderate rank without having to explicitly determine points and calculating determinants of height matrices.

Subsets of F_q[x] Free of 3-Term Geometric Progressions

Steven Miller (with *Megumi Asada '17, Eva Fourakis '16*, Sarah Manski, Gwyneth Moreland and Nathan McNew)

Finite Fields and Their Applications, 44, 135-147, 2017

Several recent papers have considered the Ramsey-theoretic problem of how large a subset of integers can be without containing any 3-term geometric progressions. This problem has also recently been generalized to number fields, determining bounds on the greatest possible density of ideals avoiding geometric progressions. We study the analogous problem over $\mathbb{F}_q[x]$, first constructing a set greedily which avoids these progressions and calculating its density, and then considering bounds on the upper density of subsets $\mathbb{F}_q[x]$ of which avoid 3-term geometric progressions. This new setting gives us a parameter q to vary and study how our bounds converge to 1 as it changes, and finite characteristic introduces some extra combinatorial structure that increases the tractibility of common questions in this area.

On Identities of Ruggles, Horadam, Howard, and Young

Steven Miller (with Curtis Cooper, Peter J.C. Moses, Murat Sahin and Thotsaporn Thanatipanonda

Fibonacci Quarterly, 55, No. 5, 52-65, 2017

Ruggles (1963) discovered that for integers $n \geq 0$ and $k \geq 1$

$$F_{n+2k} = L_k F_{n+k} + (-1)^{k+1} F_n.$$

Horadam (1965), Howard (2001), and Young (2003) each expanded this identity to generalized linear recurrence relations of orders 2, 3, and integers $r \geq 2$, respectively. In this paper we let $r \geq 2$ be an integer and $w0, w1, \ldots, wr-1$, and $p1, p2, \ldots, pr \neq 0$ be integers. For $n \geq r$ set

$$w_n = p_1 w_{n-1} + p_2 w_{n-2} + \cdots + p_r w_{n-r}$$

We find identities like those of Ruggles, Horadam, Howard, and Young, of the form $w_{n+rk} = R_k(r-1, r)w_{n+(r-1)k} + R_k(r-2, r)w_{n+(r-2)k} + \cdots + R_k(1, r)w_{n+k} + R_k(0, r)w_n$, where, by a result of Young, $R_k(i, r)$ is a linear recurrence relation of order $\binom{r}{i}$ for $i = 0, 1, \ldots, r-1$. Our proof uses the Cayley-Hamilton theorem. Next, we find the recurrences $R_k(0, r)$ and $R_k(r-1, r)$ for arbitrary r. Finally, we explicitly find identities for orders $r = 3$, $r = 4$ and $r = 5$.

A Collection of Central Limit Type Results in Generalized Zeckendorf Decompositions

Steven Miller (with Ray Li)

Fibonacci Quarterly, 55, No. 5, 105-114, 2017

Zeckendorf 's Theorem states that if the Fibonacci numbers are indexed as $F_1 = 1$, $F_2 = 2$, $F_3 = 3$, $F_5 = 5, \ldots$, then every positive integer can be written uniquely as the sum of non-adjacent Fibonacci numbers. This result can be generalized to certain classes of linear recurrence relations $\{Gn\}$ with appropriate notions of decompositions. For many decompositions, the distribution of the number of summands in the decomposition of an $M \in [Gn, Gn+1)$ is known to converge to a Gaussian as $n \to \infty$. This work discusses a more general approach to proving this kind of asymptotic Gaussian behavior that also bypasses technical obstructions in previous approaches. The approach is motivated by the binomials $a_{n,k} = \binom{n}{k}$. The binomials satisfy the recursion $a_{n,k} = a_{n-1,k} + a_{n-1,k-1}$ and are well known to have the property that the random variables $\{X_n\}_{n=1}^{\infty}$ given by $\mathbf{Pr}[X_n = k] = a_{n,k} / \sum_{i=0}^{\infty} a_{n,i}$ converge to a Gaussian as $n \to \infty$. This new approach proves that appropriate two-dimensional recurrences exhibit similar asymptotic Gaussian behavior. From this, we can reprove that the number of summands in decompositions given by many linear recurrence relations is asymptotic ally Gaussian and additionally prove that for any non-negative integer g, the number of gaps of size g in the decomposition of an $M \in [G_n, G_{n+1})$ also converges to a Gaussian as $n \to \infty$.

On the Asymptomatic Behavior of Variance of PLRS Decompositions

Steven Miller (with Dawn Nelson, Zhao Pan, and Huanzhong Xu)

Fibonacci Quarterly, 55, No. 5, 135-143, 2017

A positive linear recurrence sequence is of the form $H_{n+1} = c_1 H_n + \cdots + c_L H_{n+1-L}$ with each $c_i \geq 0$ and c1cL > 0, with appropriately chosen initial conditions. There is a notion of a legal decomposition (roughly, given a sum of terms in the sequence we cannot use the recurrence relation to reduce it) such that every positive integer has a unique legal decomposition using terms in the sequence; this generalizes the Zeckendorf decomposition, which states any positive integer can be written uniquely as a sum of non-adjacent Fibonacci numbers. Previous work proved not only that a decomposition exists, but that the number of summands $K_n(m)$ in legal decompositions of $m \in [H_n, H_{n+1})$ converges to a Gaussian. Using partial fractions and generating functions it is easy to show the mean and variance grow linearly in n: $an + b + o(1)$ and $Cn + d + o(1)$, respectively; the difficulty is proving a and C are positive. Previous approaches relied on delicate analysis of polynomials related to the generating functions and characteristic polynomials, and is algebraically cumbersome. We introduce new, elementary techniques that bypass these issues. The key insight is to use induction and bootstrap bounds through conditional probability expansions to show the variance is unbounded, and hence $C > 0$ (the mean is handled easily through a simple counting argument).

Fringe Pairs in Generalized MSTD Sets

Steven Miller (with Sarah Manski and Hong Suh)

International Journal of Number Theory, 13, No. 10, 2653-2675, 2017

A More Sums Than Differences (MSTD) set is a set A for which $|A + A| > |A - A|$. Martin and O'Bryant proved that the proportion of MSTD sets in $\{0, 1, \ldots, n\}$ is bounded below by a positive number as n goes to infinity. Iyer, Lazarev, Miller and Zhang introduced the notion of a generalized MSTD set, a set A for which $|sA - dA| > |\sigma A - \delta A|$ for a prescribed $s + d = \sigma + \delta$. We offer efficient constructions of k-generational MSTD sets, sets A where $A, A + A, \dots, kA$ are all MSTD. We also offer an alternative proof that the proportion of sets A for which $|sA-dA|-|\sigma A-\delta A| = x$ is positive, for any $x \in \mathbb{Z}$. We prove that for any $\epsilon > 0$, $\Pr(1-\epsilon < \log|sA-dA|/\log|\sigma A-\delta A| < 1+\epsilon)$ goes to 1 as the size of A goes to infinity and we give a set A which has the current highest value of $\log|A+A|/\log|A-A|$. We also study decompositions of intervals $\{0, 1, \dots, n\}$ into MSTD sets and prove that a positive proportion of decompositions into two sets have the property that both sets are MSTD.

New Behavior in Legal Decompositions Arriving From Non-Positive Linear Recurrences

Steven Miller (with M. Catral, P. Ford, P. Harris, D. Nelson, Z. Pan and H. Xu)

Fibonacci Quarterly, 55, no. 3, 252-275, 2017

Zeckendorf's theorem states every positive integer has a unique decomposition as a sum of non-adjacent Fibonacci numbers. This result has been generalized to many sequences $\{a_n\}$ arising from an integer positive linear recurrence, each of which has a corresponding notion of a legal decomposition. Previous work proved the number of summands in decompositions of $m \in [an, an+1)$ becomes normally distributed as $n \to \infty$, and the individual gap measures associated to each m converge to geometric random variables, when the leading coefficient in the recurrence is positive. We explore what happens when this assumption is removed in two special sequences. In one we regain all previous results, including unique decomposition; in the other the number of legal decompositions exponentially grows and the natural choice for the legal decomposition (the greedy algorithm) only works approximately 92.6% of the time (though a slight modification always works). We find a connection between the two sequences, which explains why the distribution of the number of summands and gaps between summands behave the same in the two examples. In the course of our investigations we found a new perspective on dealing with roots of polynomials associated to the characteristic polynomials. This allows us to remove the need for the detailed technical analysis of their properties which greatly complicated the proofs of many earlier results in the subject, as well as handle new cases beyond the reach of existing techniques.

Low-Lying Zeros for L-Functions Associated to Hilbert Modular Forms of Large Level

Steven Miller (with Sheng-Chi Liu)

Acta Arithmetica, 180, 251-266, 2017

We investigate the moments of a smooth counting function of the zeros near the central point of L-functions of weight k cuspidal newforms of prime level N. We split by the sign of the functional equations and show that for test functions whose Fourier transform is supported in $\left(-\frac{1}{n},\frac{1}{n}\right)$, as $N \to \infty$ the first n centered moments are Gaussian. By extending the support to $\left(-\frac{1}{n-1},\frac{1}{n-1}\right)$, we see non-Gaussian behavior; in particular the odd centered moments are non-zero for such test functions. If we do not split by sign, we obtain Gaussian behavior for support in $\left(-\frac{2}{n},\frac{2}{n}\right)$, if $2k \geq n$. The nth centered moments agree with Random Matrix Theory in this extended range, providing additional support for the Katz-Sarnak conjectures. The proof requires calculating multidimensional integrals of the non-diagonal terms in the Bessel-Kloosterman expansion of the Petersson formula. We convert these multidimensional integrals to one-dimensional integrals already considered in the work of Iwaniec-LuoSarnak, and derive a new and more tractable expression for the nth centered moments for such test functions. This new formula facilitates comparisons between number theory and random matrix theory for test functions supported in $\left(-\frac{1}{n-1},\frac{1}{n-1}\right)$, by simplifying the combinatorial arguments. As an application we obtain bounds for the percentage of such cusp forms with a given order of vanishing at the central point.

One-Level Density for Holomorphic Cusp Forms of Arbitrary Level

Steven Miller (with Owen Barrett, Paula Burkhardt, Jon DeWitt and Robert Dorward)

Research in Number Theory 3, no. 25, DOI10.1007/s40993-017-0091-9, 2017

In 2000 Iwaniec , Luo, and Sarnak proved for certain families of L-functions associated to holomorphic newforms of square-free level that, under the Generalized Riemann Hypothesis, as the conductors tend to infnity the one-level density of their zeros matches the one-level density of eigenvalues of large random matrices from certain classical compact groups in the appropriate scaling limit. We remove the square-free restriction by obtaining a trace formula for arbitrary level by using a basis developed by Blomer and Mili¢evi¢, which is of use for other problems as well.

When Almost All Sets Are Difference Dominated Z/nZ

Steven Miller (with Anand Hemmady and Adam Lott)

Integers, 17, Paper No. A54, 15 pp., 2017

We investigate the behavior of the sum and difference sets of $A \subseteq \mathbb{Z}/n\mathbb{Z}$ chosen independently and randomly according to a binomial parameter $p(n) = o(1)$. We show that for rapidly decaying $p(n)$, A is almost surely difference-dominated as $n \to \infty$, but for slowly decaying $p(n)$, A is almost surely balanced as $n \to \infty$, with a continuous phase transition as $p(n)$ crosses a critical threshold. Specifically, we show that if $p(n) = o(n^{-1/2})$, then $|A - A|/|A + A|$ converges to 2 almost surely as $n \to \infty$ and if $p(n) = c \cdot n^{-1/2}$, then $|A - A|/|A + A|$ converges to $1 + \exp(-c^2/2)$ almost surely as $n \to \infty$. In these cases, we modify the arguments of Hegarty and Miller on subsets of $\mathbb{Z}$ to prove our results. When $\sqrt{(\log n)} \bullet n^{-1/2} = o(p(n))$, we prove that $|A - A| = |A + A| = n$ almost surely as $n \to \infty$ if some additional restrictions are placed on n. In this case, the behavior is drastically different from that of subsets of $\mathbb{Z}$ and new technical issues arise, so a novel approach is needed. When $n^{-1/2} = o(p(n))$ and $p(n) = O\left(\sqrt{\log n} \bullet n^{-1/2}\right)$, the behavior of $|A + A|$ and $|A - A|$ is markedly different and suggests an avenue for further study. These results establish a "correspondence principle" with the existing results of Hegarty, Miller, and Vissuet. As $p(n)$ decays more rapidly, the behavior of subsets of $\mathbb{Z}/n\mathbb{Z}$ approaches the behavior of subsets of $\mathbb{Z}$ shown by Hegarty and Miller. Moreover, as $p(n)$ decays more slowly, the behavior of subsets of $\mathbb{Z}/n\mathbb{Z}$ approaches the behavior shown by Miller and Vissuet in the case where $p(n) = 1/2$.

On Smoothing Singularities of Elliptic Orbital Integrals on GL(n) and Beyond Endoscopy

Steven Miller (with Oscar Gonzalez, Chung Hang Kwan, Roger Van Peski and Tian An Wong)

Journal of Number Theory 183, 407-427, 2018

Recent work of Altuğ continues the preliminary analysis of Langlands' Beyond Endoscopy proposal for $GL(2)$ by removing the contribution of the trivial representation by a Poisson summation formula. We show that Altuğ's method of smoothing real elliptic orbital integrals by an approximate functional equation extends to $GL(n)$. We also discuss the case of an arbitrary reductive group, and remaining obstructions for applying Poisson summation.

Optimal Point Sets Determining Few Distinct Triangles

Steven Miller (with *Alyssa Epstein '18*, Adam Lott and Eyvindur Palsson)

Integers, 18, #A16, 17 pages, 2018

We generalize work of Erdos and Fishburn to study the structure of finite point sets that determine few distinct triangles. Specifically, we ask for a given t, what is the maximum number of points that can be placed in the plane to determine exactly t distinct triangles? Denoting this quantity by $F(t)$, we show that $F(1) = 4$, $F(2) = 5$, and we completely characterize the optimal configurations for $t = 1, 2$. We also discuss the general structure of optimal configurations and conjecture that regular polygons are always optimal. This differs from the structure of optimal configurations for distances, where it is conjectured that optimal configurations always exist in the triangular lattice. We also prove that the number of distinct triangles determined by a regular n-gon is asymptotic to $n^2/12$; so if the conjecture about regular n-gons being optimal is true, we identify the constant for the lower bound of distinct triangles determined by any point configuration.

Bedford Behavior of Generalized Zeckendorf Decompositions

Steven Miller (with *Andrew Best '15*, Patrick Dynes, *Xixi Edelsbrunner '15, Brian McDonald '15*, Kimsy Tor, Caroline Turnage-Butterbaugh and Madeleine Weinstein

Combinatorial and Additive Number Theory II: CANT, New York, NY, USA, 2015 and 2016 Springer, New York, 2017

We prove connections between Zeckendorf decompositions and Benford's law. Recall that if we define the Fibonacci numbers by $F_1 = 1, F_2 = 2$ and $F_{n+1} = F_n + F_{n-1}$, every positive integer can be written uniquely as a sum of non-adjacent elements of this sequence; this is called the Zeckendorf decomposition, and similar unique decompositions exist for sequences arising from recurrence relations of the form $G_{n+1} = c_1 G_n + \cdots + c_L G_{n+1-L}$ with c_i positive and some other restrictions. Additionally, a set $S \subset \mathbb{Z}$ is said to satisfy Benford's law base 10 if the density of the elements in S with leading digit d is $\log_{10}\left(1+\frac{1}{d}\right)$; in other words, smaller leading digits are more likely to occur. We prove that as $n \to \infty$ for a randomly selected integer m in $[0,G_{n+1})$ the distribution of the leading digits of the summands in its generalized Zeckendorf decomposition converges to Benford's law almost surely. Our results hold more generally: one obtains similar theorems to those regarding the distribution of leading digits when considering how often values in sets with density are attained in the summands in the decompositions.

Ramsey Theory Problems Over the Integers: Avoiding Generalized Progressions

Steven Miller (with *Andrew Best '15*, *Karen Huan '16*, Nathan McNew, Jasmine Powell, Kimsy Tor and Madeleine Weinstein)

Combinatorial and Additive Number Theory II: CANT, New York, NY, USA, 2015 and 2016 Springer, New York, 2017

Two well studied Ramsey-theoretic problems consider subsets of the natural numbers which either contain no three elements in arithmetic progression, or in geometric progression. We study generalizations of this problem, by varying the kinds of progressions to be avoided and the metrics used to evaluate the density of the resulting subsets. One can view a 3-term arithmetic progression as a sequence $x, f_n(x), f_n(f_n(x))$, where $f_n(x) = x + n$, n a nonzero integer. Thus avoiding three-term arithmetic progressions is equivalent to containing no three elements of the form $x, f_n(x), f_n(f_n(x))$, with $f_n \in \boldsymbol{F}_t$, the set of integer translations. One can similarly construct related progressions using different families of functions. We investigate several such families, including geometric progressions ($f_n(x) = nx$ with $n > 1$ a natural number) and exponential progressions ($f_n(x) = x^n$). Progression-free sets are often constructed "greedily," including every number so long as it is not in progression with any of the previous elements. Rankin characterized the greedy geometric-progression-free set in terms of the greedy arithmetic set. We characterize the greedy exponential set and prove that it has asymptotic density 1, and then discuss how the optimality of the greedy set depends on the family of functions used to define progressions. Traditionally, the size of a progression-free set is measured using the (upper) asymptotic density, however we consider several different notions of density, including the uniform and exponential densities.

Benford's Law and Continuous Dependent Random Variables

Steven Miller (with Thealexa Becker, *David Burt '17*, Taylor C. Corcoran, *Alec Greaves-Tunnell '13, Joseph Iafrate '14, Joy Jing '13, Jaclyn Porfilio '15*, Ryan Robab, *Jirapat Samranvedhya '14*, Frederick W. Strauch and Blaine Talbut)

Annals of Physics 388, 350-381, 2018

Many mathematical, man-made and natural systems exhibit a leading-digit bias, where a first digit (base 10) of 1 occurs not 11% of the time, as one would expect if all digits were equally likely, but rather 30%. This phenomenon is known as Benford's Law. Analyzing which datasets adhere to Benford's Law and how quickly Benford behavior sets in are the two most important problems in the field. Most previous work studied systems of independent random variables, and relied on the independence in their analyses. Inspired by natural processes such as particle decay, we study the dependent random variables that emerge from models of decomposition of conserved quantities. We prove that in many instances the distribution of lengths of the resulting pieces converges to Benford behavior as the number of divisions grow, and give several conjectures for other fragmentation processes. The main difficulty is that the resulting random variables are dependent. We handle this by using tools from Fourier analysis and irrationality exponents to obtain quantified convergence rates as well as introducing and developing techniques to measure and control the dependencies. The construction of these tools is one of the major motivations of this work, as our approach can be applied to many other dependent systems. As an example, we show that the n! entries in the determinant expansions of $n \times n$ matrices with entries independently drawn from nice random variables converges to Benford's Law.

Irrationality Measure and Lower Bounds for \pi(x)

Steven Miller (with *David Burt '17*, Sam Donow, Matthew Schiffman and Ben Wieland)

Pi Mu Epsilon Journal 14, no. 7, 421-429, 2017

In this note we show how the irrationality measure of $\zeta(s) = \pi 2/6$ can be used to obtain explicit lower bounds for $\pi(x)$. We analyze the key ingredients of the proof of the finiteness of the irrationality measure, and show how to obtain good lower bounds for $\pi(x)$ from these arguments as well. While versions of some of the results here have been carried out by other authors, our arguments are more elementary and yield a lower bound of order $x/\log x$ as a natural boundary.

Random Matrix Ensembles With Split Limiting Behavior

Steven Miller (with Paula Burkhardt, Peter Cohen, Jonathan Dewitt, Max Hlavacek, Carsten Sprunger, Yen Nhi Truong Vu, Roger Van Peski, and an appendix joint with Manuel Fernandez and Nicholas Sieger)

Random Matrices: Theory and Applications, 7, no. 3, 30 pages, DOI: 10:1142/S2010326318500065, 2018

We introduce a new family of $N \times N$ random real symmetric matrix ensembles, the k-checkerboard matrices, whose limiting spectral measure has two components which can be determined explicitly. All but k eigenvalues are in the bulk, and their behavior, appropriately normalized, converges to the semi-circle as N tends to infinity; the remaining k are tightly constrained near N/k and their distribution converges to the k x k hollow GOE ensemble (this is the density arising by modifying the GOE ensemble by forcing all entries on the main diagonal to be zero). Similar results hold for complex and quaternionic analogues. We are able to isolate each regime separately through appropriate choices of weight functions for the eigenvalues and then an analysis of the resulting combinatorics.

Problem Session Notes from CANT Conferences

Steven Miller (currently 2009 through 2018, inclusive)

Distributed to interested parties and posted on the *arXiv*, 35 pages, 2018

These notes are a summary of the problem session discussions at various CANT (Combinatorial and Additive Number Theory Conferences). Currently they include all years from 2009 through 2018 (inclusive); the goal is to supplement this file each year. These additions will include the problem session notes from that year, and occasionally discussions on progress on previous problems. If you are interested in pursuing any of these problems and want additional information as to progress, please email the author. For more information, visit the conference homepage at http://www.theoryofnumbers.com/ or email either the typist at sjm1@williams.edu or Steven.Miller.MC.96@aya.yale.edu, or the organizer at melvyn.nathanson@lehman.cuny.edu.

Mathematics of Optimization: How To Do Things Faster

Steven Miller

AMS, Pure and Applied Undergraduate Texts, 30, 327 pages, 2017

Optimization Theory is an active area of research with numerous applications; many of the books are designed for engineering classes, and thus have an emphasis on problems from such fields. Covering much of the same material, there is less emphasis on coding and detailed applications as the intended audience is more mathematical. There are still several important problems discussed (especially scheduling problems), but there is more emphasis on theory and less on the nuts and bolts of coding. A constant theme of the text is the why and the how in the subject. Why are we able to do a calculation efficiently? How should we look at a problem? Extensive effort is made to motivate the mathematics and isolate how one can apply ideas/perspectives to a variety of problems. As many of the key algorithms in the subject require too much time or detail to analyze in a first course (such as the run-time of the Simplex Algorithm), there are numerous comparisons to simpler algorithms which students have either seen or can quickly learn (such as the Euclidean algorithm) to motivate the type of results on run-time savings.

The Isoperimetric Problem With Density

Frank Morgan

Math. Intelligencer, 39, 2-8, 2017

Enhanced write-up of talk at 2015 Lázló Fejes Tóth Centennial, including recent proofs of Log-Convex Density Theorem, the analog for perimeter and volume densities r^k and r^m, and the isoperimetric solution for density r^p.

The Complex Body Isoperimetric Conjecture in R2

Frank Morgan, *John Berry '18,* Eliot Bongiovanni, *Wyatt Boyer '17*, Bryan Brown, Matthew Dannenberg, Paul Gallagher, David Hu, Jason Liang, Alyssa Loving, *Zane Martin '15*, Maggie Miller, *Byron Perpetua '16*, Sara Tammen, and Yingqi Zeng

Rose-Hulman Und. Math. J., 2018

Morgan's 2012-2015 NSF SMALL undergraduate research Geometry Groups provide partial results on the convex body isoperimetric conjecture in R2.

The Isoperimetric Problem for the Sum of Two Gaussian Densities

Frank Morgan, *John Berry '16*, Matthew Dannenberg, Jason Liang, Yingyi Zeng

Involve, 11, 4, 549-567, 2018

Morgan's 2015 NSF SMALL undergraduate research Geometry Group solves the isoperimetric problem for the sum of two Gaussian densities.

Strict Doubly Ergodic Infinite Transformations

Cesar E Silva with Isaac Loh

Dynamical Systems 32, no. 4, http://arxiv.org/abs/1512.09340, 519 - 543, 2017

We give examples of rank-one transformations that are weakly doubly ergodic and rigid (so all their Cartesian products are conservative), but with non-ergodic two-fold Cartesian product. We give conditions for rank-one infinite measure-preserving transformations to be weakly doubly ergodic and for their k-fold Cartesian product to be conservative. We also show that a weakly doubly ergodic nonsingular group action is ergodic with isometric coefficients, and that the latter strictly implies W-measurable sensitivity.

On Mixing-Like Notions in Infinite Measure

Cesar E. Silva

Amer. Math. Monthly, 124, no. 9, 807 - 825, 2017

Measurable dynamical systems are defined on a measure space, such as the unit interval or the real line, with a transformation or map acting on the space. After discussing dynamical properties for probability spaces such as ergodicity, weak mixing, and mixing, we consider analogues of mixing and weak mixing in infinite measure, and present related examples and definitions that are the result of research with undergraduates. Rank-one transformation are introduced and used to construct the main examples.

On Conservative Sequences and Their Application to Ergodic Multiplier Problems

Cesar E. Silva with *Madeleine Elyze '18, Alexander Kastner '17*, Juan Ortiz Rhoton, Vadim Semenov

Colloquium Mathematicum, 151, no. 1, https://arxiv.org/abs/1610.01438, 123 - 145, 2018

The conservative sequence of a set A under a transformation T is the set of all integers $n \in \mathbb{Z}$ such that $T^n(A) \cap A \neq 0$. By studying these sequences, we prove that given any countable collection of nonsingular transformations with no finite invariant measure $\{T_i\}$, there exists a rank-one transformation S such that T_i x S is not ergodic for all i. Moreover, S can be chosen to be rigid or have infinite ergodic index. We establish similar results for actions of $\mathbb{Z}^d$ actions and flows. We then find sufficient conditions on rank-one transformations T that guarantee the existence of a rank-one transformation S such that T x S is ergodic, or alternatively, conditions that guarantee that T x S is conservative but not ergodic.

Infinite Symmetric Ergodic Index and Related Examples in Infinite Measure

Cesar E. Silva with Isaac Loh, Ben Athiwaratkun

Studia Mathematica 243, no. 1, https://arxiv.org/abs/1702.01455, 101-115, 2018

For infinite-measure-preserving rank-one transformations, we give a condition guaranteeing that all finite Cartesian products of the transformation with its inverse are ergodic. We show that the infinite Chacon transformation satisfies this condition. We then explore the relationship between product conservativity and product ergodicity and answer a question of Danilenko. Finally, we define a class of infinite Chacon type transformations and show they do not have products of all powers conservative and are therefore not power weakly mixing.

Band Depth Clustering for Nonstationary Time Series and Wind Speed Behavior

Laura L. Tupper, David S. Matteson, C. Lindsay Anderson, and Luckny Zephyr

Technometrics 60(2), 245-254, 2018

We explore the behavior of wind speed over time, using a subset of the Eastern Wind Dataset published by the

National Renewable Energy Laboratory. This dataset gives modeled wind speeds over three years at hundreds of potential wind farm sites. Wind speed analysis is necessary to the integration of wind energy into the power grid; short-term variability in wind speed affects decisions about usage of other power sources, so that the shape of the wind speed time series becomes as important as the overall level. To assess differences in intra-day time series, we propose a functional distance measure, the band distance, which extends the band depth of Lopez-Pintado and Romo (2009). This measure emphasizes the shape of time series or functional observations relative to other members of a dataset, and allows clustering of observations without reliance on pointwise Euclidean distance. We show a method for adjusting for seasonal effects in wind speed, and use these standardizations as input for the band distance. We demonstrate the utility of the new method in simulation studies and an application to the MOST power grid algorithm, where the band distance improves reliability over standard methods at a comparable cost.

Physics

Simple, low-noise piezo driver with feed-forward for broad tuning of external cavity diode lasers

Doret, S. Charles

Review of Scientific Instruments 89, 023102 (2018)

We present an inexpensive, low-noise (<260 μVrms, 0.1 Hz-100 kHz) design for a piezo driver suitable for frequency tuning of external-cavity diode lasers. This simple driver improves upon many commercially available drivers by incorporating circuitry to produce a “feed-forward” signal appropriate for making simultaneous adjustments to the piezo voltage and laser current, enabling dramatic improvements in a mode-hop-free laser frequency tuning range. We present the theory behind our driver’s operation, characterize its output noise, and demonstrate its use in absorption spectroscopy on the rubidium D1 line.

Direct Measurement of Strain-Dependent Solid Surface Stress

Q. Xu,* K.E. Jensen,* R. Boltyanskiy, R. Sarfati, R.W. Style, E.R. Dufresne (*equal contribution)

Nature Communications 8, 555 (2017)

Surface stress, also known as surface tension, is a fundamental material property of any interface. However, measurements of solid surface stress in traditional engineering materials, such as metals and oxides, have proven to be very challenging. Consequently, our under- standing relies heavily on untested theories, especially regarding the strain dependence of this property. Here, we take advantage of the high compliance and large elastic deformability of a soft polymer gel to directly measure solid surface stress as a function of strain. As anticipated by theoretical work for metals, we find that the surface stress depends on the strain via a surface modulus. Remarkably, the surface modulus of our soft gels is many times larger than the zero-strain surface tension. This suggests that surface stresses can play a dominant role in solid mechanics at larger length scales than previously anticipated.

Strain-Dependent Solid Surface Stress and the Stiffness of Soft Contacts

K.E. Jensen, R.W. Style, Q. Xu, E.R. Dufresne

Physical Review X 7, 041031 (2017)

Surface stresses have recently emerged as a key player in the mechanics of highly compliant solids. The classic theories of contact mechanics describe adhesion with a compliant substrate as a competition between surface energies driving deformation to establish contact and bulk elasticity resisting this. However, it has recently been shown that surface stresses provide an additional restoring force that can compete with and even dominate over elasticity in highly compliant materials, especially when length scales are small compared to the ratio of the surface stress to the elastic modulus, Y/E. Here, we investigate experimentally the contribution of surface stresses to the total force of adhesion. We find that the elastic and capillary contributions to the adhesive force are of similar magnitude and that both are required to account for measured adhesive forces between rigid silica spheres and compliant, silicone gels. Notably, the strain dependence of the solid surface stress contributes to the stiffness of soft solid contacts at leading order.

The contact mechanics challenge: tribology meets soft matter

R.W. Style, B.A. Krick, K.E. Jensen, W.G. Sawyer

Soft Matter 14, 5706 (2018)

In the fall of 2015, Martin Müser suggested a Contact Mechanics Challenge for the Tribology com- munity. The challenge was an ambitious effort to compare a wide variety of theoretical and computational contact mechanics approaches, and involved researchers voluntarily tackling the same hypothetical contact problem. The result is an impressive collection of innovative approaches – including a surprise experimental effort – that highlight the continuing importance of surface contact mechanics and the challenges of solving these large-scale problems. Here, we describe how the Contact Mechanics Challenge also reveals exciting opportunities for the Soft Matter community to engage intensely with classical and emerging problems in tribology, surface science, and contact mechanics.

Phase sensing beyond the standard quantum limit with a modified SU(1,1) interferometer

Kevin Jones and others

Optica 4(7) 752-756 (2017)

An SU(1,1) interferometer, which replaces the beam splitters in a Mach–Zehnder interferometer with nonlinear inter- actions, offers the potential of achieving improved phase sensitivity in applications with low optical powers. We present a novel variation on the SU(1,1) interferometer in which the second nonlinear interaction is replaced with balanced homodyne detection. We show theoretically that this "truncated SU(1,1) interferometer" can achieve the same potential phase sensitivity as the conventional SU(1,1) interferometer. We build an experimental realization of this device using seeded four-wave mixing in 85Rb vapor as the nonlinear interaction, thus employing a bright two- mode squeezed state as the phase-sensing quantum state inside the interferometer. Measurements as a function of operating point show that even with ≈35% loss, this device can surpass the standard quantum limit by 4 dB. This device is simpler to build and operate than the conventional SU(1,1) interferometer, and also eliminates some sources of loss, thus making it useful for applications in precision metrology.

Optimal phase measurements with bright and vacuum-seeded SU(1,1) interferometers

Kevin Jones and others

Physical Review A 95, 063843 (2017)

The SU(1,1) interferometer can be thought of as a Mach-Zehnder interferometer with its linear beam splitters replaced with parametric nonlinear optical processes. We consider the cases of bright- and vacuum-seeded SU(1,1) interferometers using intensity or homodyne detectors. A simplified truncated scheme with only one nonlinear interaction is introduced, which not only beats conventional intensity detection with a bright seed, but can saturate the phase-sensitivity bound set by the quantum Fisher information. We also show that the truncated scheme achieves a sub-shot-noise phase sensitivity in the vacuum-seeded case, despite the phase-sensing optical beams having no well-defined phase.

Improved measurement of two-mode quantum correlations using a phase-sensitive amplifier

Kevin Jones and others

Optics Express 25(18), 21301-21311 (2017)

We demonstrate the ability of a phase-sensitive amplifier (PSA) to pre-amplify a selected quadrature of one mode of a two-mode squeezed state in order to improve the measurement of two-mode quantum correlations that exist before degradation due to optical and detection losses. We use four-wave mixing (4WM) in 85Rb vapor to generate bright beams in a two-mode squeezed state. One of these two modes then passes through a second 4WM interaction in a PSA configuration to noiselessly pre-amplify the desired quadrature of the mode before loss is intentionally introduced. We demonstrate an enhancement in the measured degree of intensity correlation and intensity-difference squeezing between the two modes.

High-precision measurements and theoretical calculations of indium excited-state polarizabilities

N. B. Vilas '17, B.-Y. Wang '18, P. M. Rupasinghe, D. L. Maser, M. S. Safronova, U. I. Safronova, and P. K. Majumder

Physical Review A 97, 022507 (2018)

We report measurements of the scalar and tensor static polarizabilities of the ^{115}In $7p_{1/2}$ and $7p_{3/2}$ excited states using two-step diode laser spectroscopy in an atomic beam. These static polarizabilities are one to two orders of magnitude larger than for lower-lying indium states due to the close proximity of the *7p* and *6d* states. For the scalar polarizabilities, we find values (in atomic units) of 1.811(4)x10^5 a_0^3 and 2.876(6)x10^5 a_0^3 $7p_{1/2}$ and $7p_{3/2}$ states, respectively. We determine the tensor polarizability component of the $7p_{3/2}$ state to be −1.43(18)x10^4 a_0^3. These measurements set high-precision benchmarks of the transition properties for highly excited states in trivalent atomic systems. We also present ab initio calculations of these quantities and other

In polarizabilities using two high-precision relativistic methods to make a global comparison of the accuracies of the two approaches. The precision of the experiment is sufficient to differentiate between the two theoretical methods as well as to allow precise determination of the indium *7p-6d* matrix elements. The results obtained in this paper are applicable to other heavier and more complicated systems, and provide much needed guidance for the development of even more precise theoretical approaches.

Detecting gravitational waves with superfluid 4 He

S. Singh, L. DeLorenzo, A. Pearlman, I. Pikovski and K. C. Schwab

New Journal of Physics, Volum 19, (2017)

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.

Ultralong Dephasing Times in Solid-State Spin Ensembles via Quantum Control

Erik Bauch, Connor A. Hart, Jennifer M. Schloss, Matthew J. Turner, John F. Barry, Pauli Kehayias, Swati Singh, and Ronald L. Walsworth

Physical Review X 8, 031025 – Published (2018)

Quantum spin dephasing is caused by inhomogeneous coupling to the environment, with resulting limits to the measurement time and precision of spin-based sensors. The effects of spin dephasing can be especially pernicious for dense ensembles of electronic spins in the solid state, such as nitrogen-vacancy (NV) color centers in diamond. We report the use of two complementary techniques, spin-bath driving, and double quantum coherence magnetometry, to enhance the inhomogeneous spin dephasing time (*T2* *) for NV ensembles by more than an order of magnitude. In combination, these quantum control techniques (i) eliminate the effects of the dominant NV spin ensemble dephasing mechanisms, including crystal strain gradients and dipolar interactions with paramagnetic bath spins, and (ii) increase the effective NV gyromagnetic ratio by a factor of two. Applied independently, spin-bath driving and double quantum coherence magnetometry elucidate the sources of spin ensemble dephasing over a wide range of NV and bath spin concentrations. These results demonstrate the longest reported *T2* *in a solid-state electronic spin ensemble at room temperature and outline a path towards NV-diamond dc magnetometers with broadband femtotesla sensitivity.

The Boltzmann distribution and the quantum-classical correspondence

Sam Alterman '18, Jaeho Choi '17, Rebecca Durst '17, Sarah M. Fleming '18, and William K. Wootters

Journal of Physics A: Mathematical and Theoretical

In this paper we explore the following question: can the probabilities constituting the quantum Boltzmann distribution, $P_n^B \alpha e^{-E_n/kT}$, be derived from a requirement that the quantum configuration-space distribution for a system in thermal equilibrium be very similar to the corresponding classical distribution? It is certainly to be expected that the quantum distribution in configuration space will approach the classical distribution as the temperature approaches infinity, and a well-known equation derived from the Boltzmann distribution shows that this is generically the case. Here we ask whether one can reason in the opposite direction, that is, from quantum-classical agreement to the Boltzmann probabilities. For two of the simple examples we consider—a particle in a one-dimensional box and a simple harmonic oscillator—this approach leads to probability distributions that provably approach the Boltzmann probabilities at high temperature, in the sense that the Kullback-Leibler divergence between the distributions approaches zero.

A practical quantum algorithm for the Schur transform
William M. Kirby '17 and Frederick W. Strauch

Quantum Information and Computation Vol. 18, pp 0721-0742 (2018)

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 simplify and extend the algorithm of Bacon, Chuang, and Harrow, and provide a new practical construction as well as sharp theoretical and practical analyses. Our algorithm decomposes the Schur transform on n qubits into $O\left(n^4 \log\left(\frac{n}{\epsilon}\right)\right)$ operators in the Clifford+T fault-tolerant gate set and uses exactly $2\lfloor \log_2(n) \rfloor - 1$ ancillary qubits. We extend our qubit algorithm to decompose the Schur transform on n qudits of dimension d into $O\left(d^{1+p} n^{3d} \log^p\left(\frac{dn}{\epsilon}\right)\right)$ primitive operators from any universal gate set, for $p \sim= 3.97$.

Psychology

Childhood Precursors of Narcissistic Personality Features
Phebe Cramer

Journal of Nervous and Mental Disease, 205, 679-684, 2017.

This study identifies childhood personality traits that are precursors of adult Narcissistic Personality Disorder (NPD) 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 measure of NPD features at age 23. The findings thus provide evidence that childhood personality traits predict adult NPD features. Identifying such childhood precursors provides an opportunity for early intervention.

Using the TAT to Assess the Relation Between Gender Identity and the Use of Defense Mechanisms
Phebe Cramer

Journal of Personality Assessment, 99, 265-274, 2017.

The purpose of this study is to explore whether 2 different dimensions of personality, when assessed at an implicit level with the Thematic Apperception Test (TAT; Murray,1943) will show a theoretically meaningful coherence not demonstrated when one is assessed at an implicit level and the other at an explicit level. Gender identity and defense mechanisms were assessed implicitly using the TAT. Gender identity was compared with a self-report measure of gender-related attributes assessed at the explicit level. The results showed a theoretically meaningful coherence when different dispositions were assessed at the same level, but a lack of agreement when similar dispositions were assessed at different levels.

The Development of Defense Mechanisms During the Latency Period
Phebe Cramer

Journal of Nervous and Mental Disease, 206, 286 – 289, 2018.

The developmental period of latency, during middle childhood, has not been previously studied for possible change in the use of defense mechanisms. Using a validated narrative method to assess defenses, the present research examines change in children's defense use during this period. As predicted from theory, there was a significant increase in the use of the defense of Identification. This finding is consistent with theory that posits a shift at this time from defense against anxiety that is based on lack of impulse control to defense that is based on anxiety due to violation of conscience.

Sustaining Outcomes Research in Residential Treatment: A 15-ear Study of the Gould Farm Program
L. Heatherington, B. Bonner, J. Linsley, D. Rosenberg and R. Patterson

Psychological Services, doi.org/10.1037/ser0000253, 2018

We present findings from a study of outcomes of residential treatment for people who have mental illness, primarily schizophrenia-spectrum and bipolar disorders. The study assesses a range of individual variables before and after participation in the program, to examine clinical and personal recovery and facilitate program improvement. To our knowledge, it is the longest ongoing outcomes study (15+ years) of its kind. The program, Gould Farm, provides recovery-focused, milieu treatment on a 700-acre working farm. It integrates counseling and medication with a work program that provides opportunities for the development of daily living, social, and work skills as well as mental and physical health. Clients were interviewed in person at intake and at discharge. Also, since study year 10 when the follow-up arm began, former clients were interviewed at 6, 18, and 36 months postdischarge via phone. Interview protocols included standard measures of psychiatric symptoms and functioning, substance use, quality of life, and treatment satisfaction. Follow-up interview protocols also assessed individuals' living, working, family, and social situations as well as their satisfaction in these areas of recovery. Statistically significant improvements on all measures were found at discharge, and were not moderated by key demographic or clinical factors. Preliminary follow-up data showed maintenance of treatment gains, and high treatment satisfaction. We discuss clinical implications of the findings as well as limitations, directions for future research, and recommendations for sustaining outcomes research in organized care settings.

Perceived Marital Support and Incident Mental Illness: Evidence from a Two-Wave National Survey of the United States

K.A. Feder, L. Heatherington, R. Mojtabai, and W.W. Eaton

Journal of Marital and Family Therapy, 1-16, DOI: 10.1111/jmft.12343, 2018.

Social support in marriage may be associated with reduced risk for mental illness. Past studies are limited by short follow up and a focus on depression. A two-wave nationally representative survey in the United States (n = 2,503) is used to examine whether social support in marriage is associated with the onset of each of four clusters of disorders—internalizing, externalizing, phobic, and bipolar—10 years later. Results indicate that higher levels of perceived marital support were protective against internalizing, fear, and bipolar disorders, and against incident externalizing disorders for women. Protective effects of social support in marriage against mental illness are long-lasting, and sometimes differ by gender. Findings suggest the importance of mental health assessment in clinical practice.

(Family) Relational Communication Control Coding System

M.L. Friedlander, V. Escudero, and L. Heatherington

In E. Brauner, M. Boos, and M. Kolbe (Eds.), The Cambridge Handbook of Group Interaction Analysis. Cambridge, UK: The Cambridge University Press (2018).

Social Constructionism in Couple and Family Therapy: Narrative, Solution-Focused and Related Approaches

L. Heatherington and *B. Johnson '91*

In B. Friese, M. Celano, K. Deater-Deckard, and M. Whisman (Eds.), APA Handbook of Contemporary Family Psychology. Washington, DC: APA (2018).

Where the Alliance and Systems Theory Meet: Relationship and Technique in Brief Family Therapy

L. Heatherington, V. Escudero, and M.L. Friedlander

In O. Tishby and H. Wiseman (Eds.), Developing the Therapeutic Relationship: Integrating Case Studies, Research and Practice (pp. 257-288). Washington, DC: American Psychological Association (2018).

A Metacognitive Illusion in Monkeys

S. Ferrigno, N. Kornell, and J.F. Cantlon

Proceedings of the Royal Society B: Biological Sciences, 284(1862), 20171541, http://doi.org/10.1098/rspb.2017.1541, 2017.

Like humans, monkeys can make accurate judgements about their own memory by reporting their confidence during cognitive tasks. Some have suggested that animals use associative learning to make accurate confidence judgements, while others have suggested animals directly access and estimate the strength of their memories. Here we test a third, non-exclusive possibility: perhaps monkeys, like humans, base metacognitive inferences on heuristic cues. Humans are known to use cues like perceptual fluency (e.g. how easy something is to see) when making metacognitive judgements. We tested monkeys using a match-to-sample task in which the perceptual fluency of the stimuli was manipulated. The monkeys made confidence wagers on their accuracy before or after each trial. We found that monkeys' wagers were affected by perceptual fluency even when their accuracy was not. This is novel evidence that animals are susceptible to metacognitive illusions similar to those experienced by humans.

Self-Regulated Learning: An Overview of Theory and Data

N. Kornell and B. Finn

In J. Dunlosky and S. Tauber (Eds.), The Oxford Handbook of Metamemory. New York: Oxford University Press, doi:10.1093/oxfordhb/9780199336746.013.23 (2016).

Effective self-regulated studying can influence students' learning in school and beyond. This chapter reviews research on two key decisions: when to study and how to study. It first reviews the decisions people make about when to start and stop studying—that is, when to study—and the metacognitive judgments that underlie those decisions. It distinguishes between small-scale and large-scale decisions, such as which problem to work on next and whether to study today at all, respectively. It then discusses decisions about how to study, for example, whether or not to take notes, underline, test oneself, or reread. It then discusses key areas for future research, with an emphasis on student-centric research and research in digital learning environments. It offers practical recommendations for studiers about how to avoid overconfidence and procrastination and how to choose study strategies that increase short-term difficulty and long term success.

Performance Bias: Why Judgments of Learning are not Affected by Learning

N. Kornell and *H. Hausman '12*

Memory & Cognition 45(8), 1270–1280, 2017.

Past research has shown a performance bias: People expect their future performance level on a task to match their current performance level, even when there are good reasons to expect future performance to differ from current performance. One explanation of this bias is that judgments are controlled by what learners can observe, and while current performance is usually observable, changes in performance (i.e., learning or forgetting) are not. This explanation makes a prediction that we tested here: If learning becomes observable, it should begin to affect judgments. In three experiments, after practicing a skill, participants estimated how they performed in the past and how they expected to perform in the future. In Experiments 1 and 2, participants knew they had been improving, as shown by their responses, yet they did not predict that they would improve in the future. This finding was particularly striking because (a) they did improve in the future and (b) as Experiment 3 showed, they did hold the conscious belief that past improvement predicted future improvement. In short, when learning and performance are both observable, judgments of learning seem to be guided by performance and not learning.

How Retrieval Attempts Affect Learning: A Review and Synthesis

N. Kornell and K.E. Vaughn

The Psychology of Learning and Motivation (pp. 183–215), http://doi.org/10.1016/bs.plm.2016.03.003, 2016.

Attempting to recall information from memory (i.e., retrieval practice) has been shown to enhance learning across a wide variety of materials, learners, and experimental conditions. We examine the moderating effects of what is arguably the most fundamental distinction to be made about retrieval: whether a retrieval attempt results in success or failure. After reviewing research on this topic, we conclude that retrieval practice is beneficial even when the retrieval attempt is unsuccessful. This finding appears to hold true in a variety of laboratory and real-world contexts and applies to learners across the lifespan. Based on these findings we outline a two-stage model in which learning from retrieval involves (1) a retrieval attempt and then (2) processing the answer. We then turn to a second issue: Does retrieval success even matter for learning? Recent findings suggest that retrieval failure followed by feedback leads to the same amount of learning as retrieval success. In light of these findings, we propose that separate mechanisms are not needed to explain the effect of retrieval success and retrieval failure on learning. We then review existing theories of retrieval and comment on their compatibility with extant data, and end with theoretical conclusions for researchers as well as practical advice for learners and teachers.

Retrieval Attempts Enhance Learning Regardless of Time Spent Trying to Retrieve

K.E. Vaughn, *H. Hausman '12* and N. Kornell

Memory 25, 298-316, 2017.

Attempting to retrieve information from memory is an engaging cognitive activity. We predicted that people would learn more when they had spent more time attempting to retrieve. In experiments 1a and 1b, participants were shown trivia questions for 0, 5, 10, or 30 seconds and then the answer was revealed. They took a final test immediately or after 48 hours. Retrieval enhanced learning, but the length of the retrieval attempt had no effect (i.e., final test performance was equivalent in the 5-, 10-, and 30-second conditions and worse in the 0- second condition). During the initial retrieval attempt, more time did increase recall, suggesting that participants continued to engage in productive retrieval activities when given more time. Showing the answer for longer (7 versus 2 seconds) increased learning in Experiments 2a and 2b. Experiment 3 examined the effect of retrieval success and Experiment 4 replicated the results using different materials. These results have direct implications for current theories of retrieval.

Defendant Stereotypicality Moderates the Effect of Confession Evidence on Judgments of Guilt

Laura Smalarz, Stephanie Madon, and Anna Turosak

Law and Human Behavior, in press.

This research examined whether criminal stereotypes—i.e., beliefs about the typical characteristics of crime perpetrators—influence mock jurors' judgments of guilt in cases involving confession evidence. Mock jurors (N = 450) read a trial transcript that manipulated whether a defendant's ethnicity was stereotypic or counterstereotypic of a crime, and whether the defendant had confessed to the crime or not. When a confession was present, the transcript varied whether the confession had been obtained using high-pressure or low-pressure interrogation tactics. Consistent with the hypothesis, the presence of a confession (relative to no confession) increased perceptions of the defendant's guilt when the defendant was stereotypic of the crime, regardless of the interrogation tactics that had been used to obtain it. When the defendant was counterstereotypic of the crime, however, the presence of a confession did not significantly increase perceptions of guilt, even when the confession was obtained using low-pressure interrogation tactics. These findings demonstrate the potentially powerful effects of criminal stereotypes on legal judgments and suggest that individuals who fit a criminal stereotype may be disadvantaged over the course of the criminal justice process.

Increasing the Similarity of Lineup Fillers to the Suspect Improves the Applied Value of Lineups without Improving Memory Performance: Commentary on Colloff, Wade, and Strange (2016)

Andrew Smith, Gary Wells, Laura Smalarz and James Lampinen

Psychological Science, in press.

Among the most robust findings in the basic recognition memory literature is that increasing the similarity of lures to the target item decreases memory performance. This truism lies at the very heart of signal detection theory (SDT). Colloff, Wade, and Strange (2016), however, reported that lineups using high-similarity fillers (lineup lures) produced better memory performance than did lineups using low-similarity fillers. Specifically, they claimed that high-similarity fillers improved memory performance by helping witnesses determine which features were relevant for making an identification (i.e., diagnostic-feature detection), thereby making witnesses less likely to "confuse innocent and guilty suspects." Using their data, we show that high-similarity fillers do not improve memory performance and that Colloff et al. used the wrong SDT model to estimate memory performance.

Early Adversity and Internalizing Symptoms in Adolescence: Mediation by Individual Differences in Latent Trait Cortisol

C. B., Stroud, F. R., Chen, L. D. Doane, & D. A. Granger

Development & Psychopathology, in press.

Research suggests that early adversity places individuals at risk for psychopathology across the lifespan. Guided by concepts of allostasis and allostatic load, the present study examined whether early adversity contributes to the development of subsequent internalizing symptoms through its association with trait-like individual differences in hypothalamic pituitary adrenal (HPA) axis regulation. Early adolescent girls (n = 113; M age = 12.30 years) provided saliva samples at waking, 30 minutes post-waking, and bedtime over 3 days (later assayed for cortisol). Objective contextual stress interviews with adolescents and their mothers were used to assess the accumulation of nine types of early adversity within the family environment. Greater early adversity predicted subsequent increases in internalizing symptoms through lower levels of latent trait cortisol (LTC). Trait-like individual differences in HPA axis activity may be among the mechanisms through which early adversity confers risk for the development of psychopathology.

Individual Differences in Early Adolescents' Latent Trait Cortisol: Interaction of Early Adversity and 5-HTTLPR

F. R. Chen, C. B. Stroud, S. Vrsheck-Schallhorn, L. D. Doane and D. A. Granger

Biological Psychology, in press.

Allostatic load theory postulates that early adversity may alter hypothalamic-pituitary-adrenal (HPA) axis functioning. However, not all individuals who experienced early adversity showed alteration in HPA axis functioning, which suggests the existence of moderators. One such moderator could be the serotonin transporter-linked polymorphic region (5-HTTLPR), a genotype that conveys sensitivity to stress. Several studies have provided initial support for the interaction of 5-HTTLPR and early adversity, but findings are inconsistent regarding whether the association between early adversity and HPA axis functioning is stronger among L-carriers or S-carriers of 5-HTTLPR. The present study aimed to examine the interaction of 5-HTTLPR and early adversity on trait-like levels of cortisol, which may prove useful in isolating individual differences in HPA-axis activity. A community sample of 117 early adolescent girls (M age = 12.39 years) provided DNA samples for 5-HTTLPR genotyping, as well as saliva samples for assessing cortisol three times a day (waking, 30 min post-waking, and bedtime) over a three-day period. Latent trait cortisol (LTC) was modeled with the latent factor approach using the first two samples of each day. Early adversity was assessed with objective contextual stress interviews with adolescents and their mothers. The significant 5-HTTLPR x early adversity interaction indicated that greater early adversity was associated with lower LTC levels, but only among those with at least one copy of L allele of 5-HTTLPR. Findings highlight the important role of 5-HTTLPR in influencing the contribution of early adversity to individual differences in HPA axis activity.

Stress Sensitization Models

C.B. Stroud

In K. Harkness and E. Hayden (Eds.), The Oxford Handbook of Stress and Mental Health, New York: Oxford University Press (in press).

The stress sensitization model was developed to explain the mechanism through which the relationship between stress and affective disorder onsets changes across the course of the disorder. The model posits that individuals become sensitized to stress over time, such that the level of stress needed to trigger episode onsets become increasingly lower with successive episodes (e.g., Harkness, Hayden, & Lopez-Duran, 2015; Monroe & Harkness, 2005). The stress sensitization model has accrued empirical support in the context of major depression and to a lesser extent in bipolar spectrum disorders. Furthermore, expanding upon the original stress sensitization model, research also indicates that early adversity (i.e., early childhood experiences) sensitizes individuals to subsequent proximal stress, increasing risk for psychopathology. In this chapter, the theoretical background underlying the stress sensitization model is reviewed, and research evidence investigating stress sensitization is evaluated. In addition, moderators and mechanisms of stress sensitization effects are reviewed, and recommendations for future research are provided.