Report of Science
at
Williams College
2019-2020

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

Williamstown, Massachusetts

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

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Almost done! What a difference a year makes.

THE SCIENCES AT WILLIAMS

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 is also sharing this space until phase II is complete early in 2021. The new building which this year received the name *The Hopper Science Center*, greatly expanded our microscopy and shop facilities to support all of the sciences and includes an updated teaching lab for biochemistry. Construction of a second building to be named the *Wachenheim Science Center* will house the Math/Stats, and Psychology departments as well as Geosciences. Construction on the new building, on the site of the *Bronfman Science Center* which was demolished in the summer of 2018, is nearly complete and is expected to enter service in the spring of 2021.

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.

Approximately 265 students graduate with a major in a science or mathematics discipline each year, and we continue to see about half of all students at Williams College with at least one major in the sciences. The quality of the our science programs has nurtured this interest and this year 65 students were inducted into the Sigma Xi Honor Society as associate members. Williams has become a leader in the training of future scientists with more than 50 former 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. This year, 93 students completed theses and 208 were engaged in research with science faculty during the summer of 2020 with many more working in labs during the school year. 57 students and recent graduates co-authored publications in peer-reviewed journals in the past academic year, including one from the class of '23.

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 places Williams near the top of all non-Ph.D granting institutions. Williams science faculty currently have 23 active research grants totalling over 4.8 million dollars. The individual faculty grants, together with grants from the Sherman Fairchild Foundation, the Henry 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. Advanced equipment and facilities together with our Emphasis on close student-faculty interactions creates opportunities in undergraduate science education at Williams that are exciting, diverse, and forward-looking.

MAJOR SCIENCE 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 grant is used to purchase new equipment, to support maintenance contracts and to repair 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 MALDI-TOF mas spectrometer, transmission and scanning electron microscopes, a UV/Vis/NIR spectrophotometer, an x-ray diffraction instrument a confocal microscope and a nuclear magnetic resonance spectrometer (NMR). In recent years, Kresge endowment funds have been used to upgrade the telescope and NMR and replace the confocal and transmission electron microscopes.

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. We are dedicated to continue to use these resources to provide state of the art equipment for research and teaching efforts in the sciences at Williams College.

Clare Boothe Luce Research Scholarships

Funded by the Henry Luce Foundation, the Clare Boothe Luce research scholars grant seeks to increase 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 initially supported cohorts of up to 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. After the initial 3 year funding period expired, the grant has been contined and has funding outstanding women in the physical sciences in subsequent years. In the 2019-20 year, the grant supported 5 young researchers.

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 31st 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.

For additional external funding sources supporting science center activities, see the chart on page 16.

MAJOR PROGRAMS

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 in terms of physical processes. This including the Sun, stars and star clusters, galaxies and galaxy clusters, quasars and active galaxies, and the cosmic background radiation. 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. New courses are continually added to our curriculum as new faculty are hired with diverse research expertise. 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.

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 interests through 1) its major program, 2) a selection of courses intended for those who are interested primarily in an introduction to computer science, and 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 two courses. The Socio-Techno Web (CSCI 102) introduces many fundamental concepts in computer science by examining the social aspects of computing, and The Art and Science of Computer Graphics (CSCI 109) introduces students to the techniques of computer graphics.

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 Introduction to Weather and Climate (GEOS 100); The Co-Evolution of Earth and Life (GEOS 101); An Unfinished Planet (GEOS 102); Global Warming and Natural Disasters (GEOS 103); Oceanography (GEOS 104); and Astrobiology (GEOS 107).

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 prob-

lem-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 (NSCI 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 400-level discussion-oriented senior seminar. A variety of research opportunities are offered in the Psychology Department through research assistantships, independent study, senior thesis work, and the Summer Science Program.

The psychology major provides an opportunity for liberal arts students to consider the nature of mind and behavior from different perspectives. It provides sound preparation for graduate study in both academic and professional fields of psychology and is relevant to careers in education, business, law, 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.

Our goal is for our students to develop each of 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 latest external review of the department concluded the following: "The Department of Psychology at Williams College offers its students an exceptional undergraduate experience. Students are taught by professors who are productive, important scholars with strong commitments to teaching, and they have rich opportunities to work alongside faculty doing serious research. Faculty are generous mentors to their students; the students with whom we met sang the praises of the department as a whole. The Department has access to a good number of resources that support faculty teaching and scholarship, and the faculty are eager to continue to grow as researchers in a changing field."

Winter Study 2020

Winter study gives students an opportunity between semesters to learn something outside of their typical studies. Options can be quite eclectic or can be be used as an introduction to research in a scientific discipline. While the science departments often sponsor outside instructors to teach on a wide variety of non-science topics, many oppotunities exist to expand a students scientific literacy. Following are some of the winter study courses that were taught by faculty and staff in the sciences in 2020. In addition to this list, each department and interdiscplinary concentration also offers an introduction to research in their dicipline:

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

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. Majors may take this course with additional reading and assignments. Adjunct Bio: Rob Wittenmyer '98 is Professor of Astrophysics at the University of Southern Queensland in Australia. He is a veteran planet hunter with more than 20 published planet discoveries, and is the Chief Investigator of the Minerva-Australis observatory which is NASA's key Southern ground support for the Transiting Exoplanet Survey Satellite.

CHEM 100: It's a Material World-What's It Made Of?

We'll talk about how underlying atomic and molecular scale structure gives rise to physical properties that you already have an intuitive sense for: things like hardness, softness, elasticity, color, brittleness, conductivity, transparency. Once we understand how these properties arise, we can start thinking about how and why we use certain materials for particular applications and consider the historical and societal changes that result from choosing or developing new materials for those specific applications. What kinds of materials (or innovations in the skills or techniques used to produce them) have been valued over time? What has been the impact of these technological advances? From there, we can start to think about how to design new materials with new kinds of properties or combinations of properties. We'll look at old materials as well as new, and venture a bit into the modern world of materials, which involves design and characterization of meso and nanoscale structures. We'll take a little time to do some lab experiments as well, to give you a peek at some strategies used in nanofabrication, as well a chance to use some of the kinds of instrumentation used in studying nanoscale materials.

CHEM 16 / ARTS 16: Glass and Glassblowing

This course provides an introduction to both a theoretical consideration of the glassy state of matter and the practical manipulation of glass. We do flameworking with hand torches for at least 12 hours per week. While no previous experience is required, students with patience, good hand-eye coordination, and creative imagination will find the course most rewarding.

CSCI 10: C, Unix and Software Tools

This course serves as a guided introduction to the Unix operating system and the C programming language. The course is designed for individuals who understand basic program development techniques as discussed in an introductory programming course (Computer Science 134 or equivalent), but who wish to become familiar with a broader variety of computer systems and programming languages. Students in this course will work on Unix workstations, available in the Department's laboratory. By the end of the course, students will have developed proficiency with Unix and the C programming language. The exact topics to be covered may vary depending upon the needs and desires of the students.

CSCI 11: Video Game Appreciation (1972-1992)

Many video games from the 1970s and 1980s are still enjoyable today. However, most classics cannot be fully [appreciated] without proper historical context. For example, [Pong] (Atari, 1972) is trivial when played with modern gamepads but is very challenging with paddle controllers; [Missile Command] (Atari, 1980) fills with

tension when its political backdrop is considered; [Pac-Man] (Namco, 1980) is a nimble orchestration when the AI governing each ghost is understood; [Super Mario Bros.] (Nintendo, 1985) is revolutionary only after playing previous platformers; [Mortal Kombat] (Midway, 1992) is only controversial when compared to previous fighting games. Students will immerse themselves in the first 20 years of commercial video game history through instruction, game play, and game development. We will meet three times a week for 2 hour lectures on digital art, music, culture, technology, business, law, and the people behind developments in these areas. The classes are augmented twice a week by 60-minute sessions in the new Williams College video game lab. Throughout the course, special emphasis will be placed on the constraints that shaped the design of classic video games. At the end of the term students demonstrate their newfound knowledge by developing a retro-inspired video game. Enrollment preference will be given to students who have completed CSCI 134 or have a skill related to video game development (e.g. programming, playtesting, level design, storytelling, pixel art, sound engineering. etc.).

CSCI 12: Stained Glass Tiling: Quasi-crystals and Geometric Solids, Building an Invisibility Cloak

In this course students learn geometric drawing, design, and the traditional craft skills needed to build a stained glass window. Each student will make a single panel of stained glass from a mosaic of transparent colored glass tiles. Students will learn how to cut glass; to paint and print on glass with kiln-fired enamels; to assemble, solder, patinate and frame a stained glass window. Instructional sessions on the use of tools and safe handling of materials are included where necessary. Exhibition of work on the last day of Winter Study is mandatory. All students must participate in setting up a group exhibition of work, and tidying the lab at the end of Winter Study.

CSCI 13: Designing for People

Many technologically-innovative and aesthetically-beautiful products fail because they are not sensitive to the attitudes and behaviors of the people who interact with them. The field of Human Factors combines aspects of psychology with software development, education, architecture, and physiology, and other fields, to design objects that provide an easy, enjoyable, efficient and safe user experience. The course will provide students with a theoretical framework for analyzing usability, as well as practical knowledge of a variety of human factors testing methodologies. The course will examine the usability of a wide variety of designed objects, including buildings, publications, websites, software applications, and consumer electronics gadgets. Students will demonstrate their understanding of human factors theory through a short paper and participation in class discussion. Students identify a usability problem and design a solution which they will evaluate by heuristic analysis and a usability test with 8-10 human test subjects. Findings will be presented on the final day.

CSCI 14: Ethics of Technology

A prominent company recently realized the machine-learning algorithm trained on its past hiring data had learned a bias against female candidates and so was unsuitable for resume evaluation. But given competing definitions of fairness, how should we decide what it means for an algorithm to be unbiased? Machine vision algorithms are systematically less likely to recognize faces of people of color. Since many face recognition algorithms are used for surveillance, would improving these algorithms promote justice? Deep fakes may pose serious challenges to democratic discourse, as faked videos of political leaders making incendiary statements cast doubt on the provenance of real videos. Do the researchers developing these algorithms, often academics funded by National Science Foundation grants, have an obligation to desist? In a field filled with such vexing questions, the ethical issue most commonly addressed by the media is whether a self-driving car should swerve to hit one person in order to avoid hitting two. In this class, we will go beyond the headlines to explore the ethics of technology. We will discuss issues such as transparency, bias and fairness, surveillance, automation and work, the politics of artifacts, the epistemology of deep fakes, and more. Our discussion will rely on articles from the course packet, enlivened by discussions with experts in the field over Skype. Students will apply their ethical knowledge to write multiple newspaper length op-eds arguing for their views. If students choose to submit these op-eds for publication, the instructor will coach them on appropriate procedures and venues.

CSCI 15: An Introduction to the Modern Internet

This course is about the basics of the modern Internet: how it works, and how it is used in our daily lives. We will focus on issues of security and privacy. We will try to answer two main questions in this course: How is in-

formation transmitted online? Who has access to this information, and how do they use it? Students will learn about and discuss these topics based on readings and lectures, and will do a small number of hands-on projects during class. The final assessment will be a 10-page paper on a related topic. No background in computer science or programming is required or expected.

CSCI 28: Solution Design and Product Management

Google Glass, Blackberry Storm, and the initial Obamacare Website represent just a few of the many failures that litter the IT project graveyard: 40 to 60 percent of large technology projects fail. All too often, the cause has little to do with the quality of technical engineering. More often, companies choose the wrong problem to solve or the wrong way to solve it. Google failed to account for the Google Glass price tag and privacy concerns. Blackberry failed to fully appreciate the touchscreen revolution. The Obamacare website failed to address management issues. The underlying conflict is that engineers and IT teams like to be told what to build, but customers often do not know what they want or how to express it. Identifying the right problem, designing the right solution, communicating the correct specifications to engineers, and delivering the right product to primary stakeholders are all difficult challenges crucial for successful product development. This course will explore various frameworks that product managers use to address these challenges. In doing so, we will model interactions between market forces, corporate directives, engineering challenges, and user experiences to interrogate the resilience of our ideas. We will also analyze and critique methodologies presented in readings by technology management prophets Marty Cagan, Steve Blank, Don Norman, Steve Krug and Eric Ries. Throughout the course, students will work in small teams to develop their own product management toolkit and deploy it towards solving a technology problem of each team's own choosing.

Math 12: The Mathematics of Lego Bricks

This course is a modification of six previous winter studies I have done on the Mathematics of LEGO bricks. Similar to those, we will use LEGO bricks as a motivator to talk about some good mathematics (combinatorics, algorithms, efficiency). We will partner with Williamstown Elementary and teach an Adventures in Learning course (where once a week for four weeks we visit the elementary school after the day ends to work with the kids). We will also submit a Lego Ideas Challenge, to try and create a set that Lego will then market and sell. Almost surely there will be a speed build challenge (college teams vs elementary school teams).

Math 15: Exploring the Primes: A Crash Course in Analytic Number Theory

This will be a crash course in analytic number theory. Given our time constraints, our goal will be to obtain a big-picture view of the field by understanding the outline of proofs of the most important results in the field. Among other topics we'll discuss the Riemann zeta function, the Prime Number Theorem, the Riemann Hypothesis, Dirichlet's theorem on primes in arithmetic progressions, and Roth's theorem on arithmetic progressions. There will be no written problem sets, but students will be expected to present solutions to problems in class. Each student will also be expected to write up a class summary (in LaTeX) for one of our meetings.

Math 16: Women and Minorities in Science

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. Students will conduct an independent research project on a scientist of their choosing and lead a discussion based on that individual. Additional reading for this course will include the book Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race, which was made into the 2016 film Hidden Figures.

Math 17: Tournament Bridge

We'll study, prepare, and play in as many bridge tournaments in the area as possible, coupled with analysis, reading, and writing. Tournament play followed by analysis and the writing up of lessons learned is an essential part of the study of bridge. At this level, it is much more than a "game": it is an intense intellectual and academic activity. Tournament time (including days, nights, and weekends) averaging about 12 hours per week, other class time about 6 hours per week, homework 4 hours per week. Text: Larry Cohen https://www.larryco.com/bridge-learning-center Adjunct Instructor Bio: Frank Morgan is Atwell Professor of Mathematics, Emeritus, at Williams College and a Silver Life Master with the American Contract Bridge League.

Stat 10: Interactive Data Visualization

Data visualization is an important means of detecting patterns in data and communicating results to the public. However, if designed poorly, data visualizations can also be ineffective or misleading. Tools for interactive data visualization have become increasingly popular in recent years, giving viewers more autonomy in data exploration. In this course, we will learn techniques for effective data visualization and use these criteria to evaluate visualizations (both static and interactive) in academic publications and in the news. This class will meet about 8 hours per week for lecture and discussion. In addition to participating in class discussions, students will be expected to keep a daily journal, complete short R programming exercises, and create a final project using interactive data visualization tools such as R Shiny.

Stat 11: Introduction to Statistical Analysis of Network Data

Networks are everywhere in our connected world, from social networks like Facebook and twitter, to information networks like citation and coauthors, from biological network like neural and ecological networks, to technological networks like internet connection or power grids. In recent years, there has been an explosion of network data. How do we learn and represent information from these data? In this course, you will see examples from different types of networks. We will learn how to organize, visualize and describe network data using proper tools. Additionally, since things are connected in networks, we will also explore statistical methods to overcome this challenge with dependent data. Tentatively course work includes 2-3 class meetings per weeks for lectures and assignments. Students are also expected to read related materials and finish a final project.

PHYS 10: Light and Holography

his 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 lecturesand discussions. Demonstrations will be presented and students will make several kinds of holograms in the lab. Thanks to a grant from the National Science Foundation, we have 7 well-equipped holography darkrooms available for student use. At the beginning of WSP, the class will meet for lecture and discussion three mornings a week and for lab 2 afternoons a week. The later part of the month will be mainly open laboratory time during which students, working in small groups, will conduct an independent project in holography approved by the instructor. Attendance at lectures and laboratory is required.

PHYS 16: The Way Things Work

How does a motor run? What do chocolate and steel have in common? How does Williams heat and power the campus? Can paper be washed?

What's inside everyday appliances? How do you build a speaker? From simple machines to complex processes, in this course we'll explore the way

things work! Class will meet three afternoons a week for a mixture of lecture, discussion, local field trips, and lots of hands-on exploration. Homework

will primarily consist of readings and exercises relevant to the current class topics and extra tinker-time. In the last part of the course, students will

have a chance to explore the functioning of some process, object, or technology of their choice.

PSYC 11: Designing Your Life and Career after Williams

This course takes a psychological approach to helping you figure out what to do with your life. We start by reviewing your life story up until now and determining how it has shaped you. We discuss, for example, whether you feel pressured to go down a certain road, whether you feel torn between your head and your heart, or whether you feel directionless. Then we take stock of who you really are now, including your core interests, tendencies, strengths, and weaknesses. We try to identify life designs that play to your signature strengths, as opposed to situations that are a setup for frustration and failure. The class encourages you to let go of comparing yourself to your peers, as different people need different things. You explore your underlying values and what you find most important in life. You consider the level of meaning you need in your work, as well as how much you care about money, status, fame, independence, connection, and creativity. The class introduces you to the concept of “flow,” the feeling you get when engaging in activities that provide ideal levels of challenge and mastery. By designing lives and careers that promote flow states, you will be most likely to thrive and not merely succeed. Indeed, it is important not to design a life that appears successful but feels miserable. Your choice of a romantic partner can also have huge implications for the trajectory of your life. The class helps you to identi-

fy typical traps, such as staying with someone who is a bad match, and discusses how to make constructive relationship choices. Ultimately, as there are likely multiple valid life and career paths for you to take, you identify and develop three different plans that feel authentic and inspiring to you.

PSYC 12: Towards a Fuller Life: The Role of Joy, Creativity, Play and Gratitude

What does it mean to live a full life? How does one bring joy, creativity, play and gratitude into daily living? In this experiential course, students will explore concepts and complexities related to play, creativity, joy and gratitude across cultures and develop realistic practices for integrating these qualities into daily life. Students will participate in discussions, experiential activities, well-being challenges, journaling and community projects. Out of class time will emphasize practice opportunities for each of the pillars of the course.

PSYC 14: JA SelCom: A Case Study in Selection Processes

The majority of the time will be dedicated toward selecting the next class of Junior Advisors, an undertaking that will allow students to examine selection processes in general. This course will explore the nature of selection processes. What does an optimal selection process look like? How do our implicit biases materialize in the 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. Readings will cover topics such as organizational behavior and human decision processes, social networks and organizational dynamics, and gendered wording and inequality.

PSYC 15: Ephquilts: An Introduction to Traditional Quilting

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. Reading list: Pieces of the Past by Nancy J. Martin; Stitching Memories: African-American Story Quilts by Eva Ungar Grudin; Sunshine and Shadow: The Amish and Their Quilts by Phyllis Haders; A People and Their Quilts by John Rice Irwin; Treasury of American Quilts by Cyril Nelson and Carter Houck; The Quilt: New Directions for an American Tradition, Nancy Roe, Editor. Requirements: attendance of all classes (including field trip), a love of fabric, design and color, an enthusiasm for handwork, participation in exhibit. Extensive time will be spent outside of class working on assigned projects.

PSYC 16: Self Compassion: The Benefits and Challenges

Ever put yourself down when things aren't going well? Offering yourself compassion is often recommended by therapists and is a skill taught in some modes of therapy. What is the basis for this recommendation? How is self-compassion put into practice? What makes it so challenging? You will learn about the elements of self-compassion, explore and experience different ways of offering yourself compassion, and discuss your experiences. You will look at ways that self-compassion can positively impact your mental health, your work, your play, and your relationships. You will be asked to practice skills between classes, do some reading, and reflect on your experiences.

PSYC 18: Peer Health Call In Walk In Training

This course is the full training for students who would like to cover Call In Walk In shifts in the Peer Health Office (Paresky 212). Students should either already be a member of Peer Health, or have an interest in joining Peer Health, as those students will get priority acceptance. Topics that we will cover include alcohol and other drug use; sex, STIs and contraception; rape, sexual assault and Title IX compliance; mental health; stress and sleep; healthy and unhealthy relationships, etc. Students will meet various on- and off-campus resources for referral. Outside of class work will include readings, video viewings, information gathering, and a possible field trip to local agencies.

PSYC 21: Psychology Internships

Would you like to explore applications of psychology in the "real world?" This course gives students an opportunity to work full-time during Winter Study in a mental health, business, education, law or other setting in which psychological theories and methods are applied to solve problems. Students are responsible for locating their own potential internships whether in the local

area, their hometowns, or elsewhere, and are welcome to contact the course instructor for suggestions on how to do this. In any case, all students considering this course must consult with the instructor about the suitability of the internship being considered before the Winter Study registration period. Please prepare a brief description of the proposed placement, noting its relevance to psychology, and the name and contact information of the agency supervisor. Before Thanksgiving break, the student will provide a letter from the agency supervisor which describes the agency, and the student's role and responsibilities during Winter Study. Enrolled students will meet the instructor before Winter Study to discuss matters relating to ethics and their goals for the course, and after Winter Study to discuss their experiences and reflections.

PSYC 23: STEAM Sandboxes: Public Pedagogy and Transformative Learning

Where, when, and how do children learn outside of school? What is STEAM education, and who has access to it? Why does creative youth development matter in our society? Creative problem solving–the flexibility, persistence, and openness to generate and apply novel solutions to problems–is essential for success in school, the workplace, and beyond. The Bay Area Discovery Museum (BADM) has developed a pedagogical framework for educators to build children's creative problem-solving skills through intentional experiences. We will use this framework to guide our exploration of informal learning environments, including museums, libraries, and other out-of-school places, investigating how children–and adults in their lives–access learning in STEAM content areas, especially the sciences and the arts. In addition to class meeting time, we plan to take two or three day-long field trips to local and regional museums and other educational sites. Alongside our research in the field and discussions in class, students will create a journal in the medium of their choice (written, visual, aural) to document and reflect on their learning. Students will also work individually or collaboratively to design a prototype for a STEAM exhibition, event, song, podcast, video, or project of their choosing that they will present at the end of the session. We welcome anyone with an interest in contributing to the field of education, making, creating, and innovating! This course is not limited to students with backgrounds in psychology, the sciences, or art.

After more than 20 years of caring for our research animals, Dan Viall retired in January of 2020. We wish all the best in his well earned retirement.

THE SCIENCE CENTER

The departments within the science center are: Astronomy, Biology, Chemistry, Computer Science, Geosciences, Mathematics and Statistics, Physics, and Psychology departments and also the interdisciplinary programs in Astrophysics, Biochemistry and Molecular Biology (BiMo), Environmental Studies (CES), and Neuroscience. The science departments are proud of our history of interdisciplinary interaction among members of the various disciplines. This interaction is facilitated through the sharing of core research equipment and services; through interdepartmental programs; and, to a great extent, by the close accociation of faculty with common interests regardless of their departmental affiliation. Several Science Center activities further promote this 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.

The science buildings at Williams have undergone extensive changes over the past several years. This effort will soon be coming to an end which will leave us with new or remodeled facilities serving nearly all of our eight departments and 4 interdisciplinary programs.

In 2018, large parts of the Biology, Chemistry and Physics departments moved into what was at the time referred to as the Scouth Science Building. That uninspired name has now been replaced with its new name *The Hopper Science Center*, named after the glacial cirque which is a signature geological feature of Mount Greylock and is visible from the building to the south.

In early 2021, we expect to move into the new building being built at the site of the former *Bronfman Science Center*. This new building, to be named the *Wachenheim Science Center*, will house the Geosciences, Mathematics/Statistics, and Psychology departments.

These new buildings are attached to the older structures (the three original Thompson Labs buildings, the Morley Science Labs, and the Schow Science Library) via bridges. This allows us to continue the tradition of collaborative work and engagement within and among the various departments that has been a hallmark of the sciences at Williams for over five decades.

Clark Hall, the traditional home of the Geosciences department, will be emptied when the department consolidates into their new home in the new *Wachenheim Science Center*. The fate of Clark Hall has not yet been determined, but in the short term it will continue to be used for classroom space while the college weighs its options for this historic building.

In addition to the construction of two new buildings, reorganization within the original structures has also occurred. The rapidly expanding Computer Science department has expanded to the third floor of the Thompson Biology Labs building into lab space that was vacated during the move to *The Hopper Science Center*. They now occupy most of the space on the top floor of all three Thompson lab buildings.

The Williams College science departments are extremely fortunate to have secured sustainable funding for equipment through generous gifts from a number of benefactors notably including the Kresge and Keck Foundations, and the Alden Trust. These equipment budgets allow the science center to maintain a suite of state of the art instrumentation which is shared by all departments. The equipment is maintained by a group of dedicated technical professionals in several departments: Nate Cook in the Chemistry department, Kevin Forkey in Physics, CJ Gillig in Psychology, Jay Racela in the Center for Environmental Studies, Brad Wakoff in Geosciences, and Audrey Werner in Biology. Nancy Piatczyc manages the Oberndorf Family Microscopy Suite in The Hopper, and Kevin Flaherty maintains our telescopes including our large 24 inch reflector on the roof of the Thompson Physics Building. Finally, Michael Taylor and Jason Mativi provide incredibly important support for all departments in our shops (wood, metal, electronics and print fabrication) allowing us to repair, maintain and design creative solutions to many issues that arise.

In the past year, we have used our funds to acquire new instrumentation in support of our research and teaching efforts. This past year we have purchased a new critical point dryer and sputter coater to support the new scanning electron microscope purchased last year. We are currently looking to replace our aging MALDI-TOF mass spectrometer which was purchased in 2005.

-Norman Bell, Editor

SCIENCE LUNCH COLLOQUIA

Tiku Majumder, Physics	Welcome & Introductions
Charlie Doret, Physics	Complex Applications for Simple Atoms: Projects Inspired by Matt Carter
Bud Wobus, Geosciences	Great Blasts from the Past - Some Favorite Ignimbrites
MSandstrom/DLoves/DBuell/TMajumder	Strategic Planning Discussion
Laura Muller, Director, Quantitative Skills Prog. & Jonathan Leamon OIT	QLAB: Designing online modules for quantitative skill building within courses
Aaron Williams, Computer Science	Randomly Generating Puzzles for Dr. Mario
Ben Thuronyi, Chemistry	Teaching a fast-growing bacterium to do tricks
Steve Swoap, Biology	Alternate nostril breathing - Serenity, Now!
Colin Adams, Math	Knotted Proteins
Eliza Congdon, Psychology	How our Hands Help us Think
Kate Jensen, Physics	The Intriguing Mechanics of Soft Interfaces
Anne Jaskot, Astronomy	Which Galaxies Lit Up the Universe?
Eva Goedhart, Mathematics	A Few Ideas to Solving Diophantine Equations
Jay Pasachoff, Astronomy	Williams College Solar Eclipse Expeditions
Sam McCauley, Computer Science	Hashing, Dictionaries, and Similarity Search

Due to the global COVID-19 pandemic, science lunches were cancelled after the college decided to shut down in mid-March 2020. Faculty who were affected by that decision and unable to present were: Phoebe Cohen (Geosciences), Jeremy Cone (Psychology), Amanda Turek (Chemistry), Graham Giovanetti (Physics), and Josh Carlson, Mathematics).

IN MEMORIAM

Professor Bill Grant passed away on November 28, 2019 at the age of 95 after a long retirement. Bill taught in the Biology department from 1956 until his retirement in 1991. He is a former chair of the Science Executive Committee. Our condolences go out to his former colleagues and friends who remember Bill.

SUMMER SCIENCE RESEARCH

Normally the summer is a relaxed, yet focused time for research, without the competition of course work to interrupt collaborative efforts between students and faculty. Summer science research (SSR) at Williams College is one of, if not the most important times of the year. Students from all science disciplines conduct focused research work under the tutelage of a faculty advisor. This is a full time, paid research position for typically nine weeks every summer for the past several decades. In 2020, As with everything else, the COVID-19 pandemic created new challenges which we needed to overcome to allow this important program to happen. Through the hard work and creativity of our faculty and staff, we found a way to engage students in research and continued our long tradition.

In late June, when we would normally be welcoming students to SSR, we were not yet ready to safely open the college. Instead, faculty found other ways for students to work and learn. Many faculty, especially in theoretical disciplines, were able to function remotely just as easily as in person. People conducting field work could often be sufficiently safe to carry on. Others needed to find creative activities and focus on library research or other preparation work to further their research for once they were able to be physically in the lab.

We had more options for students based on the amount and nature of the work that their advisor had available for them. A student might be offered a full 10 week appointment with a $4200 stipend. Half and quarter appointments were also available based on the amount of work available. In addition to college funds, funding for our 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.

Obviously, SSR Tuesday lunches and seminars were cancelled for this year. We were also unable to host the normal end of the summer poster session. Hopefully we can safely return to the old model in summer of 2021.

Summer Research Fellowships were awarded to 208 individuals at Williams during the summer of 2020, which is actually an increase of 26 from 2019. Many of the summer research students entering their senior year are beginning work that will lead to senior honors research. This summer, we continued to receive support from the Henry Luce Foundation through the Claire Booth Luce Scholorship for Women in Science. This award is for sophomore women majoring in one of the six physical science disciplines (Astronomy, Chemistry, Computer Science, Geosciences, Mathematics/Statistics or Physics). In addition to their summer stipends, Clare Boothe Luce Scholars were each granted $1,100 for research materials. Normally this fund also covers conference expenses, but COVID-19 made that unnecessary. 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.

2020 SSR FUNDING

Contributors	Number of Stipends Supported
1966 Grant Science Summer Research	2
Alison Davis resaerch Fellowship	1
Arnold Bernhard Foundation Summer Fellows Program	49
Bronfman Science Center Fund	6
Clare Boothe Luce Scholarships for Women in Science	2
Class of 1951	10
Freeman Foote Fund	1
Grant Science Research Fellow	4
Louis 1950 Summer Science Research Fellowship	2
Lowe 1940 Summer Science Research Fellows	3
Lowe JA III 1973 Chemistry Fellowship	6
Markgraf JH 1952 Fellowships	4
NASA (Astronomy)	2
NSF/NIH grants to individual faculty	22
SMALL	15
Somers B&L 1948 Physics Internships	6
Sperry Family (Geosciences)	2
Synnott 1958 Fund	1
Wege-Markgraf Chemistry Fellowships	14
Whitehead Scholars Program (Biology)	1
Williams Bicentennial Psychology Scholarship	2
Williams Science Center Funding	44
Williams Summer Science Program Alumni	17
Total Student Stipends	**216**

2020 SSR Faculty and Students

Astronomy	
Kevin Flaherty	Michael Arena
	Peter Knowlton
	Amina Diop
Anne Jaskot	Eric Drybread
	Noor Alsairafi
	Achref Dhahbi
	Patricia Fofie
	Anneliese Silveyra
Jay Pasachoff	Renée DePencier Piñero
Biology	
Sonya Auer	Emily Agreda
	Angela Chen
Lois Banta	Maya Huffman
	Rachel Cross
	Surabhi Iyer
	Georgia McClain
	Sofia Neaher
Janis Bravo	Yuchen Wang
Matt Carter	Sarah Willwerth
	Brennan Lee
Pei-Wen Chen	Ben Maron
	Katya Khalizeva
	Yoshimura Maki
Joan Edwards	Elise Kuwaye
	Alexandra Grusky
Allison Gill	Rollie Grinder
	Crystal Ma
Cynthia Holland	Irfa Qureshi
	Jessica Hem
	Miriam Li
Tim Lebestky	Lee Dasol
	Brian Greenstein
	Katherine Melkonian
	Raphael O Rakosi Schmidt
Luana Maroja	Nevyn Neal
	Alina Luchyshyn
Martha Marvin	Elida Lopez
	Erin Courville
	Nat Davidson
Martha Marvin	Gursajan Gill
Claire Ting	Kiersten Campbell
	Chloe Heiting
Damian Turner	Elizabeth Kwon
	Gabrielle Martin
Chemistry	
Anthony Carasquillo	Andrew Hallward-Driemeier
Nathan Cook	Xiaoyi Zhang
	Alexa Roldan
Amy Gehring	Angel Ibarra
	Steve Menjivar
	George Yacoub
Christopher Goh	Lilianne Au
Sarah Goh	Harrison Toll
	Vanessa Quevedo Barrios
	Andrei Draguicevic
	Kevin Garcia Rios
Kerry-Ann Green	Chulwoo Kim
Katie Hart	Devin Biesbrock
Lee Park	Tong Gao
Enrique Peacock-Lopez	Marcelo Mazariego
	William Bock
	Delaney Soble
	Chloe Hysore
Bob Rawle	Olivia Graceffa
	Eunice Kim
	Abraham Park
	Papa Anderson
	Amy Lam
Thomas Smith	Cody Carrier
Jay Thoman	Mia Holtze
	Anna Jackowski
	Marika Massey-Bierman
Ben Thuronyi	Aspen Pierson
	Russell Blakey
	Michelle Laker
	Madeline Ohl
Amanda Turek	Maria Roman
	Uriel Garcia
	Carolina Martinez

Computer Science	
Duane Bailey	Madeline Burbage
Iris Howley	Hannah Ahn
	Kelsie Hao
	Minh Phan
Bill Jannen	Chris Chung
Bill Lenhart	Nasim Borazjanizadeh
Samuel McCauley	Ammar Eltigani
	Petros Markopoulos
	Max Stein
Kelly Shaw	Jared Berger
	Karol Regula
	Atlas Yilmaz
Shikha Singh	Tai Henrichs
	David Lee
Aaron Williams	Jack Ellert-Beck
	Jennifer Lee
	Trang Ngo
Geosciences	
Alice Bradley	Galen Cassidy
	Davis Collison
Phoebe Cohen	Roman Ruiz
	Mariana Hernandez
José Constantine	Molly Lohss
	Ruby Bagwyn
	Maxine Ng
	Michael Armstrong
Mea Cook	Rheanna Fleming
	Dayana Manrique
	Alex Quizon
Ronadh Cox	Aria Mason
	Niku Darafshi
	Devon Parfait
Lisa Gilbert	Hayden Gillooly
	Cameron Weiner
	Jennifer Crandall
Jay Racela	Catherine Powell
Mathematics and Statistics	
Colin Adams	Michele Capovilla-Searle
	Darin Li
	Jacob McErlean
	Natalie Stewart
	Qiao Li
Colin Adams	Alex Simons
	Xiwen (Miranda) Wang
Julie Blackwood	Tommy Kirby
Xizhen Cai	Nick Langel
Josh Carlson	Emily Lopez
	Ashley Zhuang
	Emily Cairncross
	Peter Hollander
	Benjamin Kitchen
Eva Goedhart	Veronica Berger
	Saisha Goboodun
Leo Goldmakher	Emil Graf
Steven Miller	Fangu Chen
	Yuxin Lin
	Sunita Bhattacharya
	Jason Zhao
	Jianhui Yu
	Jack Murphy
	Akihiro Takigawa
	Fernando Trejos Suarez
	Rodrigo Bravo
	Elena Kim
	John Lentfer
	Phuc Huu Lam
	Elzbieta Bolydriew
	John Haviland
Ralph Morrison	Marino Echavarria
	Liza Jacoby
	Vlad Raluca
	Max Everett
	Robin Huang
	Benjamin Weber
Cesar Silva	Alexander Trevithick
Mihai Stoiciu	Chenyang Sun
Chad Topaz	Rain Condie
	Cameron Edgar
	Kelli Garrant
	Eyobel Gebre
	Hailey Han
	Elias Lindgren
	Jason Meintjes
	Saud Shafi
	Kanjanasaratool Unchitta

Chad Topaz	Diego Esparza
	Kasey Stern
Physics	
Daniel Aalberts	Brendan Hall
	Shayan Moazeni
Charlie Doret	Paige Robichaud
	Matthew Roychowdhury
	Aidan Ryan
Graham Giovanetti	Save Koontaweepunya
	Duncan McCarthy
	Filip Niewinski
	Declan Smith
Kate Jensen	Nick Patiño
	Brianna Binder
	Sophia Millay
	Eshaan Patel
	Caroline Tally
	Ryan Watson
	Charlotte Jones
Catherine Kealhofer	Nelly Lin-Schweitzer
	Ilana Albert
	Declan Daly
	Josh Reynolds
Tiku Majumder	Gabriel Patenotte
	Patrick Postec
Fred Strauch	Paige Robichaud
	Irfan Durmic
	Hyeongjin Kim
	Tim Saffold
David Tucker-Smith	Justin Berman
	Jihoon Kim
	Benny Weng
Psychology	
Victor Cazares/ Noah Sandstrom	Gwyneth Maloy
Jeremy Cone	Jacob Fink
	Sam Mermin
Eliza Congdon	Karla Mercedes
	Erica Qin
	Elijah Tamarchenko
Steven Fein	Matan Levine-Janach
Amie Hane	Cynthia Masese
	Victoria Saltz
	Grace Yang
	Laura Westphal
Shivon Robinson	Andrea Orozco
	Daniel Hahn
Shivon Robinson	Simone Veale
Stephanie Steele	Nigel Jaffe
	Cailin Stollar
Safa Zaki	Angela Wang

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-third summer in 2020, twenty-one students took classes in chemistry, 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.

This year due to the COVID-19 pandemic, SSP was held entirely remotely. As such, we were unable to provide students withan in-person lab experience or various field experiences as we have done in previous years. Nevertheless, We participation levels were similar to past years and the students finished the summer with an invaluable experience that left them better prepared for the rigors of college life.

Faculty involved in teaching the Summer Science Program included: Professors Chris Goh, Sarah Goh and Amy Gehring (Chemistry), Professors Lori Pedersen and Mihai Stoiciu (Mathematics), Professor Matt Carter (Biology), Professor Cassandra Cleghorn (English).

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

2020 SSP PARTICIPANTS

Student Participants

Eli Andrade
Wongi Ayele
Ivy Dang
Sarah Fida
Hanna Garcia
Berenize Garcia Nueva
Gabby Gonzalez
Megan Groomes
Will Huang
Steven Lee
Skyla Lumbard
Lucy Ly
Hector Mendoza
Kevin Molina
Ruby Navarro
Emily Rodriguez
Ella Serrano-Wu
Morgan Steckler
Melia Vega
Lina Wang
Daniel Yuan

Student Tutors

Joseph Flores
Chloe Hysore
Cinthya Maldonado
Laurel Swanson

Faculty

Chris Goh, Chem., SSP Director
Cassandra Cleghorn, English
Amy Gehring, Chemistry
Sarah Goh, Chemistry
Matt Carter, Biology
Lori Pedersen, Math
Mihai Stoiciu, Math

SUMMER SCIENCE LAB PROGRAM

For over 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 undergraduate or a Mount Greylock Regional School student and investigates a variety of chemical reactions relating to solids, liquids, and gasses. Williams College chemistry professors Dave Richardson and Chip Lovett have presented 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.

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. Williams College has also generously sponsored elementary student scholarships and busing to make this opportunity widely available.

This year, it was determined that we could not safely hold the Summer Science Lab Program due to COVID-19 concerns. This was a difficult decision to make, but we are committed to bringing this important program back to halls of Williams as soon as it is safe to do so.

SIGMA XI

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 2019-20 were Professor Jay Pasachoff of the Astronomy Department (President), and Professor Lois Banta of the Biology Department (Secretary/Treasurer).

This year, the local Sigma Xi chapter was able to sponsoronly one talk. In a normal year there would be two which are directed to broad community audiences. In the fall of 2019, Manuel Morales of the Biology department delivered a talk titled *"Mutualism: When is good-good too much of a good thing"*. The lecture was followed by a lively and well-attended reception in the Science Center Atrium.

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

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. This year the 65 inductees were celebrated with a pre-recorded virtual ceremony on June 6, 2020.

Detailed descriptions of their honors research projects are presented in this report starting on page 94. This year's honorees are as follows:

Astronomy	Sarah Michels	Konnor Herbst
Nicol Ford	Dylan Millson	Geunho Kye
John Inoue	Larissa Silva	Benjamin Logsdon
Christian Lockwood	Computer Science	Jacob Pesikoff
Connor Marti	Yo Akiyama	Alison Robey
Allen Wang	William Burford Jr.	Teresa Yu
Biology	Noah Cowit	**Neuroscience**
Sierra Diaz	Emmie Hine	Carmen Bango
David Gorestki	Minwoo Kang	Masen Boucher
Jenks Hehmeyer	Adly Templeton	**Physics**
Breelyn Karno	Tongyu Zhou	Qiyuan Hu
Calla Khilnani	**Environmental Science**	Heather Kurtz
Grace Kromm	Summer-Solstice Thomas	Jacob Lezberg
Sierra Loomis	**Geosciences**	Edgar Lyons
Cristina Mancilla	Jared Bathen	Abdullah Nasir
Eily Mixson	Marshall Borrus	Mariam Ughrelidze
Matthew Newman	Ethan Lopes	**Psychology**
Rio Salazar	Katherine Pippenger	Tristan Colaizzi
Robert Smith	Matthew Wiseman	Chloe Kaplan
Abraham Steinberger	**Mathematics**	Sarah Kelly
Joelle Troiano	Alex Bank	Carl Porto III
Chemistry	Michael Curran	Whitney Sandford
Maia E. Czaikowski	Eli Cytrynbaum	**Statistics**
Joseph Flores	Akhil Dayal	Dzung Pham
Ching-Hsien Ho	Nicholas Goldrosen	Jacob Shuman

ASTRONOMY NEWS

A field of stars and the milky way. Photographed at the top of Petersburg Pass on the New York/Massachusetts border. The beacon on the war memorial on Mount Greylock's summit can be seen in the lower left corner.

The Astronomy faculty includes Jay Pasachoff, Chair, Field Memorial Professor of Astronomy and Director of the Hopkins Observatory; Anne Jaskot, Assistant Professor of Astronomy; and Kevin Flaherty, Lecturer in Astronomy and Observatory Supervisor. Marcos Peñaloza-Murillo, Professor Emeritus at the Universidad de los Andes, Mérida, Venezuela, served as a visiting scientist remotely from Venezuela.

Because of COVID-19, in campus instruction ceased in mid-March, a week ahead of the normal spring break. After spring break, instruction resumed remotely.

The Astonomy Department participates in the Class of 1960 Scholars program. The following students wer selected as scholars this year in Astronomy and Astrophysics:

Christian Lockwood	Astronomy
Nicole Ford	Astrophysics
Jonny Inoue	Astrophysics
Connor Marti	Astrophysics

Professor **Jay Pasachoff** and his students continue to study the data from previous solar eclipse observations including the Great American Eclipse of August 2017, and the total solar eclipe observed in July 2019 from La Higuera, Chile. Work is underway with former students *Christian Lockwood '20* and *John Inoue '20* to view and study the next total solar eclipse from Las Grutas, Argentina which will occur on December 14, 2020. The latter 2 viewings are supported by a 3-year NSF (renew-

al) grant with Pasachoff serving as the principal investigator on behalf of Williams College.

The Pasachoff team is especially focused on study of the solar corona, which is now in the minimum of the solar-activity cycle. This most obviously affects the sunspot cycle, but also affects the shape and temperature of the solar corona and other aspects of the sun.

Pasachoff gave his Heliophysics senior seminar as a tutorial in fall 2019. *Alan Wang '20*, one of the participants, completed a senior thesis joint with the Mathematics Department on power spectra of high-cadence eclipse data taken in collaboration with Michael R. Person of MIT at the 2017 eclipse. The 2019 eclipse was at an altitude of only 13° above the horizon, so didn't seem suitable for oscillation observations because of possible confusion with terrestrial complications, but a repeat of the experiment is planned for the 2020 total solar eclipse. Alan was elected to Sigma Xi at graduation.

Christian Lockwood also did a senior thesis, based on his computer analysis of multiple images of the corona at the 2019 eclipse in order to overcome the difficulty of the extreme dynamic range of the solar corona. In addition to also being elected to Sigma Xi, Christian was elected to Phi Beta Kappa and was awarded the Milham Prize in Astronomy.

Pasachoff observed the annular solar eclipse of 26 December 2019 from south India, near the Kodaikanal Solar Observatory, with liaisons including Robert Lucas of Australia, Jagdev Singh of the Indian Institute of Astrophysics, and Stephen Inbanasan of The American College in Madurai. The university had been founded by missionaries inspired the Haystack event of 1804 at Williams College, and Prof. Inbanasan had even made a pilgrimage a decade ago to our campus to see the monument. Due to COVID-19 restrictions, International travel was not possible for the 21 June 2020 annular solar eclipse that passed over East Africa, and into parts of China, Taiwan, and near Guam. However, Pasachoff helped advise and coordinate observations from the path of annularity. *Edwin Carpio '21* assembled the web page https://sites.williams.edu/eclipse/ring-of-photosphere-eclipse-21st-june-2020/.

Pasachoff is Chair of the International Astronomical Union's Working Group on Solar Eclipses, which is joint between the heliophysics and education/outreach/heritage "Interdisciplinary" divisions of the IAU, with a website he maintains, assisted by Edwin Carpio '21, 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.

Pasachoff arranged sessions at the joint meeting of the American Astronomical Society's Division of Planetary Sciences and the European Planetary Science Congress in Geneva, Switzerland, in October; and at the main American Astronomical Society meeting in Honolulu in January 2020.

Images and descriptions of the solar eclipses Pasachoff has observed are available at http://eclipses.info = http://sites.williams.edu/eclipse/; as of those observations, Pasachoff has observed 72 solar eclipses including 35 total solar eclipses.

Pasachoff continued his solar-system work, together with 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.

Following Pasachoff's spring 2019 sabbatical, he remains a Visitor at the Carnegie Observatories, Pasadena. He observed the November 11, 2019, transit of Mercury across the face of the Sun, the last such until 2032, at the Big Bear Solar Observatory in California with colleagues including *Muzhou Lu '13*. Lu is now working at SpaceX in California and has qualified as a flight engineer for them.

Pasachoff continued as Chair of the Working Group on Solar Eclipses of the International Astronomical Union's as part of the IAU's reorganized Division structure that put the Interdivisional Working Group as part of both the Education, Outreach, and Heritage Division and the Sun and Heliosphere Division. He is a member of the Organizing Committee of the History of Astronomy commission in which he is also a member of the Johannes Kepler Working Group. He continues as U.S. National Liaison to the successor IAU commission on Education and Development.

Pasachoff continues as representative of the American Astronomical Society to the American Association for the Advancement of Science's Astronomy Division, of which he was twice chair. Pasachoff was one of the first group of 200 Legacy Fellows of the American Astronomical Society, elected in 2020: https://aas.org/press/aas-announces-first-class-aas-fellows

Results from the August 2019 IRAM (Institut de Radioastronomie Millimétrique) observations of deuterat-

ed molecules in gas clouds of the Milky Way Galaxy were sufficient for them to receive more observing time at IRAM which occurred on June 24, 2020 (remotely). more information can be found at http://cosmicdeuterium.info.

For information about Williams College's eclipse and transit expeditions, visit the following websites:

http://www.eclipses.info, http://totalsolareclipse.org, and http://www.transitofvenus.info.

Pasachoff continued as President of Williams College's Sigma Xi chapter. He continued as the Williams College representative to the NASA-sponsored Massachusetts Space Grant Consortium. With Pasachoff's sponsorship, *Christian Lockwood '20* received a $5000 Grant in Aid of Research (GIAR) from Sigma Xi for his participation in the December 14, 2020, total solar eclipse expedition planned for Las Grutas, Argentina.

Pasachoff continues as physical-science book reviewer for The Key Reporter, the Phi Beta Kappa newsletter.

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

In November 2019, Pasachoff received the Klumpke-Roberts Award of the Astronomical Society of the Pacific, "for his lifelong endeavor as a popular and scholarly communicator." He received the award at the Gala event in San Francisco. The award is named for Dorothea Klumpke (1861-1942) who, in 1893, was the first woman to earn an advanced degree in astronomy. (https://www.lindahall.org/dorothea-klumpke-roberts/)

Pasachoff continued to supervise the activities at the Old Hopkins Observatory, which are scheduled by Astronomy Administrative Assistant Michele Rech. Students operating the planetarium (suspended in March 2020) included *Christian Lockwood '20; Patrick Postec '21;* and *Peter Knowlton '21*. Students operating the observatory included *Isaac Wilkins '22* and *Jadon Cooper '22*.

In June 2020, the Hopkins Observatory received a gift of an 1874 Alvan Clark 4 inch refracting telescope. The telescope was a gift was from Harriet and David Borton, grandparents of *Eva Borton '23*. The telescope is from the same maker as the 7" telescope in the dome of the historical 1836 Observatory building.

Pending decisions on in-person vs. remote teaching for fall 2020, Pasachoff revised his Leadership in Astronomy (ASTR 240 = LEAD 240 = HSCI 240 = Science and Technology Studies 240) through study of the rare books in the Chapin Library in preparation for teaching it for a third time, in fall 2020, jointly with Chapin Librarian Wayne Hammond. Among the leaders discussed will again be Copernicus, Galileo, Kepler, and Einstein, with first editions of their major books on display, as were First, Second, Third, and Fourth Folios of Shakespeare along with a discussion of astronomy in Shakespeare's works.

http://chapin.williams.edu/pasachoff/checklist.html

Lecturer **Kevin Flaherty** has continued his research on the formation of planets. With data from the Atacama Large Millimeter/submilleter 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 young stars. This work led to the publication of a paper looking for turbulence around three young stars, the largest such sample examined in the literature using molecular line emission, with the detection of turbulence around one of these systems. These results were presented last summer at a conference at Ringberg Castle in Germany. Kevin was also co-author on a review paper on the dynamics of planet-forming disks submitted for consideration in the Protostars and Planets VII conference in Japan next year.

Kevin's research in this area continues with the help of Williams students. This past year *John Inoue '20* completed a senior thesis studying the molecular line emission from a warped planet forming disk. Johnny adapted the existing code to handle a warped system, while applying advanced statistical techniques in comparing the models and the observations. This summer, and continuing into her senior thesis this coming year, *Amina Diop '21* is using emission from the molecules N2H+ and DCO+ to examine the spatial structure of turbulence in the one system in which turbulence has been detected. Kevin was awarded time on ALMA this past year to complete the observations for this project. *Michael Arena '23* is spending the summer searching through the ALMA archive for additional plant-forming disks within which turbulence could be potentially be measured.

Extending beyond turbulence, Kevin continues his interest in other aspects regarding the conditions of planet formation. This summer, and continuing into his thesis, *Peter Knowlton '21* is examining the mass budget around young close binary stars, also known as proto-Tatooine systems (after the planet in Star Wars, notable for having two suns). Kevin is also interested in the debris left over from the collisions of Pluto-sized bodies in more mature systems, and was awarded time on ALMA to search for such debris around nearby young low mass stars. He also contributed as co-author to two papers studying the structure of such debris disks around nearby systems.

Over the past year Kevin has attended the KNAC fall symposium at Vassar College, the virtual meeting of the American Astronomical Society this past summer, as well as the conference at Ringberg Castle in Germany.

Assistant Professor **Anne Jaskot** continued her research on rare dwarf starburst galaxies, nearby galaxies that resemble galaxies from the early universe. Her research focuses on understanding "reionization", a period of time in the early universe when ultraviolet light escaped galaxies and ionized the universe's intergalactic hydrogen gas.

She is currently leading a team of more than 40 international researchers in the Low-Redshift Lyman Continuum Survey, a program that uses the Hubble Space Telescope to detect escaping ultraviolet light from 66 nearby galaxies. The survey's observations took place this year and have more than doubled the number of known nearby galaxies with escaping ionizing ultraviolet emission. For her thesis this year, *Nicole Ford '20* performed some of the first analyses for the survey; she derived galaxy properties from their optical spectra and tested correlations between these properties and the observed ultraviolet light. Ford received a prestigious Chambliss award from the American Astronomical Society for her research poster at the January annual meeting. *Anneliese Silveyra '21, Noor Alsairafi '22,* and *Achref Dhahbi '23* will continue working on the Lyman Continuum Survey this summer.

Williams College is a member of the Northeast Astronomy Participation Group of colleges that have access to Apache Point Observatory (APO) in New Mexico. In December, Jaskot and Ford traveled to APO to obtain additional optical spectra for several of the galaxies in the sample. This effort will continue over the coming years.

In addition to the Lyman Continuum Survey, Jaskot is studying the emission from "Green Pea" galaxies, a type of galaxy that may be similar to the early galaxies that reionized the universe. Jaskot's latest paper, published in The Astrophysical Journal, analyzes the hydrogen Lyman-alpha emission from Green Peas and how it relates to their gas properties and escaping ultraviolet light. Jaskot also used two radio telescopes, the Very Large Array radio telescope in New Mexico and the Large Millimeter Telescope in Mexico, to observe cold gas in Green Peas.

Connor Marti '20 completed a thesis on a sample of Green Pea galaxies, using ultraviolet spectra from the Hubble Space Telescope. Marti fit the observed spectra with theoretical models for the light from stellar populations of various ages. From these fits, he was able to estimate the ages of the Green Peas' ultraviolet-emitting stars and assess the relative importance of stellar radiation, stellar winds, and supernova explosions on the Green Peas' gas. He presented his work at the January meeting of the American Astronomical Society. *Patricia Fofie '21* will continue studying the Green Peas' gas and its connection with supernovae this summer.

This spring, Jaskot introduced a new tutorial, ASTR 404, on unsolved problems in galaxy evolution. Students dove into four topics: the mysterious multiple stellar populations of globular clusters, the unexplained lack of star formation in elliptical galaxies, the debated universality of the initial mass function for stars, and the cause of reionization. By reading and discussing scientific papers in these fields, students have become opinionated experts on these topics. Jaskot also taught the introductory ASTR 111 course in the fall and ASTR 211 on astronomical observations in the spring with Dr. Flaherty.

Jaskot and her students presented their research at several meetings this year. In October, Ford and Marti gave talks at the annual Keck Northeast Astronomy Consortium symposium at Vassar College. Also in October, Jaskot was an invited participant at the Lorentz Center workshop, Revolutionary Spectroscopy of Today as a Springboard to Webb, held in Leiden, the Netherlands, where she presented her recent Green Pea research and joined fellow astronomers in planning future projects for the James Webb Space Telescope. In January, at the 235th Meeting of the American Astronomical Society in Honolulu, Hawaii, Jaskot gave a talk, and students Ford and Marti presented posters.

Post-Graduate Plans of Astronomy Majors

Nicole Ford	Computational Astrophysics Research Internship at Lawrence Berkeley National Laboratory
Johnny Inoue	
Christian Lockwood	
Ethan Lopes	Seismic imaging project of carbon capture at Lawrence Berkeley National Lab
Connor Marti	Graduate school in physics and astronomy, Purdue University
Erin Meadors	

Astronomy Colloquia

On-campus colloquia are held jointly with the Physics Department. See Physics colloquia on pp. 85-86 for listings.

Off-Campus Astronomy Colloquia

Jay M. Pasachoff

"HISTSCI 123CS: Starstruck! The History, Culture, and Politics of American Astronomy"
Meeting Sara Schechner's class at Harvard, via Zoom April 2020

"Solar Eclipses"
Science @ Home, from Charles Fulco, via Zoom April 2020
Friends Community School, 5th grade, College Park, MD, via Zoom May 2020
Presentation for Iran, preparation for the June 21 annular solar eclipse, via Zoom June 2020

"Solar Eclipses: Math, Science, and Spectacle"
National Museum of Mathematics (New York), via Zoom May 2020

BIOLOGY NEWS

Working closely with the many interdisciplinary programs on campus, including the Biochemistry/Molecular Biology (BIMO) Program, the Neuroscience Program, the Environmental Studies Program, the Bioinformatics/Genomics/Proteomics Program and the Public Health Program, the Biology Department's goal is to provide students with the opportunity to do hands-on, one-on-one research with a professor in addition to offering state-of-the-art academic courses. To this end, the department had 21 honors students working in faculty labs this past year. Of these, 13 were inducted into the Sigma Xi Honors Society. For the academic year 2020-2021, the department has 31 students who will be doing honors work. The department is committed to providing a positive research and learning experience for all biology students. As a result of this commitment, several of our students were awarded grants or fellowships to pursue their studies after graduation. *Eily Mixson '20* and *Abe Steinberger '20* received Stratton Fellowships for graduate work leading to a Ph.D. Ben Maron '21 was named a Goldwater Scholar. Ben's mentors include Assistant Professor Pei-Wen Chen and Williams Biology Department alum *Zuzana Tothova '01*, currently an investigator at the Dana Farber Cancer Institute/Harvard University Medical School. The department also has approximately 34 students doing summer research in 2020; due to COVID-19, all summer research internships this year are remote. *Maya Huffman '22* will be working at the Whitehead Institute. Funding for summer research comes from various sources including individual research grants and Division funding. At least half of the biology faculty members have had outside research funding from either NSF or NIH, or both. This funding allows many students to travel to professional meetings throughout the year giving poster presentations on their research at Williams. Associate Professor Luana Maroja was awarded a new NSF grant to study speciation—the process through which new species are formed and a fundamental driver of biodiversity—using a combination of field work and new genomic analysis tools.

Each year at graduation, the Biology Department awards prizes to several outstanding majors. David Goretski

and Matthew Newman each received the Benedict Prize in Biology. Robert B. Smith IV received the Dwight Botanical Prize. Calla Khilnani received the Conant-Harrington Prize for exemplary performance in the biology major, and Jenks Hehmeyer received the William C. Grant, Jr. Prize for demonstrating excellence in a broad range of areas in biology. Because Commencement was postponed due to the global pandemic, the department held a virtual celebration for our graduating seniors.

This year we were delighted to welcome Cynthia Holland as a new Assistant Professor in Biology. Cynthia was an NSF Graduate Fellow at Washington University in St. Louis, and an NSF Post-doctoral Fellow at the Boyce Thompson Institute/Cornell University before joining the department in January, 2020.

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 schools to life after Williams. The poster presentations following the panel allowed our scholars to interact one-on-one with our visiting scientists. The topics were:

Achala Chittor '15, fifth year PhD student in the Molecules, Cells and Organisms (MCO program at Harvard University, and a previous NSF Graduate Research Fellow: The conserved transporter SdaC links identity communication to nutrient utilization in the bacterium *Proteus mirabilis*

Hector Trujillo '16: 4th year graduate student at Berkeley, recipient of a National Science Foundation Graduate Research Fellowship. Hector joined the Komeili lab, where he is currently a studying the cell biology of a novel bacterial organelle called the "ferrosome" (which was first observed by a Williams alumna). Due to nascent nature of the field, very little is understood on how the ferrosome forms. To this end, he is using super-resolution microscopy to understand the localization of key ferrosome proteins and making genetic deletions to assess the steps of ferrosome formation.

Rachel Essner '16: Second year PhD student in the Program in Neuroscience in Mark Andermann's lab at Harvard University: Sustained NPY signaling enables AgRP neurons to drive feeding

Nico MacDougall '17: Second year PhD student in Biological Sciences at The George Washington University in Washington, DC studying the systematics and biogeography of New Zealand *Neopilionidae* harvestmen in the Hormiga lab.

Class of 1960 Scholars in Biology

Kiersten Campbell	Jenks Hehmeyer
Breelyn Karno	Marya Rana
Derrick Spencer	Abraham Steinberger
Joelle Troiano	

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. This year, Honors student *David Gorestki '20* and Independent Study student *Derrick Spencer '20* pursued this line of investigation. *Sonya Lee '22* and *Matthew Long '22* spent the summer of 2019 doing research in the lab. *Amy Wang '23* and *Sofia Neaher '22* joined the lab for Winter Study and continued working through the spring. Professor Banta gave a talk on the lab's recent findings at the 40th Annual Crown Gall Conference in October, and presented a poster at the International Molecular Plant-Microbe Interactions XVIII Congress in Glasgow, Scotland.

During this academic year, Professor Banta served as Biology Department Chair, and taught a 300-level Microbiology course in the Spring. She was a reviewer for the journals *Molecular Plant Microbe Interactions*, the *International Journal of Molecular Sciences*, and *Scientific Reports*, as well as for NSF. Within Williams, she served on the Advisory Committees for Public Health, Biochemistry/Molecular Biology, and Bioinformatics/Genomics/Proteomics. 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 The Organism (BIOL 102) 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).

Professor Bassar published five papers in the last year in both theoretical and empirical ecology and evolution. He gave one talk at society meetings and gave one seminar on his research. He also continues to serve as Associate Editor for the *Journal of Animal Ecology*.

Associate Professor **Matt Carter** taught Neural Systems and Circuits (BIOL 311) in Fall 2019 and Physiology (BIOL 205) in the Spring. In the Summer of 2020, Carter was thrilled to receive the Nelson Bushnell ’20 Prize for Excellence in Teaching and Writing from Williams College. Outside of the classroom, Professor Carter continued his research into the neural basis of food intake and sleep behaviors using mice as a model organism. His research is funded by a grant from the National Institutes of Health (#DK105510) and National Science Foundation (#1652060). During the past academic year, Professor Carter gave talks at Kallyope in October 2019, the annual meeting of The Obesity Society in November 2019, and the Winter Conference on Brain Research in January 2020. Additionally, students in Professor Carter’s lab presented two posters at the annual meeting of the Society for Neuroscience in October 2019. Finally, Professor co-authored a review article in the journal *Sleep*.

The Carter lab was extremely busy with five ongoing thesis projects: *Lauren Heuer ’20*, *Grace Kromm ’20, Sierra Loomis ’20*, *Matthew Newman ’20* and *Maxwell Stukalin ’20* all completed their theses. Abstracts of their work can be found later in this report. In addition, these students were joined in the lab by *Faris Gulamali ’21 and Kenneth Han ’21* who will be conducting thesis research during the next academic year. Finally, the lab was supported by a full time laboratory technician, *Jessica Kim ’19*. Together, the nine-person lab completed two research projects which the lab is currently preparing for publication.

Assistant Professor **Pei-Wen Chen** was on leave for the 2019-20 academic year and focused primarily on research. She continued her research on the regulation of actomyosin cytoskeletal networks by ASAPs, a subtype of Arf GTPase-activating proteins implicated in cancer metastasis. She published a research paper with two Williams student co-authors, *Ben Maron ’21* and *Jeffrey Sload ’17*. In this paper, they discover that ASAP1 BAR domain, which is conventionally considered as a membrane binding/bending domain, binds actin filaments. Furthermore, the BAR domain bundles actin filaments into unipolar thick filaments and stabilizes them against depolymerization, providing mechanistic insights in how ASAP1 may contribute to migratory and invasive behaviors of cancer cells by regulating the higher-ordered organization, as well as the dynamics of actin cytoskeleton. This work was published in the *Journal of Biological Chemistry*. Ben Maron was also named as a 2020 Goldwater Scholar based on his work in this project. Professor Chen gave an invited talk on this work at the national meeting, Mechanobiology Across Length Scales Symposium in Maryland.

Lecturer **Derek Dean** teaches BIOL102 and Genetics labs and has been working to infuse these classes with primary research. For example, students started to map an interesting *D. melanogaster* mutation to its gene: Ocellularless (Oce), a mutant trait causing the light-sensing ocelli on the top of the fly head to have abnormal structure. This mutation was described in the 1950s, but its gene has still not been identified. Last fall, Genetics students identified some strong candidate Oce genes, and this coming fall, remote or in person, we are optimistic that students will be able to identify the Oce gene.

To provide other educators with resources to bring research into their Genetics labs, Dean, along with Professors Banta and Loehlin at Williams, and Professor David Deitcher of Cornell University recently submitted an education article to the journal CourseSource (in review). In research, Dean, Loehlin, *Caleigh Paster '21*, and *Manting Xu '21* are preparing a manuscript to report mapping of sable, a classic Drosophila body color mutation, to its gene. Also, Dean has continued his collaboration with David Deitcher, using Drosophila as a model to study seizure disorders. *Alvin Pacheco-Omaña '21* and *Breelyn Karno '20* worked with Dean at Cornell last summer on this project. Back at Williams in the fall, they were joined by *Rio Salazar '20* and *Cassie Deshong '21*.

Professor **Joan Edwards** continued with her research on pollinator networks. During the spring and summer of 2019, she worked with Hunter Phillips (MCLA, ‘19), *Cristina Mancilla ’20* and *Henry Newell ’21* to collect data on visitors to flower species in the Williamstown area that had previously been filmed on Isle Royale. Cristina used these data in her senior honors thesis to compare the pollination networks in the Williamstown area with those at Isle Royale Wilderness National Park.

Professor Edwards also continued with her study of experimental plots in Hopkins Forest where she is studying how different mowing regimens affect floral resources for pollinators. *R.B. Smith '20* and *Sierra Diaz ’20*, both conducted senior theses research on these study plots

Professor Edwards continues to maintain a study of the invasive plant, Alliaria petiolata (garlic mustard), where she has tracked populations in early, mid and late successional forests since 1998.

Professor Edwards gave a Summer Science lunch talk on her “Fast Plants” on 9 July 2019. She also gave a field

lecture at the spruces in Williamstown in August of 2019 and two invited talks at UMass, Amherst in March and June of 2020.

In the fall semester she taught The Tropics: Biology and Social Issues and in the spring she taught Field Botany and Plant Natural History. When the spring term was interrupted by Covid-19, she switched the course to focus on the local flora of each student who collected herbarium specimens for the Williams College Herbarium from their own home base. The specimens included a cactus from the South West and Spanish moss from South Carolina. These will all enrich our collection and serve as a reminder of a very unusual semester.

Assistant professor **David Loehlin** and students continued research into evolution and genetic mechanisms of how genes are expressed. The lab continues to research an exciting problem: genes that are duplicated in tandem often do not produce twice the RNA and protein as single-copy genes. We know basically nothing about how this happens, making this an exciting new area for students to explore. Over this past year, we have been developing new gene-editing and engineering techniques to build and separate tandem duplicate genes in Drosophila flies. The lab is also collaborating with the Dean lab to understand the genetic basis of classic mutations and with the Bassar lab to investigate the role of telomere length in fish with different lifespans.

Lab members this year included *Hafidh Hassan '21, Caleigh Paster '21, Manting Xu '21, Catherine Powell '22,* and *VanNashlee Ya '22*.

Professor **Luana Maroja** continued her research on speciation working primarily with crickets and fruit flies. She presented talks in two meetings: Evolution, and Animal Behavior. Two of Maroja's students (*Sehwheat Manna 19',* and *Julie Kim 19'*) were awarded the Evolution Undergraduate Diversity grants to attend and present posters in the Evolution meeting (Providence 2020). This year she was awarded a new NSF grant to continue studying speciation and diversification in crickets.

In the Fall Professor Maroja taught a new non-major's course: Evolution as Fact and theory (BIOL 135), 64 students enrolled in the new course.

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 *Calla Khilnani '20*, who was a senior honors thesis research student. With the goal of understanding the evolution of niche differentiation within the *Prochlorococcus* lineage, Calla characterized the effects of key environmental factors on strains belonging to different clades within the Prochlorococcus lineage. Using flow cytometry to measure changes in cell densities and chlorophyll fluorescence characteristics, Calla demonstrated that strains have the capacity to acclimate rapidly to increases in irradiance levels. Her data have important implications for *Prochlorococcus* cells in the open oceans, where mixing events within the water column can expose bacterioplankton cells to large fluctuations in photon flux densities. In addition, *Kiersten Campbell '21* continued as a research assistant in the Ting laboratory during the academic year. Kiersten continued to work on the laboratory's comparative genomic and metagenomic projects that involve *Prochlorococcus*, as well as other cyanobacteria and marine bacterioplankton. With her strong interest in both biology and computer science, Kiersten focused on characterizing and comparing core and flexible genomes and in developing genomic databases for future metagenomic analyses.

Professor Ting taught Integrative Plant Biology: Fundamentals and New Frontiers (BIOL 308) in the fall semester. In this course students used an integrative approach to understand the mechanisms by which plants grow, develop and respond to their environment. Through laboratories and special projects, students explored the strategies plants have evolved to survive in vastly different habitats on Earth, as well as recent advances in using plants in agriculture, biomedicine and as an energy resource. In the spring, Professor Ting taught the capstone tutorial course Genome Sciences: At the Cutting Edge (BIOL 430T). This course explored current (meta) genomic, (meta)transcriptomic and (meta)proteomic research and how recent discoveries have revolutionized our understanding of organisms in the three domains of life, and their interactions and evolution.

Assistant Professor **Damian Turner** continued his research on lung resident memory T cells and their role in the pathogenesis of allergic asthma. Students from his lab, *Patricia Loazano '19* and *Omar Kawam '20*, presented their work at the New England Immunology Conference, held in Wood's Hole MA. Their poster presentation was titled "Reducing Pathological Tissue-Resident Memory T Cells in Allergic Asthma via JAK/STAT Cytokine Signaling Pathway Inhibition". At the meeting Patricia won an award for one of the best poster pitches.

In the Fall of 2019 Professor **Heather Williams** reworked the Sensory Biology course, adding a new lab program based on the nematode worm *C. elegans* and its sensory capabilities (which are remarkably complex for an organism with about 300 neurons). She continued her research on bird song, working *Kiri Peirce '20* on the syntactic structure of house finch song and with *Ellie Sherman '20* on zebra finches. In addition, two papers appeared as part of the ongoing Savannah sparrow song project: one reporting on how the interactions between adult singers do not appear to influence song learning and the other describing how the daily pattern of singing shifts from early morning to evening as the breeding season progresses

Post-Graduate Plans of Biology Majors

Name	Plans
Andrea Alvarez	Undecided
Kimberly Andreassen	Undecided
Gabriella H. Bal	Accepted into the MOST Fellowship Program at the Cleveland Clinic for medical scribing and research
Masen L. Boucher	Research Assistant, Emergency Medicine Department, Boston Children's Hospital, Boston, MA
Emily Chang	Plans to entering the workforce as a research assistant/clinical research coordinator
Christina A. Chavarria	Undecided
Eugene Y. Cho	Research Associate, Dana-Farber Cancer Institute, Boston MA
Peter S. Christie	Undecided
Sierra M. Diaz	Laboratory technician for B. Braun Medical in Irvine, CA. I perform microbiology tests in the quality control department to ensure the safety and sterility of medical fluids provided by the company.
Caroline E. Dignard	Undecided
Azar Dixit	Undecided
Michael C. Elmasian	Undecided
Annabelle S. Feist	I am applying to MD programs to start in 2021. In the meantime I will be working as a ski patroller at Sugarbush Resort in Vermont and finishing my EMT certification to work for EMS while spending my free time rock climbing.
David Gorestki	PhD in Biology at MIT
Janelle C. Gowgiel	MPH in Behavioral, Social, and Health Education Sciences at Rollins School of Public Health, Emory University.
Jessica E. Gutierrez	Undecided
Morgan E. Harris	Research Assistant, HHRI, Minneapolis, MN
Brendan I. Harshberger	Undecided
Jenks A. Hehmeyer	Applying to a PhD program in the fall.
Chloe G. Henderson	Studying for the MCAT and volunteering, Las Vegas, NV
Lauren B. Heuer	Clinical Research Coordinator, Cancer Outcomes Research and Education Program, Massachusetts General Hospital, Boston, MA
Marlena R. Horton	Undecided
Breelyn A. Karno	UMass Boston Dana-Farber/Harvard Cancer Center U54 Partnership's Post-Baccalaureate Research Education Program Fellow
Omar Kawam	AVD Interfaith Fellow, Charles P. Scott Center for Spiritual and Religious Life, Middlebury College
Calla K. Khilnani	Medical school (MD) at the Icahn School of Medicine at Mount Sinai in New York City, NY.
Orville O. Kirkland Jr.	Research Associate, Li Lab, Koch Institute for Integrative Cancer Research at the Massachusetts Institute of Technology, Cambridge, MA
Thea A. Lance	Currently working as a COVID-19 Contact Tracer for Partners in Health / MA Dept Public Health
Yang W. Lee	Undecided

Sierra A. Loomis	Undecided
Alison K. Lu	Master of Health Science in Biochemistry and Molecular Biology, Johns Hopkins University
Amanda L. Lugo	Undecided
Nicholas I. Madamidola	Undecided
Cristina L. Mancilla	Undecided
Noah J. McCoy	Duke MBS
Crystal P. McIntosh	NIH POSTBACCALAUREATE IRTA Program
Mykel L. Miller	Undecided
Dylan R. Millson	Research Associate, Tothova Lab, Dana Farber Cancer Institute
Madison S. Miura	MS in Genetic Counseling, Icahn School of Medicine at Mount Sinai
Eily R. Mixson	Research Assistant, Haroush Primate Lab, Stanford University
Matthew C. Newman	Software Engineer, Bloomberg, NY
Christopher J. Ochoa	Undecided
Kiri E. Peirce	Undecided
Masa M. Peterson	Undecided
Claudia I. Portugal	Interning at a tech startup called the dtx company based in NYC
Megan P. Powell	Princeton in Latin America fellowship recipient, Caminos de Agua, San Miguel de Allende, Mexico
Amanda R. Reisman	DMD, University of Pennsylvania School of Dental Medicine
Ryan G. Rilinger	Undecided
Andrew K. Rim	Undecided
Audrey L. Rustad	2 gap years then MD/PhD program in cancer biology or just MD
Rio J. Salazar	Ph.D. in Cell and Molecular Biology, University of Chicago
Paul J. Sheils II	Corps member, Teach for America, Baltimore. I plan to teach high school biology for two years while I apply to medical schools.
Elinor A. Sherman	Undecided
Robert B. Smith IV	I will move to Nome, Alaska in the middle of June to work for the Nome Nugget, a local newspaper where I'll write on a wide range of issues including climate change and the environment. At some point in January or later (depending on COVID-19 travel restrictions), I will then travel to Amman, Jordan to complete a Fulbright Fellowship researching the effects of traditional agricultural practices on biodiversity.
Derrick M. Spencer	Research Technician at Weill Cornell
Abraham R. Steinberger	My expected employment was cancelled because of COVID-19, so right now I am trying to find a lab to work in somewhere and planning on applying to graduate school for plant science this coming fall.
Maxwell J. Stukalin	Working as an EMT in Boston, MA while applying to Medical School to become an MD
Dylan C. Syben	Undecided
Joelle F. Troiano	Undecided
Cindy L. Wang	MS in Biomedical Science, Icahn School of Medicine at Mount Sinai
Alan Y. Zhang	UNC Adams School of Dentistry
Ashley Z. Zhou	Clinical Research Coordinator, Massachusetts General Hospital
Kevin N. Zhou	Undecided

Biology Colloquia

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

Amy Rosenzweig, Northwestern University
"Biological methane oxidation"

Jason Andras, Mt. Holyoke
"Learning the steps of the host-parasite dance: Molecular genetic insights into the ecology & evolution of an invertebrate-bacterial pathosystem"

Matt Walsh, University of Texas, Arlington
"Why are organisms (and their offspring) phenotypically plastic in response to environmental change?"

Jennifer Raymond, Stanford University
"Neural Learning Rules in the Cerebellum"

Lisa Leon, US Army Research Institute of Environmental Medicine
"Prior viral illness as a risk factor for heat stroke in mice"

Scott Kanoski, University of Southern California
"Western diet consumption and memor impairment: what,when, and how?"

Leah Katzelnick '10, University of California, Berkeley
"The danger zone: dengue viruses and the search for a protective vaccine"

Jessica Malisch, St. Mary's College of Maryland
"Should I Stay Or Should I Go Now? Predictors of Facultative Altitudinal Migration in Mountain White-crowned Sparrows (Zonotrichia leucophrys oriantha)"

Off-Campus Biology Colloquia

Lois Banta, *Ruby Froom '17, Rebecca Gorelov '18, William Doyle'18* and Janis Bravo.
"Abscisic Acid-Mediated Signaling is a Nexus of Host Modulation by the A. tumefaciens Type VI Secretion System."
International Molecular Plant-Microbe Interactions XVIII Congress, Glasgow, Scotland. July, 2019 (Poster presentation)
40th Annual Crown Gall Conference, Columbia, MO (October, 2019)-Oral Presentation
Boston Bacterial Meeting, Boston, MA. June, 2019 (Poster presentation by student)

Ron Bassar
"Intraguild predation and cannibalism drives species coexistence in Trinidadian streams"
Annual Meeting of the American Naturalist Society. Asilomar, California.

Sehwheat Manna '19, Manuel Morales, Luana S. Maroja
"Population Genetic Structure of the treehopper Publilia concave"
EVOLUTION 2019, Providence, RI.

Luana S. Maroja, Steve Bogdanowicz, Jose Andres and *Francesca Barradale '19*
"Genome heterogeneity in Gryllus firmus and G. pennsylvanicus: differential introgression or local adaptation?"
EVOLUTION 2019, Providence, RI.

Julie Kim '19, Roman Yukilevich, Thai LaGraff, Luana Maroja
"The Genetic Basis of Speciation Loci in the Drosophila athabasca complex"
EVOLUTION 2019, Providence, RI.

Luana S. Maroja, Brianna Heggeseth, *Danielle Sim '23,* and *Laura Partida '16*

"Female cuticular hydrocarbon (CHC) profile and male courtship behavior in two hybridizing field crickets"
Animal Behavior 2019, Chicago, Ill.

Matt Carter

"Hypothalamic neurons that regulate feeding can influence sleep/wake states based on homeostatic need"
Winter Conference on Brain Research, Big Sky, MT, January 2020

"Active learning strategies in STEM courses"
(January 2020). Winter Conference on Brain Research, Big Sky, MT.

"To Sleep or Eat? Neural Circuitry of Competing Behaviors"
(November 2019). The Obesity Society, Las Vegas, NV.

"Characterization of the Parasubthalamic Nucleus as an Appetite Suppression Center"
(October 2019). Kallyope, New York, NY.

Pei-Wen Chen

"ASAP1 directly binds to actin filaments via its N-BAR domain"
Platform talk at Mechanobiology Across Length Scales Symposium, November 22, 2019.

David Loehlin

"Tandem duplicate overexpression and quantitative evolution of gene activity"
Invited seminar at Brown University, July 2019

"Regulatory mutations play the major role in the evolution of gene activity"
Boston Area Drosophila Meeting (virtual), June 2020

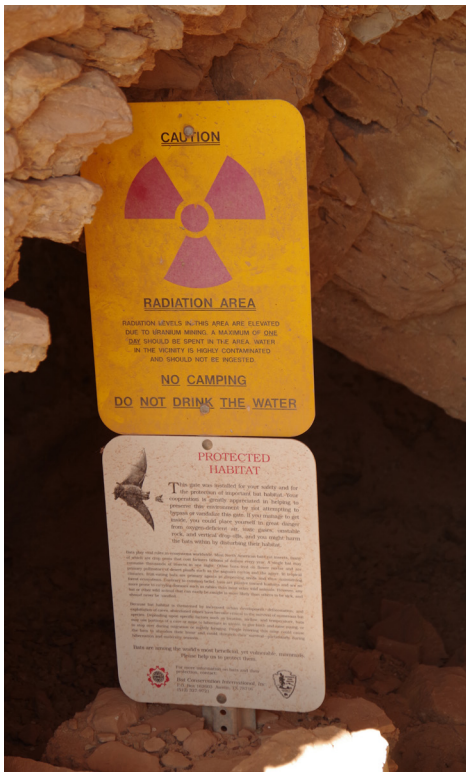
Joan Edwards

"Field Lecture: Pollinators & Flowers"
Talk given at The Spruces for *Bee Friendly Williamstown*. August, 10 2019.
This was a workshop held in the field with hand lenses and lots of flower examples so that the audience could explore firsthand the wonders of flowering plants.

"The Evolutionary Impact of Ultra-fast Plants"
Invited seminar at the University of Massachusetts, Amherst, March 5, 2020.

"BioInspiration from Ultra-fast plants"
Invited Symposium Speaker, New Frontiers in BioInspiration Zoom Seminar Series at the Center for Evolutionary Materials, University of Massachusetts, Amherst. June 22, 2020.

CHEMISTRY NEWS



The editor and Williams College radiation safety officer visited the site of an abandoned early 20th century Uranium mine in central Utah. The state of radiation safety has improved somewhat over the decades. The signs indicate that this area is both highly contaminated and dangerous AND ALSO critical bat habitat...poor bats!

In 2019, the Chemistry Department welcomed two new faculty members. Assistant Professor Ben Thuronyi, a bioorganic chemist/synthetic biologist, began by teaching Chemical and Synthetic Biology (CHEM 326) in the fall and Introductory Organic Chemistry (CHEM 156) in the spring. Assistant Professor Amanda Turek, an organic chemist, taught Intermediate Organic Chemistry (CHEM 251) in the fall and Physical Organic Chemistry (CHEM 344) in the spring. We welcome them both to our department.

The department also bid adieu to a beloved faculty member who retired in June 2020. After 34 years at Williams College, David Richardson, the William R. Kenan, Jr. Professor of Chemistry, is now looking forward to spending quality time outside of the classroom and lab. Professor Richardson, an organic chemist, molded the minds of countless students teaching Organic Chemistry, Toxicology and Cancer, the Summer Science Program, and was a founding member, along with his fellow faculty member and kindred spirit, Professor Chip Lovett, of the Summer Science Camp Program. We will miss him dearly but wish him all the best in his retirement.

Finally, Professor Sarah Goh began her first year as Chair of the Department. As with the rest of the world, the spring of 2020 proved to be challenging and unique. Along with the entire campus community, we pulled together to achieve our goals. Highlights of the spring semester were the senior thesis talks, delivered over Zoom. As well, friends and family were able to join us to celebrate our wonderful seniors in a graduate tribute on Saturday, June 6th.

In 2019-20, we had 43 graduating senior chemistry majors, with 20 completing senior theses under the guidance of faculty. As always, we awarded a number of prizes to our graduating seniors and other students:

Prize Name	Honoree
John Sabin Adriance prize for outstanding work throughout his chemistry career	Selin Gumustop ’20
James F. Skinner prize for distinguished achievement in chemistry	Maia Czaikowski ‘20
Leverett Mears prize in recognition of strength in chemistry and future in medical career	Drew Cohen ‘20
ACS Connecticut Valley Section Award	Ryan Rilinger ‘20
American Institute of Chemists Award	Oliver Yang ‘20
ACS Division of Organic Chemistry Award	Brooke Horowitch ‘20
ACS Division of Inorganic Chemistry Award	Julie (Hyo) Ha ‘20
ACS Division of Physical Chemistry Award	Justin (Ching-Hsien) Ho ‘20
ACS Division of Analytical Chemistry Award	Alex Quizon ‘21
Warren Prize	Matthew Long ’22
Warren Prize	Abigail Matheny ‘22
CHEM 151 Freshman Achievement Award	Mohammed Faizaan ‘23
CHEM 153 Raymond Chang Achievement Award	Elliot Wolf ‘23
CHEM 155 Freshman Achievement Award	Isabel Albores ‘23
Frank C. Goodrich 1945 Award	Abraham Park ’22
Skinner Award	Amy Lam ’22

We also continued to participate in the Chemistry Class of 1960 Scholars Program. This year’s speaker were Professor Angel Marti from Rice University and Professor Jesse Kroll from MIT. 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

Rebecca Christainsen ’21	Andrew Hallward-Driemeier ’21
Faris Gulamali ’21	Vanessa Quevedo Barrios ’21
Kimberly Hadaway ’21	Patrick Zhuang ’21

Finally, even though most faculty were working remotely during the summer of 2020, we had 36 students doing summer research in faculty labs. Funding for these research students comes from individual research grants as 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.

Professor **Amy Gehring** enjoyed teaching in both the introductory chemistry and biochemistry curriculum as well as working with a talented 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) as well as the capstone seminar for the BIMO concentration, Topics in Biochemistry and Molecular Biology (BIMO 401). Despite the shortened in-person spring semester, the students in both courses maintained their high level of engagement and completed a productive remote semester.

Gehring was thrilled to have the opportunity to mentor an enthusiastic group of students pursuing biochemistry research in her laboratory over the course of the academic year. The Gehring lab continued its long-standing work to define the biochemical and genetic features of secondary metabolism and development in antibiotic-producing soil bacteria, the Streptomyces. This large bacterial genus is well-known for its biosynthesis of molecules with important applications in medicine, such as antibiotics. One research area focused on the post-translational modification of the antibiotic biosynthetic machinery, examining both the enzymes that install this required modification and those that remove it. Senior thesis student *Jeromy DiGiacomo ’20* began a new project to clone the encoding genes and then biochemically characterize the phosphopantetheinyl transferases from the industrially-important organism *Streptomyces avermitilis*. Senior thesis student *Kevin Zhou ’20* pursued the complementary project to study phosphodiesterase activity from *S. avermitilis*. Another research area con-

cerned the regulation of gene expression in *Streptomyces coelicolor*. Senior thesis student *Anastasia Tishena '20* examined sigma factors that influence antibiotic production in this organism through a combination of metabolic assays and microscopy approaches. During January 2020, the lab welcomed six new students taking the Introduction to Research in Biochemistry (CHEM 18) Winter Study course: *Kaiz Esmail '23, Chloe Hysore '23, Elise Kuwaye '23, AbuBakr Sangare '23, Laurel Swanson '23,* and *Christie Yang '23*. The group displayed excellent teamwork and an infectious lab spirit as Chloe, Elise, Laurel and Christie worked with Kevin and Jeromy, and Kaiz and Abu worked with Nastia to ably assist and expand the research related to the thesis projects. Finally, fall independent study student *Natalie Albright '20* and spring independent study student *Selin Gumustop '20* pioneered a new project to identify the *Streptomyces* metabolites produced throughout the life cycle using a microfluidics system developed by Dr. *Ashleigh Theberge '06*, Assistant Professor of Chemistry at the University of Washington. This will be an exciting area for future collaboration and growth of the research program.

Professor **Christopher Goh** taught Introductory Chemistry (CHEM 151) in the fall semester, and continued his work as a Faculty Fellow in the Office of Institutional Diversity and the Davis Center and as Director of the Summer Science Program. In that capacity, he organized a research workshop for the first-year SSP students in the fall semester, introducing them to aspects of scientific research and to on-going research in the STEM fields at the college. *Astia Innis '20* and *Jonathan Lee '20* continued their research on metal-binding polymers for environmental remediation as senior thesis students. They were joined in their efforts by *Lili Au '22, Mohammad Faizaan '23, Samuel Liu '23, Irfa Qureshi '22, Alexa Roldan '23* and *Ashley Xu '22* who participated either as research assistants during the semesters or as participants in an introduction to research winter study course. With no course teaching responsibilities in the spring semester, Chris started to participate in an environmental justice project for the residents of a community in Florida, an effort led by colleagues José Constantine and James Manigault-Bryant. The spring semester quickly turned into one of concern, disruption and support for our students through the impacts of COVID 19 and the killings of George Floyd, Breonna Taylor, Ahmaud Arbery and many others. These efforts have continued into the summer.

The research of Professor **Sarah Goh** is focused on the design and synthesis of block copolymers for drug delivery applications. Members of this year's lab: *Justin Ho '20* (thesis), *Julie Ha '20* (thesis), *Uriel Garcia '21*, *Dasol Lee '21, Carolina Martinez '21, Will Bock '22, Marcelo Mazariego '22, Shreyas Rajesh '22, Brian Valladares '22, Lexi Poindexter '23,* and *Joanna Tan '23*. Julie and Justin were set to present their thesis work at the National American Chemical Society's spring meeting when COVID-19 restrictions prompted its cancellation. While most of the students continued to work on copolymer synthesis and characterization, Uriel and Shreyas were inspired by some coursework that they pursued in the spring semester, and Will spent his winter study generating experimental data to complement his computational work in the Peacock lab from last summer. Overall, the students very much enjoyed the camaraderie of lab (and the smell of solvent?) as they had a hard time leaving in mid-March. Although Justin and Julie's thesis work was cut short by a few weeks, the switch to remote learning gave them ample time to consider their results and writing. In the end, they presented their work, albeit over zoom, but it gave their friends and families a chance to see them in action!

Professor Goh taught Polymer Chemistry (CHEM 348) in the fall of 2018 along with the Ford lab section of Intermediate Organic Chemistry (CHEM 255). Both are always a joy to teach! CHEM 348 capped off with a poster session of literature research the students had completed, along with treats from Goodrich. Ford students had a little more direction than in year's past, delving into fluorescent materials. In the spring, Goh co-taught Introductory Organic Chemistry (CHEM 156) with Prof. Ben Thuronyi. This marked the first year that the department had split the largest class in the department into two smaller sections. It was a hit! The discussions were richer, the grading more manageable, and the interactions with students more meaningful, despite the 8 am start time. Remote learning was certainly a challenge for everyone, and the students really pulled through had a very successful semester.

Assistant Professor **Katie Hart** taught Biochemistry I (BIOL/CHEM/BIMO321) in the spring. She mentored two thesis students, *Drew Cohen '20* and *Ryan Rilinger '20*, and one research assistant, *Sonya Lee '22*. This year she received an R15 AREA research grant from the National Institutes of Health ($377,820 over 3 years) and served as a reviewer for two publications: *Biophysical Journal* and *Proteins: Structure, Function and Bioinformatics*. She also continued as a board member for the BioBuilder Foundation, consulting on how best to train the next generation of bioengineers and synthetic biologists.

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 was invited to present her research to the Amherst College Department of Chemistry in Spring 2020, but her seminar was rescheduled due to the pandemic.

This year, Professor **Lee Park** taught Inorganic/Organometallic Chemistry (CHEM 335) and Instrumental Methods of Analysis (CHEM 364) in the spring. In lab *Lesly Mejia '20, Janeth Rodriguez '20, Megalan Tso '22,* and *Tong Gao '23* all continued projects related to the self-assembly of gold nanoparticles. Obviously everyone's spring was disrupted when we switched to remote learning in the middle of the spring semester. It was a tough transition, but we all managed as best we could. Park was planning on beginning a sabbatical in July, 2020, but that has been postponed due to COVID-related complications. In work outside the department, she completed her term as an external science advisor for Lingnan University in Hong Kong, and continued her work for the American Chemical Society Petroleum Research Fund Standing Panel for Materials Science. She's also designed workshops for the Flying Cloud Institute's Young Women in STEM summer program.

During the 2019-20 academic year, Professor **Enrique Peacock-López** taught the lectures and two lab sections of Current Topics in Chemistry (CHEM 155) and, under exceptional circumstances, Physical Chemistry: Thermodynamics and Statistical Mechanics (CHEM 366). In these courses, Peacock-López extended the use of MATHEMATICA to solve problems and data analysis. In particular, he covered the basics of probability theory, chemical modeling, and Monte Carlo simulations. As a result of the inclusion of MATHEMATICA in CHEM 366, students could consider complex thermodynamics systems and the Carnot cycle operation at maximum power.

During the academic year, Professor Enrique Peacock-López continued his collaboration with Ben-Gurion University, where Professor Gonen Ashkenazy's group has synthesized artificial peptide networks. In collaboration with Nathaniel Wagner, Peacock-López analyzed the smallest closed peptide network that shows bistability. For this network, under open conditions, he characterized the bistable peptide network and its emergent behavior. Their findings have been published in Nature Communications. Also, out of the collaboration with Professor Morales, supported by an NSF grant, he has published a paper on protection-based mutualism.

In parallel with his collaborative work, Professor Peacock-López worked with one thesis student, *Ingrid Osul '20*, who analyzed the condition for Turing patterns under non-Fickian diffusion. And, with Dr. *Desire T. Gijima '10*, he published their work on biochemical self-replication. The work at distance continued early summer, with *Will Bock '22*, who analyzed chiral oscillations and spontaneous mirror symmetry breaking in a simple polymerization model, and *Laney Soble '23* examined the role of Rev in the regulation of HIV proteins translation. A third student, *Marcelo Mazariego '22* analyzed a mechanism that yields bursting oscillations in a modified Ricker map.

Finally, Peacock-López has served as a reviewer forthe following journals: *Chemical Engineering Science, Complexity, Chaos, Fractals and Solitons, Life, Mathematics, Mathematical Biosciencesinally,* and *Engineering, Proceeding of The Royal Society A, Symmetry,* the National Science Foundation, and joined the Reviewer Board of *Entropy*.

This was Assistant Professor **Bob Rawle**'s second year in the Chemistry Department. He is a biophysical chemist who is interested in viruses and lipid membranes. In the fall, he taught Biochemistry I (BIOL/CHEM/BIMO 321), to an engaged group of new biochemists. In the spring, he was teaching Biophysical Chemistry (CHEM 367) to a wonderful group of juniors and seniors, when the COVID-19 pandemic hit and we switched to online instruction for the remainder of the semester.

Rawle has established his research laboratory in the South Science Center (now renamed The Hopper!) His research program has three principal areas, all of which fall under the general field of the biophysics of lipid membranes. In the first two areas, he studies molecular events at the heart of the initial stages of infection of all

membrane-enveloped viruses – binding of the virus to the host cell membrane and fusion of the viral membrane with the host cell membrane. Prior to his arrival at Williams, he studied Zika virus and influenza virus. Here at Williams, he is studying viruses from the paramyxovirus and flavivirus families, both of which are responsible for substantial disease in humans and animals worldwide. He studies viral binding and fusion using both wet lab experiments and computational approaches. In the third research area, he is developing and applying methodologies to make bioanalytical measurements of model lipid membranes, which are commonly used in basic science, drug delivery, and drug formulation applications.

This year, Bob was excited to carry out his research with the following outstanding group of Williams students: *Orville Kirkland '20* (thesis student)*, Joshua Choi '20* (thesis student)*, Papa Freduah Anderson '21, Amy Lam '22, Abraham Park '22, Nandini Seetharaman '22, Harrison Toll '22,* and *Eunice Kim '23*. The students did a remarkable job collecting data in all three project areas, with many follow-up directions to pursue.

In February, Professor Rawle attended the 63rd Annual Biophysical Society Meeting in San Diego, CA together with students Amy Lam and Abe Park. They presented two research posters relating to their studies on Sendai virus membrane binding and West Nile virus fusion, respectively. In June 2020, he also delivered the opening talk on virology for the Science Boot Camp for Librarians, hosted by the Network of the National Library of Medicine, Northeast Region.

Rawle was pleased to have a manuscript accepted for publication in the *Biophysical Journal* and another in *PNAS*. These were primarily based on work that he had completed as a postdoctoral researcher.

During the fall semester of the 2019-20 academic year, and into the subsequent Winter Study Period, Professor **David Richardson** enjoyed a mini sabbatical, working in his laboratory and writing rather than teaching classes. During the spring semester, for his final teaching assignment, he covered the Tuesday morning lab section of Organic Chemistry, Introductory Level (CHEM 156), which was converted to an online program in the final 5 weeks of the semester owing to the College's closure by the onset of the Covid-19 pandemic. Throughout the year, and together with Professor Tom Smith, he supervised the senior honors thesis research of *Sarah Michels '20*, who continued a project with the Development of New Drugs Initiative (DNDi) directed at the synthesis of new lead compounds for the treatment of leishmaniasis. Owing to the continued closure of the College by the pandemic, Professor Richardson was unable to cohost in his usual summer commitment: the Department's Summer Science Lab Program for local 4th and 5th graders. This was the first time in 27 years that the program was not offered by the Chemistry Department. On 1 July Professor Richardson officially retired from the College at the close of a 34-year career.

Anne Skinner, senior lecturer emerita, continues her research studies on dating the tempo and mode of human evolution. This year she supervised a thesis student, *Larissa Silva '20*, and an independent study student, *Gabrielle Wolfe '20*. Both were studying the timing of the transition from Neanderthal to modern Homo Sapiens in the Caucusus. Plans for Larissa to present her results at the national Paleoanthropology meeting in April, of course, were cancelled. Dr. Skinner has an invitation to work at the early site of Ubediya in Israel. Originally that was to be done in April 2020. The investigation now is likely to take place in April 2021.

Professor **Tom Smith** spent his twenty-second year at Williams teaching Intermediate Organic Chemistry (CHEM 251) to a group of 48 eager Williams students. This was the first time that CHEM 251 had been split into two sections, the other section being taught by Professor Amanda Turek. Among other activities, Professor Smith settled into a beautiful new laboratory and office in the South Science Building and welcomed three new senior thesis students to his research program in organic synthesis and methods development. *John Velez '20* and *Conrad Wahl '20*, continued Smith's grant-supported work in the area of Asymmetric Methods for the Synthesis of Pyran-Based Anticancer Natural Products. John and Conrad attacked the key step in the ongoing synthesis of the marine natural product, enigmazole A. *Sarah Michels '20*, continued work on a relatively new project co-directed by Professor David Richardson. Sarah became just the second student from Williams to collaborate with the Drugs for Neglected Diseases Initiative (DNDi), an international non-profit organization. Sarah prepared a series of pre-identified analogs based upon a lead compound shown to have activity against Leishmaniasis, a tropical parasitic disease that has about 1 million new cases per year. Professor Smith also taught a lab section of Introductory Organic Chemistry (CHEM 156) which went "virtual" after spring break. Sadly, spring and summer research activities were cut short by the COVID pandemic, but we remain confident that science will prevail in the fullness of time.

In the fall semester, Professor **Jay Thoman** returned to teaching at the 300 level, covering Quantum Chemistry

and Chemical Dynamics (CHEM 361), and it associated lab program. During January 2020, he offered Glass and Glassblowing (CHEM/ARTS 016) with the large glass annealing oven in its new location, next to the glassblowing lab. In the spring semester, Thoman taught a 60-student course, Advanced Chemical Concepts (CHEM 256), and the lead lab section. He enjoyed working with Lab Instructor Laura Strauch to record demonstrations, pre-labs, and lab experiments, for the emergency remote teaching of CHEM 256 after spring break.

During summer 2019, Thoman was joined by *Anna Jackowski '21* and *Huijun Huang '21* in the continuing investigation of PFOA in Bennington, VT. Jackowski and Huang were able to quantify PFOA in samples collected by *Jill Jenkin '19* and thesis student *Neena Patel '19*. Huang continued as a work-study student in the fall, and helped *Kevin LaFleche '20* on his independent study of PFOA uptake by kale. In summary, greenhouse-grown kale does indeed accumulate PFOA in its roots and leaves when watered with PFOA-containing water. In a second ongoing research project, thesis student *Katina Massad '20* studied polychlorinated biphenyl, PCB, contamination of Hoosic River sediments. During January 2020, she welcomed *Mia Holtze '22* to the lab to study dioxin-like PCBs. Massad found that PCB congeners with fewer chlorine atoms were degraded more rapidly in this environment. Massad only needed Thoman to make some loss-on-ignition measurements (after the campus shutdown) to have a complete story to tell.

As College Marshal, Thoman co-chaired the honorary degrees advisory committee and helped to plan Convocation, and the COVID-19-impacted graduation of the Williams College Class of 2020. In June 2020, there were marvelous online gatherings, celebrations, and messages. But for the Class of 2020, everyone hopes for an in-person Commencement ceremony, with elements of Class Day and Senior Week, in Summer 2021. Better late than never!

Assistant Professor **Ben Thuronyi** joined the Chemistry department in July 2019. Their background is in synthetic organic chemistry, biochemistry, and synthetic biology. Their research at Williams centers on the fast-growing bacterium *Vibrio natriegens*, an organism with exceptional properties for biotechnology that has only recently attracted focused attention. The Thuronyi lab aims to characterize and develop *V. natriegens* as a platform for synthetic biology, with an emphasis on genome engineering and directed evolution applications. At the Synthetic Biology Gordon Research Conference in July, Thuronyi organized a meeting to connect research groups interested in *V. natriegens* and is excited to be working to enrich this growing community.

This year, Thuronyi set up their lab in the South Science Building. They advised thesis student *Dylan Millson '20*, who in collaboration with the Obermeyer group at Columbia University developed a modular parts system for studying polyelectrolyte coacervation in E. coli. Work-study students *Vanessa Oeien '22* and *Madeline Ohl '23* built the lab's DNA construction pipeline from scratch and helped create methods and protocols to support future students. Although the COVID-19 pandemic forced a stop to in-person bench work midway through the spring, summer students Madeline Ohl, *Aspen Pierson '21, Michelle Laker '22* and *Russell Blakey '23* worked remotely to learn synbio principles and queue up genetic parts for future assembly.

Thuronyi taught Chemical and Synthetic Biology (CHEM 326) in the fall, an immersive literature-based exploration of advanced techniques and very recent developments in these related fields, and Introductory Organic Chemistry (CHEM 156) in the spring. Work from Thuronyi's postdoctoral appointment was published in Nature Biotechnology and Thuronyi coauthored a *V. natriegens* synthetic biology review in Environmental Microbiology.

Professor **Amanda Turek** joined the Chemistry Department in July 2019 as an organic chemistry. In fall 2019, she taught one section of Intermediate Organic Chemistry (CHEM 251), and in spring 2020, she taught Physical Organic Chemistry (CHEM 344) with an exciting, redesigned lab program. Her lab has been set up in Morley, where she and her outstanding research students are synthesizing organic compounds for use as novel photoredox catalysts, and developing new methods for the synthesis of these molecules. Current efforts in the Turek lab are focused on the synthesis of a library of these exciting molecules. *Maia Czaikowski '20* and *Joseph Flores '20* both pursued honors thesis research with Professor Turek, and made great strides in designing and optimizing the synthesis of these potential photocatalysts. They were joined in the lab by *George Arrowsmith '21* and *Maria Roman '22*, who both joined Professor Turek's lab for summer research in 2019, shortly after she arrived on campus. *Ginger Atwood '22* joined the group at the end of the fall semester, and all three students contributed to our synthetic efforts toward these new catalysts. Professor Turek was looking forward to presenting her research at a Science Lunch for Division III Faculty in the Spring, but this was unfortunately cancelled due to the pandemic.

Post-Graduate Plans of Chemistry Majors

Natalie Albright	Working at Regeneron Pharmaceuticals, then medical school
Lucy Alexander	Medical School
Adrienne Banks	High School Chemistry Teaching Fellow, St. Luke's School, New Canaan, CT
Joshua Choi	Fulbright Scholar '20-21 (Malaysia), Temple University School of Podiatric Medicine
Dominic Chui	Software Developer, Intersystems, Cambridge, MA
Drew Cohen	Research Technician, Dana Farber Cancer Institute, then to graduate/medical school
Michael Curran	DPhil in Mathematics, University of Oxford
Maia Czaikowski	Ph.D. in Chemistry, University of Chicago
Jeromy DiGiacomo	Research Assistant, Dana-Farber Cancer Institute, then medical school
Evette Eweka	Unknown
Joesph Flores	Ph.D. in Chemistry, New York University
David Gorestki	Ph.D. in Biology, MIT, Cambridge, MA
Selin Gumustop	Medical School
Julie Ha	Research Technician, Caravan Group at MGH, then medical school
Negasi Haskins	Working in finance/consulting, New York
Maria Heredia	Unknown
Ching-Hsien Ho	Ph.D. in Polymer Science, University of Massachusetts-Amherst
Brooke Horowitch	Research Associate, Yale New Haven Hospital, then medical school
Astia Innis	Unknown
Emaun Irani	Working for Teach for America in NYC as high school chemistry teacher
Orville Kirkland, Jr.	Research Associate, Koch Institute for Integrative Cancer Research, MIT, Cambridge, MA
Grace Kromm	Ph.D. in Clinical Neurosciences, University of Cambridge, then medical school
Geunho Kye	Analyst at Cornerstone Research, New York, NY
Kevin LaFleche	M.S. in Molecular & Cellular Physiology, Albany Medical College, NY
Jonathan Lee	Unknown
Katherine Mahoney	Associate at Close Concerns, San Francisco, CA, then medical school
Katina Massad	Clinical Research Coordinator, Massachusetts General Hospital
Lesly Mejia	Working at Pfizer
Sarah Michels	MPH in Epidemiology, Yale University
Dylan Millson	Research Associate, Dana Farber Cancer Institute, then graduate school
Ingrid Onul	Research Assistant, Vanderbilt University, then medical school or Ph.D. in Mathematics
Ryan Rilinger	Research Technician, Beth Israel Deaconess Medical Center, Boston, MA
Janeth Rodriguez	Graduate School in Forensic Science
Larissa Silva	Research Technician, then graduate school
Anastasia Tishena	Research Assistant, Brigham and Women's Hospital, then medical school
Anne-Sophie van Wingerden	M.D., Columbia Vagelos College of Physicians & Surgeons (Columbia-Bassett Track)
John Velez	Unknown
Brandon Vuong	Unknown
Conrad Wahl	Unknown

Hallie Whitmore	Unknown
Gabrielle Wolfe	Unknown
Oliver Yang	M.A. in Education, Stanford University's Graduate School of Education

Chemistry Colloquia

Andrew Berke, Smith College, September 13, 2019
"Peering Inside: Understanding Aerosol Chemistry Through Bulk-Phase Reactions"

Jamie Keller '83, Kenyon College, October 25, 2019
"Mr. Tompkins in Wonderland: A Chemist's Exploration of Cold Physics"

Jesse Kroll, MIT, Class of 1960 Scholars, March 6, 2020
"Laboratory Studies of the Atmospheric Oxidation of Reactive Organic Carbon"

Angel Marti, Rice University, Class of 1960 Scholars, September 27, 2019
"Light Activated Metal Complexes for Sensing, Studying and Inhibiting Amyloid-Beta Aggregation",

Rabi Musah, University of Albany, February 28, 2020
"New Frontiers in Forensic Science-Applications of Ambient Ionization Mass Spectrometry to Carrion Insect Identification, Wild-life Trafficking, and the Characterization of "Legal High" Plant Materials"

Off-Campus Chemistry Colloquia

Amy Lam '22, Nandini Seetharaman '22, Robert J. Rawle
"Single virus investigation of Sendai virus binding and fusion to supported lipid bilayers"
Biophysical Society Annual Meeting, San Diego, CA, 2020.

Abraham Park '22, Robert J. Rawle
"Kinetic and cellular automaton models of West Nile Virus hemifusion"
Biophysical Society Annual Meeting, San Diego, CA, 2020.

Members of the Rawle lab enjoy some outdoor ice cream on Spring Street in Williamstown in the time before mandatory masks.

COMPUTER SCIENCE NEWS

Increased student interest in computer science continued in 2019-2020 with 64 graduating seniors and 56 junior majors. This year the department welcomed four new faculty members including Sam McCauley (PhD Stony Brook), Shikha Singh (PhD Stony Brook), Kelly Shaw (PhD Stanford), and Aaron Williams (PhD Univ of Victoria), as well as staff member *Lida Doret '02*. We are grateful for the new ideas and course offerings they provided. Last fall we hosted Tomas Ekholm as a STINT fellow from KTH Royal Institute of Technology in Sweden. Brent Heeringa transitioned to a new role as a Research Associate of Computer Science at Williams as well as a Senior Engineering Manager at Dropbox. Morgan McGuire resigned to pursue a new opportunity as a Director of Research at NVIDIA. This fall, we will welcome Molly Feldman (PhD Cornell) as a Visiting Assistant Professor. Last but certainly not least, Tom Murtagh retired this year. He will be deeply missed but we can only feel happy for him after his 40 year career as a professor (with 34 of those years at Williams). We wish him all the best in his future adventures!

In the fall, the department hosted *Kathi Fisler '91* and *Josh Smith '91* as Class of 60s speakers. Dr. Fisler is a Research Professor of Computer Science at Brown University and co-director of Bootstrap, a national K-12 outreach program. She presented two wonderful talks on improving programming education at all levels. Dr. Smith is the Milton and Delia Zeutschel Professor in the Allen School of Computer Science and Engineering and the Department of Electrical and Computer Engineering at the University of Washington. He presented two fascinating talks on the energy efficiency of computing, specifically in the context of wireless power and communication in sensor systems. The department also sponsored events and talks from more recent alumnae including *April Shen '13* and *Melanie Subbiah '17*.

Several members of the department attended computing conferences. *Tiffany Zheng '20* and faculty member Kelly Shaw attended the ACM Richard Tapia Celebration of Diversity in September. In October, *Karmen Liang '21, Alyssa Wang '20, Emmie Hine '20, Emma Corbett '20, Betsy Button '21, Fiona Yonkman '20, Louisa Nyhus '20, Catherine Yeh '22, Nyla Thompson '20,* and *Julia Tucher '21*, attended the Grace Hopper Celebration of Women in Computing. Also attending the conference in Orlando, FL were professors Jeannie Albrecht and Andrea Danyluk.

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 meals with faculty once again.

Two of out students earned competitive prizes in Computer Science this year: *Josh Kang '20* was awarded the Goldberg Prize and *Maddie Burbage '22* was the recipient of the Ward Prize.

The Computer Science department continued to be very active in the Class of 1960 Scholars program with 30 students being named as scholars this year:

Class of 1960 Scholars in Computer Science

Yo Akiyama	Josh Kang
Maddie Burbage	Ben Logsdon
Matt Bock	Grace Murray
Betsy Button	Matt Newman
Jonathan Carraco-Noriega	Vy Nguyen
Amelia Chen	Louisa Nyhus
Emma Corbett	Dzung Pham
Noah Cowit	Lily Shao
Javier Esparza	Adly Templeton
Markus Feng	Nyla Thompson
Sean Fontellio	Aidan Lloyd Tucker
Gaurnett Flowers	Gatherine Yeh
Sam Gilman	Daniel Yu
Emmie Hine	Peter Zhao
Phoebe Huang	Tiffany Zheng

This year Professor **Jeannie Albrecht** continued to investigate techniques for using computing to decrease the energy impact of society. She primarily focused on challenges related to the Class of 1966 Environmental Center on campus. The building is striving to satisfy the Living Building Challenge (http://living-future.org/lbc), which requires the building to be net zero for both energy and water usage over a 12-month period. If successful, this building will be the first historical building to achieve LBC certification. So far it has achieved 6 out of 7 requirements had been met. The remaining unmet requirement is net zero energy usage. The building poses some unique challenges due to its intended use: it consists of classrooms, faculty and staff offices, and a public kitchen. The kitchen is a point of concern regarding energy usage; it contains commercial-grade appliances—including a powerful range hood—that consume significant quantities of electricity 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 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.

This year Professor **Duane Bailey** was on sabbatical and chose to stay at Williams to work with research students. Part way through the Spring semester, he joined the CS134 staff to help students working remotely during the pandemic.

During the Fall, Professor Bailey worked with *Minwoo "Josh" Kang '20, Adly Templeton '20,* and *Daniel Yu '20* on honors research. Bailey, Kang, and Yu worked on computer architecture support for acceleration and power-loss mitigation. Modern processors are burdened with dark silicon—the inability to power significant portions of chips because of strict thermal budgets that keep processors from overheating. Bailey, Kang, and Yu investigated the migration of heavily utilized code from inefficient general purpose hardware to dedicated, power-efficient "accelerators". These devices can be used to extract faster execution or lower power consumption, or, in many cases, both. Yu, who has worked with Bailey for several years on a variety of projects, used the Fall to investigate how to mitigate power consumption in portable devices that use neural networks. Kang began work with Bailey over the summer to embed an open-source implementation of the RISC-V architecture on reconfigurable FPGA hardware. During the year Kang's work focused on supporting adaptable hardware that selects accelerators from a much larger "bullpen" of devices. Over time, the hardware learns how to configure itself based on usage patterns. Such hardware could be used to improve computation effectiveness and extend battery life. Josh received High Honors for his work and won the Goldberg Prize for the year's best student presentation. He'll be attending Berkeley, seeking a Ph.D. in Computer Science and Engineering, with an initial focus on computer architecture.

Adly Templeton's work, with Bailey, investigated word embeddings, an encoding of words learned by natural language processors using automated analyses of word context. Word embeddings are high-dimensional vectors that are not directly meaningful, but whose relationships may give a hint at meaning. Templeton's work re-codes these vectors in a space where dimensions are labeled using prominent basis words from the vocabulary. Mean-

ings of words are then seen as sparse linear combinations of the meanings of these basis words. Important to this work is its automation; manual human intervention is not necessary to establish effective, interpretable word embeddings that can form the basis of more advanced natural language tools. She received High Honors for her research. During the year, Templeton received an Honorable Mention for Undergraduate Research from the Computing Research Association for her already long record of research. She will be attending the Ph.D. program in Computer Science at UPenn after a year of work at Facebook AI Research in Seattle.

Throughout the year, Bailey also worked with *Maddie Burbage '22*, on hardware acceleration of stateless combination generators. This hardware, based on the work of Professor Aaron Williams and his colleagues, may improve efficient exhaustive search techniques. Burbage's work was accepted in the poster competition at this year's Grace Hopper Celebration. Burbage's work also earned her the Ward Prize for best student project. Burbage continues her work with Bailey over the summer, hardening the infrastructure necessary to support hardware adaptability.

Bailey continues his role as a national reader in computer science for the Goldwater Foundation, the group that oversees the congressionally mandated identification of the top 250 undergraduate scientists in the country.

Assistant Professor **Daniel Barowy** continues to research ways to improve the usability and expressiveness of programming languages. Last summer, Barowy worked with four Williams students on his research, and with two additional Williams students during the school year.

Vy Nguyen '21 and *Peter Zhao '21* worked on "error-correcting parsers." This new project was inspired by the previous year's summer's research, "Evaluating ProDirect Manipulation in Hour of Code," which was published and presented by Barowy at the SPLASH-E symposium in November 2019 in Athens, Greece (co-authors: *Quan Do '19, Kiersten Campbell '21, Emmie Hine '20, Alex Taylor '20*, and Professor Iris Howley). That work observed that a key struggle of novice programmers is mastering the syntax of programming—literally how code is written—even if they understand the underlying logic. Vy and Peter's work over the summer was to produce a proof-of-concept programming language parser that can automatically offer helpful feedback for novice programmers. Independent study student *Lily Shao '20* carried on this work in the fall and spring, investigating how to incorporate efficient error-finding algorithms into Vy and Peter's preliminary work.

Two other summer students, *Karmen Liang '21* and *Max Stein '21* worked on extending the expressiveness of Barowy's existing project, AutoMan. AutoMan is a programming language for crowdsourcing: programmers define "human functions" and the language automatically recruits, pays, and quality-checks responses from humans tasked to perform work on Amazon's Mechanical Turk crowdsourcing platform. Their research focused on extending AutoMan to the Google Ads platform, which potentially has orders of magnitude more workers than Mechanical Turk. Senior thesis student, *Emmie Hine '20* picked up where Karmen and Max left off, designing and implementing a new language dialect of AutoMan, called "ExperiMan," to support online behavioral experiments performed by psychology researchers and other scientists. Emmie's research, which is a collaboration with UMass Amherst Professor Emery Berger, focused on ensuring that such experiments were "correct by construction," in other words, guaranteed to be bug free and therefore scientifically valid. Emmie was awarded her CS degree with honors for this work. Emmie's research poster was also accepted to be presented at the student research competition at this coming fall's ACM Grace Hopper Celebration.

This past summer, Barowy also started a new collaboration with Assistant Professor Charlie Curtsinger at Grinnell College on developer infrastructure designed to eliminate bugs in build specifications. Build specifications are an essential part of reliably producing and distributing real world applications. Part of the goal of the project, which is called "intelligent developer infrastructure," is to automatically infer correct specifications by watching developers work. A prototype was developed with the help of two Grinnell students, Alyssa Johnson and Jonathan Sadun. Curtsinger and Barowy also submitted a grant proposal to the National Science Foundation to further fund this work, titled "Collaborative Research: CNS Core: Small: RUI: Intelligent Developer Infrastructure."

Finally, Barowy presented his work on the ExceLint project, which finds bugs in spreadsheet programs, at the Microsoft Research Faculty Summit in Redmond, WA in July 2019. He published research on using software to meet the CS department's enrollment demands ("Infrastructor: Flexible, No-Infrastructure Scaling Tools for CS") with CS department co-author, Professor Bill Jannen, at the ACM SIGCSE technical symposium in February 2020. And lastly, Barowy served on the program committee for the 41st ACM SIGPLAN Confer-

ence on Programming Language Design and Implementation (PLDI 2020) and the external review committee for the ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications (OOPSLA 2020).

Prof. **Andrea Danyluk** returned from her year on leave at Northeastern University. Back at Williams, she continued her work in computer and data science education, as well as in diversity and inclusion in computing education and research. She is co-chair of the Association for Computing Machinery (ACM) Task Force on Data Science. This international effort is developing recommendations for the computing-based competencies that should be part of an undergraduate degree in Data Science. A second draft of the curricular recommendations was released in the past year, and the steering committee is in the process of editing it for a final draft release. She is also co-chair of the CRA-WP, the Computing Research Association's Committee on Widening Participation in Computing Research.

Professor Danyluk continued her research in machine learning, specifically in the areas of classifier learning and their applications. She co-supervised a project with Williams College alum *Josh Frankel '02*. Frankel, an artist and animator, was commissioned to create a short animated film titled "Emergent System." He wanted to create the final 20 seconds of his film using machine learning, trained on frames from the same film. *Chan Woo Kim '23* worked on this project. "Emergent System" premiered at Peak Performances at Montclair State University in February. The final 20 seconds were Frankel's edit of the generated animation that emerged from Chan's work.

Professor **Stephen Freund** continues to explore ways to help programmers write more reliable and efficient multithreaded software designed to run 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.

Freund also recently began a project on synthesizing concurrent software from sequential specifications. Generally speaking, a synthesis framework takes as input a simple high-level specification of what a program should do and then automatically generates code meeting that specification. Freund's long-term goal is to target synthesis to the type of concurrent code that he has previously studied in his defect detection work. *Margaret Allen '20* and *David Lee '21* worked with Freund last summer laying the groundwork for some experimental aspects of the Synchronicity project.

Assistant Professor **Iris Howley** continued research this summer on artificial intelligence (AI) explainability as part of her NSF grant, "Understanding Learning Analytics Algorithms in Teacher and Student Decision-Making." Machine learning and AI algorithms make assumptions and learn biases of which the users of the systems may not be aware. Empowering teachers and students to appropriately interrogate questionable output from the educational technology they use to make decisions in the classroom is an important contribution of this work. She began work with *Noah Cowit '20* and *Catherine Yeh '22* on building an explainable for an AI algorithm, Bayesian Knowledge Tracing, which was presented at the IEEE VIS workshop on Visualization for AI Explainability. Continued work on this topic with *Haoyu Sheng '20,* and *Tongyu Zhou '20* was presented at the AAAI/ACM conference on Artificial Intelligence, Ethics, and Society in New York.

Research on AI explainables applies methods from Howley's fall semester course on Human-Computer Interaction (CSCI 376) and will form the basis of topics in a future course on Human Artificial Intelligence Interaction (CSCI 378). At the introductory level, she created a new course, Electronic Textiles (CSCI 103), in which students use Arduino computer microcontrollers to build and program wearable, interactive technology. She also taught Introduction to Computer Science (CSCI 134) with Shikha Singh, continuing to develop active learning worksheets to encourage peer interaction and guided inquiry in the introductory computer science classroom. Howley's work adapting these guided inquiry worksheets to the spring 2020 teaching context was published in the *Journal of Information and Learning Sciences*.

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 tackle fundamental systems problems through a theoretician's lens. One such long-standing, open problem is how to efficiently copy files. Duplicating large objects is so prevalent in modern computing workflows that many file systems support operations that make logical copies without making full physical copies. In the paper How

to Copy Files, coauthored by Yang Zhan (UNC Chapel Hill), Alexander Conway (Rutgers), Yizheng Jiao (UNC Chapel Hill), Nirjhar Mukherjee (UNC Chapel Hill), Ian Groombridge (Pace), Michael A. Bender (Stony Brook), Martín Farach-Colton (Rutgers), Rob Johnson (VMware), Donald E. Porter (UNC Chapel Hill), and Jun Yuan (Pace), Bill presented the new technique "Copy on Abundant Write", and showed how to implement logical copies that are fast to create, edit, and read, all while being space-efficient.

In collaboration with fellow Assistant Professor Daniel Barowy, Bill created a workflow and set of tools to efficiently manage and scale course assignments. They presented their new collection of open source tools and their experiences using them in the paper Infrastructor: Flexible, No-Infrastructure Tools for Scaling CS. Bill also served on the program committees for both the USENIX Conference on File and Storage Technologies and the USENIX Annual Technical Conference.

William 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.

A 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, has been published in the journal Discrete and Computational Geometry.

Joint work with Felice De Luca, Emilio Di Giacomo, Seok-Hee Hong, Stephen Kobourov, Giuseppe Liotta, Henk Meijer, Alessandra Tappini and Stephen Wismath, begun at BWGD: 2019 Bertinoro Workshop on Graph Drawing, was accepted at the conference Walcom 2020 : The 14th International Conference and Workshop on Algorithms and Computation, held earlier this year at the Institute for Mathematical Sciences at the National University of Singapore.The paper, entitled Packing Trees into 1-planar Graphs, describes various methods for decomposing (some or all) edges of a 1-planar graph into a small number of simpler graphs.

Assistant Professor Samuel McCauley uses algorithms to improve computational performance. He is particularly interested in randomized algorithms, and has recently been working on Bloom filters and similarity search.

McCauley's research on Bloom filters has largely focused on adaptivity. Bloom filters are a data structure for lossy compression---some stored data is lost in exchange for drastic space savings. This line of research focuses on adapting that loss as the data structure is used to improve performance. This past year, McCauley has been working with collaborators at Bar-Ilan University to apply adaptivity to cuckoo filters, one of the best-performing Bloom filter implementations. This research, currently in submission, shows that a small modification to the cuckoo filter leads to a data structure that has theoretically optimal bounds, while outperforming state of the art heuristics in practice. This summer, McCauley will be working with Shikha Singh, as well as David Lee '21 and Max Stein '21, on a project to investigate the practical performance of theoretically optimal adaptivity.

Recently, McCauley's interest in similarity search has focused specifically on edit distance. Edit distance measures the similarity of two text documents, and it is an important similarity measure in text processing and bioinformatics. Interestingly, while this distance notion is important, it is poorly understood from the point of view of similarity search: while some heuristics work well on certain kinds of datasets, the best known methods perform poorly in the worst case. In the past year, McCauley has been working on closing this gap, and is currently submitting a paper on this topic to the PODS (Principles of Database Systems) conference. The basic idea of this project is centered around a randomized embedding technique. It appears that this technique has even broader applications, and McCauley is beginning two new projects centered around these ideas, one in collaboration with Shikha Singh, and one in collaboration with summer research students Ammar Eltigani '23 and Petros Markopolous '23.

A collaborative research project this summer with Bill Jannen, Christopher Chung '22, and Nasim Borazjanizadeh '23 is on a new topic: scheduling database updates. A particularly exciting aspect of this project is the potential to leverage results to speed up the actual large-scale databases that are involved in Bill Jannen's research.

In summer 2019, McCauley served on the program committee for Track B (the implementation track) of the European Symposium on Algorithms. In fall 2019, McCauley taught Data Structures (CSCI 136) with William Lenhart. In spring 2020, McCauley developed a new elective on Applied Algorithms, CSCI 358. This course seeks to bring together important computer science principles: how can the theoretical guarantees that students learn in algorithmic courses be combined with the programming techniques they learn in applied courses?

Can bringing them together improve computational performance? The content of this course centered around a series of important algorithms that drastically improve practical running times. The course focused on both the fundamental theory of how each algorithm worked, as well as student implementations to investigate performance.

Assistant Professor **Shikha Singh** joined the Computer Science department this year. Her research is in the area of algorithmic game theory, and algorithms and data structures for big data. In algorithmic game theory, her focus is on analyzing how incentives and rational behavior influence the outcome of algorithms. In algorithms, her focus is on the design of I/O-efficient, randomized and adaptive data structures.

Earlier this year, Singh received an NSF CRII award, aimed to support early-career academics, for her project titled "Verifiable Computation Outsourcing: A Non-Cooperative Approach". The project focuses on the research problem that emerges from the growing trend of outsourcing computation: how can the client outsourcing the computation efficiently verify that it has been performed correctly, without having to redo it? The goal of the project is to design simple and efficient payment-based mechanisms to verify the correctness of outsourced computation, where the payment directly incentivizes honest behaviour on the part of the service providers. The project will use techniques and ideas from non-cooperative game theory and apply it to the framework of interactive proofs. The resulting proof systems are thus called "rational proofs." As part of this project, this year Singh's work on 'Non-Cooperative Rational Proofs' was published at the European Symposium on Algorithms (ESA 2019), which she presented at the conference in Munich Germany in September.

Singh is also active in the field of algorithms and data structures. She has a long-term collaboration with Sandia National Labs on designing cache-efficient data structures to support high-throughput cyber streams. Part of this work, titled 'Timely Reporting of Heavy Hitters using External Memory', was published this year in the ACM International Conference on Management of Data (SIGMOD 2020). Singh gave an invited talk at UMass Amherst in Fall on this topic. Singh's two-year research collaboration with the database company, LogicBlox (now acquired by Infor), culminated this year in a conference paper titled 'A Scheduling Approach to Incremental Maintenance of Datalog Programs' that was accepted in the International Parallel and Distributed Processing Symposium (IPDPS 2020). This paper presents several new scheduling algorithms that improve on the production scheduler used by LogicBlox. Singh was the primary author on both these papers, but unfortunately due to the COVID-19 crisis, missed the opportunity to present her results in-person at these conferences.

Singh served on several program committees this year: Symposium on Simplicity of Algorithms 2020, FUN with Algorithms 2020, and European Conference on Parallel and Distributed Computing (Euro-Par 2020).

Singh taught Algorithm Design and Analysis (CS 256) both in the Fall and Spring, and Introduction to Computer Science (CS 134) in the Spring. This summer, she is developing her new elective on Algorithmic Game Theory (CS 357) for Fall 2020. The course will focus on the interplay between game-theoretic incentives and computation, with the overarching goal of analyzing whether selfish behaviour can or should influence system design. Topics include auction design, efficiency of equilibria, network games, market design and strategic voting.

This summer, she will be working with student *Tai Hendrichs '23* on her NSF project on rational proofs and with Professor McCauley and *David Lee '21* on designing adaptive filters tailored to perform well on heavy-tailed distributions. Singh is also working on a collaborative project with researchers at Pace University on a repeated-games framework to study crowdsourcing.

Post-Graduate Plans of Computer Science Majors

Yo Akiyama	Associate Computational Biologist, Broad Institute, Cambridge, MA
Margaret Allen	undecided
Elvira Alonso Rivera	Software Engineer, Equitable, Syracuse, NY
Kenneth An	undecided
Christopher Anton	Software Engineer, Microsoft, Redmond, WA
Liam Bardong	undecided
Taylor Beebe	Software Engineer, Microsoft, Redmond, WA
Nevin Bernett	undecided
Matt Bock	Quantitative Developer - Research, Arrowstreet Capital, Boston, MA
Will Burford	Software Development Engineer, Amazon Alexa, Boston, MA
Jonathan Carrasco-Noriega	undecided
Spencer Carrillo	undecided
Peter Christie	undecided
Dominic Chui	undecided
Jack Consenstein	undecided
Emma Corbett	Software Engineer, JP Morgan Chase & Co., Jersey City, NJ
Noah Cowit	Information Sciences PhD Student, University of Colorado Boulder
Ryan Cox	Risk Analyst, Karen Clark and Company, Boston, MA
Rudy Crisostomo	undecided
Javier Esparza	undecided
Lucas Estrada	Engineer, Nevo Technologies, Cambridge, MA
Sean Fontellio	undecided
Kirby Gordon	undecided
Dietrich Hartman	undecided
Emmie Hine	Social Science of the Internet MSc Program, University of Oxford
Qiyuan Hu	Software engineer, Amazon, Boston, MA
Phoebe Huang	undecided
Charles A. Ide	Consultant, Oliver Wyman, Boston, MA
Jacob Justh	undecided
Minwoo (Josh) Kang	PhD Student in EECS, UC Berkeley
Jamie L. Kasulis	Software Engineer, Chewy, Boston, MA
Hee-Sung Kim	undecided
Audrey Lee	Software Engineer, Privy, Boston, MA
Jacob Lezberg	Software Engineer, General Dynamics Mission Systems, Pittsfield, MA
Ben Logsdon	Math Ph.D. Program, Dartmouth College
Dysron Marshall	Software Engineer, Oscar Health, New York, NY
Maria Mejia	undecided
Grace Murray	Clinical Research Assistant, McLean Hospital, Belmont, MA
Matthew Newman	Software Engineer, Bloomberg, New York, NY
Noah Nsangou	undecided

Louisa Nyhus	Systems Engineer, Google, Sunnyvale, CA
Steven Omondi	undecided
Shivam Patel	Software Development Engineer, Amazon Web Services, Seattle, WA
Dzung Pham	Software Engineer, Facebook, Seattle
Oluwatobi Popoola	undecided
Ryan Schmidt	Software Engineering Analyst, Accenture, Boston, MA
Matthew Seligson	Quantitative Developer, Arrowstreet Capital, Boston, MA
Leting (Lily) Shao	undecided
Haoyu Sheng	undecided
Alex Taylor	Software Engineer, Microsoft, Seattle WA
Kelvin Tejeda	Engineering Resident, Google, Mountain View, CA
Adly Templeton	Software engineer, Facebook, Seattle WA
Nyla Thompson	Business Advisory Consultant for Financial Services Organizations, Ernst & Young, New York, NY
Alyssa Wang	Software Engineer, MITRE Corporation, Bedford, MA
Nick Weed	undecided
Sam Wischnewsky	Engineer, PillPack, Boston, MA
Fiona Yonkman	undecided
Daniel Yu	Software Engineer, PillPack, Boston, MA
Emily L. Zheng	Strategy Consultant, OC&C, Boston, MA
Qianwen (Tiffany) Zheng	Software Engineering Resident, Google, New York, NY.
Tongyu Zhou	Computer Science Ph.D Program, Brown University

Computer Science Colloquia

April Shen '13, Babylon Health
"Thinking Outside the Box: Non-Geometric Perspectives on Semantic Similarity", September 2019

Joshua Smith '91, University of Washington Seattle
"Perpetual Computing: Technologies for Banishing Batteries", September 2019

"Electric Field Sensing, Pretouch Sensing & Robotics", September 2019

Charlie Curtsinger, Grinnell College
"The Dark Art of Software Performance", September 2019

Jeff Huang, Brown University
"Personalized Behavior-Powered Systems", November 2019

Katherine Keith, UMass Amherst
"Methodological Challenges in Computational Text Analysis", November 2019

Kathi Fisler, Brown University
"Curriculum Design as an Engineering Problem: Lessons from the Field", November 2019

"In Defense of Little Code", November 2019

Iris Bahar, Brown University
"Combined Discriminative-Generative AI Techniques for Robust Scene Perception in Adversarial Environments", December 2019

Melanie Subbiah '17, OpenAI
"AI Research at OpenAI: Language Models and Unsupervised Learning", January 2020

Nate Derbinsky, Northeastern University
"Adventures in Hybrid Architectures for Intelligent Systems", March 2020

Off-Campus Computer Science Colloquia

Andrea Danyluk
"So You're Full: Now What?" (with Carla Brodley, Marie desJardins, and Penny Rheingans)

"How Universities are Creating New Pathways to Diversify Tech" (with Valerie Barr, Carla Brodley, and Colleen Lewis)

"Building Your Professional Persona" (with Ayanna Howard)
Grace Hopper Celebration of Women in Computing Conference, Orlando, FL, October 2019

Shikha Singh
"Timely Detection of Heavy Hitters in External Memory"
Theory Seminar, University of Massachusetts Amherst, October 1st, 2019.

GEOSCIENCES NEWS

Construction of the Geosciences department's new home, the Wachenheim Science Center, is nearing completion and we've begun to prepare to move our offices, teaching and research lab spaces, and rock and fossil collections this winter. Even with the disruptions caused by the COVID-19 pandemic, the Geosciences department had a full and active year of student-faculty research. Research projects that could be conducted remotely continued when students transitioned to remote learning in the spring. We were able to shift many summer research students to projects that could be conducted remotely. The 2020 senior honors thesis presentations were held as a video conference call, with students, families and alumni participating.

There was a large contingent of our majors that attended national conferences this year where they gave poster presentations on the summer research they did with faculty: *Kyrien Edwards '17*, *Ava Palmo '19, Erikka Olson '19, William Downs '19*, *Jared Bathen '20, Kate Pippenger '20*, and *Matt Wiseman '20*, and *Devon Parfait '22* all attended the Geological Society of America (GSA) Annual Meeting in Phoenix, Arizona, in September 2019. In December, 2019 *Caroline Hung '19*, *Marshall Borrus '20, William Downs '19, Lucas Estrada '20,* and *Matt Wiseman '20* attended the annual meeting of the American Geophysical Union (AGU). *Ethan Lopes '20* and *Christian Lockwood '20* were planning on attending the annual NE GSA meeting in March but unfortunately it was canceled due to COVID-19.

Marshall Borrus was the recipient of the Lauren Interess Fellowship award this year. He spent 3 weeks from the end of May and beginning of June 2019 exploring the stone walls of Ireland by bike. On November 11 the Interess family joined the department for a lunchtime presentation by Marshall detailing his adventure.

Michael Armstrong '21 was also awarded a Lauren Interess Fellowship for a planned trip in June to explore the surficial geology in northwestern Montana. Due to COVID-19 he postponed that trip until sometime next spring or early summer when hopefully the pandemic will be over.

Marshall Borrus was given the Outstanding Student Presentation award at the AGU Fall Meeting in San Francisco in December. He was also awarded the Freeman Foote Award for the best presentation of his thesis to the

Geosciences Department. The David Major award, given to the student who makes an invaluable contribution to the Geosciences Department, was awarded to Kate Pippenger. Every year a top senior student in Mineralogy and Petrology is nominated for the American Mineralogist Undergraduate Award given by the Mineralogical Society of America. This year for the first time we had two outstanding students so they both were given the award - Christian Lockwood and Kate Pippenger.

Class of 1960 Scholars in Geosciences

Galen Cassidy '22	Henry Newell '21
Matthew Chicoye '20	Kate Pippenger '20
Christian Lockwood '20	Matthew Roychowdhury '21
Ethan Lopes '20	Marco Vallejos '20
Aria Mason '21	

Assistant Professor **Alice Bradley** finished her second year at Williams. She has continued her research in coastal sea ice processes and methods of observation. This includes work using written community records of sea ice conditions as a tool for expanding and validating scientific datasets, work that she presented at the 2019 International Glaciological Society Sea Ice Symposium. This project continues, with the assistance of *Galen Cassidy, '22*.

Alice serves on the Executive committee of the Arctic Observing Summit and as co-chair of the Observation System Design and Implementation working group, and successfully ran an online conference on this topic during the beginning of the COVID-19 pandemic. Following this work, Alice received NSF funding to investigate the large-scale system of observations that inform Arctic communities on issues related to the impact of climate change on food security. *Davis Collision '21* has started working on a senior thesis investigating the role of sea ice observations in decision making around the subsistence walrus hunt.

Bradley worked with thesis student *Marshall Borrus '20* on developing a method to use seismometers for detecting collision events between coastal sea ice and drifting pack ice. These collisions produce ice ridges that can stabilize shore-fast ice into a safe platform for subsistence hunting activities and protects the shoreline from erosion. Marshall presented this work at the 2019 American Geophysical Union (AGU) Fall Meeting, where he won an Outstanding Student Presentation Award.

She also worked with thesis student *Matthew Wiseman '20* to study the influence of the length of the ice-free season in coastal Alaska on coastal erosion rates. This project used commercial satellite imagery to measure the rate of erosion along ~200 km of Arctic coastline. Matt presented this work at the 2019 AGU Fall Meeting.

Both of these projects were assisted by work with *Zia Saylor '23* on developing a database of major storms in northern Alaska since 2010. Additional ongoing research in Alice's group relates to the timing of sea ice freeze-up and melt across the Arctic, which she presented at the 2019 AGU Fall Meeting. Her former thesis student, *Will Downs '19*, also presented on his thesis work at this conference.

In addition to the work on sea ice, Alice led an effort to gather information from the international early career researcher community in the polar sciences on equity in travel funding. The results of this project have been published in Advances in Geosciences, in a special issue on diversity and equity in geosciences. Alice also gave a talk the results of this survey at the 2019 AGU Fall meeting

Associate Professor **Phoebe Cohen** spent the summer of 2019 working with thesis students *Kate Pippenger '20* and *Quinlan Byrne '20* and research student *Annalee Tai '19*. Kate worked on her ACS-funded thesis research on the causes and patterns of the late Devonian mass extinction; Quin worked on his NSF-funded research on using organic carbon isotopes of single microfossils to shed light on Proterozoic ecosystems; Annalee also worked on this NSF project, and traveled to work with collaborators at UCSB in August of 2019. In the fall of 2019, Phoebe taught her introductory course Co-Evolution of Earth and Life as well as a new course – Being Human in STEM – co-taught with physics visiting professor Savan Kharel. Phoebe took on two new research assistants in the fall – *Nicholas Ambeliotis '23* and *Caroline Douglas '23*, who worked to help Quin and Kate with their thesis research. In the spring of 2020, Phoebe taught Paleobiology, where she continued to integrate the programming language R into the curriculum and transitioned the course to an online format after the campus closure. In addition to her research and teaching, she continued her work as an inaugural member of the Paleontological Society's Ethics Committee, and was elected as Councilor-at-Large for the Paleontological Society's council. In September 2019, she attended the Royal Society Meeting on framing an agenda for understanding the origin and rise of complex life where she gave a presentation on "Using Organic Carbon Isotopes of Single Microfossils to Illuminate Proterozoic Eukaryotic Ecosystems."

Assistant Professor **José Antonio Constantine**'s re-

search areas include fluvial geomorphology and environmental justice. Ongoing work focuses on the evolution of oxbow lakes, the role of plants in the development of floodplains, and the impacts of urban flooding and pollution on communities of color.

Summer-Solstice Thomas '20 completed a senior thesis in the research lab where she examined the role of oxbow lakes in sequestering pollutants from the Housatonic River. She is now embarking on a Luce Scholar Fellowship to Cambodia, but has plans to attend graduate school upon her return. *Marco Vallejos '20, Molly Lohss '21, Maxine Ng '22,* and *Ruby Bagwyn '23* worked in the lab as research assistants to address environmental injustice in Tallevast, Florida, where continued air and water pollution impacts the community. Molly will continue this work as her senior thesis in the upcoming academic year. *Michael Armstrong '21* also worked in the lab as a research assistant, studying fluctuations in water quality on the Green River in Williamstown. He will continue this work as a senior thesis, but adding the transport of sediment as a variable to investigate.

José was awarded a grant from the National Science Foundation (no. 2026789) to study the triggers of urban flooding afflicting the community of Centreville, Illinois. With Claire Masteller (Washington University of St. Louis) collaborating on the grant, he hopes the work will provide a plan for alleviating environmental injustice and highlight how communities of color are more broadly impacted by similar problems.

José was invited to give lectures at the annual meeting of the Geological Society of America (Phoenix) and the Geology Department of Colby College. He presented his environmental justice work at the annual meeting of the American Geophysical Union (San Francisco).

Three manuscripts were published from the lab focusing on the geomorphology of submarine channels (*Geological Society of America Bulletin*), the controls on wildfires (*Advances in Biology & Earth Sciences*), and the impacts of climate change on soil erosion (*Science of the Total Environment*).

Seven research assistants worked on projects in **Mea Cook**'s lab. *Alex Quizon '21* and senior honors thesis student *Jared Bathen '20* studied how the ocean circulation and nutrient delivery to the sea surface varied over the last 500,000 years in the Bering Sea to test whether there are systematic changes in carbon dioxide leaking from the ocean to atmosphere between ice ages and interglacials. As part of a project funded by the National Science Foundation, *Madeline Rawson '21*, *Dayana Manrique '21, Matthieu Chicoye '20* and *Rheanna Fleming '23* studied the chemistry of volcanic ash layers from sediment cores in the Bering Sea and Sanak Island in order to match the layers between land and sea to improve the precision of radiocarbon dating of climate events. *Alan Lin '22* measured a time series of stable isotopes of H and O rain, ground and stream water in Hopkins Memorial Forest, as well as the stable isotopes of C in inorganic and organic carbon in stream water. Cook is a member of the American Geophysical Union, the National Association of Geoscience Teachers, and the Earth Science Women's Network.

Professor **Rónadh Cox** continues to work on coastal erosion projects, focusing on megagravel creation and movement by storm waves. In collaboration with research groups at University College Dublin and the University of Limerick she and her students continue to measure and document the power of storm waves on coasts.

In the past year, Rónadh was appointed to an honourary Visiting Professor position in the School of Earth Sciences at University College Dublin, and received new research grants from the EU Marine Robots program and from the National Science Foundation. Rónadh successfully petitioned the Geological Society of America last year to create a new Division of Marine and Coastal Geoscience. The Division organised itself at the 2019 Annual Meeting in Phoenix, and has grown rapidly to include several hundred members, with Rónadh as chair for this formative first year. Other officers include *Kyrien Edwards '17*, currently finishing up his M.S. in tsunami studies at Kyoto University, who is the student representative for the new Division.

Although travel restrictions related to COVID-19 prevented Rónadh and her students from doing planned fieldwork this year, digital data will permit her students to continue their thesis research. *Niku Darafshi '21* and *Aria Mason '21* will analyse photogrammetry from boulder accumulations in western Ireland (both onshore and offshore) to evaluate transport histories and coastal erosion rates. And *Devon Parfait '22*, will use Geographic Information Systems (GIS) to investigate differential land loss on the Mississippi delta in southern Louisiana, and disproportionate effects on marginalised populations in Native American tribes. This builds on initial results that Devon (along with co-author *Will Downs '19*) presented at the 2019 GSA annual meeting last fall. Also represented at the GSA meeting was *Ava Palmo '19*, who was first author on a poster about her Megagravel documentary project (which can be seen on YouTube at

https://www.youtube.com/watch?v=u9PuDY7QyBo).

Edward Brust Professor of Geology and Mineralogy Emeritus **David Dethier** continued his research based at Williams, focusing mainly on Hopkins Memorial Forest, and the long-term geomorphic and geochemical impacts of historic charcoal production in western New England (in cooperation with *Will Ouimet '01*, University of Connecticut, and colleagues from Germany). He also continued a project on the water chemistry of Cuban rivers in cooperation with *Paul Bierman '85* (University of Vermont) and Jay Racela (Environmental Studies).

Working with Jay Racela, Dethier helps with the ongoing collection of weather, streamflow, precipitation chemistry and other environmental data from Hopkins Memorial Forest and other nearby areas and their analysis in the Environmental Science Lab in the Morley Science Center. 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.

Lisa Gilbert was promoted to full professor in July 2020. Lisa hosted several Williams College field trips to the New England shore this year. In addition to the Summer Science Program's overnight visit in July and Mea Cook's GEOS 104 class visit in November, Mea Cook and Alice Bradley brought 11 summer research students to Williams-Mystic for a day of joint tide pooling, short research talks, and exploring Mystic Seaport Museum with the 5 Mystic research students. Although in-person interactions are restricted during summer of 2020, Gilbert is supervising a remote research group of another 5 undergraduate students. Two of the students are focused on hydrogeology of the seafloor: Maggie Zhang (Carnegie Mellon '22) is using her programming skills to tackle image processing of seafloor lavas and Jennifer Crandall (Middlebury '20.5) is working to constrain models of a subseafloor biosphere living within the cracks between lava flows. Three of the students are engaged in interdisciplinary projects: Lily Schauefele (Smith '21) is taking systems thinking approach to examining place during the COVID19 pandemic, Cameron Weinier (Middlebury '20.5) is adapting Gilbert's co-authored InTeGrate module Systems Thinking for middle school use, and *Hayden Gillooly (Williams '21)* is researching sustainability in experiential education. Gilbert also continued to collaborate with *Caroline Hung '19*, now a PhD student at UC Riverside. Hung presented results from her thesis at the American Geophysical Union Meeting in San Francisco in December 2019 and has submitted a co-authored article (with Gilbert and others) to New Zealand Journal of Geology & Geophysics.

At the Earth Educators' Rendezvous in July 2019, Gilbert led a Town Hall on the future of sustainability education, which helped inform her NSF-funded workshop entitled, "Earth Education for Sustainable Societies"(EESS) in October 2019. The EESS workshop brought together leaders from higher education, K-12, science museums, and government and non-profit organizations to draft community vision and priority work areas, with a strong focus on diversity, equity, and inclusion. A forthcoming article in EOS highlights this work. As she has been doing since 2015, Gilbert co-convened a 3-day workshop for aspiring faculty in the geosciences at the 2019 Earth Educators' Rendezvous. Before school closures in March 2020, she collaborated with educators at Mystic Seaport Museum, Project Oceanology, and local schools to design and implement a new place-based environmental science and maritime skills curriculum aimed at helping develop middle school leaders.

Emeritus Professor **Markes Johnson** and Research Associate B. Gudveig Baarli visited Norway in July 2019 to work on parallel research projects. Gudvieg collected brachiopods from the Ordovician-Silurian boundary in the Oslo region in continuance of her project on survival and recovery faunas around the Late Ordovician mass extinction event and Markes was her field assistant. Markes traveled to the Norwegian National Geological Monument on Leka Island near the Polar Circle to gather data on an unusual Holocene beach deposit formed by dense chromite boulders, during which she was his field assistant. Part of the Leka project was in preparation for a Williams Alumni trip to Norway scheduled for June 2020, but that trip was cancelled due to the coronavirus pandemic. Field work conducted in prior years in Mexico's Baja California and the Azorean island of Santa Maria continued to yield dividends with papers published in 2020 based on Pliocene rocky-shore biotas and Pleistocene to Holocene storm deposits. A book manuscript under the provisional title "Coastal Landscapes of Baja California" was submitted by Markes to the University of Arizona Press in January 2020 and won a contract for publication sometime in 2021.

Professor **Paul Karabinos** continued research on the stratigraphy and tectonics 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 and collaborators Maureen Long (Yale University) and Vadim Levin (Rutgers University) continued their geophysics project to image the lithosphere from the surface to the asthenosphere in New England. They have installed six seismometers (one in the basement of Clark Hall) between Petersburg, New York, and Greenfield, Massachusetts, and an additional six instruments in Vermont and New Hampshire. The project is designed to search for structures preserved in the lithosphere from the mountain building history of the New England Appalachians, look for overprinting features that may have developed during the rifting of Pangea and formation of the Atlantic, and assess the importance of ongoing mantle dynamics. Karabinos and Long jointly supervised research by *Ethan Lopes '20* on seismic anisotropy in northern Connecticut. They published an abstract based on this research for the Joint Northeastern-Southeastern Section Meeting of the Geological Society of America in Reston, Virginia, in March, 2020.

Karabinos and collaborators Laura Webb and Keith Klepeis (both from the University of Vermont) continued their geochronology project using K-Ar methods to date the history of faults in the Green Mountains of Vermont and the Berkshires in Massachusetts. They presented some preliminary results at the National Geological Society of America Meeting in Phoenix, Arizona, in September, 2019.

Karabinos led a field trip for the New England Intercollegiate Geologic Conference in October, 2019, examining the structures and stratigraphy of Silurian and Devonian rocks in northern Vermont.

Karabinos attended the National Meeting of the Geological Society of America in Phoenix, Arizona, in September, 2019. He planned to attend the Joint Northeastern-Southeastern Section Meeting of the Geological Society of America in Reston, Virginia, in March, 2020, but the meeting was canceled at the last minute due to the Covid-19 pandemic.

Professor **Bud Wobus** continues his study of "The Big Flat," the extensive subalpine Late Eocene Erosion Surface that is one of the most prominent landscape features of Colorado's Front Range. It is also the datum that divides the two major parts of his career studying the geology of that region: the Proterozoic crystalline rocks lying beneath the surface and the Tertiary volcanic and surficial deposits laying above with a billion-year gap in between. Sixteen of his thesis students over the years have contributed to this study, which has been supported by the USGS, the Keck Geology Consortium, and the Geosciences Department. Several of these students organized a session at the forthcoming Geological Society of America annual meeting in Montreal to recognize his contributions to Colorado geology, igneous petrology, and geoscience education. However, the session will be postponed for a year due to the decision that the Montreal meeting will be entirely remote.

The most recent focus of his study has been on Tertiary volcanic and surficial deposits. *Erikka Olson '19* completed a thesis and made a presentation at GSA/Phoenix last September about deposits of giant boulders (up to 7 meters in diameter) atop the surface near Lake George and Florissant. *Christian Lockwood '20* did an independent study last fall semester on the geochemical correlation of the 36.7 Ma Wall Mountain Tuff on both sides of the Puma Hills (South Park and Florissant regions), providing an estimate of the time of uplift of the Hills. Lockwood and Wobus will present their data at a GSA meeting in 2021. Wobus gave a talk to the Science Faculty in October about the Wall Mountain Tuff and other pyroclastic flows, entitled "Great Blasts from the Past."

Wobus was also a poster co-author with his other 2019 thesis student *Caroline Hung '19* (co-advised with Prof. Lisa Gilbert at Mystic) at the December meeting of the American Geophysical Union in San Francisco. This study deals with hydrothermal alteration in an ophiolite complex along the shoreline of New Zealand's South Island, and is currently in review by the *New Zealand Journal of Geology and Geophysics*.

Last summer Wobus directed the 25th, and last, "Alumni College of the Rockies" at The Nature Place Conference Center near Pikes Peak in Colorado. This was the program that inaugurated the Williams Alumni Travel Program in 1981. The week of geology and natural history field trips has been attended by nearly 500 alumni and sponsors over the years. While in Colorado he also led a weekend field seminar for the Florissant Fossil Beds National Monument about "The Big Flat." Still a member of the board of the Colorado Outdoor Education Center near Florissant, he is delighted that three recent Geosciences majors (*Nell Davis '15, Noah Williams '17,* and *Erikka Olson '19*) have taught for a semester in COEC's High Trails Outdoor Education Center during the last few years.

Post-Graduate Plans of Geosciences Majors

Jared Bathen	eventually work with the USGS or related agency
Marshall Borrus	Unknown
Quinlan Byrne	Unknown
Matthieu Chicoye	Unknown
Jack Consenstein	Unknown
Lucas Estrada	software engineer in Cambridge
Gray Livingston	Environmental consulting in Asheville, NC
Christian Lockwood	Unknown
Ethan Lopes	Geophysics research assistant for Lawrence Berkeley National Lab
Katherine Pippenger	USGS, Wyoming-Montana Water Science Center, graduate school eventually
Daniel Russell	Unknown
Marco Vallejos	Unknown
Matthew Wiseman	Working at a bike shop for the summer; unknown after that
Tyra Wynn	Teaching wilderness medicine for SOLO schools, Chewonki Foundation

Geosciences Colloquia

Rónadh Cox, Bronfman Summer Science Lunch
"Megagravel"

Alex de Sherbinin, Columbia University, Class of 60's Scholar
"The Groundswell Climate Migration Modeling Project"

Kim Cobb, Georgia Institute of Technology
"Life and Death on a Remote Pacific Reef: Lessons in Resilience"

Saleem Ali, University of Delaware, Sperry Lecture
"Elemental Power – How Geoscience and Chemistry will Define our Transition to Clean Energy"

J. Dykstra Eusden, Bates College, Class of 60's Scholar
"New Hampshire's White Mountains: Geology, Tectonics and Landscape"

Maureen Long, Yale University, Class of 60's Scholar
"Seismic Evidence for a Recently Formed Mantle Upwelling Beneath New England"

Terry-Ann Suer '05, Harvard University, Joint Physics, Astronomy and Geosciences Colloquium
"Interpreting Signals from the Early Earth Through High-Pressure Temperature Experiments"

Robert Gaines, Pomona College, Class of 60's Scholar
"Exceptional Fossil Preservation in the Early Phanerozoic: Implications for Seawater Chemistry During the Flowering of Complex Life on Earth"

Geosciences Student Colloquia

Jared Bathen '20
"A Dive into the Bering Sea: Reconstructing the Drivers of North Pacific CO2 Flux through Glacial-Interglacial Cycles of the Pleistocene"

Marshall Borrus '20
"Ireland's Stone Walls from a Bike"

"sICEmic Sea Ice: Detecting Collisions with Seismology"

Ethan Lopes '20
"SKS Splitting Beneath Connecticut: Constraints from the SEISConn Array"

Kate Pippenger '20
"Microfossils and Geochemistry of the Late Devonian Extinction Events in the Appalachian Basin"

Matt Wiseman '20
"Impact of the Length of the Sea Ice-free Summer Season on Alaskan Arctic Coastal Erosion Rates"

Off-Campus Geosciences Colloquia

Phoebe Cohen

"Using Organic Carbon Isotopes of Single Microfossils to Illuminate Proterozoic Eukaryotic Ecosystems"
Royal Society Meeting, London, September 9-10, 2019

José Constantine

"Maintenance of a Single-Threaded Channel Without Persistent Floodplain Vegetation in a Gravel-Bedded River"
Geological Society of America Annual Meeting, Phoenix, AZ, 2019

"Invisible Floods on the Mississippi River Floodplain: Causes and Consequences of an Urban River Avulsion in Centreville, Illinois"
Annual Meeting of the American Geophysical Union, December 2019

"Tropical Insights into Meandering Rivers"
Colby College (postponed until next year due to Covid-19)

Rónadh Cox

"Coastal boulders and wave events: relevant data and potential funded collaborations"
Notre Dame University, College of Engineering (at Kylemore Abbey Global Centre), October 17-19, 2019

"Land-ocean connections: coastal boulder deposits as an example showing the importance (and challenges) of integrating onshore-offshore topography"
INFOMAR (Irish Seabed Mapping body) Annual Seminar, October 16th, 2019

Lisa Gilbert

"Deep Sea Hydrothermal Vents and Volcanoes"
Clifford Symposium on the Future of the Global Ocean, Middlebury College, Middlebury, VT, September 19, 2019

Bud Wobus

"The Big Flat: Colorado's Subalpine Erosion Surface"
Florissant Fossil Beds National Monument, July 2019

"Geology of Stone Hill"
Williamstown Rural Lands Formation hike, October 2019

"From Shore to Shore: The Geological History of Williamstown"
Williamstown Rotary Club, November 2019

MATH & STATS NEWS

At the end of the Academic Year 2019-2020, marked by the unprecedented COVID-19 disruption, we are very proud of the 19 seniors who graduated with a major in Statistics and the 52 who graduated with a major in Mathematics. The Department of Mathematics and Statistics is located in Bascom House, our temporary home, and we are hoping to move into our new building next year.

We are thrilled to have hired a new colleague, John Wiltshire-Gordon, who joined us in July 2020 as a Visiting Assistant Professor. He received his Ph.D. from University of Michigan in 2016 and since then has been a faculty at ICERM and at University of Wisconsin Madison. Our colleague Andrew Bydlon left Williams at the end of June to work as a data scientist at Amazon.com. We will miss him and we wish him the best. Three mathematics faculty, Josh Carlson, Eva Goedhart, and Haydee Lindo, and two statistics faculty, Shaoyang Ning and Elizabeth Upton completed their first year at Williams. They did a great job during this challenging year, and we are lucky to have them in our department!

We celebrated many faculty accomplishments over the year: Pamela Harris and Leo Goldmakher earned tenure, Pamela Harris won the Mathematics Association of America's Henry L. Alder Award for Distinguished Teaching, and Steve Miller won the 2020 CUR-Goldwater Scholars Faculty Mentor Award.

Professors Pamela Harris, Bernhard Klingenberg, Susan Loepp, Ralph Morrison, Cesar Silva, Laurie Tupper, and Daniel Turek were on leave for 2019-2020. Professors Colin Adams, Julie Blackwood (spring), Thomas Garrity, Eva Goedhart (fall), Haydee Lindo, Cesar Silva, and Elizabeth Upton (spring) will be on leave during 2020-2021.

We thank the members of our student advisory board, SMASAB, who organized many Math/Stat events, including gelato socials and Math/Stat snacks: Benjamin Beiers (president), Caroline Case, Jesus Estrada, Michael Gao, Erika Jung, Alessandra Miranda, Miranda Wang, and Teresa Yu.

We are very proud of the accomplishments of our math and stats majors. The following prizes were awarded to students this past year for their accomplishments:

Award Name	**Recipient(s)**
Rosenberg prize for outstanding senior	Michael Curran '20 and Teresa Yu '20
Goldberg award for outstanding colloquium	Blake Bullwinkel '20, Isabelle Furman '20, and Alison Robey '20
Wyskiel award for teaching	Megan Siedman '20
Morgan prize in applied math	Geunho Kye '20
Kozelka award for outstanding student in statistics:	Sofie Netteberg '20
Beaver prize for service to the department and math/stat community	Konnor Herbst '20
Benedict prize for outstanding sophomore	First Prize: Benjamin Baily '22 and Chenyang Sun '22; Second Prize: Liza Jacoby '22
Witte problem solving prize	Hunter Wieman '20
Colloquium attendance prize	Konnor Herbst '20 and Allen Wang '20
National Science Foundation Graduate Research Fellowships in the mathematical sciences	Daniel Maes '18 and Teresa Yu '20
Fulbright Scholarship recipients	Ariel Kolton Fromm '20 and Margaret Siedman '20
Goldwater Scholar	Ben Maron '21

Finally, the Math and Stats department hosted or co-hosted several speakers fot the Class of 60 Scholars program:

Invited Speakers for the Class of 1960 Scholars Program
Moon Duchin, Tufts University
Linda Chen, Swarthmore College
Jennifer Crodelle, New York University
Hugh Montgomery, University of Michigan
Dimitris Koukoulopolos, Université de Montréal
Felipe A Remirez, Wesleyan University
Carolyn Reinhart, Iowa State University

Professor **Colin Adams** was a co-organizer of the conference UnKnot IV, funded by the National Science Foundation, and taking place at the University of Washington-Bothell in July, 2019. This is the fourth iteration of the undergraduate conference on knots he founded with Lew Ludwig in 2009. In 2020, Adams won the Halmos-Ford Award from the Mathematical Association of America for the publication "Knots Related by Knotoids" in the American Mathematical Monthly. His article "What is a hyperbolic 3-manifold?" from the *Notices of the American Mathematical Society* was selected for inclusion in *The Best Writing in Mathematics 2020*, to be published by the Princeton University Press.

At the Joint Math Meeting in Denver in January, he put on humorous math theater with the help of a variety of actor/mathematicians. He continues as humor columnist for the Mathematical Intelligencer and managing editor for the journal *Knot Theory and its Ramifications*.

In the spring, he taught Tiling Theory. He is in the process of producing a text for the course, with incredibly helpful feedback from his students.

Over the past year,Associate Professor **Julie Blackwood** has continued several ongoing projects in mathematical ecology. In particular, she continues to work on modeling the dynamics of infectious diseases in both humans and animals, exploring questions related to identifying the drivers of spatiotemporal patterns of disease and implications for control. Diseases of interest to Blackwood include dengue virus and white nose syndrome in North American little brown bat populations. Her work over the past year also focused on developing optimal management strategies for populations when decisions are made by multiple levels of government. Applications of this work include fisheries and disease management.

Blackwood advised three thesis students: *Nicholas Goldrosen '20, Geunho Kye '20,* and *Alison Robey '20*. Nick's work focused on invasive fish population management, Geunho's work focused on the population dynamics of periodical cicadas in the U.S., and Alison's work focused on the design of biosecurity efforts to minimize invasive species spread and establishment.

In the past year, Assistant Professor **Xizhen Cai** taught Introduction to Statistical Modeling (STAT 202) and the core course of the major, Regression and forecast (STAT 346). She also continued her research on the methodology of analyzing intensive longitudinal data and the application of casual inference models. Two collaborative works were accepted to publish in the past year. Last summer, *Ryan Cox '20* was involved in one related project and the corresponding work will be presented in the coming JSM 2020 virtual conference in August. Cai also extended her research work to various other fields of statistics, including variable selection in the ultra-high dimensional setting, machine learning and statistics education. There are currently two submitted manuscripts under review and revision, and the work on statistical education was presented in the electronic conference on teaching statistics in June 2020. Her interdisciplinary collaborations with faculty in English and Political Science at other institutions on rhetorical analysis continues this summer. *Nicholas Langel '23* is currently working with Cai in developing interactive visualizations as supplementary of the project.

Visiting Assistant Professor **Josh Carlson** continued his research in combinatorics and graph theory. In September, 2019, he co-organized a special session called Zero Forcing, Propagation Time, and Throttling at an American Mathematical Society sectional meeting in Madison. During a 2019 STEAM expo at Bucknell University, hosted by the Girl Scouts in the Heart of Pennsylvania, Professor Carlson operated a booth for the Association for Women in Mathematics which used interactive activities to showcase the importance of mathematics for all ages.

In Spring 2020, Carlson developed and taught a Senior Seminar course (MATH 428) which exposed students to recent research on combinatorial games such as Zero Forcing and Cops and Robbers. This course culminated in a final project designed to facilitate mathematical discovery. Professor Carlson also taught an Independent Study course (MATH 498) in which he worked with Williams students *Robin Eagleton '22, John Petrucci '21,* and *Preetul Sen '22* as well as Jesse Geneson and Carolyn Reinhart (Iowa State University)on a research project related to the game of Cops and Robbers. This

project resulted in a paper called "The damage throttling number of a graph" which has been submitted to *The Australasian Journal of Combinatorics*.

Throughout the past academic year, Carlson collaborated with a variety of students and colleagues to produce four other papers that were accepted for publication in various journals. He also presented his work at multiple conferences including an invited talk at the Joint Mathematics Meetings in Denver. Currently, he is leading a group of five students as part of the SMALL Undergraduate Research Project.

Professor **Dick De Veaux** continued his work in data science, writing textbooks and gave a variety of keynote addresses, talks and workshops on teaching and data science throughout the world. He gave the Presidential Address at the International Statistics Institute Congress in Kuala Lumpur, Malaysia. He continued his term as Vice President of the American Statistical Association (2019-21). He served as chair of the department during the 2019-20 school year and was on the Williams Committee for Data Science.

Professor **Thomas Garrity** has continued his research in number theory. In the summer of 2019 he led a SMALL group consisting of Amy Bradford (University of Utah), Dingding Dong (University of Chicago), *Konnor Herbst '20, Daniel Jordan Alvarez '20, Ariel Koltun-Fromm '20*, Brian Mintz (Brandeis) Vaughn Osterman (University of Texas at Dallas) and Mary Stelow (University of Chicago). He was invited to spend most of January, 2020 at the University of Pisa, where he began a collaboration with a number of people and gave a talk in their dynamical systems seminar. Garrity advised three thesis students last year: *Akhil Dayal, Konnor Herbst and Jacob Pesikoff.*

Associate Professor **Pamela Harris** was on AP leave during the 2019-2020 academic year.

In 2019, Professor Harris was a recipient of the Mathematics Association of America's Henry L. Alder Award for Distinguished Teaching. This award honors beginning college or university faculty whose teaching has been extraordinarily successful and whose effectiveness in teaching undergraduate mathematics is shown to have influence beyond their own classrooms. Based on her mentoring of undergraduate research students, she was selected as the 2019 recipient of the Council on Undergraduate Research's Early Career Mentoring Award.

A highlight of her 2019-20 academic year was the completion of the book *A Resourceful Guide to Undergraduate Research in Mathematics: Starting and Sustaining Accessible Undergraduate Research*. Harris served as Lead Editor, along with Erik Insko, and Aaron Wootton. In addition, she published five research articles and had many other accepted for publication Professor Harris presented 12 invited lectures.

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. This year, Professor Harris had a grant renewed to support the website www.lathisms.org whose mission is to provide an accessible platform that prominently features the extent of the research and mentoring contributions of Latinxs and Hispanics in different areas of the Mathematical Sciences.

Prof. **Chad Higdon-Topaz** and his research group worked in two primary areas. First, they studied complex and nonlinear systems in the natural sciences through several lenses, including data science, modeling, analysis, topology, geometric dynamical systems, numerical simulation, and experiment, all with an eye towards understanding and predicting complex behavior. Second, they applied quantitative tools to expose and remedy social injustice.

Professor **Stewart Johnson** remains active in dynamical systems, focusing on massively parallel computing methods for scientific modeling. This basic research furthers our understanding of spatially organized systems such as systems of neurons, grain boundaries in crystal formation, and cellular tissue growth. Johnson is also furthering his work in optimal control and applied dynamics.

Professor **Bernhard Klingenberg** was on leave, teaching in the graduate Data Science program at New College of Florida and continuing his research into the analysis of categorical response data. He co-presented a continuing education workshop on this topic at the Joint Statistical meetings in Denver. Professors Klingenberg and Topaz and stats major *Sophie Netteberg '20* took part in the 3-day event "Coding our Collection: Datathon", sponsored by the National Gallery of Art in Washington, D.C., where they analyzed and presented on multiple aspects of the museum's permanent collection. Together with Professor Heatherington in Psychology and *Chanel Zhan '17*, Klingenberg published a paper in the *Journal of American College Health*. Prof. Klingenberg continued as associate editor for the journal *Statistical Modeling*, and creating instructional apps for his website ArtofStat.com, on which he delivering several talks at statistical education conferences.

Professor **Susan Loepp** was on leave for the 2019-20 academic year, and she enjoyed working on her research in commutative algebra. In summer 2019, Loepp advised the Commutative Algebra research group as part of the department's SMALL program. The group included the two Williams students *Erica Barrett '21* and *Emil Graf '21*. Two papers based on the groups' original results were submitted to refereed research journals, and one of the papers has been accepted for publication in the *Rocky Mountain Journal of Mathematics*. In January at the Joint Mathematics Meetings in Denver, Loepp gave a talk based on the groups' work. During the academic year 2019-20, Loepp advised the senior honors thesis of *Teresa Yu '20*. Two manuscripts resulted in this collaboration, and both have been submitted for consideration for publication in refereed mathematics research journals.

Past research collaborations have resulted in recent publications. In summer 2015, the SMALL Commutative Algebra group included *Sarah Fleming '18, Peter McDonald '16,* and *Nina Pande '17*. A research paper based on their work recently appeared in the *Journal of Commutative Algebra*. Former students had work published based on their thesis work with Professor Loepp: *Alex Semendinger '18* in the *Rocky Mountain Journal of Mathematics*; *Anya Michaelsen '19* in the *Transactions of the American Mathematical Society;* and *Sarah Fleming '18* in the journal *Involve*

Loepp is an elected member of the Council of the American Mathematical Society. She attended the Council meeting, as well as many mathematical talks and events in January at the Joint Mathematics Meetings in Denver. She also participated in the April Council meeting (virtually). Loepp is serving in her second 5-year term as an associate editor for the *Mathematical Monthly*, and, over the past year, she served on several committees for the American Mathematical Society and the Mathematical Association of America.

Professor **Steven Miller** continued his work in number theory and probability, writing 10+ papers and giving 20+ talks with students. He was the Director of the SMALL summer math research program, where he advised 13 students. He continues to serve on the Mount Greylock Regional School Committee, where he has used mathematics to solve problems for the district and chairs the Education Sub-committee. He and his students successfully consulted on a variety of projects, including a multi-million dollar MLB lawsuit. He has been active in numerous education initiatives, from continuing education classes for teachers to writing computational modules for schools to running a shared, on-line Introduction to Data Science class through LACOL. He continues to serve on several editorial boards, especially *Pi Mu Epsilon* (Problem Editor) and the *Journal of Number Theory* (one of four Managing Editors). Talks, papers, and all class lectures are online at https://web.williams.edu/Mathematics/sjmiller/public_html/.

Professor **Frank Morgan**, in his fourth year of retirement, returned to Williams to cover two real analysis courses in the fall and reprise his Tournament Bridge for Winter Study. His bridge students all returned from a regional tournament with Masterpoints, and they published their adventures in the *Bulletin of the American Contract Bridge League*.

Last summer Morgan conducted an undergraduate research Geometry Group at Yale, resulting in three papers for publication.

Assistant Professor **Ralph Morrison** spent his 4th year at Williams on AP Leave, which was based in Amherst, MA for most of the year with a few months in Leipzig, Germany at the Max Planck Institute for Mathematics in the Sciences. He continued his research on tropical, algebraic, and discrete geometry. Morrison gave many talks and attended many conferences this year, including the "Illustrating Geometry and Topology" Workshop at ICERM in Providence, RI.

During the past year, Assistant Professor **Shaoyang Ning** taught Statistics and Data Analysis (STAT 201), Statistical Inference (STAT 360), and Nonparametric Statistics (STAT 368).

Professor Ning continued his research on the study and design of statistical methods for integrative data analysis, in particular, to address the challenges of increasing complexity and connectivity arising from "Big Data". He has been primarily working on projects utilizing Google search data for high-resolution, local level flu activity prediction as well as using digital data to track economic index such as Unemployment Initial Claims. Ning has been working with *Nikhil Palanki '20* on modeling the transmission of COVID-19 based on geographical connectivity. During the past year, he published two papers, one on regional flu tracking with Internet data in *Scientific Reports* and another on cancer genetics in *Nature Medicine*. He has also submitted a manuscript on unemployment indicator prediction. He presented at Joint Statistical Meetings in Denver, CO and attended NEISM in Wellesley, MA.

Assistant Professor **Anna Plantinga** continued her research in statistical methods for analysis of human

microbiome data, particularly with complex study design features such as longitudinal data or multiple data sources. She also works collaboratively with biologists and clinicians investigating the role of the microbiome in diseases such as irritable bowel syndrome, perinatal mood disorders, and bacterial vaginosis. Plantinga is currently working with two summer research students, *Daniel Park '21* and recent graduate *Selin Gumustop '20*. During the year she published two collaborative papers, one with Biology Professor Steve Swoap and his thesis student *Sarah Becker '20*. In the past year she has also published an R package, given a seminar at Vanderbilt University, presented her work at the Joint Statistical Meetings in Denver, CO, and participated as a panelist in a session entitled "Working and Thriving with Disability in the Statistical Sciences" at the Women in Statistics and Data Science (WSDS) meeting. She taught Statistical Genetics (STAT 410) and Introductory Statistics for Social Science (STAT 161).

In spring 2019, Professor **Cesar Silva** taught Real Analysis (Math 350) and Measure and Ergodic Theory (Math 403). His thesis student *Yuxin Wu '19* worked with Silva studying symbolic dynamics. Since August 2019 Silva has been serving as a program director in the Division of Mathematical Sciences at the National Science Foundation, on leave from Williams.

Professor **Mihai Stoiciu** served as the Associate Chair for Mathematics during the Academic Year 2019-20, and, starting from July 1 2020, is serving as the Chair of the Department. During the Academic Year 2019-20 he advised the senior honors theses of *Alex Bank '20* and *Eli Cytrynbaum '20* and served as a faculty in the Williams College Summer Science Program. During the Academic Year Stoiciu presented his research at a conference at University of Connecticut and at a scientific seminar hosted by the University of South Florida.

Assistant Professor **Daniel Turek** was fortunate to spend this past academic year on sabbatical, which he spent working in Montpellier, France. While there, Turek collaborated with statisticians at the Centre d'Ecologie Fonctionnelle et Evolutive, which is a branch of France's National Center of Scientific Research (CNRS).

Assistant Professor **Elizabeth Upton** completed her first year at Williams where she taught Introduction to Statistics and Data Analysis (STAT 101) and developed and taught a new course for the Mathematics and Statistics Department: Introduction to Stochastic Processes (STAT 342).

Professor Upton continued her research in statistical methods for network-indexed data. She also continues to work collaboratively with epidimiologists on social network analysis for public health research. More specifically, she recently prepared a longitudinal analysis aimed at identifying network predicors of recent and sustained injection drug use cessation among a cohort of participants who use drugs in rural Appalachia. During the year, Upton coauthored three papers (one accepted for publication and two moving through the review process) and presented her work at the INSNA Sunbelt conference.

Post-Graduate Plans of Mathematics and Statistics Majors

Spencer Allyn	Unknown
Elvira Alonso Rivera	Unknown
Alex Bank	Working as a Data Scientist for Foundryai in Washington, DC
Ben Beiers	Unknown
Madeleine Boutet	Working as an Analyst at the Analyst Institute in Washington, DC
Blake Bullwinkel	Pursuing a Master of Science in Data Science at Harvard University
William Burford	Working as a Software Development Engineer at Amazon.com in Cambridge, MA
Amelia Carroll	Unknown
Ryan Cox	Working as a Risk Analyst at Karen Clark and Company in Boston
Michael Curran	Pursuing a DPhil at Oxford University
Eli Cytrynbaum	Research position in the Bernstein Lab at Massachusetts General Hospital investigating the epigenetics of cell fate decisions involved in diseases such as cancer
Akhil Dayal	Unknown
Louisa Ebby	Teaching math at the Groton School in Groton, MA
	Unknown
Mateo Fiorentino Molina	Working in the Investment Banking Division at Goldman Sachs in NYC
Isabelle Furman	Unknown
Demian Gass	Working at IBM as a Data Scientist for the Data Science Elite team in NYC
Joshua Gilkenson	Unknown
Nicholas Goldrosen	Pursuing an MPhil in Criminological Research at the University of Cambridge
Selin Gumustop	Unknown
Clara Hathorne	Unknown
Konnor Herbst	Teaching high school math for Teach for America in Oklahoma City, OK
Emma Herrmann	Working as a Tax Consultant at Ernst and Young in Chicago, IL
Will Howie	Unknown
Nkem Iregbulem	Working in Data Analytics at Capital Group, an investment management firm in Los Angeles, CA
Gyung Hyun Je	Unknown
Daniel Jordan Alvarez	Unknown
Erika Jung	Unknown
Vijay Kadiyala	Unknown
Harper Kerkhoff	Paralegal then attending law school
Chris Kim	Unknown
Ariel Koltun-Fromm	Unknown
Geunho Kye	Analyst at Cornerstone Research in New York, NY
Dong Joo Lee	Unknown
Alina Lin	Working at Goldman
Benjamin Logsdon	Pursuing a Ph.D. in Mathematics at Dartmouth College
Andrew Mathew	Trading at JP Morgan in New York City
Alessandra Miranda	Unknown
Benjamin Myatt	Unknown

Giebien Na	Unknown
Sofie Netteberg	Working at McKinsey and Company, a management consulting firm in Minneapolis, MN
Ruairi O'Cearuil	Unknown
Ingrid Onul	Unknown
Nikhil Palanki	Unknown
Inaya Payne-Wilkes	Unknown
Jeffrey Pearson	Unknown
Isabel Perry	Unknown
Jacob Pesikoff	Unknown
Dzung Pham	Working as a Software Engineer at Facebook, Inc.
Ryan Pruss	Unknown
Sydney Rainer	Unknown
Alison Robey	Unknown
Jack Roche	Unknown
Leting Shao	Unknown
Jacob Shuman	Analyst at Cornerstone Research, an economic consulting company
Megan Siedman	Granted a Fulbright to teach in Bulgaria upon graduating
Melissa Swann	Unknown
Adly Templeton	Working as a Software Engineer for Facebook in Seattle, WA
Ingrid Thyr	Unknown
Borivoje Vitezovic	Working at PillPack by Amazon Pharmacy as a Business Analyst in Boston, MA
Allen Wang	Unknown
Ting Da Wang	Unknown
Hunter Wieman	Working at the Federal Reserve Bank in New York
Samuel Wischnewsky	Unknown
Divya Wodon	Unknown
Veronica Wolff	Unknown
Brenda Xu	Working as an Associate Consultant at Bain & Company in Boston, MA
Xiwei Yang	Unknown
Angela Yu	Working at Analysis Group as an Analyst
Teresa Yu	Pursuing a PhD in mathematics at the University of Michigan
Matt Zappe	Unknown
Qianwen Zheng	Unknown
Tiffany Zheng	Working as a Software Engineer at Google in NYC
Tongyu Zhou	Pursuing a Ph.D. in Computer Science at Brown University

Mathematics and Statistics Colloquia

Colin Adams, Williams College
"Knotted Proteins"

"What Exactly Are Virtual Knots, and Can They Be Hyperbolic? Oh, Yes, They Can!"

Julie Blackwood, Williams College
"Transboundary Management Under Alternative Objectives With Applications to Diseases"

Andrew Bydlon, Williams College
"Perfected Cartier Algebras"

Xizhen Cai, Williams College
"Variable Selection for Dynamic Citation Networks"

Josh Carlson, Williams College
"Throttling for the Game of Cops and Robbers and PSD Zero Forcing"

"Zero Forcing at Full Throttle"

Linda Chen, Swarthmore College
"Enumerative Geometry, Combinatorics, and Algebra"

Moon Duchin, Tufts University
"Making Models that Matter: Computation, Gerrymandering, and the Search for Fairness"

Thomas Garrity, Williams College
"On Partition Zeta Functions"

"Using Thermodynamics to Understand Number Theory"

Eva Goedhart, Williams College
"Progress in Solving a Family of Thue Equations Over Imaginary Quadratic Fields"

Leo Goldmakher, Williams College
"An Elementary Approach to the Distribution of Primes"

Leah Katzelnick, University of California, Berkeley
"The Shadow of the Virus: Measuring Antibodies to Track Viruses As They Move Across Populations"

Dimitris Koukoupoulos, Universite de Montreal
"On the Duffin-Schaeffer Conjecture"

Susan Loepp, Williams College
"The Prime Ideal Structure of Precompletions"

Steven Miller, Williams College
"Extending Pythagoras"

Hugh Montgomery, University of Michigan
"Generating Functions"

Frank Morgan, Williams College
"Optimal Tiles"

Shaoyang Ning, Williams College
"Accurate, Real-Time Flu Tracking With Internet Search Data"

Felipe Ramirez, Wesleyan University
"Approximation by Random Fractions"

Carolyn Reinhart, Iowa State University
"The Normalized Distance Laplacian"

Mihai Stoiciu, Williams College
"Extensions of Wigner's Semicircle Law"

Francis Su, Harvey Mudd College, Co-sponsored by Phi Beta Kappa
"Voting in Agreeable Societies"

Elizabeth Upton, Williams College
"Regression Methods for Network Indexed Data: Modeling Occurrences of Burglary and Identifying Correlates of Injection Drug Use Cessation"

Off-Campus Mathematics and Statistics Colloquia

Colin Adams
"Blown Away: What Knot to Do When Sailing"
Distinguished Lecturer COSMOS Program, University of California, Davis, July 17, 2019
West Chester University, West Chester, PA, September 23, 2019

"Mathematically Bent Theater"
"Making Calculus Fun"
"Undergraduate Research Panel"
Joint Math Meetings, Denver, CO, January 17, 2020

"Hyperbolicity of Virtual Knots"
UnKnot IV Conference, University of Washington, Bothell, July 20, 2019

"Hyperbolic Volume and Turaev Hyperbolic Volume of Knots and Virtual Knots"
Columbia University Topology Seminar, February 14, 2020
Online talk for Topology Seminar, Ohio State University, April 15, 2020

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

Xizhen Cai
"Estimation and Inference for Time-Varying Mediation Model 2019"
Joint Statistical Meetings, August 2019

Poster Presentation: "Educational Tool and Active-Learning Class Activity for Teaching Agglomerative Hierarchical Clustering"
The 2020 Symposium on Data Science and Statistics Virtual Conference, June 2020

Josh Carlson
"Characterizations of Throttling Numbers"
AMS Sectional Meeting, Madison, WI, September 2019

"Extreme Throttling Numbers"
Joint Mathematics Meetings, Denver, Co, January 2020

Richard De Veaux

"The Seven Deadly Sins of Data Science"
International Statistics Institute Congress, Kuala Lumpur, Malaysia, August 2019
International Statistical Engineering Association, Gaithersburg, MD September 2019
Second Conference on Statistics and Data Science, Salvador, Brazil, November 2019
The 1th International Zhejiang University of Finance & Economics, Conference, Hangzhou, China, December 2019
Statistically Speaking, Virtual Conference, June 2020

"Some Tips for Effective Presentations"
Second Conference on Statistics and Data Science, Salvador, Brazil, November 2019
"Data Science for All. Sure, but Who, What, Where and How Much?"
International Association for Statistics Education, Kuala Lumpur, Malaysia, August 2019

"How to get your Paper Published"
Second Conference on Statistics and Data Science, Salvador, Brazil, November 2019

"Using JMP™ For Data mining and Advanced Analytics"
SDSS Virtual Conference, June, 2020

"Building Better Models Through Predictive Analytics"
Minneapolis MN, August 2019
San Diego CA, August 2019
Baltimore MD, September 2019

"Workshop on Presentation Skills"
Joint Statistical Meetings, Denver, CO, Aug 2019

Thomas Garrity

"Dynamical Systems Stemming from a Family of Multi-Dimensional Continued Fraction Algorithms"
Dynamical Systems Seminar, University of Pisa, Italy, January 2020

Pamela Harris

"Parking Functions: Choose Your Own Adventure"
SIDE Math 2020, Virtual Conference on June 15, 2020

"New Results and Open Problems in (t,r) Broadcast Domination"
(Cancelled due to COVID-19) 22nd Conference of the International Federation of Operations Research Societies, Graph Theory and Linear Algebra session, June 2020

"New Results and Open Problems in (t,r) Broadcast Domination"
(Cancelled due to COVID-19) SIAM Mini Symposium "Advances in Discrete Structures," Portland, Oregon, June 2020

"Kostant's Partition Function and Multiplex Juggling Sequences"
(Cancelled due to COVID-19) MAA Seaway Section Meeting, University of Waterloo, May 1, 2020

"Invisible Lattice Points" (video)
Talks by Inspiring Mathematicians, Virtual Speaker Series, May 2020

"Recent Results on Kostant's Partition Function"
(Cancelled due to COVID-19) Marquette University, Mathematics Colloquium, April 2020

"The Lonely Reality of an Academic Dreamer"
(Cancelled due to COVID-19) Marquette University, EOP Celebration, April 2020

"Recent Results on Kostant's Partition Function"
Freie Universitat Berlin, Germany, Discrete Geometry Seminar, February 2020

"Recent Results on Kostant's Partition Function"

Mittag-Leffler Institute, Djursholm, Sweden, February 2020

"The Lonely Reality of an Academic Dreamer"
Hidden No More: Stories of Triumph, Excellence, and Achievement in Math and Computer Science, Southwestern University in Georgetown, Texas

"DREAMing"
SACNAS National Conference, Honolulu, Hawaii, October 2019

"From Invisible to Visible: The Reality of an Academic Dreamer"
SUNY Oswego, Virtual Mathematics Colloquium, November 2019

"The Academic Savior Complex: How NOT to Mentor Underrepresented Faculty"
Johns Hopkins University, Conference: A conversation on professional norms in mathematics, September 2019

"A Mathematical Journey of Culture, Community, and Collaboration"
Swarthmore College, Start of the year mathematics colloquium, September 2019

"The Academic Savior Complex: How NOT to Mentor Underrepresented Faculty"
Arizona State University, September 2019, AWM Luncheon Talk, September 2019

"Invisible Lattice Points"
Arizona State University, September 2019, Math Colloquium

"Kostant's Partition Function and Multiplex Juggling Sequences"
Florida Gulf Coast University, Mathematics Colloquium, May 2019

Chad Higdon-Topaz
"Invited Seminars and Colloquia"
University of Canterbury, February 2020
University of Auckland, February 2020
University of California, LA, January 2020
Clarkson University, November 2019

Bernhard Klingenberg
"Seeing is Believing"
2020 Electronic Conference on Teaching Statistics, online, May 2020

"Simulations to Show the Beauty and Robustness of the CLT and Classical Inference"
32nd International Conference on Technology in Collegiate Mathematics, online, March 2020

"Diversity of Artists in U.S. Museums"
Annual Meeting of the American Statistical Association, Florida Chapter, Pensacola, FL, March 2020
New College of Florida, Sarasota, FL, September 2019

"A Data Scientist Goes to the Museum"
Annual Meeting of the American Statistical Association, Florida Chapter, Pensacola, FL, March 2020
New College of Florida, Sarasota, FL, September 2019

"Diversity on Display: Who's on the Wall at NGA?"
Coding Our Collection: Datathon, National Gallery of Art, Washington D.C., October 2019

"Analysis of Categorical Data"
Continuing Education Workshop, Joint Statistical Meetings, Denver, August 2019

Susan Loepp
"Uncountable Excellent Regular Local Rings with Countable Spectra"
Special Session on Commutative Algebra: in Celebration of the 150th Birthday of Roger and Sylvia Weigand, AMS Sectional Meeting, University of Wisconsin, September, 2019

"The Prime Spectra of Precompletions"
AMS Special Session on Commutative Algebra, Joint Mathematics Meetings, Denver, January, 2020

Steven Miller

"Inrtoduwtion to Erorr Dwtetcion and Czorrectmon"
TCNJ Math Camp, July 28, 2019
MathFest, August, 2019

"From M&Ms to Mathematics, or, How I Learned to Answer Questions and Help my Kids Love Math"
TCNJ Math Camp, July 29, 2019

"Computational Mathematics Lectures, Continuing Education Session"
Albany, November 9, 2019

"Funding Opportunities for Research, panelist at the Field of Dreams Conference"
St Louis, November 15, 2019

"Undergraduates and Students in Post-Baccalaureate Programs, I"
Joint Math Meetings, January 15, 2020

"YouTube University II: Shared Upper Level Math Courses Across Schools"
Joint Math Meetings, AMS Special Session on Pedagogical Innovations That Lead to Successful Mathematics, Denver, January 16, 2020, (online: https://youtu.be/rjn1sn3WLZg)

"From the Manhattan Project to Elliptic Curves"
MASON IV (plenary talk), March 7, 2020

"From Zombies to Fibonaccis: An Introduction to the Theory of Games I"
Michigan Math Circle, April 23 & April 30, 2020

"From C to Shining Sea: Complex Dynamics from Combinatorics to Coastlines"
Michigan Math Club, April 30, 2020

"The Role of Academia in Entrepreneurship"
Techapreneur Radio, June 1, 2020

"Fibonacci Quilt Game Speakers"
Alexandra Newlon, Neelima Borade, Annie Xu, Catherine Wahlenmayer
Conference for New England REUs, July 23, 2019

"Distribution of Missing Sums in Correlated Sumsets"
Thomas Martinez, Dylan King and Chenyang Sun, Conference for New England REUs, July 23, 2019

"Generalizing Zeckendorf's Theorem to Homogeneous Linear Recurrences Speakers"
Clayton Mizgerd, Thomas Martinez and Chenyang Sun '21, Conference for New England REUs, July 23, 2019

"Zeros of L-Functions Near the Central Point and Optimal Test Functions"
Charles Devlin, Conference for New England REUs, July 23, 2019

"ABBA and the Random Matrix Discotheque"
Keller Blackwell and Wanqiao Xu, Conference for New England REUs, July 23, 2019

"Spies and Traitors: Random Matrix Kaleidoscopes and their Turncoat Eigenvalues"
Neelima Borade and Renyuan Ma, Conference for New England REUs, July 23, 2019

"Crescent Configurations In Non-Euclidean Norms"
Sara Fish, Dylan King, Catherine Wahlenmayer, Conference for New England REUs, July 23, 2019

"ABBA and the Random Matrix Discotheque"
Keller Blackwell and Wanqiao Xu

"AMS-MAA-SIAM Special Session on Research in Mathematics by Spies and Traitors: Random Matrix Kalei-

doscopes and their Turncoat Eigenvalues”
Neelima Borade, Joint Math Meetings, January 17, 2020, Won an Outstanding Poster Award

“Distribution of Missing Differences in Diffsets”
Fei Peng, CANT June 5, 2020

“Distribution of Missing Sums in Correlated Sumsets”
Dylan King, CANT June 5, 2020

Frank Morgan

“Double and Multiple Bubbles in Gauss Space”
Workshop on Filling Volumes, Geodesics, and Intrinsic Flat Convergence, Yale University, July 30, 2019

“Double Bubbles in Spaces With Density”
Union College, September 14, 2019

“Optimal Partitions and Tiles”
Yale University, February 15, 2020

“Soap Bubble Geometry Contest”
Yale University, February 15, 2020

“Least-Area Polyhedral Tiles of Space”
University of Tennessee, Knoxville, February 27 – 28, 2020

“Isoperimetric Problems”
University of Tennessee, Knoxville, February 27 – 28, 2020

Ralph Morrison

“Graphs of Gonality Three”
SIAM cCnference on Applied Algebraic Geometry, Bern, Switzerland, July 2019

“The Moduli Space of Tropical Curves with Fixed Newton Polygon”
“Algebra Meets Combinatorics in Neuchatel" Conference, Neuchatel, Switzerland, July 2019
“Tropically Planar Graphs”
Binghamton University, Combinatorics Seminar, October 2019

“Chip-firing Games on Graphs”
Yale University, Yale Undergraduate Mathematics Society Colloquium, November 2019
Wesleyan University, Wesleyan Undergraduate Math Club, February 2020
Mentor Project “1 Hour Mentor” series, April 2020

“Gonality of Cartesian Products of Graphs”
Yale University, Algebraic and Tropical Geometry Seminar, November 2019

“Undergraduate Research Topics in Tropical Geometry”
Joint Math Meetings AMS-MAA Special Session on Getting Started in Undergraduate Research: Topics, Tools and Open Problems, Denver CO, January 2020

“Higher Distance Commuting Varieties”
Valley Geometry Seminar, UMass Amherst, February 2020

“Tropically Planar Graphs: Geometry and Combinatorics”
Discrete Geometry Seminar, TU Berlin, February 2020

“Higher Distance Commuting Varieties”
Nonlinear Algebra Seminar Online, MPI Leipzig, March 2020

“Undergraduate Research in Tropical Geometry”
Mentor Project “1 Hour Mentor” series, April 2020

Shaoyang Ning

"ARGO2: Accurate, Real-time Flu Tracking with Internet Search Data"
Joint Statistical Meetings, Denver, CO, July 29, 2019

Anna Plantinga

"Covariate-Adjusted Ordination Plots and Distance-Based Longitudinal Microbiome Analysis"
Joint Statistical Meetings, Denver, CO., August 2019

"Community-Level Analysis for Complex Microbiome Association Studies"
Department of Biostatistics, Vanderbilt University, November 2019

Cesar Silva

"On weak mixing notions in infinite measure", UNT Mathematics Millican Lecture Series, University of North Texas, Denton, Texas, October 21, 2019

"On nonsingular transformations and the ergodic with isometric coefficents property", AMS Special Session on Fractal Geometry and Dynamical Systems, University of Florida, Gainsville, November 3, 2019

"On ergodic properties of powers of finite and infinite measure-preserving transformations,"
AMS Special Session on Quantization for Probability Distributions and Dynamical Systems, AMS Annual Meeting, Denver, January 15, 2020

Mihai Stoiciu

"The 2019 Northeast Analysis Network Conference",
University of Connecticut Storrs, September 2019

"Mathematics Colloquium"
University of South Florida, February 2020

Daniel Turek

"Leading a 2-day Bayesian Statistics Workshop"
Home Laboratory Montpellier France

"Leading a 1-day Bayesian Statistics Workshop"
Institute National de la Recherche Agronomique (INRA), Saint-Pée-sur-Nivelle, France

"Visiting Collaborators"
CIRAD Agricultural Research for Development laboratory, Montferrier-sur-Lez, France

"Leading a 1-day Bayesian Statistics Workshop"
Norwegian University of Science and Technology, Trondheim, Norway. (This was sponsored by the Fulbright Inter-Country Lecturing Program)

"Articipating in the Project Wildmap Wildlife Management Program,"
Norwegian University of Life Sciences, in Ås, Norway

"Invited Talk"
Statistical Sciences Group of the University of Exeter, in Exeter, UK (This was sponsored by the Fulbright Inter-Country Lecturing Program)

Elizabeth Upton

"Examining the Role of Social Norms and Social Influence on Injection Drug Use Cessation"
Sunbelt: International Network for Social Network Analysis, Montreal QC, Canada, June 22, 2019

Mathematics and Statistics Student Colloquia

(All students are members of the class of '19)

Spencer Allyn
"Backfitting: Estimating the Smooth Components of a Generalized Additive Model (GAM)"

Elvira Alonso-Rivera
"An Algebraic Approach to the 15-Puzzle"

Alex Bank
"Asymptotic Expansions for Bounds of Epsilon-Pseudospectra of Nonnormal Matrices"

Benjamin Beiers
"The Mathematics of Political Conflict and the India-Pakistan Crisis"

Madeleine Boutet
"A Network Approach to Analyzing Information Gerrymandering and Undemocratic Decision Making"

Blake Bullwinkel
"Early Epidemiological Model Parameters for the 2019 Novel Coronavirus (2019-nCoV)"

William Burford
"Matrix Multiplication in Sub-Cubic Runtime"

Amelia Carroll
"The Singular Value Decomposition and Its Applications to Digital Image Compression"

Ryan Cox
"Time-Varying Mediation Models: Inference for the Mediation Effect Using a Simulation-Based Approach"

Michael Curran
"Ehrhart Theory and an Explicit Version of Khovanskii's Theorem"

Eli Cytrynbaum
"Point Process Convergence and the Circular Beta Ensemble"

Akhil Dayal
"Using Modified Rauzy-Veech Induction to Relate Interval Exchange Maps and Continued Fractions"

Louisa Ebby
"The Recurrence of Random Walks and Polya's Theorem"

Mateo Fiorentino Molina
"The Topology and Combinatorics of Soccer Balls"

Isabelle Furman
"Hyperbolic Geometry and Crochet"

Demian Gass
"The Finding that Shocked the World: Stein's Paradox"

Nicholas Goldrosen
"Control Strategies for Invasive Grass Carp and the Dynamics of Ecosystem Federalism"

Selin Gumustop
"Exploring Minimax Linkage: Hierarchical Clustering With Prototypes"

Clara Hathorne
"Polynomial Resultants and Applications"

Konnor Herbst

"Ergodicity and Transfer Operators for Continued Fraction (TRIP) Maps"

Emma Herrmann
"The Damage Number of a Graph for the Game of Cops and Robbers"

William Howie
"Gale-Shapley & the Stable Marriage Problem"

Paul Hwang
"Sentiment Analysis and Latent Dirichlet Allocation"

Gyung Hyun Je
"Multi-Armed Bandit Problem: Finding an Optimal Solution When We Don't Have Enough Time and Resources"

Nkem Iregbulem
"Exploring Stern's Diatomic Sequence"

Daniel Jordan Alvarez
"The Rauzy Fractal"

Vijay Kadiyala
"The Infamous Gaussian Copula and the 2008 Financial Crisis"

Harper Kerkhoff
"Arrow's Impossibility Theorem"

Chris Kim
"Lambert's Proof of the Irrationality of Pi"

Ariel Koltun-Fromm
"Triangle Sequences and Cubic Irrationals"

Geunho Kye
"Modeling Developmental Synchrony and Equilibrium in Cicada Populations"

Dong Joo Lee
"A Taste of Constructivism"

Erika Jung
"PageRank: Google's Application of the Perron-Frobenius Theorem"

Alina Lin
"Time Series Modelling Using GARCH"

Benjamin Logsdon
"Asymptotic Formulas for Mean Values of Multiplicative Functions"

Andrew Mathew
"Monte Carlo Tennis"

Alessandra Miranda
"A Successive Random Sampling Approach to Clustering Global Climate Data and Other Large Datasets"

Benjamin Mygatt
"A Foray into Fourier and Fejér"

Giebien Na
"Exploring the Square Root of 2"

Sofie Netteberg
"The Gap Statistic: Intuitive Determination of Cluster Counts"

Ruairi ÓCearúil

"Does My Vote Matter? A Statistical Approach to Understanding Electoral Politics"

Ingrid Onul
"Morphogenesis in Biological and Chemical Systems"

Nikhil Palanki
"Applied Bayesian Methods for Macroeconomic Forecasting"

Jeffrey Pearson
"A Sketch of Mordell's Theorem"

Isabel Perry
"Conformal Mapping: The Joukowski Transformation"

Jacob Pesikoff
"Row, Row, Row, Your Fraction"

Dzung Pham
"Exploring Variable Important With Stacked Models"

Ryan Pruss
"Who Wrote the Beatles Songs: Authorship Attribution in Lennon-McCartney Songs"

Sydney Rainer
"Matching and its Applications to the Admission Processes"

Alison Robey
"Invasive Spread Modeling in Manhattan"

Jack Roche
"A Renormalization Approach to the Zeta Function at -1"

Lily Shao
"Best Rational Approximation Using Continued Fractions"

Jacob Shuman
"Copula-Based Measures of Dependence on Ordinal Data Using Latent Distributions"

Megan Siedman
"Math on the Moon: Houston, We Have a Prime"

Melissa Swann
"An Inhomogeneous Poisson Process for Modeling Neural Spike Data"

Adly Templeton
"Modern Approaches for Representing Text Data"

Ingrid Thyr
"A Math Model of Overgrazing: Getting Beyond Counting Sheep"

Borivoje Vitezovic
"Pseudoinverse Matrices and Applications"

Allen Wang
"Principal Component Analysis (PCA) and Some of its Applications"

Ting Da Wang
"Ergodicity of the Gauss Map"

Hunter Wieman
"Bernstein Polynomials and Applications"

Divya Wodon

"ABC Conjecture and Fermat's Last Theorem"

Veronica Wolff
"Branching Processes and Local Species Vulnerability"

Brenda Xu
"Hartog's Theorem"

Xiwei Yang
"Introduction to Space-Filling Curves"

Angela Yu
"Modeling Language Death and Dynamics"

Teresa Yu
"Characterization of Completions of Uncountable Local Rings With Countable Spectra"

Matthew Zappe
"The SIS Epidemic Model and Virus Dynamics on Hub-and-Spoke Graphs"

Qianwen Zheng
"(k,p)-Planarity: A Relaxed Planar Representation of Cluster Graphs"

Tongyu Zhou
"Survival Analysis on Botnet C&C Traffic"

NEUROSCIENCE NEWS

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. The following courses were offered in the Neuroscience program during the past year: Tim Lebestky and Shivon Robinson co-taught the core course Introduction to Neuroscience (NSCI 212). Robinson also taught the capstone Topics in Neuroscience senior seminar (NSCI 401) and Opioids and the Opioid Crisis (NSCI 313). Matt Carter taught an advanced elective, Neural Systems and Circuits (NSCI 311). Tim Lebestky taught the Neurobiology of Emotion (NSCI 347), in the spring. Noah Sandstrom taught the tutorial Neuroethics (NSCI 319). Finally, Betty Zimmerberg taught the interdisciplinary seminar The Brain and Visual Arts (NSCI 318). 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 diet on drug seeking behavior in rats (Matt Clasen) 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 sections. Eleven graduating seniors completed the Neuroscience concentration. Five completed senior honors theses in Neuroscience and two concentrators completed honors theses in Biology.

Carl Porto '20 was awarded the 2020 Patricia Goldman-Rakic prize for his demonstrated exceptional achievement in research within the field of neuroscience.

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

Martha Marvin teaches the laboratories for Neuroscience (NSCI 201). She co-taught her Winter Study course, Project BioEyes, which for the past eleven 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 Elementary School and combined classes from Lanesborough Elementary School and Hancock Elementary School (at Lanesborough) for one week each. Dr. Marvin mentored seven undergraduate research assistants. Research in the Marvin lab investigates aspects of zebrafish development, including the response to stresses that activates the hormone cortisol, and the effect of endocrine disruptors on the development of the cardiovascular system.

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, Robinson, Sandstrom, Clasen, and Zimmerberg.

For post-graduate plans of neuroscience students, please visit the Biology and Psychology sections of this report.

PHYSICS NEWS

Research with students is a central activity of physics department faculty. In the summer of 2019, we had a robust research program in the Physics department. 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).

The Physics department continues to participate in the 1960 Scholars program. This year 6 physics students wer named as scholars:

Class of 1960 Scholars in Physics	
Qiyuan Hu	Edgar Lyons
Heather Kurtz	Abdullah Nasir
Jacob Lezberg	Mariam Ughrelidze

Professor **Daniel Aalberts** taught the Electrodynamic Theory (PHYS 405T) to a record 27 tutorial students, Mathematical Methods for Scientists (PHYS/MATH 210), and Computational Biology (PHYS/CSCI 315). In Summer 2019, *Qiyuan Hu '20, Tarun Yadav '21,* and *Sakim Aleem '21* discovered evidence of structured RNA elements in the introns of genes and measured the biases in Ribosome Profiling experiments. In Summer 2020, *Brendan Hall '21* and *Shayan Moazeni '22* are simulating Ribosome kinetics, measuring the statistics of ribosome pausing, and modeling mRNA decay.

Assistant Professor **Charlie Doret** taught Quantum Physics (PHYS 301) during 2019-20 to a record setting enrollment of 31 students as our large group of physics and astrophysics majors from the class of 2021 arrived in their junior year. The spring saw Doret continue his revisions to the format of Foundations of Modern Physics (PHYS 142), replacing some time in lecture guided small-group problem solving and an introduction to numerical work in *Mathematica*.

Outside of the classroom, Doret's research focuses on work with trapped atomic ions. Such ions can be exquisitely controlled using lasers and electric fields, allowing them to be used as tools to emulate the behavior of more complicated quantum systems of interest. One particular focus for Doret's lab is to try 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. However, the same exceptional control over atomic systems can also be used to make precise measurements of atomic structure to test models for physics beyond the Standard model. Along these lines, during summer 2019 Doret published part-per-billion measurements of isotope shifts in the forbidden $^2S_{1/2} \rightarrow {}^2D_{5/2}$ and $^2S_{1/2} \rightarrow {}^2D_{3/2}$ transitions in Ca^+ in *Physical Review A* along with coauthors *Felix Knollmann `19* (starting a PhD at MIT in Fall '20) and *Ashay Patel `18* (enrolled in a PhD program at CalTech). Over the course of the academic year Doret worked towards a related measurement on the $^2S_{1/2} \rightarrow {}^2D_{3/2}$ transition with thesis student *Jacob Lezberg `20*.

Jacob was joined in the lab by *Paige Robichaud `21, Matthew Roychowdhury `21, Tim Saffold `22,* and *Timmy Chang `23*. Paige and Tim spent Winter Study working on incorporating a new ion trap into the laboratory, while Matthew and Timmy built electronics for a new laser. Paige and Matthew will be starting theses during summer '20, where they will be joined by *Aidan Ryan '20*, who is also starting a thesis.

COVID-19 has, understandably, led to the cancellation of large events such as physics conferences. But, physics soldiers on, and the American Physical Society managed to put together an extensive virtual conference for this year's meeting of the Division of Atomic, Molecular, and Optical Physics (DAMOP), where Doret chaired a session on `Novel Applications of Atomic Spectroscopy.' As always, the conference saw a strong Williams contingent, with a virtual meet-up featuring alums and present students ranging from `66 to `21. We all look forward to getting together again in person whenever circumstances permit, hopefully for DAMOP 2021.

Assistant Professor **Graham Giovanetti** had an enjoyable and productive first year at Williams. He is currently involved in two experimental collaborations searching for new physics using low-background, underground detectors. The DarkSide collaboration is using liquid argon time projection chambers to search for particle dark matter. And the MAJORANA collaboration is searching for the neutrinoless double-beta decay of ^{76}Ge, a hypothetical nuclear decay that, if observed, would give insight into the fundamental nature of the neutrino. Professor Giovanetti is currently constructing a liquid argon test-bed at Williams for developing and testing novel detector technologies with the help of several students, including *Sne Das '23, James Suh '23,* and *Aidan Dun-*

can '23. In summer 2020, *Save Koontaweepunya '21, Duncan McCarthy '21, Fil Niewinski '22,* and *Declan Smith '21* are undertaking a simulation study to design a new liquid argon detector optimized for a particular class of dark matter candidates with masses lighter than the proton.

Professor Giovanetti taught Introduction to Mechanics (PHYS 131) in Fall '19 and Vibrations, Waves, and Optics (PHYS 202) in Spring '20. This winter, he served as a member of the Department of Energy (DOE) Detector R&D Basic Research Needs Study. The study was organized by DOE to identify priority research directions necessary to drive high energy physics in the coming decades. He was a coauthor on several papers, including a new result limiting the allowable neutrinoless double-beta decay half-life of ^{76}Ge to longer than 2.7×10^{25} years.

Assistant Professor **Kate Jensen** taught Mechanics and Waves (PHYS 141) and her interdisciplinary Introduction to Materials Science (PHYS/GEOS 234) this year. She also taught her hands-on, experiential Winter Study course, The Way Things Work (Phys 16), which was able to include much more extensive machine shop and electronics experiences this year thanks to the support of Michael Taylor and Jason Mativi in the Science Center Shop.

The research in Jensen's Materials Physics Lab focuses on understanding the mechanics of soft materials and interfaces. Fifteen Williams students contributed to research efforts in Jensen's laboratory in the past year, working to understand the physics underlying soft adhesion and surface mechanics, and expanding research in newer directions including structures and properties of colloidal materials and the evolutionary adaptations of plants to harness mechanical energy from water. The lab also added significant new experimental capabilities with the addition of an Anton Paar MCR-301 rheometer as well as home-built interferometry and mechanical testing setups.

Edgar (Zed) Lyons '20 completed his senior thesis involving combined theory and experimental components, co-advised with theoretical physicist Tim Atherton at Tufts University. Zed worked with Atherton during the summer of 2018 with the support of an Alumni Sponsored Internship Program (ASIP) grant. This project building on earlier foundational work by *Joey Headley '21,* and *Emily Kuwaye '23,* made new experimental contributions to the project in early Spring 2020. We are currently writing up these results for publication.

Meanwhile, *Minwoo (Josh) Kang '20, Abdullah Nasir '20, Eshaan Patel '21, Aidan Ryan '21, Nico Coloma-Cook '21, Adam Dionne '22,* and *Aidan Duncan '23* worked on various projects studying the physics of soft adhesion. *Anneliese Silveyra '21* continued her experimental work at the intersection of botany and fluid physics, co-advised by Professor Joan Edwards in biology, and *Nick Patiño '21* worked towards using interferometry to study membrane vibrations; both Nick and Anneliese are Allison Davis Research Fellows, and Nick started a senior thesis in the lab this summer. *Sophia Millay '21, Harrison Toll '22, Charlotte Jones '22,* and *Caroline Tally '21* spent summer 2020 investigating various fluid surface dynamics and instabilities, combining theory, simulation, and at-home experiments for productive remote research. Meanwhile, *Ryan Watson '22* and *Brianna Binder '22* sinulated colloidal materials in preparation for future on-campus experiments, and *Aidan Duncan '23* worked on a new collaboration with colleagues at Harvard's School of Engineering and Applied Sciences using machine learning to investigate defects in colloidal glasses.

McElfresh Professor of Physics **Kevin Jones** '77 continues to do research in quantum optics. Working with longstanding colleagues at the Joint Quantum Institute (JQI) located on the University of Maryland campus, he has most recently been exploring the advance and delay of optical pulses travelling through a phase-sensitive optical amplifier operating near the limits set by quantum mechanics. This builds on earlier work exploring pulse propagation and information transfer through a quantum limited amplifier of a different type, namely one insensitive to the optical phase of the input signal. These two types of amplifiers have fundamentally different quantum properties. This work is part of an ongoing experimental research program, conducted with his host at the JQI Dr. Paul Lett, studying the generation of non-classical states of light, the operation of different types of quantum limited optical amplifiers and ways to perform measurements beyond the standard quantum limits. Jones, with colleagues, students and post-docs at the JQI, has recently published two papers, one demonstrating the generation of non-classical light at low sideband frequencies and one exploring the signal advance/delay mentioned above. Both are in *Optics Express*, a rapid publication journal of the Optical Society of America.

In fall 2019 Jones taught a course Energy Science and Technology aimed largely at non-physics majors. Originally developed by Professor Emeritus Jeff Strait, this course has become a regular offering of the department and serves to provide students from a variety of back-

grounds a quantitative understanding of the energy challenges - and possible solutions - that are, and increasing will be, a major feature of the lives of current students and their fellow citizens. Jones also taught upper level students in the lab portion of our junior level quantum mechanics course, which is class that he always enjoys returning to.

In the spring of 2020, Jones was away from Williams and served as a Program Director at the National Science Foundation, the major funding agency for much of academic science. With an NSF colleague he ran the Experimental Atomic, Molecular and Optics (AMO) program in the Physics Division at NSF. In this role, he selected expert reviewers for pending proposals, helped lead a panel evaluating the full slate of proposals and ultimately recommended funding or declination of proposals. He also sought out opportunities for his program to collaborate with other programs at NSF to jointly fund interdisciplinary work. He has been enjoying the opportunity to step back from his own research, take a broader view of the field of AMO physics and the many fields it intersects with, and help steer the future direction of the field. He will return to NSF next spring, after teaching at Williams in the fall.

Assistant professor **Catherine Kealhofer**'s research focuses on 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.

Kealhofer spent the 2019-20 year on research sabbatical, continuing the development of an ultrafast electron diffraction apparatus in her lab. Thesis student *Heather Kurtz '20* took the lead on learning to make thin samples of graphite (using the famous "sticky-tape" method), with the aim of preparing thin samples of graphite and other 2D materials for ultrafast electron diffraction. She learned how to characterize samples using a combination of optical microscopy and atomic force microscopy, and *Ilana Albert '21* will take over this project as part of her thesis work in the coming academic year. For her thesis, Heather also performed the first characterization of electron emission from our electron sources. Post-graduation, Heather is working at Sinovia Technologies, a start-up company manufacturing flexible displays.

Ilana, *Josh Reynolds '21, Declan Daly '21,* and *Filip Niewinski '22* continued doing research over the course of the 2019-20 academic year, and *Nelly Lin-Schweitzer '21* is joining the group for the summer research program. Students have been working on several aspects of the experiment—sample preparation, sample holder design, ultrafast optics, and electron optics. Since students left campus in March due to COVID-19, they have been working remotely on simulations and planning in support of the projects they look forward to taking up again once they return to campus in the fall. Josh and Declan are simulating pulse propagation in fiber amplifiers, Ilana is simulating ultrafast heating of samples, and Nelly is simulating electron deflector designs.

Kealhofer was the recipient of a Cottrell Scholar Award from the Research Corporation for Science Advancement; the award will support her group's research on ultrafast non-equilibrium phonon dynamics in 2D materials using ultrafast electron diffraction, as well as incorporating original research literature into a first-year physics course, Seminar in Modern Physics (PHYS 151).

Professor **Tiku Majumder** supervised three students in his lab during the summer of 2019, and published a paper in the journal *Physical Review A* in the fall, with two former thesis students and two former postdocs as co-authors. He also taught labs for PHYS 301 (Introductory Quantum Mechanics) in the fall semester, and taught 22 juniors and seniors in Statistical and Thermal Physics (PHYS 302) in the spring. This last experience was notable both because the enrollment was the largest in memory (due to our record number of class of '21 majors), and also because, after Spring Break, it moved to all-remote when Williams shut down campus due to the coronavirus pandemic. This was a challenging, humbling, stressful, but inspiring experience in which these 22 students stepped up to the challenges in every way to make it the best possible educational experience.

Professor Majumder also continued his work, now extending over the past decade, as Science Center Director, overseeing budgets, supporting student/faculty research programs, working with science chairs, and remaining closely involved with ongoing construction progress of the new "Wachenheim Science Center" building.

Abdullah Nasir '20 completed a uniquely challenging senior thesis this year, for which in-lab work ceased in mid-March. His thesis outlines plans to incorporate our highly sensitive Faraday rotation polarimetry technique (outlined in the 2019 publication), into our atomic beam apparatus. This apparatus had been used for a series of experiments in its old home (Bronfman Science Center) to study Stark shifts in indium and thallium. Abdullah worked with newly arrived postdoc Dr. John Lacy

(Ph.D. 2019 U. Sussex, UK), to rebuild our source/furnace for use with lead (Pb), and to incorporate all the magneto-optic components to be able to detect microradian-sized optical rotations when a transverse laser interacts with the Pb atomic beam. He also pursued a series of theory/modeling projects to support the planned work.

Also part of the team during this past academic year was *Declan Smith '21* who continued summer 2020 work through the fall with our vapor cell / furnace polarimeter, and *Gabriel Patenotte '21* who worked through March developing and testing a new UV (368 nm) laser system that must be operated at temperatures below zero Celsius. Gabriel, along with *Patrick Postec '21* have begun (remote summer) internships in anticipation of beginning their in-person senior thesis work for 2020-2021. All of the research projects in the lab are aimed at making highly precise spectroscopic measurements of the atomic properties of key heavy elements to support and test state-of-the-art theoretical modeling of the quantum mechanics of these complex systems. Our postdoc John has been an amazing partner in all of this, leading and mentoring and pushing forward the work especially through difficult and lonely periods in the lab this spring and summer! Work in the Majumder lab is currently supported by a 3-year, $365,000 grant from the National Science Foundation.

In the fall semester, Professor **David Tucker-Smith** taught Electricity and Magnetism (PHYS 201). In the spring, he taught Gravity (PHYS 418) and team-taught Mathematical Methods for Scientists (PHYS 210) with Professor Daniel Aalberts.

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. During the summer of 2019, Tucker-Smith worked with *Justin Berman '21* and *Declan Daly '21*, on a theoretical framework that connects baryogenesis and dark matter. Justin is continuing this work during the summer of 2020, and it will form the basis for his senior honors thesis. *Benny Weng '22* and *Jihoon Kim '22* also joined our group as summer-2020 research students.

Professor Emeritus **Bill Wootters** returned to the classroom in the spring semester of 2020 to teach Electromagnetism and the Physics of Matter (PHYS 132) with much help from another retired professor, Jeff Strait, who was in charge of the laboratory portion of the course. Like most Williams professors, in the second half of the semester Bill had the experience of teaching remotely for the first time in his career.

In June of 2020, Bill served as the external examiner for a doctoral thesis at Dartmouth. Later in the summer, he will be offering a new course, Gravity, for the Osher Lifelong Learning Institute. Beginning with Aristotle, the course will trace the history of theories of gravity through Newton and Einstein, leading up to a study of contemporary topics such as dark matter, gravitational radiation, and the effort to reconcile general relativity with quantum theory.

Post-Graduate Plans of Physics Majors

Name	Plans
Marshall Borrus	Winemaking assistant at Foris Vineyards in Oregon
Robert Bradford	
Kirby Gordon	
Qiyuan Hu	Software engineer at Amazon in Boston, MA
Minwoo Kang	Ph.D program in computer science at University of CA, Berkeley
Heather Kurtz	Working at Sinovia Technologies in San Carlos, CA
Jacob Lezberg	Software engineer at General Dynamics in Pittsfield, MA
Edgar Lyons	
Abdullah Nasir	Ph.D program in physics at Harvard
Jacob Pelton	Working in investment banking in Boston, MA
Rock Stewart	Professional lacrosse player for New York Lizards, working with Audax in Boston
Mariam Ughrelidze	Graduate degree at Dartmouth

Physics Colloquia

[Colloquia are held jointly with the Astronomy Department.]

Antoniya Aleksandrova '11, National Institutes of Health
"Exploring Symmetry to Understand Function in Membrane Proteins"

Don Fahey, Joint Quantum Institute
"Squeezing the Spin in a Bose-Einstein Condensate"

Steven Johnson, MIT
"Upper Limits of Light-Matter Interactions"

Aaron Kammerer '98, iRobot
"Physics Skills in the Workforce"

Catherine Kealhofer, Williams College, Summer Talks July 2018
"Ultrafast electron diffraction: Illuminating the fast and the small"

Raghu Mahajan, Princeton
"Quantum Black Holes"

David Poland, Yale University
"Critical Phenomena and the Conformal Bootstrap"

John Scofield, Oberlin College
"Measured Energy Savings and Greenhouse Gas Emissions from LEED-Certified Buildings"

N.R. Sheeley, Jr., Astrophysicist
"Understanding the Sun's Magnetic Fields"

Amy Steele '08, University of Maryland
"Rocky Remnants of Stellar Evolution: Polluted White Dwarf Stars"

Alphonse C. Sterling, NASA Marshall Space Flight Center
"Solar Coronal Jets – Miniature Versions of Large-Scale Solar Eruptions"

Off-Campus Physics Colloquia

Charlie Doret

"Complex Applications with Simple Atoms"
Union College, October 2019

"Atoms at Work: Quantum Mechanics, Qubits, and Quool Tools for Research and Technology"
Sci Tech Café, Northampton, February 2020

Kate Jensen

"Investigating the Role of the Gel Fluid Phase in Soft Adhesive Contact"
Contributed Talk, ACS Colloid and Surface Science Symposium, June 2020

"Investigating the Role of the Gel Fluid Phase in Making and Breaking Adhesive Contacts"
Contributed Talk, Annual Meeting of the Adhesion Society, February 2020

Tiku Majumder

"Heavy metals, cheap lasers, and test of fundamental physics"
Amherst College department colloquium, February 2020

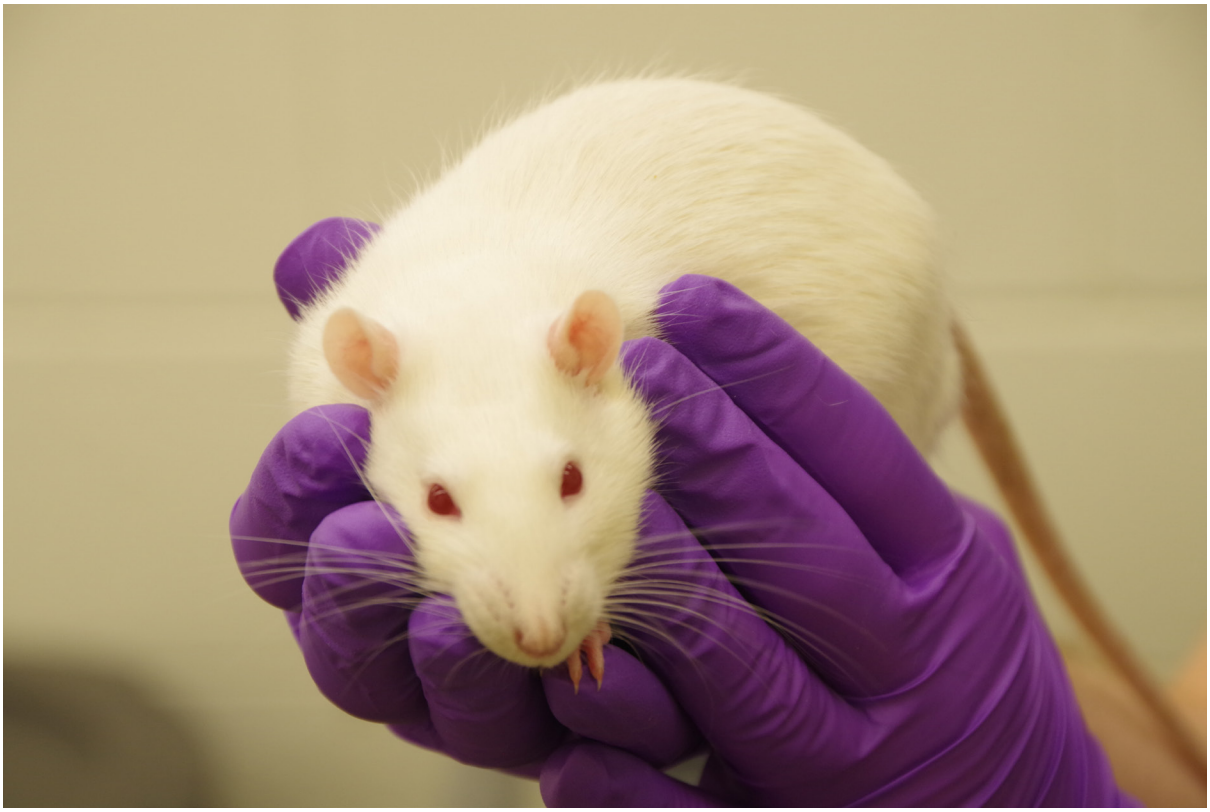
David Tucker-Smith

"Baryogenesis and dark matter from freeze-in"
Seventh Workshop of the LHC LLP Community: Searching for long-lived particles at the LHC (this was a remote/virtual conference that would have been held at CERN, Geneva), May 2020

Bill Wootters

"The Scrooge distribution: Finding a classical interpretation of a quantum formula"
Dartmouth College, October 2019

PSYCHOLOGY NEWS



The psychology major at Williams College attracts a 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 many opportunities to conduct research collaboratively with professors including empirical projects conducted within required 300-level lab courses, work-study or research assistant positions, and in independent research projects and senior honors theses in faculty research labs. In 2018-19, thirteen students completed senior honors thesis research under the direction of Psychology faculty. Their projects are listed in the Student Thesis Abstracts section of this report.

During the fall and spring semesters, the Psychology department held several information sessions including programs focused on “Graduate Study in Psychology,” “Careers in Psychology,” and "How Psychology Professors First Got Interested in Psychology." In addition, the Student Liaison Committee again organized the “Psych Buddies” program that matches interested first-year and sophomore students with upper-class majors who are available to help them think about the major, their interests in psychology, course selection, and help them generally become more involved in the department. To encourage students to explore careers in psychology, the Class of 1960 Scholars Program brought accomplished researchers from universities to campus to give colloquia. The junior and senior 1960 Scholars read the speaker’s published works and then join the speaker and faculty for a reception and dinner afterward.

This year marked the thirteenth 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 *Masen Boucher '20* for her outstanding thesis and contributions to teaching and departmental life.

At the beginning of the 2019-20 school year, the psychology department had several new faculty additions: Eliza Congdon, a developmental psychologist specializing in the children's mathematical thinking, joined us as an Assistant Professor. In addition to establishing her research lab, Congdon taught courses in developmental psychology and a laboratory seminar on children's mathematical thinking and learning. *Shivon Robinson '11* also returned to Williams as an assistant professor wher she taught courses in neuroscience, including a laboratory seminar in her area of research specialization -- opioids and the opioid epidemic. Finally, Stephanie Steele joined us as a Visiting Assistant Professor. She is a clinical psychologist studying self-injurious behavior. She taught courses in clinical psychology including a laboratory seminar in suicide and other self-injurious behaviors. We were thrilled with these new courses and the exciting research opportunities these new faculty brought to share with our students.

This spring saw the transition of Betty Zimmerberg, one of our longest-serving faculty members, to Professor of Psychology, Emeritus. Professor Zimmerberg retired after 31 years in the department! During that time, she published nearly 75 papers, most with student co-authors. She developed (with a team of students) a widely used collection of video animations illustrating the mechanisms underlying synaptic transmission. More recently, she was the head curator for an exhibit at the Williams College Museum of Art, Landscapes of the Mind, that explored art and the brain. The department is grateful for Prof. Zimmerberg's many years of innovative teaching, sophisticated scholarship, and her deep commitment to mentoring both students and faculty.

We are thrilled to have assistant professor Victor Cazares join the departmen for the start of the 2020-21 school year. He is a behavioral neuroscientist who studies genetic and environmental influences on learning, memory, and forgetting. He brings a sophisticated toolbox of techniques to explore cutting-edge questions in behavioral neuroscience.

Through all of these activities, we could not function without the invaluable help of Christine Russell, Department Administrative Assistant, and C.J. Gillig, Psychology Department Technical Assistant. 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.

The campus shutdown in March, though obviously necessary, was a huge disappointment for our faculty and students. For the first time, our thesis students presented their final presentations via Zoom. Among other losses to the pandemic: We could not offer the opportunity to hold advising meetings in person with our new crop of psychology majors and our spring picnic for majors was cancelled. Despite these adverse circumstances, faculty and students remained dedicated to working together and found innovative new ways of teaching and learning. While we expect students to return to campus soon, we are committed to creating excellent learning environments for our students whether they are on campus or remote.

Finally, we are excited to see the progress on the new North Science Building. In February, psychology faculty and staff had the opportunity to tour the building and are thrilled to see the progress where we saw the new state-of-the-art teaching and laboratory spaces, beautiful offices, and spacious common rooms for discussions and socializing. We can't wait to share this space with our students.

Class of 1960 Scholars in Psychology	
Gabriella Bal '20	Juna Khang '20
Ashley Conroy '20	Benjamin Lewis '20
Shaheen Currimjee '20	Grace Murray '20
Joana Fernandez '20	Whitney Sandford '20
Chloe Kaplan '20	Elizabeth Webber '20
Sarah Kelly '20	Patrick Zhuang '21

Assistant Professor **Jeremy Cone** completed his fifth year in the Psychology department this year. In 2019-20, he published 6 new papers, three of them with student co-authors. Two of these publications were based on research conducted during thesis projects.

Cone gave three talks this year: One talk was presented in Northampton as part of the NSF-funded SciTech Café speaker series hosted by Mount Holyoke; He presented an early career researcher talk at the 20th annual Attitudes & Social Influence pre-conference at the Society for Personality and Social Psychology's (SPSP) annual convention; Finally, he presented "Disentangling Empathy: Opposing Contributions of Different Facets of Empathy to Interpersonal Accuracy" at the SPSP full conference in the single-presenter format. This talk was

one of 72 accepted proposals out of a total of 2289 submissions.

The Implicit Cognition and Evaluation (ICE) lab continued to be active (at least before the pandemic shut things down). The following three students completed senior honors theses in the lab: *Alex Medeiros '20* studied the influence of motivated reasoning in people's acceptance of new evidence at the implicit level; *Krystal Hahn '20* examined the extent to which people implicitly associate defendants in a criminal case with guilt as a function of visual cues to race and trustworthiness as well as the actual evidence presented in a trial; and, finally, *Stephanie Brown '20* worked to develop a new measure of moral inconsistency—the extent to which people provide different answers to morally equivalent moral dilemmas or provide different answers to the same moral dilemmas over multiple time points. Alex also presented her thesis work in a poster at this year's SPSP in New Orleans.

Six students served as research assistants in the lab this year: *Krystal Hahn '20, Iris Park '21, Gaston Aime '23, Allison Lu '22, JoJo Fernandez '20,* and *Jenny Hickey '21*. They worked to construct a new subliminal (i.e., outside of conscious awareness) measure of implicit evaluations, as well as several new lines of work focused on how learning new diagnostic information can increase resistance to subsequent counter-attitudinal information, the role of causal attribution processes in implicit impression formation, and several others. For more information about the lab and what we're currently up to, check out: http://jeremycone-icelab.com.

During the 2019-20 academic year, new Assistant Professor of Developmental Psychology **Eliza Congdon** established the CALF lab (Cognition, Action, Learning, and Fun!). Research in the lab centers around how children learn new ideas through their own actions and the actions of teachers and parents. The research has a particular emphasis on math learning in preschool through grade 5, as research shows that children who start behind in math performance tend to stay behind. Examples of current questions in the lab include 1) Can gesture instruction improve children's understanding of linear measurement? 2) Which kinds of hand gestures help ease spatial working memory load across development (ages 4-11 years)? 3) How is math anxiety related to a child's own belief in gender stereotypes in 5th grade students? 4) Can a brief lesson with gesture help to improve children's phonemic awareness?

Over the course of the academic year, Eliza worked with a total of eleven undergraduate research assistants, including two independent study students, *Masa Peterson '20* and *Campbell Day '20*, who investigated how individual differences in children's own spontaneous rates of gesture production might predict whether they are able to learn from a gesture demonstration during a math lesson. This ambitious and well-designed student project was, sadly, impacted by the campus wide Covid-19 shut-down, but as soon as operations return to normal, data collection will resume with the continued engagement of both Peterson and Day. In the meantime, Congdon is working with Summer Science Scholars *Elijah Tamarchenko '23, Erica Qin '22,* and *Karla Mercedes '23* on ways to pivot parts of the CALF lab's research program to an online format in anticipation of continued Covid-19 disruptions. Current projects include designing apps that can be used remotely, organizing a new online participant database and interface for parents and children to sign up for research via Zoom, designing a lab website, and continuing the analyses of existing data, including a meta-analysis of dozens of studies with third and fourth grade children to explore hypotheses about how gesture instruction might be particularly useful for children with English as their second language.

This past year, Professor Congdon's work was featured on several posters at the Cognitive Development Society's 2019 professional conference. It also led to two peer-reviewed journal articles, a book chapter that is currently under review, a published conference paper, and a published encyclopedia entry.

Professor **Amie Hane**'s work examines the social regulation of stress in infants and children. Most recently, Hane has extended her research in behavioral pediatrics and has co-developed a new screening tool to measure emotional connection in parents and children ages 0-5 that is designed for implementation in pediatrics, home-visiting, and community settings. Hane published five papers in the 2019-20 academic year.

Professor **Laurie Heatherington** was on sabbatical leave in Fall 2019 and continued her research and writing on family therapy change processes and psychotherapy in general. She conducted a large study in Fall 2019 on Williams first year students, revisiting and extending some classic findings from her lab and others on the tendency of women to be overly modest in the self-presentation of their achievements. This work was done with three student research collaborators, *Peter Barry '21, Mariane St. Juste '21,* and *Theresa Morley-McLoughlin '21*, and seven sophomore experimenters. She collaborated with *Gabrielle Illagan '18* and *April Su '23* on two studies extending Gabs' honors thesis research on

preferences for a racial and gender match with their psychotherapists and the role of empirical research on the effects of information about whether matching affects therapy outcomes, in their preferences. Halfway through the spring semester she joined the rest of her colleagues in "adventures on remote learning" and discovered that zoom breakout rooms features works almost as well as in-person learning for small groups of students doing empirical projects on psychotherapy.

The posters of 2019 honors students were accepted for presentation at national conferences in summer 2020: *Isabel Benjamin '19*, "What's Age Got To Do With It? Three Studies of Emotional Reactions to and Treatment Propositions for Late-Life Depression", and *Alexandra (Lesya) Melishkevich '19*, "Public Perceptions of a School Shooter: When a Shooter Profile Matters" Unfortunately, conferences were cancelled due to the pandemic, so they were not able to present their work. A manuscript based on the thesis research of *Chanel Zahn '16*, was accepted for publication by the Journal of American College Health. The research found that varsity athletic participation and basing a lower amount of one's self-worth on appearance were protective against subclinical disordered cognitions and behaviors

Professor Heatherington served on the Editorial Boards of *Psychotherapy Research*; *Journal of Family Psychology*; and *Psychotherapy: Theory, Research, Practice, and Applications*; and as Chair of the Publications & Communications Board of the Society for the Advancement of Psychotherapy/Division 29 of the American Psychological Association. She served on the Directors and Associates Board, and chaired the Program Committee, of Gould Farm, a treatment center/working farm in Monterey, MA, which serves people with schizophrenia and other serious mental illness. She continued pro bono consulting there on a long term study of treatment outcomes.

Professor **Shivon Robinson**'s research interests focus primarily on understanding the neural basis of mood and substance use disorders. Most recently, her work has centered around using animal models to investigate the genetic and environmental factors that contribute to the neurobehavioral outcomes of early-life opioid exposure and withdrawal.

She was excited to have several students working in the lab this year: *Carmen Bango '20, Daniel Hahn '21, Gwyneth Maloy '21, Andrea Orozco '21, Kasey Stern '21, Simone Veale '21,* and *Grace Reynolds '23*. Over the summer Daniel became the first official member of the lab and provided some much-needed assistance in physically setting up the lab space. He also began developing a protocol that utilizes signal processing software to visualize and rapidly analyze repertoires of mouse ultrasonic vocalizations. This will eventually allow the Robinson Lab to determine whether early life drug exposure changes how mice "speak".

During winter study, Kasey, Simone and Grace conducted a research project that carefully characterized somatic signs of opioid withdrawal in neonatal versus adult animals. In the spring semester, Carmen designed an independent study project investigating the effects of neonatal opioid exposure on development, pain sensitivity, and stress response later in life. With the help of the rest of the lab, Carmen was able to collect a good amount of data, even with research plans being disrupted by the campus closure in March. Her preliminary findings suggest that early life opioid exposure does not significantly impact baseline pain sensitivity in mice, but does produce long-lasting changes in anxiety-like behavior and behavioral response to novelty. We hope to be able to present this research at the annual meeting for the Society for Neuroscience in October 2020. For more information and updates on the lab check out our website: https://sites.williams.edu/sar1/

Visiting Asssitant Professor **Stephanie Steele**'s lab at Williams, the Behavioral Assessment of Self-Injury Lab (BASIL), is now up and running. Our research covers the following three areas: 1) understanding psychiatric correlates and risk factors (e.g., substance use disorders) associated with the onset and maintenance of non-suicidal self-injury (NSSI), 2) elucidating the role of identity formation in clinical (e.g., identifying with NSSI) and more general (e.g., sexual orientation) areas of study, and 3) examining the impact of comorbid psychopathology on treatment outcome. Together, these three areas are unified by Professor Steele's desire to understand and identify risk factors and transdiagnostic mechanisms that lead to onset and maintenance of self-injurious thoughts and behaviors (SITBs) in emotional disorders. Consistent with clinical, developmental, and social psychology models of SITBs, Prof. Steele utilizes cross-sectional, behavioral, and both quantitative and qualitative methodologies in her research.

Two students, *Nigel Jaffe '22* and *Cailin Stollar '21*, worked as remote research assistants in summer 2020 through the Williams College Summer Science Program in BASIL. The lab currently has one study under review with the IRB, and one in development that is expected to launch in Fall 2020. The current study - Targeting Identity through App-Based Skills Training for Non-Suicidal

Self-Injury - involves exploration of identification with NSSI as a transdiagnostic mechanism involved in the recurrence of NSSI, and examination of whether cognitive and behavioral skills training via smartphone app can be used to modify the strength of implicit and explicit identification with NSSI. The study in development - Disgust in SITBs - will explore the experience, severity, and intensity of disgust and self-disgust as transdiagnostic indictors in SITBs. The lab will employ both self-report and behavioral measures to elicit and measure disgust reactions.

Professor Steele received a National Institute of Health Clinical Research Loan Repayment Program (LRP) Award that extends through 2021 to continue her work on SITBs. This award was originally obtained during her postdoctoral fellowship at Boston University, and was successfully transferred to Williams College under Professor Laurie Heatherington's mentorship last summer.

Professor **Catherine Stroud** continued her research program focusing on stress, interpersonal relationships, and the development of psychopathology among adolescents and young adults. In March of 2020, she completed a two-year longitudinal study examining biological, psychological, interpersonal, and environmental factors that affect risk for psychopathology among female-identifying young adults. During the 2019-20 academic year, she conducted this study alongside six students, including thesis students *Sarah Kelly '20* and *Chloe Kaplan '20*. At the Annual Meeting of the Association for Behavioral and Cognitive Therapies, *Erin Lamberth '19* and Stroud presented findings demonstrating that early adolescent girls with a history of early adversity are at greater risk for generating stressful life events in their relationships when they have high levels of parent-adolescent conflict, but lower risk when they have lower levels of conflict as compared to their peers without a similar history of early adversity. At the same conference, Stroud and her colleagues presented novel evidence showing that early adversity is associated with lower levels of latent trait cortisol, which in turn predicts subsequent increases in depressive and anxiety symptoms.

Stroud also published a first-author manuscript in *Journal of Youth and Adolescence*. Results indicated that the tendency to overestimate self-blame for uncontrollable stressful life events was associated with lower latent trait cortisol, a risk factor for the development of psychopathology. Moreover, maternal warmth (coded based on a speech sample) buffered the impact of cognitive risk on latent trait cortisol, suggesting that mothers may continue to serve as "social buffers" even into early adolescence. This paper built upon the independent research of co-author *Blair Curzi '14*.

Along with her colleagues, Stroud co-authored a manuscript showing that serotonergic genetic variation interacts with acute interpersonal stress and early adversity to predict depressive symptoms in two samples of adolescents. This paper, to be published in *Development & Psychopathology*, suggests that the interplay of early adversity and serotonergic genetic variation shapes sensitivity to interpersonal, but not non-interpersonal events, thereby increasing risk for adolescent depression.

Grace Murray '20 designed and created the BASIL logo for Professor Stephanie Jarvi Steele's lab.

Post-Graduate Plans of Psychology Majors

Steven Bohling	Business Development Representative at Forrester Research
Masen Boucher	Research Assistant at Boston Children's Hospital
Cameron Brown	Fiber 1 Sales Executive at AT&T
Stephanie Brown	Technical Research Assistant at McLean Hospital
Olivia Carlson	Incoming Associate at EY-Parthenon
Emily Chang	Clinical Research Coordinator at Boston Children's Hospital
Amanda Chen	Incoming Associate at EY-Parthenon
Julia Choi	Social Media Manager at Delicien, Inc.
Ashley Conroy	Associate Consultant at OC&C Strategy Consultants
Shaheen Currimjee	Media Sales Associate at SmartBrief
Campbell Day	Associate Consultant at Trinity Life Sciences
Emma Egan	Photographer and Graphic Designer
Joana Fernandez	Operational Contract Tracer and Case Investigator at New Mexico Department of Health
Max Fuld	Incoming Upper School Spanish Teaching Fellow at Brunswick School
Aanya Kapur	Business Development Analyst at Axiom
Sarah Kelly	First Year Clinical Psychology Master's Student at Teachers College, Columbia University
Grace Kromm	PhD Student in Clinical Neurosciences at the University of Cambridge
Alexandra Medeiros	Teacher at Teach for America
Grace Murray	Research Assistant at McLean Hospital
Alexandra Newton	Project Coordinator at Pella Mid-Atlantic, Inc.
Alexander Okinaka	Fixed Income Analyst at J.P. Morgan
Masa Peterson	Elementary School Teacher in California through Teach For America
Aiyana Porter	Doctoral Candidate, Psychology and Law at John Jay College (CUNY)
Carl Porto	Enrolled in the Johns Hopkins Premedical Post-Baccalaureate program
Simran Sohal	Copywriting Intern at Serviceplan Group Middle East
Ashish Solanki	Energy Finance Research Associate at Institute for Energy Economics and Financial Analysis
Ayahiro Takashima	Biology Teaching Fellow at Noble and Greenough School
Elizabeth Webber	Incoming Associate at EY-Parthenon

Psychology Colloquia

Mark Feuerstein, Actor & Producer
"An Evening with Mark Feuerstein", November 21, 2019

Deborah Kelemen, Boston University
"How Children Learn Complex Scientific Ideas", February 18, 2020

Off-Campus Psychology Colloquia

Jeremy Cone
"Life Around the Digital Watercooler: Forming Impressions of Others in the Era of Fake News, Social Media, & Gossip"
SciTech Café speaker series hosted by Mount Holyoke College, December 2019

"When Fast Becomes Slow: Rapid Revision in Response to Diagnostic Revelations Results in Durable, Stable Evaluations"
Attitudes & Social Influence pre-conference at the Society for Personality and Social Psychology (SPSP), New Orleans, LA, February 2020

"Disentangling Empathy: Opposing Contributions of Different Facets of Empathy to Interpersonal Accuracy"
Society for Personality and Social Psychology (SPSP), New Orleans, LA, February 2020

Eliza Congdon
"Is She a Good Teacher? Children Learn to Use Representational Gesture as a Marker of a Good Informant"
Poster presented with co-authors at the Cognitive Development Society 2019 meeting, Louisville, KY, October 2019

"The Effects of Gesture and Action Training on the Retention of Math Equivalence"
Poster presented with co-authors at the Cognitive Development Society 2019 meeting, Louisville, KY, October 2019

"Learning through Seeing versus Doing: Exploring the Best Way to Teach Mathematical Equivalence
Poster presented with co-authors at the Cognitive Development Society 2019 meeting, Louisville, KY, October 2019

Stephanie Jarvi Steele
"Evaluation of Global Measures of Improvement in the Unified Protocol"
Poster presented with co-authors at the Annual Convention for the Association for Behavioral and Cognitive Therapies (ABCT) in Atlanta, GA, November 2019

HONORS THESES

Each year, many students elect to complete a thesis in their major. Students begin work generally in the summer prior to their senior year and engage in a rigorous course of study guided by their faculty advisor. The culmination of this work is a poster presentation in the spring which is open to the public, and the publication of the thesis which is archived by the college. This work feeds into future students' research efforts and often leads to co-authorship in peer-reviewed papers.

On the following pages are abstracts outlining the work of our student researchers. For many of our former students, the publication of their thesis was the first in a long list of professional publications in a successful career in science. I have no doubt that many of the names in this section will follow their predecessors on this path.

Astronomy

Optical Properties of Low-Redshift Star-Forming Galaxies with Potential Lyman Continuum Escape

Nicole Ford

It is currently unclear which sources reionized the universe at redshift $z > 6$ (~12.4 billion years ago), shifting the intergalactic medium from being predominantly neutral to predominantly ionized. Young massive stars formed in high-redshift starburst galaxies are capable of producing ionizing Lyman continuum (LyC) radiation ≥ 13.6 eV. Unfortunately, LyC radiation from galaxies at $z > 6$ is not observable due to absorption by neutral gas in the intergalactic medium. I study Sloan Digital Sky Survey (SDSS) optical spectra and Hubble Space Telescope (HST) ultraviolet (UV) data for 66 low-redshift star-forming galaxies with potential LyC radiation escape. The galaxies are located at z~0.3 (~3.4 billion years ago), close enough that direct LyC detection is possible. I examine proposed diagnostics of LyC escape and calculate properties such as gas ionization level, Hβ emission line strength, star formation rate surface density, and Lyα escape fraction. Preliminary results indicate that at least 13 galaxies in the sample are leaking LyC radiation with significant escape fractions of $5\% \lesssim$ fesc LyC $\lesssim 20\%$. In some cases, these 'leaking' galaxies' characteristics contradict proposed diagnostics such as high [O III]λ5007/[O II]λ3727 ratios and low Hβ emission line strength, lending a more nuanced perspective to the exploration of LyC escape.

Investigating a Warped Protoplanetary Disk Around HD 100546

Johnny Inoue

Protoplanetary disks are vast disks of dust and gas that surround young stars. Thanks to large radio arrays like the Atacama Large Millimeter/Sub-millimeter Array (ALMA) we may examine these disks in great detail. In this thesis we utilize ALMA data to make progress towards characterizing the gas disk around the star HD 100546. Previous research indicates that this disk may be warped, meaning it could have two concentric gas disks instead of a single, uniform disk. We developed modeling and statistical pipelines capable of robustly modeling a warped system and, based off of a well constrained single disk model, confirmed that the inner portion of the HD 100546 gas disk does not align with the single disk prescription.

Compositing and Analyzing White-Light Coronal Eclipse Images from the 2017 and 2019 Total Solar Eclipses

Christian Lockwood

We have made significant progress towards fully automating the process of producing a high-contrast high dynamic range composite image of the solar corona. We created a calibration script based on basic astronomical principles and refined it to the specific needs of eclipse images. We also developed a novel two-step alignment process that accurately aligns eclipse images to ± precision. This alignment process was rigorously tested with eclipse images from both the 2017 and 2019 total solar eclipses. Using these accurately aligned images, we tested and report the results from several algorithms designed to produce high dynamic range images. We hope to further advance the field of coronal eclipse compositing with further refinements to these algorithms and alignment processes.

Green Pea Galaxy Stellar Population Ages and Lyman Continuum Escape Mechanisms

Connor Marti

Starburst galaxies that contributed to reionizing the universe are incredibly distant, and their ionizing Lyman continuum (LyC) radiation gets absorbed before we can detect it. We use Hubble Space Telescope Cosmic Origins Spectrograph ultraviolet (UV) observations of 17 local, Green Pea galaxies (GPs) that have similar properties to reionization-era galaxies. UV spectra probe the properties of the young stellar populations in GPs. We fit stellar population synthesis models with various ages and metallicities to our GP spectra and determine whether the stellar population ages are old enough for SNe to occur and clear out gas for LyC escape. To account for UV gas emission, we include Cloudy photoionization models with a range of ionization parameters and gas densities. The best-fit ages of the GPs range from 1.0 Myr to 7.9 Myr while SNe occur in stellar populations with ages ~ 2.5Myr, suggesting that SNe are not required for LyC escape. We also explore the possibility of two-stage starbursts in GPs, finding 12 potential candidates.

Comet NEOWISE was dimly visible, but easily photographable in the early evenings in July of 2020 over Williamstown, MA

Biology

Arousal on the optomotor performance and walking speed of Drosophila

Eugene Cho

For fruit flies of the genus Drosophila, arousal is characterized as a state of increased locomotor activity and sensitivity to environmental stimuli. Arousal can be modeled with the Yerkes-Dodson Law, which postulates that performance follows a bell-curve with increasing arousal levels – as such, there exists an intermediate arousal at which an organism will perform a given task optimally. In the present work, we sought to examine the relationship between arousal and performance through the Fly Stampede Assay, a behavioral test that tracks the optomotor performance of fruit flies. Previous work had suggested that two indicators of arousal, optomotor performance and walking speed, are negatively correlated when flies are under high arousal states. Through parametric variations to the Stampede Assay, we found evidence to support that suboptimal arousal levels (as predicted through the Yerkes-Dodson Law) manifest as an inverse relationship between optomotor performance and walking speed. This suggests that under high-arousal states such as panic, flies have trouble processing environmental stimuli and thus exhibit poor optomotor performances. Relatedly, the optomotor performance of aroused flies did not reflect changes in the Stampede Assay visual stimulus, suggesting that visual processing can be impaired under elevated arousal states. The patterns observed in this work may inform future investigations into the mechanistic details of arousal and sensory processing.

Breaking the One-way Reproductive Incompatibility in Hybridizing Field Crickets Gryllus Firmus and Gryllus Pennsylvanicus: Can Genomic Data Tell Us Why?

Yvonne Xiaoyong Cui

The hybridizing field crickets Gryllus firmus and Gryllus pennsylvanicus form an extensive mosaic hybrid zone in the Northeastern United States. It has been shown that G. pennsylvanicus are unable to fertilize G. firmus eggs even though the reciprocal cross is viable. However, our research has shown that this prezygotic postmating barrier is not absolute. Here, I analyze the genomic data of both infertile and fertile crosses of G. firmus female and G. pennsylvanicus male at a subset of previously characterized loci that exhibited significant allele frequency differences between allopatric parental populations of each species. Fertile crosses displayed deviations from Mendelian segregation patterns as well as allele frequency and genomic combinations differences from those of the infertile crosses. The offspring sample was biased toward females. However, these results were not statistically significant after the Bonferroni correction. Hence, there is no conclusive evidence suggesting that genomic incompatibility associated with barrier loci are responsible for the observed one-way reproductive incompatibility and species differentiation.

Late Mowing Of New England Fields Supports Native Flower Populations & Hinders Invasive Species Growth

Sierra Diaz

Promoting the growth of native species in the New England field habitat is essential to protect late season pollinator resources. Invasive species are a potential threat to these native New England flowers, and thus a threat to pollinators. Mowing is a common practice for land management of open fields in New England, but the effects of mowing on native flowering field species, invasive species, and interactions between them is not well established. We test the effects of mowing frequency (annual or biennial) and mowing season (early or late) on both native New England flowering species and invasive species over a period of four years (2016 - 2019). Our study is part of an established field study in Hopkins Forest, Williamstown, MA that uses a full factorial randomized block design with four blocks of four treatments (early annual, late annual, early biennial, late biennial). Each year we counted the flowering stems for all native species and noted the presence or absence of invasive species in each 0.25 m^2 quadrat. Analysis of these data will expand our understanding of the impacts of invasive species on the native New England field habitat and demonstrate which mowing treatments may best be used to combat these native species. Native species have a significantly higher flowering stem count in the 0.25 m^2 quadrats without invasive species than in quadrants with invasive species, suggesting that invasive species have may negatively impact the growth of native species and their removal may enhance the growth of native goldenrods and asters. Mowing time and frequencies also affect both native and invasive species with the annual late mow resulting in the greatest number of flowering

stems followed closely by late biennial mow treatments. We also demonstrated that early annual mowing negatively impacts both native and invasive species. These two late treatments also resulted in the greatest number of quadrants with invasives. However, native species showed a continuous increase from 2016 - 2019 indicating the native species populations are still growing. In contrast, the invasives only increased up through 2018. In 2019, the area covered by invasive showed a marked decline. Early annual mowing prevents the establishment of invasive species, but also hinders the production of flowering stems of native species, making this mowing practice poor for promoting pollinator diversity. Early biennial mowing was similar to the late mow plots in non-mow years and similar to the early mow plots in mow years. Our data indicate that removal of invasive and late annual mowing are two land management practices that are likely to increase the production of flowering stems and promote the conservation of pollinator resources in New England fields.

May Leptin be With You: Leptin Attenuates Normal Torpor Regardless of AgRP Leptin Receptor Functionality

Annabelle Feist

In order to survive cold and food deprived environments, mice enter daily torpor, defined as a significant reduction in metabolic rate and core body temperature, to conserve energy. Torpor bouts are both centrally and peripherally controlled, and the central control centers are often the same as those involved in both thermoregulation and metabolic homeostasis. One hormone associated with the control of all three systems is the metabolic hormone leptin. Additionally, over two decades ago it was discovered that leptin prevents mice from entering normal daily torpor bouts, but the mechanisms through which it does so are unknown. As such, this study sought to identify the system or systems through which leptin acts to attenuate daily torpor bouts. Three main experiments were conducted to do so: identification of appropriate methods, breeding and genotyping of animals lacking a leptin receptor in agouti-related peptide (AgRP) neurons using the cre/lox system, and determination of the effect of leptin on torpor in such animals. It was found that twice-daily injections of exogenous mouse leptin consistently prevent torpor in effectively wild-type mice with twice-daily injections of saline as a control. Exogenous leptin injections increased minimum and average core body temperature as well as disrupted normal circadian torpor temperatures. Experimental mice were bred as the F2 generation of mice originating with the cross of a male with loxP sites on either side of exon one of his leptin receptor alleles and a female expressing cre-recombinase drive by the AgRP protein. These experimental mice presumably lacked a functional leptin receptor in AgRP neurons and could be identified using PCR and gel electrophoresis genotyping. The experimental mice then underwent the torpor and injections paradigm along with effectively wild-type control mice. Leptin caused an increase in core body temperature and a disruption of the circadian temperature cycles of torpor for all mice regardless of genotype. This revealed that AgRP neurons are not the main processing center through which leptin attenuates normal torpor. This suggests that leptin prevents normal torpor separately from blood glucose regulation and reduction in AgRP neural activity. These results establish the first consistent methods for this experimental and provide baseline results for moving forward to discover the system or systems through which leptin acts to prevent daily torpor.

Dissecting the mechanism by which agrobacterial T6SS modulates host ABA signaling

David Gorestki

Agrobacterium tumefaciens contains a Type VI Secretion System (T6SS), a transmembrane complex that delivers effectors into host cells or the extracellular space. The Banta lab has shown that the T6SS enhances tumorigenesis by *A. tumefaciens* on mature *Arabidopsis thaliana*, but also appears to elicit host defenses, as evidenced by reduced transient transformation (TT) in seedlings relative to a T6SS-deficient strain. Prior work in the lab has identified the plant hormone abscisic acid (ABA) as a central modulator of the defense response. We hypothesize that the T6SS exerts its effects on host defenses by modulating ABA signaling. The goal of this thesis is to characterize regulators upstream of ABA and downstream of the T6SS. In this project, we investigated the effects of suction infiltration, strain type, humidity, stomatal function, and ABA synthesis on the T6SS-dependent limitation on TT in seedlings, whereby the amount of DNA transiently expressed in the plant cells is a proxy for the initial infection efficiency. We found that suction infiltration is required to observe the T6SS-dependent effects on TT, which suggests that the T6SS-triggered responses limiting TT are post-stomatal. This conclusion is supported by our observation that the T6SS mutant, but not the WT bacterial strain, transforms more effectively on an open stomata mutant (ost1) than on the WT (Col) seedlings, again indicating that stomates are not the primary barrier for T6SS-containing strains. We

also studied a mutant (abcg22) in which stomates are slow or unable to close in response to vapor pressure differential (i.e. changes in ambient relative humidity). Our findings suggest that open stomates are not only insufficient for successful TT, but they may increase stress in the plant such that defenses are upregulated and TT is inhibited, abolishing the advantage normally conferred by the absence of the T6SS. Finally, based on relative TT rates on an ABA synthesis mutant (aao3-2), we propose that ABA levels, rather than stomatal function is the main driver for the T6SS effects on TT. Future studies should focus on investigating the role of host Ios1, an inhibitor of ABA signaling, in mediating the T6SS-dependent effects on defenses and/or virulence.

Evolution of a transcriptional regulator of cup cell differentiation in Dictyostelium discoideum

Jenks Hehmeyer

The emergence of novel cell types contributed extensively to the emergence of new organismal functions in animals, plants, and other multicellular lineages. However, very little is currently understood about cell type evolution. A major challenge is understanding how transcription factor evolution contributes to the origination of new cell types. I characterized the developmental roles of two paralogous transcription factor genes, fasA and fasB, in the slime mold *Dictyostelium discoideum*, a Eukaryote that forms simple fruiting bodies consisting of only three terminal cell types. fasA is essential for the generation of the cups, structures that play critical somatic roles. Specifically, fasA initiates the sorting of precup cells to their ultimate locations, a process that seems to occur upon cup cell differentiation. fasB plays a minor role in the formation of the stalk of the fruiting body. The cup cell is a genus-specific cell type that evolved from the stalk cell, and the segmental duplication that gave rise to fasA and fasB also took place at the base of *Dictyostelium*. However, sequence and expression pattern analyses demonstrate that the evolution of fasA is unlikely to have contributed to the origination of cup cells.

Through Thick and Thin: The Effects of High-Fat and Low-Fat Alternate Day Fasting Compared to Caloric Restriction in Improving "Health" in Diet- Induced Obese Mice

Chloe Henderson

Intermittent fasting, in particular alternate day fasting (ADF), has become a popular diet to lose weight and improve health. Multiple studies have shown improvements in glucose tolerance, insulin sensitivity, weight loss, decreases in cholesterol, and increases in lifespans, among other measures of "health" in organisms that undergo ADF. The purpose of this study was to determine which diet regimen would result in the best "health" in diet-induced obese male C57BL/6J mice after ten weeks. More specifically, the purpose was to determine if there are health differences in high fat (HF) versus low fat (LF) ADF and in HF caloric restriction (CR) pair-fed with HF ADF. It was hypothesized that ADF (HF and LF) mice would become "healthier" than the other diet regimens and would become as "healthy" as controls. The diet- induced obese male mice (41.0 ± 3.3g) (n=25) were split up into one of four diet regimens: LF ad lib, LF ADF, HF ADF, and HF CR (n=5 in each group). An additional group of the obese male mice continued on a HF ad lib diet (n=5) as a control (HF ad lib). Meanwhile, non-obese C57BL/6J male mice continued on a LF ad lib diet as another control (Control) (n=11). The mice followed their respective diet regimens for 10 weeks, during which body weight and food intake was measured daily at the onset of the dark phase. A glucose tolerance test was administered six weeks into the feeding paradigm and an insulin-assisted glucose tolerance test was administered nine weeks into of the feeding paradigm. At the end of the ten weeks, other measures of "health" were determined using assays such as plasma corticosterone, plasma IL6, plasma TEAC equivalence, plasma triglycerides, and liver triglyceride concentrations. The ranking from the "most healthy" mice to the "least healthy" mice was calculated as (1) a tie between Control and LF ADF, (3) HF ADF, (4) LF ad lib, (5) HF CR, and (6) HF ad lib, which is almost exactly the same as the hypothesis. The only originally obese mice to return to the weight of the Control mice and to have similar "health" measures were the LF ADF mice, suggesting that this diet regimen is sufficient to return obese mice to "normal" "health." These results are the first to directly compare the "health" of all of these diet regimens to one another. These results support ADF's efficacy for an obese mouse to lose weight and to improve "health."

Anatomical Characterization of the Parasubthalamic Nucleus (PSTN)

Lauren Heuer

In mammals, the motivation to eat is regulated by a complex system of orexigenic and anorexigenic neural populations. The parasubthalamic nucleus (PSTN) was recently identified as a possible novel anorexigenic region, yet the

cell types that make up the PSTN remain relatively uncharacterized, and the roles of specific PSTN subpopulations in appetite regulation are unknown. This study addressed the following three aims: 1) To evaluate and quantify different cell types based on gene expression in the PSTN; 2) To discover whether these cell types also co-localize with other genes known to be expressed in specific lateral hypothalamic populations; and 3) To determine which subpopulations of PSTN neurons are activated following a large meal. Our results indicate that corticotropin-releasing hormone (CRH) and tachykinin-1 (Tac1) PSTN neurons are distinct, glutamatergic populations that are both active during a state of satiety. About 15% of labeled PSTN cells expressed CRH, about 85% of labeled PSTN cells expressed Tac1, and a very small number expressed both CRH and Tac1. We found that no PSTN neurons express parvalbumin, but some PSTN neurons co-express calbindin 1 and calbindin 2. We observed significant co-expression of Fos, an indirect marker of neuronal activity, in CRH and Tac1 PSTN cells in animals following consumption of a large meal. These results provide new anatomical insights into the PSTN and also substantial opportunities for future research about the functional roles of these cell types in food intake circuits.

julius seizure: New Dimensions of Epileptogenesis in *Drosophila melanogaster*

Breelyn Karno

The bang-sensitive (BS) mutants of *Drosophila* provide an important model for studying epilepsy. Previous research identified a novel BS locus, julius seizure (jus), encoding a protein containing two transmembrane domains and an extracellular cysteine-rich loop. In this study, we discovered that expression of jus by the putative brain enhancers GMR90B09 and GMR55G02 significantly rescued bang-sensitivity in both heterozygous and homozygous jus mutants. UAS-mCherry, expressed by the GMR90B09-GAL4 driver reveals overlap with endogenous jus expression in the previously characterized jus critical period. RNAi knockdown revealed that the GMR55G02-GAL4 driver most effectively drives cold-sensitivity via the expression of RNAi-jus, implying that the populations of cells responsible for the bang-sensitive phenotype and the cold-sensitive phenotype may not entirely overlap. We found that supplementing fly diet with milk whey powder significantly reduced bang-sensitivity; however, we also found that this effect was not due to the lecithin component of whey powder. Additional experiments using RNAi allowed us to show that jus interacts with the gene encoding a Na^+/K^+ ATPase, Atpalpha, in the same neurons to drive bang-sensitivity, but that treatment of jus mutants with the ATPase inhibitor ouabain did not significantly affect bang-sensitivity. Finally, we found that we could not reliably induce seizure activity in bang-sensitive mutants with visual stimuli, implying that further testing must be done to establish a relevant model of photosensitive epilepsy in these mutants.

Reducing Tissue-Resident Memory T Cells in the Lung via Inhibition of the JAK/STAT Signaling Pathway

Omar Kawam

Murine models for allergic asthma have identified a non-circulating population of memory T cells within the lung following immune responses to inhaled allergens. This population of CD4 tissue resident memory cells (TRMs) remains within lung tissue for extended periods of time and exhibit basal levels of activation even without antigen exposure. Their location within the lungs allows these CD4 TRMs to be poised for an immediate response upon antigen re-exposure, but also to contribute to severe asthmatic symptoms. Removing these resident cells may be a promising trajectory for allergic asthma treatment. In this thesis, we attempt to understand the role local cytokine signaling has in facilitating CD4 TRM recruitment, establishment, and long-term maintenance within the lung. We used murine models for allergic asthma and treated mice with Ruxoltinib and Fludarabine, two JAK/STAT cytokine signaling inhibitors, at different time points during an immune response. Ruxolitinib was given during the acute immune response, the memory establishment, or the long-term memory phases. Fludarabine was given at the acute immune response phase or without any antigen challenge. In our study, we found that Ruxolitinib does not significantly reduce the numbers or frequencies of CD4 TRMs in the lung or systemically. Fludarabine, however was found to increase T cell frequencies systemically and, with no challenge, significantly reduced the B cell population globally. These data do not give conclusive evidence on the role of cytokine signaling in CD4 TRM recruitment, establishment, and maintenance, but does suggest that Fludarabine may have a cytotoxic effect on the B cell populations. Further research must be conducted to corroborate the role these drugs have on lymphocyte populations within the allergic asthma model.

Light Acclimation in the Marine Cyanobacterium *Prochlorococcus*: A Comparative Physiological and Genomic Analysis

Calla Khilnani

Following its identification in 1988, the marine cyanobacterium *Prochlorococcus* has come to be recognized as a key contributor to global primary production, especially as it is likely the planet's most abundant photosynthetic organism (Partensky et al. 1999). *Prochlorococcus* owes much of its ability to dominate the open ocean from 40˚N to 40˚S to the existence of extensive genetic and physiological diversity within the lineage (Partensky et al. 1999). We hypothesize that *Prochlorococcus* strains have evolved different strategies to respond and acclimate to changes in their light environment. To address this, we characterized the growth of strains at low irradiance levels, responses to light fluctuations that mimic mixing events in the open ocean water column, and a key protein involved in light acclimation.

We studied the growth of strains MED4 and MIT9312, which belong to the ecotypes (eMED4, eMIT9312) that are abundant throughout the water column, particularly in surface waters (Johnson et al. 2006). Using in vivo Chlorophyll a fluorescence measurements, we found that MED4 and MIT9312 exhibited similar growth rates at low irradiance levels (10 µmol photons m-2 s-1), with average doubling times of 35.61 ± 2.26 hours and 36.64 ± 1.09 hours, respectively. Furthermore, while cell concentrations for MED4 ranged from 8.05 x 107 ± 7.69 x 106 to 7.26 x 108 ± 1.44 x 107 cells ml-1 depending on where in the growth curve the measurements were performed, cell concentrations for MIT9312 ranged from 2.28 x 108 ± 1.16 x 107 to 6.19 x 108 ± 1.92 x 107 cells ml-1. Our preliminary data suggest that the growth rates and cell concentrations of MED4 and MIT9312 are comparable at 10 µmol photons m-2 s-1. In regions of the water column where both ecotypes have been detected, cell abundances of eMIT9312 are often greater than those of eMED4 (Johnson et al. 2006). At low irradiance levels, our data for strains belonging to these ecotypes suggest that the availability and utilization of light energy might not be major factors contributing to differences in ecotype abundances. Instead, it is likely that other factors, such as nutrient utilization, could be critical.

In the open ocean, currents and other mixing events can result in the exposure of *Prochlorococcus* cells to rapid changes in depth and thus irradiance level. We used in vivo Chlorophyll a fluorescence measurements and flow cytometry to examine the response of MED4 when shifted from a low to high irradiance level (10 to 100 µmol photons m-2 s-1). Overall, chlorophyll fluorescence decreased in response to the light shift, which likely reflected a decrease in cell chlorophyll concentrations. Notably, MED4 cells exposed to a light shift exhibited an increased growth rate in the first 24 hours when compared to the control culture maintained at the low irradiance level. This suggests that the MED4 strain, and possibly other members of eMED4, can acclimate rapidly to fluctuations in irradiance level.

Finally, we performed a comparative genomic analysis to investigate a potential light acclimation mechanism mediated by plastoquinol terminal oxidase (PTOX). We compared PTOX sequences from nine *Prochlorococcus* strains and several other cyanobacterial strains. Unexpectedly, PTOX sequences from *Prochlorococcus* demonstrate greater percent identity with those from the more distantly-related *Nostoc* and *Gloeobacter* than with those from the closely-related *Synechococcus*. This suggests that mechanisms such as phage-mediated horizontal gene transfer might play a role in the movement of PTOX genes among even distantly-related cyanobacterial lineages. We found that there is a high level of conservation between phage-encoded and *Prochlorococcus*-encoded sequences, and this conservation was greatest between sequences from a phage and the particular *Prochlorococcus* strain infected by that phage. Thus, these data support the possibility that cyanophages may acquire PTOX genes from their *Prochlorococcus* hosts and subsequently serve to mediate the transfer of these genes.

Functional Characterization of Tachykinin-1-Expressing Neurons in the Parasubthalamic Nucleus in Appetite Suppression

Grace Kromm

Neural regulation of ingestive behaviors is coordinated by the balance of activity in appetite-inducing and appetite-suppressing brain areas. The parasubthalamic nucleus (PSTN) is a relatively uncharacterized brain region in the lateral hypothalamus that has recently been implicated in the negative control of food intake. In particular, PSTN neurons that express tachykinin-1 (Tac1) are active following food consumption and show increased activity during the detection and consumption of food, suggesting that they might function to suppress appetite. In this thesis, we

tested the hypothesis that Tac1 PSTN neurons send projections to brain areas that regulate homeostasis. Additionally, we tested the hypothesis that stimulation of Tac1 PSTN neurons, or of Tac1 PSTN projections to a known appetite-suppressing neuronal population in the parabrachial nucleus (PBN), is sufficient to suppress appetite. We found that Tac1 PSTN neurons project to several brain areas that regulate food intake behaviors and to several brain areas that regulate other homeostatic behaviors. We also found that selective stimulation of Tac1 PSTN neurons, as well as of Tac1 PSTN projections to the PBN, is sufficient to suppress cumulative food intake and food consumption. Therefore, we propose that Tac1 PSTN neurons negatively regulate food intake, in particular through Tac1 PSTN projections to the PBN.

Stimulation and Mapping of Corticotropin–Releasing Hormone (CRH) Neurons in the Parasubthalamic Nucleus (PSTN)

Sierra Loomis

Hunger and satiety are regulated by a complex network of appetite-inducing and appetite-suppressing neural circuits. Recent work from the Carter Lab shows that the parasubthalamic nucleus (PSTN), located in the lateral hypothalamus, is active under conditions of appetite suppression. However, little is known about the functional role of neural subgroups in the PSTN, as well as other downstream PSTN projections. The present study sought to characterize the role of corticotropin-releasing hormone-expressing (CRH) neurons in the PSTN. Here, we genetically targeted CRH PSTN neurons for optogenetic stimulation, as well as the mapping of downstream projections. We found that optogenetic activation of CRH neurons in the PSTN does not suppress appetite. However, we also found that CRH PSTN neurons project to appetite-regulating brain regions including the bed nucleus of the stria terminalis (BNST) and the central nucleus of the amygdala (CEA). Additionally, CRH PSTN neurons project to nuclei in the reticular formation, which may implicate CRH PSTN neurons in locomotion and sleep regulation.

Near-complete Records of Insect Visitors to Six Flower Species Show Diptera, Habitat Quality, and Local Pollinators are Important for Maintaining Resiliency of Plant-Pollinator Networks.

Cristina Mancilla

With the unpreceded rate of pollinator decline that the world is facing today, the resiliency of plant-pollinator communities is challenged, so it is important to understand what qualities make plant-pollinator networks robust. We compared the plant-pollinator networks of six plant species: *Maianthemum canadense, Rhododendron groenlandicum, Trientalis borealis, Clintonia borealis, Sambucus racemosa,* and *Sibbaldiopsis tridentata* on Edwards Island in Isle Royale Wilderness National Park and in the western Massachusetts area. Our study is the first to document near-complete records of diurnal visitors to simultaneously blooming flowers. We scored a total of 18,620 insect visitors. Dipterans were the most frequent and diverse visitors to five of the six flowers highlighting the critical role of flies in plant-pollinator networks. Sarcophagid flies, *Sericomyia militaris*, and ants were the super-generalists in Isle Royale, visiting all six flower species. Muscid flies were the only super-generalist in the western Massachusetts area. Fine scale spatial heterogeneity in insect visitors, suggests that plants recruit local pollinators, supporting the neighborhood pollination model. The relatively undisturbed Isle Royale network was more nested and connected than the more fragmented network in western MA, suggesting that high quality habitat supports greater insect abundance and diversity, thereby increasing network participants and robustness. Maintaining a strong core of abundant generalists is critical for plant-pollinator network persistence, so we urge conservation efforts to focus on Diptera.

Sweater Weather: The effect of skin temperature on regulation of torpor in *Mus musculus*

Eily Mixson

Mice are known to initiate torpor when faced with conditions of food shortage and cold environmental temperatures, which cause maintaining a high metabolic rate and high core temperature to be an unsustainable energetic expense. While the importance of cold ambient temperature to the process of torpor is known, the mechanism for the initial signal by which cold triggers torpor in a calorically-restricted mouse is unknown. It is possible that mice initiate torpor when cooling is sensed somewhere within their core or when it is sensed at the level of the skin. This study evaluates the role of peripheral temperature sensing on torpor. Topical application of menthol, an agonist of the cold-sensitive TRMP8 receptor, was used to artificially signal external cold to the fasted mice, and capsaicin, an agonist of heat-sensitive TRPV1, was used to signal external heat to the fasted mice, altering the signals of skin temperature without necessarily altering the Tb of the animal. It was found that menthol application does not initiate

torpor in fasted mice at 30°C Ta, while capsaicin application may have initiated shallow torpor in fasted mice at 30°C Ta. A subsequent analysis of control data from these two experiments demonstrated that application of Vaseline blunts torpor when a fasted mouse is transferred to a 20°C environment, while application of ethanol facilitates torpor.

Exploring the Effects of Inhibiting the Parasubthalamic Nucleus (PSTN) on Food Intake in Mice

Matthew Newman

In mammals, the motivation to eat is regulated by the relative activity of orexigenic and anorexigenic neuronal populations in the brain. Recently, the parasubthalamic nucleus (PSTN) has been implicated as a potential anorexigenic neuronal population. However, the specific role of the PSTN in appetite regulation remains largely unknown. This study tested the effects of a loss of function of tachykinin-1 (Tac1)-expressing PSTN neural activity on food intake behavior in mice. Specifically, we tested the following hypotheses: (1) inhibition of Tac1 PSTN neurons is sufficient to increase food intake; (2) inhibition of Tac1 PSTN neurons reduces the appetite-suppressing effects of anorexigenic hormones; and (3) long-term silencing of Tac1 PSTN neurons causes an increase in body weight. Chemogenetic inhibition of these neurons did not result in changes in food consumption, nor did it affect aspects of meal architecture. However, following administration of anorexigenic hormones, chemogenetic inhibition of Tac1 PSTN neurons was sufficient to increase food intake, supporting our hypothesis that these neurons are involved in the integration of peripheral satiety signals. Specifically, Tac1 PSTN inhibition rescued the number of meals over time that were decreased due to the effects of CCK, amylin, and PYY, leading to an increase in cumulative food consumption. Finally, long-term silencing of Tac1 PSTN neurons did not lead to changes in body weight in mice. Overall, these results demonstrate that Tac1 PSTN neurons are required for the full anorexigenic effects of appetite-suppressing hormones.

Novel Bang-sensitive Mutants nrv3, skap and sqd, and their Genetic Interactions with julius seizure in *Drosophila melanogaster*

Rio Salazar

Seizures are defined as sudden, uncontrollable movements of the body resulting from abnormal neuronal excitability. In the fruit fly, *Drosophila melanogaster*, various mutants have been isolated that exhibit a seizure-like, or bang-sensitive, phenotype. The bang-sensitive mutant julius seizure (jus) has recently been found to encode a protein Jus that physically associates with Na+ pump α subunit (ATPα), Nervana3 (Nrv3), Succinyl-coenzyme A synthetase β unit (Skap) and Squid (Sqd). However, the roles of these Jus protein partners in Drosophila bang-sensitivity have not been investigated. This study used a behavioral vortex assay to mechanically stimulate flies with the mutant protein partner genes to determine if they were bang-sensitive. nrv3 and sqd mutants were found to exhibit bang-sensitive paralysis. Double mutant heterozygote flies were created and assayed to test for genetic interactions between jus and the protein partner genes. jus/nrv3 and jus/sqd double mutants expressed percentages of bang-sensitivity varying from the single mutant percentages, implying the pairs of alleles genetically interact. To test for Jus-protein partner gene expression in various cells, flies with various jus-Gal4 drivers and nrv3, sqd and skap gene expression knocked down by RNAi were assessed for bang-sensitivity. Results showed that the 59D01 jus-Gal4 construct was overall the most effective at expressing bang-sensitivity in the mutant nrv3-, sqd- and skap-RNAi lines, in contrast to previous findings that bang-sensitivity using jus- and ATPα-RNAi flies exhibited the greatest amount of bang-sensitivity in jus-Gal4 enhancer 90B09. This could suggest that jus and ATPα interact in different cells than jus and the other protein partner genes. Finally, male flies were much more likely to seize in the jus-Gal4/UAS-RNAi experiments, implying a presence of sexual dimorphism.

Microsatellite analysis of Solidago goldenrods shows high relatedness among non-clonal individuals in spatial patches and reduced genetic diversity in response to mowing

Robert B. Smith IV

With populations of insect pollinators declining at alarming rates around the world, the preservation of pollinators and the resources they rely on is of crucial concern to both agricultural production and global biodiversity. In New England, fall-blooming Solidago goldenrods offer a critical late-season food resource for many species of insect pollinators as they prepare to overwinter. With New England field habitats becoming increasingly rare, maintaining robust, genetically diverse goldenrod populations and understanding their reproduction is increasingly important.

We analyzed two species of goldenrod (*Solidago gigantea* and *Solidago rugosa*) across ten microsatellite loci in four plots under two mowing regimens (annual and biennial) in a field in Williamstown, Massachusetts, USA. Our goal was to measure the amount of clonality and the effect of mowing on allelic diversity. We found no evidence for cloning, but we did find a much lower heterozygosity in all populations than we would expect from allele frequencies, and a high degree of relatedness within spatial patches. We also found that *Solidago rugosa* forms smaller patches than *Solidago gigantea* and has a greater overall allelic diversity that is reduced under annual mowing compared to biennial mowing. Our results suggest that less frequent mowing may be an effective way to promote genetic diversity in goldenrod populations, and provide previously lacking genetic support for the neighborhood model of pollination, shedding light on the reproductive dynamics of these important plants.

Investigating sphingolipid function in *Physcomitrella patens* using CRISPR/Cas9 knockouts

Abraham Steinberger

Sphingolipids are a class of molecule found mostly in the cell membranes of eukaryotes and are known to play a role in both cell signaling and structure in plants. Sphingolipids have up to three parts, one of which, the long-chain base (LCB), has two or three hydroxyl groups. Here we used a CRISPR/Cas9 system to separately knockout the function of the protein that synthesizes all LCB, serine palmitoyl transferase (SPT), and the protein that synthesizes trihydroxy LCBs from dihydroxy LCBs in the moss model system P. patens. In combination, these knockouts have shown that while P. patens can survive without trihydroxy LCBs, it exhibits some odd cell morphology, increased pigmentation, smaller chloronemal cell size, and reduced gametophore size. Complementation assays with t17:0 show that the hypothesized system for the regulation of LCB synthesis in A. thaliana posited by Chen et al. 2008 is consistent with *P. patens* regulation as well, indicating it may be conserved across all land plants. The knockout moss without a functional SPT produced no LCB, allowing us to determine what species of LCB the moss requires to survive. Cultures of this moss indicate that P. patens cannot make effective use of unnatural isomers of d18:0 and does not need dihydroxy, or even unsaturated, LCBs for growth. These results demonstrate the utility of P. patens for studies of lipids in plants.

Characterization of AgRP Neural Activity Across the Sleep/Wake Cycle in Sated Mice

Maxwell Stukalin

In mammals, food intake behaviors and energy homeostasis are regulated by orexigenic and anorexigenic neuronal populations throughout the brain. Because it is impossible for animals to both sleep and consume food at the same time, it is likely that the neural systems regulating each homeostatic need reciprocally affect each other. This study utilized fiber photometry to record neural activity in agouti-related protein-expressing (AgRP) neurons, first order hunger neurons found in the arcuate nucleus of the hypothalamus, in tandem with electroencephalography (EEG) and electromyography (EMG) recordings across the sleep/wake cycle. These techniques allowed for the characterization of AgRP neuronal activity dynamics during and between the three arousal states, Wake, non-rapid eye movement (NREM) sleep, and rapid eye movement (REM sleep). We hypothesized that, in sated mice, AgRP neuron activity would decrease before Wake to NREM sleep transitions and REM sleep to NREM sleep transitions to allow sleep homeostasis systems to initiate the transition into slow-wave sleep. We also hypothesized that AgRP activity would increase preceding NREM sleep to Wake transitions and NREM sleep to REM sleep transitions as an animal transitioned into more neurologically active arousal states. We found that during NREM sleep, average AgRP activity was greater than during either Wake or REM sleep. We also found that AgRP activity decreased preceding NREM sleep, and that activity increased before transitioning out of NREM sleep. Therefore, our results support our hypothesis that AgRP neurons are arousal state-dependent, likely inhibited by sleep homeostasis systems to ensure the animal commits to a state of sleep.

Toll in the *Drosophila* CNS: Mapping Expression and Colocalization in the Brain and Ventral Nerve Cord

Joelle Troiano

The Toll superfamily of receptors in *Drosophila* has been widely studied for its role in innate immunity. The receptors' immune function in the body is important, one which translates from insects to mammalian species through the family of Toll-like receptors (TLRs) found in mammals, but there are many other potential roles played by Toll receptors which have not been studied. One of these is Toll's function in the nervous system. Though a presence of these receptors in the Drosophila central nervous system (CNS) is known, little has been done to elucidate the exact

patterns of this expression or the function it entails. In the present work, we investigate the expression of several Toll genes in the *Drosophila* brain and ventral nerve cord (VNC). In particular, we focus on Toll receptor expression in dopaminergic neurons, an overlap which is promising for future work on the impact of Toll receptors in the brain on sickness-related behavior, learning, and memory.

Characterizing Substrate Specificities Of Phosphodiesterases SAV1749 And SAV2904 from *Streptomyces avermitilis*

Kevin Zhou

While most *Streptomyces* species have one carrier protein phosphodiesterase, few have two. The aim of this study was to understand why *Streptomyces avermitilis* encodes two carrier protein phosphodiesterases, SAV1749 and SAV2904, through in vitro characterization of their substrate specificities. This was done by isolating, purifying, and testing as phosphodiesterase substrates several types of holo-carrier proteins involved in biosynthesis of various classes of secondary metabolites in *S. avermitilis*. The proteins chosen for this study were type I ACP domains SAV419, SAV938 (Aves1), SAV939 (Aves2), SAV2892 (OlmA4), and SAV2895 (OlmA7), the type II ACPs SAV608 and SAV2840, and the type I PCP domain from SAV845. Recombinant plasmids were successfully constructed for the genes corresponding to each of these proteins, and E. coli overexpression strains for SAV419, SAV608, SAV845, SAV938, SAV939, and SAV2840 demonstrated clear soluble protein after IPTG induction. The two carrier proteins from the oligomycin biosynthesis pathway, SAV2892 and SAV2895, were poorly expressed or completely insoluble. Due to time constraints only holo-SAV608, holo-SAV845, and holo-SAV2840 were isolated and reacted with the phosphodiesterases. Analysis using MALDI-TOF mass spectrometry showed that holo-SAV845 and holo-SAV2840 were substrates for SAV1749 and SAV2904, while holo-SAV608 was not a substrate for either. After compiling these MALDI-TOF mass spectrometry data with previous lab results, it appears that SAV1749 and SAV2904 act similarly with the carrier proteins tested to date and have a preference for type I holo-carrier protein substrates.

Chemistry

Development of a Microfluidic Bulk Fusion Assay for Quantifying Sendai Virus Fusion to Target Lipid Membranes

Joshua Choi

Paramyxoviruses are responsible for respiratory infections in rodents, swine, and mammals, and are common causes of measles and mumps in children One such virus is the murine parainfluenza type 1 Sendai virus. Upon binding to a target host membrane, Sendai virus proceeds to transmit its genetic material via lipid transfer through a process known as fusion which ultimately marks the onset of viral infection. Due to their unique process of host infection, Sendai viruses are exemplary models to study viral activity so that we may engineer them to develop gene therapies and regenerative medicines. Herein, I present a microfluidic bulk assay for Sendai virus fusion with fluorescently labelled lipid vesicles. The goals for developing a microfluidic assay was to use less virus, minimize bias, and yield substantial fusion events in channel solution of a microfluidic flow cell. I first demonstrate successful construction of the PDMS-based microfluidic device using dry film lithography and a negative photoresist to construct the mold. I then optimize the microfluidic assay for usage in viral fusion assays. Initial results with Sendai virus suggest that the influence of the fluorescent dye labelling is rather complicated, and that further optimization measures must be taken to observe fusion events.

Comparing Partially-Folded Intermediates in Homologous β-Lactamases

Drew Cohen

Proteins fold spontaneously into the most thermodynamically favorable structures determined by their amino acid sequence. An energy landscape relates all of a protein's possible folded conformations to their thermodynamic stabilities. To better understand the exact relationship between a protein's sequence and its energy landscape, we study a pair of homologous β-lactamases, TEM-1 and CTX-M-9, by spectroscopically monitoring their denaturation. TEM-1 and CTX-M-9 occupy highly similar native structures consisting of two folded domains, α and α/β. These enzymes have different thermodynamic stabilities and are thought to occupy a different number of states at equilibrium: CTX-M-9 denatures in a two-state fashion, and TEM-1 exhibits a partially-folded intermediate state, detectable by circular dichroism (CD) but not by fluorescence. Our data support an intermediate model for TEM-1 with a fully folded α-domain and unfolded α/β-domain. To test the sequence determinants of this intermediate, we engineered a disulfide bridge in the α-domain of CTX-M-9 to match the endogenous disulfide bridge in the α-domain of TEM-1. This revealed a structurally-distinct intermediate state, visible by fluorescence but not by CD. Tryptophan mutations in this engineered-disulfide background of CTX-M-9 support an intermediate model with a folded α-domain and an α/β-domain that lacks only tertiary structure. We provide evidence here that a structurally similar intermediate may also exist in CTX-M-9 lacking an engineered disulfide by constructing an intermediate structural mimic via truncation of the α-domain. Characterizing intermediate mimics will allow us to better compare our models and decode the relationship between amino acid sequence and protein structure to model rare and novel states.

Synthesis of Perchlorotriphenylmethyl Compounds Toward the Study of Organic Mixed-Valence Species

Maia Czaikowski

Electron transfer in chemical processes is widespread and essential to our understanding of biological systems, materials, and synthesis. Model systems are powerful tools that offer insights into electron transfer processes. Organic mixed-valence (OMV) compounds have emerged as a compelling model system in which intramolecular single electron transfer occurs between a donor and acceptor site. In this work, three organic compounds, (perchlorophenyl)-4-bromo-perchlorophenylmethyl (PCTM), (4-methyl-perchlorophenyl)-4-bromo-perchlorophenylmethyl (Me–PCTM), as well as the precursor compound Bis(4-methoxyphenyl)-4-bromophenylmethyl (OMe–TM), were synthesized as electron-acceptor moieties of a radical perchlorotriphenylmethyl–triarylamine (PCTM–TARA) dyad. One of the reported compounds, PCTM, was cross-coupled with two TARA derivatives, creating analogous dyads differing in electronic properties at the donor site.

Here, the synthesis of PCTM, Me–PCTM, and OMe–TM is detailed, and the characterization of these compounds by NMR is reported. Further synthetic targets, including (Me–PCTM)–TARA dyads, are planned for the next stage of this project to achieve a library of dyad structures.

In vitro Characterization of *Streptomyces avermitilis* SAV1748 and SAV3637 Phosphopantetheinyl Transferase Substrate Specificities

Jeromy DiGiacomo

The *Streptomyces* are a genus of soil-dwelling bacteria that produce an array of structurally and functionally diverse secondary metabolites, compounds that are not required for the survival of an organism in the laboratory. An important subset of these secondary metabolites are those with antibiotic activity. The *Streptomyces* produce nearly half of the current clinically relevant antibiotics, making research into their secondary metabolism uniquely important. Secondary metabolite compounds are synthesized by two major classes of biosynthetic enzymes: polyketide synthases (PKS) and non-ribosomal peptide synthetase (NRPS). These enzymes use carrier protein domains (type I) or distinct carrier proteins (type II) to tether the growing secondary metabolite using a 4'-phosphopantethinyl (Ppant) moiety. The Ppant moiety is post-translationally added to carrier proteins by a phosphopantetheinyl transferase (PPTase) enzyme.

The *S. avermitilis* genome has seven putative PPTase-encoding genes whose products extend across three PPTase families. Well-characterized *S. coelicolor* and *E. coli* genomes contain only three PPTase-encoding genes, one in each family. For this reason, it was hypothesized that PPTases in *S. avermitilis* might have unique substrate specificity within each PPTase family to allow for greater control of secondary metabolite biosynthesis. In this study, we present the novel purification and characterization of substrate specificity characterization for two of the seven putative PPTases in S. avermitilis.

Of the seven putative PPTase-encoding genes, successful expression constructs were created for three genes: SAV1748, SAV3193, and SAV3637. Out of these three, purified active protein was isolated for SAV1748 and SAV3637, two distinct enzymes from two different structural families. Substrate specificity of these two PPTases was categorized for a variety of carrier protein substrates across metabolic classes using MALDI-TOF mass-spectrometry.

For the PPTases and carrier proteins examined here, a high degree of substrate redundancy was observed. Surprisingly, both purified PPTases tended to utilize the same carrier protein substrates and neither showed a clear preference for a certain carrier protein metabolic class. Potential explanations for this observed redundancy could be experimental or evolutionary. Consistent use of highly concentrated reactants for in vitroPPTase specificity assays and long incubation periods, differential PPTase expression under changing life-cycle or environmental conditions, and the need for "back-up" enzymes in the competitive soil environment are all potential explanations for the observed substrate redundancy.

Synthesis of Functionalized Triarylamines Towards the Development of Organic Mixed-Valence Compounds

Joseph Flores

Electron transfer is a fundamental chemical process, ubiquitous to virtually all areas of chemistry and essential to the sustaining the conditions and energy necessary for life on earth. Thus, the study of electron and charge transfer is a critical area of research, particularly the development of models designed to undergo these processes in a controlled and measurable manner. In this investigation, we aim to study light-promoted electron and charge transfer by developing organic mixed-valence compounds, perchlorotriphenymethyl-triarylamine (PCTM–TARA) radicals to serve as photoredox catalysts. Ultimately, we sought to generate a library of these molecules by varying the functionalization of its moieties, accessing a library of potential catalysts with a range of redox potentials for study.

Here, we describe the synthesis of series of substituted triarylamines, designed with a range of electron-withdrawing strengths to allow incremental tuning of the oxidizing strength of potential catalysts. Furthermore, we attempted the cross-coupling of triarylamine and perchlorotriphenymethyl molecules to form a closed-shell precursor to one of the molecules of our target library.

Toward Formation of Lead, Cadmium and Mercury Complexes: Small Molecule Systems to Mimic Polymeric Chelation of Heavy Metals in Environmental Remediation

Astia Innis

Heavy metal pollution poses health risks to humans, animals and plants, making environmental remediation of these metals immensely important. Polymeric systems that encapsulate heavy metals with high binding affinity and selectivity are a promising solution. They utilize the high affinity of ligands with soft donor atoms, such as sulfur, for soft heavy metals. For this thesis, we targeted thiol and thioether containing ligands and their complexes of lead (II), cadmium (II) and mercury (II) as small molecule systems of the binding units of these metals in polymer systems. The ligand analogs contain an amide group to mimic the point of attachment of the ligand sidechains in the polymer. Working with small molecule analogs facilitated the study of the nature of metal binding and presented likely structures of the complex in metal-bound polymers.

Ligand analogs, methyl acetyl methioninate (L134) and methyl isobutyryl methioninate, (L135) were formed by reactions of the acyl chlorides, isobutyl chloride or acetyl chloride, with amines containing a sulfur donor atom. Subsequently, the synthesis and characterization of zinc, lead and cadmium complexes were explored. The complexes [Zn(L134)2Br2], [Zn(L134)2(OTf)2], [Zn(L135)2Br2], [Zn(L135)2(OTf)2] and [Cd(L135)2(NO3)2] were synthesized and their formation supported by NMR and ESI-MS measurements. Future determination of these structures by X-ray crystallography will confirm the metal-ligand interactions in the complexes. The corresponding complexes with lead and cadmium were hindered by low solubilities and prevented characterization by NMR and ESI-MS under the conditions studied. Future work is proposed to improve ligand yields and purity of both ligand and complexes.

Synthesis and Characterization of pH-Sensitive, Amphiphilic Diblock Copolymers for Potential Applications in Medicine

Julie Ha

Nanoparticle therapeutics involving the use of pH-sensitive, amphiphilic diblock copolymers have risen as an improved mode of chemotherapeutic drug delivery, which takes advantage of the self-assembly of these polymers into micelles that encapsulate drugs. Micelles can deliver and unload these drugs at target sites by taking advantage of pathophysiological processes that differentiate cancer from healthy cells. In this work, poly(methyl salicylate acrylate)57-block-poly(n-butyl acrylate)35 (PMSA57-b-PBuA35) was synthesized through reversible addition fragmentation chain transfer (RAFT) polymerization. PMSA57-b-PBuA35 was used as a parent copolymer that reacted with two amines, N,N-diethylethylenediamine (DEEN) and 2-(aminomethyl)pyridine (AMP), to produce poly(N-(2-(diethylamino)ethyl)acrylamide)57-b-PBuA35 (PDEAEAM57-b-PBuA35) and poly(N-(pyridine-2-ylmethyl)acrylamide)57-b-PBuA35 (PPMA57-b-PBuA35). This synthetic strategy leads to polymers of the same length, enabling direct comparison.

Following synthesis, PDEAEAM57-b-PBuA35 was characterized to determine its critical micelle concentration (CMC) and aggregation behavior. The CMC in sodium phosphate buffer at pH 5.8, 6.5, and 7.2, were calculated as 3.63 x 10-2 mg/mL, 4.17 x 10-2 mg/mL, and 2.92 x 10-2 mg/mL, respectively. Aggregate size was measured at pH 5.8, 6.5, and 7.2 via dynamic light scattering (DLS). DLS experiments supported the formation of polymeric micelles at these pH values and suggested modest pH-sensitivity. Antibacterial assays of the polymer at 0.075 mg/mL and 0.015 mg/mL in Escherichia coli showed there was no antibacterial activity. These preliminary studies demonstrated modest self-assembly into micelles with modest pH-sensitivity, and also suggest that PDEAEAM57-b-PBuA35 may have potential applications in delivery of chemotherapeutic drugs. The polymer may also have antibiotic properties at higher concentrations. To more firmly establish the characteristics of PDEAEAM57-b-PBuA35, it is important to improve conditions and repeat the CMC measurements in 1.0 M sodium phosphate buffer and repeat the antibacterial assay with a higher concentrations of polymer solution. Future studies, including confirmation of micelle formation via transmission electron microscopy (TEM), cytotoxicity studies to assess the polymer's compatibility with the mammalian cells, and encapsulation studies with chemotherapeutic agents, are necessary to support the potential applications of these polymers in nanoparticle therapeutics.

Amine Substitutions of Lignin-Based Polymers

Ching-Hsien (Justin) Ho

As polymer chemistry evolves away from oil-based monomers, a growing demand for other sustainable sources suggests looking at lignin, the second most abundant plant material only to cellulose. This underutilized natural resource would provide aromatic precursors such as vanillin and syringaldehyde which contain multiple functional groups for further modification. Herein, we report successful polymerization of acrylate monomers using syringaldehyde and vanillin and post-polymerization processes that take advantage of the benzaldehyde moiety.

A series of primary amines were reacted with our lignin-based homopolymer in the hopes of creating Schiff bases that would serve as a cross-linker between adjacent chains. Due to the presence of an acrylate group with a good leaving group and a benzaldehyde, the substitution reaction would either form an imine or an amide. Via 1H-NMR analyses, the substitution rate and the preference for the desired imine product over all other products were determined. That, alongside a couple of kinetics tests, suggest that the imine product is kinetically favored while the amide product is thermodynamically favored. As a proof of concept, we also successfully created hydrogels out of copolymers of syringaldehyde with N, N-dimethylacrylamide, and syringaldehyde with N-isopropylacrylamide using cystamine dihydrochloride as a cross-linker.

Inhibition of Single Particle Sendai Virus Binding using a Monoclonal Antibody to the HN-Attachment Protein

Orville Kirkland, Jr.

Paramyxoviruses are a family of enveloped-membrane viruses containing a negative-sense, single-stranded RNA genome. Several of these viruses, including human parainfluenza viruses, respiratory syncytial virus, measles virus and mumps virus are highly infectious and very pathogenic to humans, causing severe respiratory tract infections in children and immunocompromised patients. There are currently no effective treatments for preventing these infections, which has motivated the development of various antiviral therapeutic strategies, including the use of monoclonal antibodies. These antiviral therapies usually target a specific aspect of the paramyxovirus infectious process, which involves the binding of a viral attachment protein to a cell-surface receptor on the target cell and the subsequent fusion of the viral envelope with the target cell membrane, allowing for the release of the RNA genome into the cell for viral replication. Here, we use Sendai virus as a model system to investigate the underlying molecular mechanisms by which the recently discovered 1A6 monoclonal antibody inhibits viral binding. To achieve this, a biophysical approach was employed, in which fluorescence microscopy and image analysis were used to observe and quantify the binding of individual fluorescently labelled virus particles inside a microfluidic device to artificial target membranes after preincubation with the antibody. The general efficiency of the 1A6 antibody at inhibiting viral binding was demonstrated after observing significant reductions in viral binding after preincubating the virus with excess concentrations of the antibody compared to a HEPES-treated control. A similar trend was observed even in the absence of viral receptor, indicating the potential of Sendai virions to bind non-specifically to target membranes. The potency of the antibody was assessed by determining its half-maximal inhibitory concentration, which was found to be <1.5 μg/mL. Additionally, negative-stain transmission electron microscopy was successfully utilized to visualize the morphology and structural features of Sendai virions.

Synthesis and Characterization of Amphiphilic Diblock Copolymers for Heavy Metal Encapsulation

Jonathan Lee

Heavy metals such as lead, cadmium, and mercury pose a persistent and growing threat to environmental and human health. Due to the limitations of conventional approaches to remediation of heavy metals in the environment, there is a compelling need for the development of new approaches to remediation that are low cost, high efficiency, and eco-friendly. Polymers that can bind and encapsulate heavy metals offer a potential solution for the removal of heavy metal ions from aqueous media. In this work, an amphiphilic diblock copolymer, poly(N,N-dimethylacrylamide)-block-poly(methyl salicylate acrylate) was synthesized for use as a parent polymer that can be functionalized with metal-binding ligands via nucleophilic substitution. In principle, this parent diblock provides a synthetic route toward a whole family of metal-binding polymers among which direct comparisons can be made due to their common origin. Here, the parent diblock was substituted to synthesize poly(N,N-dimethylacrylamide)-block-poly(N-(2-(methylthio)ethyl)acrylamide) (PDMA-b-PMTEA). The formation of PDMA40-b-PM-

TEA52 aggregates in aqueous solution was studied using DLS, which showed an increase in aggregate size in the presence of lead(II) nitrate, consistent with the encapsulation of Pb(II) ions in polymeric micelles. Further metal binding studies such as IR, AAS, and TEM experiments, are needed to substantiate this result and evaluate the polymer's potential for use in remediation.

Polychlorinated Biphenyl Contamination of Hoosic River Sediment: Congener Degradation from 2004 to 2019

Katina Massad

Polychlorinated biphenyls (PCBs), persistent organic pollutants, were first detected in the Hoosic River in 1990 at hazardous levels in sediment, crayfish, and brown trout. The source of contamination originates at the Sprague Electric Company (now the Massachusetts Museum of Contemporary Art) where toxic waste was buried for over 30 years, constantly seeping into the Hoosic. After many cleanup efforts in the 1990s-2000s, a comprehensive study of the Hoosic River ecosystem in 2004 showed a decrease in average PCB levels at many sediment sampling sites along the river from North Adams to the New York border. PCBs are of particular interest because at high levels they can cause cognitive defects, liver problems, hormone deficiencies, and potentially cancer. PCBs toxicity varies depending on their structure (number of chlorine substitutions, position of substitutions, and dihedral angle) and stability.

This study focused on determining the persistence of PCBs in Hoosic River sediment based on the number of chlorine substitutions per congener. We found that average PCB levels in Hoosic River sediment have significantly decreased since 2004. By calculating individual PCB congener concentrations, we determined that the average percent chlorine by mass at each sampling site increased over the past ~15 years. Furthermore, the average percent decrease of tetrachlorobiphenyls levels in sediment over time was greater than that of hexachlorobiphenyls. Tetrachlorobiphenyls were shown to have a shorter average half-life than hexachlorobiphenyls in Hoosic River sediment. Together, these results indicate that lesser-chlorinated PCBs degrade at a faster rate than more-heavily chlorinated PCBs. Finally, levels of dioxin-like PCBs were individually determined, providing insight into the levels of dioxin-like PCBs along the Hoosic at recreational sites. This study provides a general and more specific look into which PCBs are more likely to degrade in the context of the Hoosic River.

Organic Synthesis of Novel Compounds with Anti-leishmaniasis Properties: A Collaboration in Drug Discovery with Drugs for Neglected Diseases Initiative

Sarah Michels

Leishmaniasis is a parasitic disease caused by the bite of a Leishmania-infected sand fly and is the second largest parasitic killer in the world, following malaria. Drugs for Neglected Diseases initiative (DNDi) is an international not-for-profit collaboration researching and developing novel therapeutic agents for diseases that possess limited economic incentive for pharmaceutical research. Williams College has been a participant in DNDi's Open Synthesis Network since 2018, and has been tasked with researching compounds in the aminopyrazole series. DNDi provided an advanced intermediate which is known to be potent against two Leishmania parasites. This thesis focused on building a library of target products identified by DNDi. The two- step synthesis of amino acid-based drug candidates consists of an initial amide coupling step followed by the subsequent removal of two protecting groups. The DNDi core, as well as targets, are highly polar and reactive compounds introducing challenges isolating desired products. Here we report a new protocol for improving efficiency of the purification procedure. Additionally, we report optimized conditions for selectively removing protecting groups from the coupled amide intermediate. Our work demonstrates the utility of this synthetic methodology on multiple targets. We successfully developed three target compounds, which were the first molecules from Williams College to be submitted to DNDi and screened for anti-Leishmanial activity. The syntheses of five additional targets was also initiated. This thesis reports the synthetic methodologies for a total of 14 intermediate and target compounds in this aminopyrazole series. The work of this thesis has contributed to the progress building the library of target compounds identified by DNDi.

A Modular DNA Parts Library to Enable the Study of Polyelectrolyte Coacervation
Dylan Millson

Polyelectrolyte coacervation represents a promising approach for the development of synthetic membraneless organelles. Preliminary studies have shown that supercharged fluorescent proteins form coacervates with RNA, but more work needs to be done to understand how features of the supercharged protein such as concentration, net charge, and charge distribution affect the properties of the condensate. Here, I develop a modular DNA parts library for Golden Gate assembly that will enable the systematic variation of these qualities to evaluate their effect on coacervation. This library consists of various promoters, ribosome binding sites, genes, N-terminal and C-terminal tags, origins of replication, and selection markers, encompassing nearly 200 parts in total. While this architecture will be useful for better understanding the role of expression level and charge in coacervation, it is not well-suited for applications of synthetic organelles as it only allows the expression of a single gene of interest per plasmid. Therefore, I developed an architecture for the assembly of vectors containing up to 25 transcriptional units from previously developed Golden Gate donors based on the Golden Braid assembly standard. This architecture retains the modularity of the previously described Golden Gate library, allowing enormous flexibility in the design of metabolic pathways and genetic circuits. Presently, many of the donor vectors for the Golden Gate library have been cloned and purified, however more work needs to be done to physically make all of the donor vectors and characterize their performance.

Mathematical Modeling of non-Fickian Reaction-Diffusion Biological and Chemical Dynamical Systems
Ingrid Onul

Dynamical systems are present in a variety of fields including biology and chemistry. Alan Turing first introduced the study of pattern formation by proposing a model for the reaction-diffusion of morphogens in early-stage embryonic development. Biological reaction-diffusion systems, encompassing different population dynamics, such as the Lotka-Volterra model, soon developed to explain oscillatory behavior. Concurrently, chemical reaction-diffusion systems emerged to sustain the observed pattern in the Belousov–Zhabotinsky reaction. This paper includes the mathematics behind the analysis of Turing pattern formation in generic 2-component reaction-diffusion systems. Historically, this type of modeling is carried with Fickian diffusion coefficients, and Turing pattern formation is constrained to having the inhibitor species diffuse at a much greater rate than the activator species. We present an extension of the Turing condition to generic non-Fickican diffusion. Thus, we introduce a concentration-dependent diffusion, one that more accurately mimics real-world conditions, where a chemical species moves through space in a nonlinear fashion. First, the analysis of herbivore-plant interactions within an ecosystem composed of mutualism introduced in trophic cascades yields the lack of Turing pattern formation. Second, we analyzed the Brusselator, the most simple model for a chemical reaction-diffusion system. Introducing non-Fickian diffusion relieves, partly, the limitation that the inhibitor must diffuse at a much greater rate than the activator. Third, we analyzed the Oregonator, the most reduced system capable to model the Belousov–Zhabotinsky reaction. Yet, the Turing conditions remain unaltered upon introducing non-Fickian diffusion. This statement remains true in any 2-component reaction-diffusion system with a duplicate steady-state and in relation to 2 species that diffuse under the same function.

Characterizing the Stabilities of Intermediate States in β-lactamases TEM-1 and CTX-M-9
Ryan Rilinger

In order to function properly, proteins must completely fold into a native state. Folding from an unfolded peptide chain into a folded native state may involve one or more partially-folded intermediate states, and if these intermediate states do not continue folding into the native state, they can have negative physiological effects. Cells cannot degrade every single protein that fails to fold properly, and therefore evolution favors protein sequences that are more conducive to reaching stable, native states. We compared the intermediate stabilities of two β-lactamase proteins, WT TEM-1 and WT CTX-M-9, which have high structural similarity but significantly different intermediate state stabilities. Past findings revealed an intermediate for WT TEM-1 that is structurally distinct from the native state.

Prior evidence for an intermediate state for WT CTX-M-9 was reclassified as an effect of pH; however new evidence for a WT CTX-M-9 intermediate was found by comparing different probes at the same pH. This intermediate state appears to be structurally more similar to the native state that the WT TEM intermediate; it is indistinguishable from the native state by CD at pH 8.0, and like the native state, resists degradation by thermolysin. Although WT TEM-1 and WT CTX-M-9 have nearly-identical native structures, their intermediates appear to differ significantly in their structures and stabilities.

Using Electron Spin Resonance (ESR) Spectroscopy to Assess Interaction Between *Homo Sapiens* and Neanderthals at Šalitrena

Larissa Silva

One of the biggest questions in paleoanthropology is what has contributed to the demise of the Neanderthals. The arrival of anatomically modern *Homo sapiens* into the Neanderthal inhabited spaces in Europe is associated with their extinction. This is further complicated when we consider what kind of interactions the two species may have had with each other – we know from genetic studies that the two species had to have interbred. The goal of this project has been to assess whether the Šalitrena cave in Serbia, which is within the path of migration that is associated with the Out of Africa movement, was a site where interactions between the two species may have occurred. Ages for three of the stratigraphic layers (6a, 6b and 6c) at the site were obtained using ESR spectroscopy and results from neutron activation analysis. Ages for the layers 6a, 6b and 6c were calculated to be 71 ± 4 ka, 72 ± 4 ka, and 73 ± 4 ka, respectively. This leads to the conclusion that this was not a site of interaction between Homo sapiens and Neanderthals, and that perhaps there was a gap of time in which the cave was uninhabited. However, the site does have an interesting progression in the tool technology found in the layers, and this could be indicative of something else interesting. Nevertheless, this provides motivation to date other sites in the area to address the question of when and where the two species interacted.

Defining the Promoter Architecture of the SCO4409 Sigma Factor Gene in *Streptomyces coelicolor*

Anastasia Tishena

The SCO4409 ECF sigma factor of *Streptomyces coelicolor* has previously been implicated in regulation of antibiotic biosynthesis in *S. coelicolor*. In a knockout mutant of the ZAS anti-sigma factor SCO4408, where SCO4409 sigma factor activity is presumed to be unregulated, reduction in undecylprodigiosin and actinorhodin antibiotic production is observed compared to wildtype. In this study, we attempted to identify the promoter recognized by SCO4409 sigma factor in order to determine which genes might be under its control (its regulon). We hoped that if we knew the SCO4409 regulon, then we could attempt to explain the observed antibiotic production defects in SCO4409 sigma factor and SCO4408 anti-sigma factor mutant strains. We used an eGFP reporter plasmid and fluorescence microcopy to try and elucidate the promoter sequence to which SCO4409 binds and from which it directs transcription. We also tried to determine if there were any obvious differences in spore health and aerial hyphal development in the SCO4409 sigma factor and SCO4408 anti-sigma factor mutants using scanning electron microscopy.

The SCO4409 sigma factor does not appear to bind and direct transcription from the promoter tested here. However, there is potential evidence for SCO4409-dependent promoter activity in liquid culture growth conditions as well as increased SCO4409-independendent promoter activity in the SCO4409 mutant during germination. SCO4408 anti-sigma factor isolates showed evidence of phenotypic instability, exhibiting normal and bald aerial hyphae phenotypes. Scanning electron microscopy observations did not reveal any major differences in spore health or aerial hyphal development for sigma and anti-sigma factor mutants. Our results invite further investigation of the differential transcription pattern from tentative SCO4409 promoter(s) in different environmental growth conditions as well as during earlier stages of the *S.coelicolor* lifecycle.

Towards the Total Synthesis of Enigmazole A: Continued Efforts Towards the Synthesis of the C1–C12 Fragment

John Velez

Enigmazole A is a phosphorylated 18-membered macrolide natural product isolated from the marine sponge *Cinachyrella enigmatica*. The molecule exhibits potent cytotoxic activity, although its mechanism of action remains unclear. Engimazole A also possesses unique architectural elements—with eight stereogenic centers, a 2,4-disubstituted oxazole moiety, a phosphate ester, and an exomethylene-substituted tetrahydropyran ring—and has thus become an appealing synthetic target. Our synthetic plan for the molecule envisioned the use of Myers diastereoselective alkylation to efficiently construct the C1–C6 aldehyde unit, and diastereoselective Maitland-Japp reaction to synthesize enigmazole's cis-substituted tetrahydropyran ring. This thesis focuses on optimizing the yield and diastereoselectivity of the Myers alkylation, and subsequent reactions, on actual enigmazole substrates, with the intention of employing the Maitland-Japp conditions optimized through model studies performed by our group. After lengthy study, we were able to successfully complete six of the eight steps of the synthetic scheme, while furnishing the crude methyl ester product of the seventh step. Our work on the real system confirms that the construction of the C1–C12 fragment is within striking distance, allowing the end target of enigmazole A to come closer in sight.

Towards the Total Synthesis of Enigmazole A: Approaching the Maitland-Japp Reaction

Conrad Wahl

Enigmazole A is an 18-membered marine phosphomacrolide isolated from the sponge *Cinachyrella enigmatica*. This macrolide belongs to a family of compounds known to selectively inhibit c-KIT-implicated tumors by an unknown mechanism of action. The Smith lab approaches the total synthesis of enigmazole A in two fragments: a C1–C12 western fragment and a C13–C25 eastern fragment. A synthetic challenge in the construction of the western fragment is a 2,6-cis-substituted tetrahydropyran ring. Our group provides an efficient three-step synthetic route to the formation of this tetrahydropyran ring via a diastereoselective Maitland-Japp reaction. Herein the two-step development of the δ-hydroxy β-ketoester that is the precursor to this Maitland-Japp reaction is reported. Challenges and revised conditions for the first of these steps, a non-Evans syn-aldol reaction, will be discussed. A synthetic challenge in the construction of the eastern fragment is a 2,5-substituted-1,3-oxazole appendage to the 18-membered ring. The successful development of this appendage in three steps is herein reported as well. Early progress in both the western and eastern fragments set the stage for the completion of the western fragment via the Maitland-Japp reaction and for the development of the latter half of the eastern fragment.

Geosciences

A Dive into the Bering Sea: Reconstructing the Drivers of North Pacific CO2 Flux through Glacial-Interglacial Cycles of the Pleistocene

Jared Bathen

Changes in high-latitude biological and physical oceanographic processes have the potential to affect global climate. The biological pump, ocean circulation, and vertical mixing are all drivers of changes in ocean-atmosphere CO2 flux and the CO2 storage capacity of the ocean. However, a lack of high-resolution proxies for productivity and vertical mixing limit our ability to assess the degree to which each of these drivers affect changes in flux and storage capacity. In this study, we present geochemical and sedimentary proxy records for productivity, nutrient utilization, and mixing in the Bering Sea over the past 550 kya. We also present the first proxy record for seafloor oxygen concentration constructed in the North Pacific. We propose that expanded sea ice during glacial periods caused slowed Bering Sea circulation, the closure of the Bering Strait, and the expansion of nutrient-poor North Pacific Intermediate Water. This in turn led to increased nutrient utilization in surface waters and greater CO2 storage capacity of the glacial North Pacific. Our findings lend support to this hypothesis while suggesting that the relationship between Bering Sea productivity and climate may be more complicated than previously indicated.

sICEmic Sea Ice: Detecting Collisions with Seismology

Marshall Borrus

This senior geoscience thesis examines how sea ice interacting with the shore produce seismic signals. We are interested in detecting ice ridging events with the end goal of being able to predict when these ridges become grounded in the sediment, making the shore ice landfast. Our research site is located in Utqiaġvik, AK and we utilize archived footage from a marine sea ice radar and seismic data from a Transportable Array seismic station during the 2014-15 ice season. We selected 10 ice ridging events via radar footage and feature tracking software, then calculated power spectral density curves for each event, and finally averaged the 10 events together across frequency bins. The result was an averaged signal of a typical ice ridging event. Similar methodology was used to create averaged signals for breakout events, high wind days, early ice season background noise levels, and late ice season background noise levels. Comparing the 5 signals we observed that ridging events have a distinct spectral signature, with a distinct frequency range, and clear signal durations.

SKS Splitting Beneath Connecticut: Constraints from the SEISConn Array

Ethan Lopes

Seismic anisotropy is the directional dependence of seismic wave speeds on wave propagation direction. By utilizing this geophysical property, one can gather information about the mantle's structure and consequently learn more about the processes that deformed the mantle in the first place. This study investigated seismic anisotropy beneath northern Connecticut using shear wave splitting observations, a technique that measures the fast and slow components of altered shear waves. I used SKS seismic wave phases, waves which propagate vertically from the core-mantle boundary, for the shear wave splitting technique. The splitting observations were taken using the Seismic Experiment for Imaging Structure Beneath Connecticut (SEISConn), a spatially dense seismic array arranged along a west-east line in northern Connecticut. The array consisted of 15 stations that sampled waves passing through tectonic landforms, including Laurentian crust, Gondwanan-derived terranes, magmatic arcs, and the Mesozoic Hartford basin. I analyzed the SEISConn data using two different splitting measurement methods: the transverse component minimization and the multichannel methods. Using the transverse component minimization technique, I identified variations in apparent splitting direction and intensity as a function of backazimuth, the direction of wave propagation. Using the multichannel analysis, I found that the single-station averaged fast polarization directions were generally consistent across the array, with relatively small delay times (0.52 s average). Synthesizing these results, I hypothesize that the complex, weak anisotropy beneath northern Connecticut has both lithospheric and asthenospheric contributions, where the lithospheric anisotropy reflects frozen-in deformation structures from past tectonic events and the asthenospheric mantle is dominated by ongoing plate motion parallel shear. The results from this study help to constrain several aspects of both present-day and past mantle deformation beneath southern New England, as well as provide a southern boundary constraint for the Northern Appalachian Anomaly.

Microfossils and Geochemistry of the Late Devonian Extinction Events in the Appalachian Basin

Kate Pippenger

The late Devonian mass extinction is recognized in the fossil record by multiple pulses of diversity depletion that devastated global ecosystems. These are the Lower and Upper Kellwasser events at the Frasnian-Famennian boundary and the Hangenberg event at the Devonian-Carboniferous boundary. The late Devonian extinctions are unusual because of their length, periodicity, and low origination rates, which has made it difficult to discern their true cause or causes. Here, we explore the micropaleontological and geochemical record of these events in the Appalachian Basin, an approach that allows us to reconstruct paleoenvironmental conditions and search for extinction causes. We study seven sites within the basin representing all three extinctions.

Contrary to previous work, we find no evidence of volcanism associated with any Devonian extinction event. One anomalous Hg spike is likely to represent a reworked local tephra, and Hg/TOC ratios suggest Hg concentration is controlled by redox. Mo and U concentrations support persistent anoxia at deep-water LK sites. At these deep-water LK sites, microfossil abundance spikes at the onset of extinction, and almost all microfossils found are leiospheres. In addition, a distinct subpopulation of large, smooth-walled leiospheres present at these sites may represent a group of prasinophyte green algae characterized as a "disaster taxa" that flourished during deleterious conditions. If so, this supports eutrophication as a cause of anoxia at deep-water LK sites. Shallower LK sites have little evidence of oxygen stress and more varied microfossil assemblages.

Mo and U data from UK sites provide evidence of intermittent or less intense anoxia, with leiosphere-dominated assemblages that lack the distinct population observed at deep-water LK sites. Mo/TOC ratios suggest increasing basinal restriction during both Kellwasser intervals at deep-water sites. This is consistent with other findings of LK regression in the Appalachian Basin. Though the UK interval is associated with anoxia caused by a global transgression, increased restriction in parts of the Appalachian Basin may explain the decreased intensity of anoxia seen at our UK sites.

Palynological analyses of the Hangenberg event in the Cleveland Shale allow us to correlate this section with the Hangenberg Black Shale in Europe. The dominance of Retispora lepidophyta in upper horizons at our site suggests that the D-C boundary is within or above the overlying Bedford Formation. Mo and U concentrations reflect intermittently anoxic conditions during the Hangenberg, but we also identify a horizon with high enough Mo values to support euxinic conditions. This horizon is also barren of microfossils. We suggest this horizon may reflect a minor transgressive event, during which an influx of water from the open ocean replenished trace metals and nutrients and could have disturbed local environments.

Impact of the Length of the Sea Ice-free Summer Season on Alaskan Arctic Coastal Erosion Rates

Matthew Wiseman

In the Alaskan Arctic, factors including permafrost degradation, storms, sea surface temperature, and sea ice cover all play a role in determining the severity of the coastal erosion. Due to anthropogenic climate change, these factors will change, potentially posing a major threat to local communities. This study looks into how the changing length of the sea ice-free season impacts coastal erosion rates. Coastal erosion rates, calculated using satellite-based imagery from Planet at study sites around the Arctic Alaska coast from 2009-2019, show the highest coastal erosion rates along exposed permafrost bluffs. The length of the ice free seasons at each site are calculated from SSMI-derived passive microwave ice concentration products. The comparison of erosion rates and ice free seasons results in an inconclusive and variable relationship, with signs of the positive relationship that was expected. To try and determine what factors may be influencing the relationship between ice free days and erosion rate, sea surface temperatures and storm data are also analyzed and combined into a multivariable linear regression model. Due to the short time frame and climatic variability, none of the additional factors revealed any statistically significant relationships. What this study does show is that coastal erosion in Arctic Alaska is a highly complex process that needs further research over a longer time frame in order to determine how large a role each of these factors play in influencing coastal erosion rates.

Mathematics and Statistics

Asymptotic Expansions for Bounds of Epsilon-Pseudospectra of Nonnormal Matrices
Alex Bank

In this thesis, we first introduce the tenants of spectral theory and the concept of pseudospectra. We briefly discuss the relevant properties of pseudospectra and its connection to potential theory. Motivated by recent research on the pseudospectra of Jordan blocks, we study the pseudospectra of nonnormal matrices. Specifically, we look at the ε-pseudospectral radius of Jordan blocks and work to improve on the best known upper and lower bounds for these radii. Finally, we end with a computational approach to the problem by using software to approximate the pseudospectral radius and its expansion as a function of epsilon. We end this thesis with propositions for further directions of study.

Ehrhart Theory and an Explicit Version of Khovanskii's Theorem
Michael Joseph Curran

An incredible result in arithmetic combinatorics due to Khovanskii asserts that given a finite subset A of any abelian group, the sumset hA obtained by taking all sums of exactly h elements of A has cardinality that grows polynomially for sufficiently large h. However, in general little is known about the polynomial or what sufficiently large means. In the case when A consists of d-tuples of integers, we obtain bounds on "sufficiently large" in Khovanskii's theorem whenever the convex hull of A is a simplex. We also find explicit formulas for |hA| whenever A is a set of d tuples of integers containing d + 2 elements, which imply that our bounds are essentially the best possible.

Point Process Convergence and the Circular Beta Ensemble
Eli Cytrynbaum

In this thesis, we explore point processes and their various types of convergence. In particular, we investigate the circular beta ensemble and its convergence to limiting states both in terms of matrix models and the associated eigenvalue point processes. We consider these limits as the coefficient β converges to zero or infinity with the eventual goal of quantifying this rate of convergence. In addition to creating a rigorous compilation of related theory, we construct several families of point processes with the same limits as the circular beta ensemble as well as new matrix models for the ensemble.

Using Modified Rauzy-Veech Induction to Relate Interval Exchange Maps and Continued Fractions
Akhil Dayal

The relationship between Traditional Continued Fractions and Interval Exchange Maps is known. This thesis will lay out a brief framework for variations on Traditional Continued Fractions, as well as a framework for Interval Exchange Maps, then link how to use a process called Rauzy-Veech induction to relate interval exchange maps to variations on the Traditional Continued Fraction factoring algorithms in both two and three dimensions. From here, using a similar framework, we will relate the variations of Continued Fraction algorithms to the renormalization process of cutting sequences in two dimensions.

Control Strategies for Invasive Grass Carp and the Dynamics of Ecosystem Federalism
Nicholas Goldrosen

This paper uses mathematical modelling to study harvesting strategies for invasive fish species control across multiple jurisdictions. After introducing background on invasive Asian carp species in the United States, management techniques, and ecosystem federalism, I examine general population dynamics of the grass carp using an age-structured, continuous- time differential equation model. I study and simulate harvesting control strategies across spatially homogeneous and heterogeneous jurisdictions. I ultimately find that dispersal and relative fitness of habitats between jurisdictions are immensely important factors in determining ideal management strategies between multiple resource managers. These results highlight that ecological factors such as dispersal levels between adjacent jurisdictions do not just determine the ecological management response, but can also predict and highlight political needs for cooperation or higher-level coordination between jurisdictions.

Invariant Measures and Transfer Operators for Continued Fraction (TRIP) Maps
Konnor Herbst

The dynamical behavior of the Classical Continued Fraction Map, the Gauss map, is well known. The invariant measure associated with the Gauss Map, the Gauss measure, has been known since the 18th century. The Gauss measure was used to show that the Gauss map is Ergodic, a result that is loosely related to the idea of the Gauss Map "mixing up" the unit interval in an even way. In this thesis I will lay out a brief framework for 7 new permutations of the Gauss map, dubbed the TRIP framework. From there I will explain how these new continued fraction maps are built from the much simpler Farey maps and prove results about the invariant measures of each new map. Lastly I will prove some preliminary results about the relationship between the Transfer operators for these TRIP maps.

Modeling Developmental Synchrony in Multiple Cicada Populations
Geunho Kye

Periodical cicadas are unique organisms. Large collections of same-age individuals, known as broods, occupy vast spatial areas underground, before synchronously emerging from the ground every 17 years. The exact cause of this synchronization remains unknown: previous studies have focused on the impacts of predator-driven Allee-effects, competition among nymphs, and off-synchronized emergence events on this phenomenon. Here we develop a nonlinear Leslie-type matrix model to study cicada movement between spatially separated broods, and its role in developing the kind of population density and spatial equilibrium that we see in nature.

Asymptotic Formulas for Mean Values of Multiplicative Functions
Ben Logsdon

In this thesis, we give asymptotic formulas for the mean values of complex-valued multiplicative functions with sufficiently small values, including all such functions with values in the unit disc. We also give necessary and sufficient conditions for the convergence of a function's finite means to an asymptotic mean. Finally, we state and prove some theorems of Elliott.

Boats Bases and Bijectivity: An Exploration of Continued Fractions and Their Manifestations
Jacob Pesikoff

This thesis begins with an introduction to continued fractions. It will then draw inspiration from the preprint \textit{-Farey Boat: Continued Fractions and Triangulations, Modular Group and Polygon Dissections} written by Sophie Morier-Genoud and Valentin Ovsienko \cite{boat}. Using eight variations of continued fractions, two of which are in the preprint and six that were more recently discovered, we will explain how to create and deconstruct boats, which are fully triangulated polygons subject to additional restrictions. Through processes that will be well-defined, boats will be shown to be unique for given fractions. From this result, we will discuss various ways or representing boats, such as through knots, snake graphs, and cutting sequences, as well as how boats relate to the fairly new subject of cluster algebras. We will conclude with practical applications of these concepts, as well as opportunities for future discovery.

Exploring Variable Importance with Stacked Models
Dzung Viet Pham

Variable importance (VI) is an essential statistical analysis tool for understanding how a variable can contribute to a model's prediction of a response. Using VI from only one model, however, can sometimes be misleading or even incorrect, regardless of the model's prediction performance. If two equally competitive models disagree on which variable is more important, which model is to be trusted? This thesis investigates the use of stacked importance -- VI from stacked models -- as a way to handle such Rashomon effect. By stacking multiple models to produce a potentially superior prediction model, we hypothesize that the resulting VI can help mitigate the Rashomon effect. To verify this, we conducted a simulation study using permutation importance and Sobol indices and found that with proper care when building the ensemble for stacking, stacked importance can show more accuracy and stability compared to VI from any individual model.

Copula-Based Measures of Dependence for Ordinal Data Using Latent Distributions

Jacob Shuman

Perhaps the most fundamental task of multivariate statistical inference is to understand and quantify the dependence between random variables. This process is considerably more challenging in the case of non-continuous data that violate the underlying assumptions of dependence tests as fundamental as Pearson correlation. The polychoric correlation coefficient (PCC) provides a method to infer Pearson correlation from a contingency table under the assumption of latent bivariate normality. Given that samples (and their underlying populations) may violate this assumption in practice, we evaluate the robustness of this estimator through simulation. We show that the PCC is quite robust to a number of non-normal families of joint distributions, or copulas. We then show how a generalization of the PCC can be used to reliably infer copula parameters from a contingency table, allowing for the investigation of dependence measures besides Pearson correlation. Finally, we evaluate a number of extensions of this method to the case of mixed ordinal-continuous samples.

Completions of Uncountable Local Rings with Countable Spectra

Teresa Yu

We characterize complete local (Noetherian) rings that are the completion of an uncountable local domain with a countable spectrum. Our results suggest that uncountable local domains with countable spectra are more common than previously thought. We also characterize complete local rings containing the rationals that are the completion of an uncountable excellent local domain with a countable spectrum, complete local rings that are the completion of an uncountable local unique factorization domain (UFD) with a countable spectrum, complete local rings that are the completion of an uncountable noncatenary local domain with a countable spectrum, and complete local rings that are the completion of an uncountable noncatenary local UFD with a countable spectrum. Along the way, we characterize complete local rings containing the rationals that are the completion of a countable excellent local domain, complete local rings that are the completion of a countable noncatenary local domain, and complete local rings that are the completion of a countable noncatenary local UFD.

Physics

Debiasing RNA-seq and Ribosome Profiling Data

Qiyuan Hu

RNA-seq and ribosome profiling reveal the details of transcription and translation. This thesis presents our work in removing biases in existing RNA-seq and ribosome profiling protocols to more accurately understand the kinetics of gene expression. First, we show how RNA-seq count data appears non-uniform with some methods of averaging because shorter genes in our datasets typically have much higher counts than longer ones. We also show that RNA-seq count distributions are largely uniform in short genes, while counts are accumulated near the start site of the coding region of long genes.

Ultrafast, Ultrasmall, Ultrathin: Nanoemitter Sources and Graphite Samples for Ultrafast Electron Diffraction

Heather Kurtz

This thesis describes developments for a medium-energy ultrafast electron diffraction experiment to be used for the study of dynamic processes in two-dimensional materials such as graphene and transition metal dichalcogenides. First, we present work on the manufacturing of tungsten nanoemitter electron sources through electrochemical etching. We have successfully developed a method for consistently producing tips with apex radii of curvature below 100 nm. We then discuss electron emission from tungsten tips, explaining how the distribution of electrons on the detector can be mapped back to the nanoemitter to estimate the surface emission distribution. Finally, we detail our progress in the production of thin graphite samples and their subsequent transfer onto transmission electron microscopy supports for installation in the vacuum chamber. Sample thickness is characterized through optical and atomic force microscopy. These methods will inform continued work on graphene and other two-dimensional materials.

→Jacob Lezberg

We have begun the process of precisely measuring the 732 nm 42S1/2 → 32D3/2 E2 transition isotope shifts between 40Ca+ and 42Ca+, 44Ca+, and 48Ca+. Our goal is sub 1-Hz precision for the frequency measurements, which would amount to multiple orders of magnitude improvement over existing results. These data will be able to provide bounds on the possible characteristics of physics beyond the Standard Model, such as a new boson that has been theorized to exist.

In this undertaking, we have constructed a new infrared diode laser and installed the associated optics, in addition to setting up a state preparation laser to achieve a better signal-to-noise ratio. We also measured the free spectral range of our ultra-low expansion Fabry-Perot etalon to a precision of 1 part per billion, which is a critical intermediate step to converting our 729 nm laser to be able to address the 732 nm transition. Last but not least, we implemented a number of improvements to equipment in the lab, including automated positioning of the fluorescence detection apparatus, more accurate calibration of the 10 MHz frequency reference, and magnetic field stabilization inside the vacuum chamber.

On the Contact Mechanics of Soft Silicone Microspheres

Edgar Lyons

This thesis explores the physics of gel microsphere adhesion and moves towards modeling rough adhesion on a larger scale. We construct experiments to bring gel microspheres into contact with glass substrates and photograph the results. We analyze these images and, from them, calculate physically relevant parameters. These data are compared to the TEA model of Thomas Salez et al., and —finding that this model is inadequate— used to motivate future theory development.

Atomic Beam Spectroscopy and Polarizability Measurements in Pb Using Faraday Polarimetry

Abdullah Nasir

We have made progress towards the precise measurement of the lead (6s2 6p2) 3P1 → (6p7s) 3P0 electric dipole (E1) polarizability using Faraday rotation polarimetry in an atomic beam. The atomic beam unit consists of a refurbished and reassembled furnace housed inside a vacuum chamber, perpendicular to which we have aligned a 1279 nm infrared laser through a newly constructed optical rotation polarimetry setup. The apparatus has been tested and can resolve optical rotations as low as 0.51 rad/ √Hz. Furthermore, we have assembled a 368 nm UV laser system by cooling a commercially bought 369 nm laser diode, and have

tested it by conducting a saturated absorption measurement on the E1 line. In addition to experimental work, we have developed a theoretical understanding of the scalar and tensor polarizabilities of 207Pb and 208Pb through various simulations. With continued testing of the atomic beam furnace and renements of the polarimetry apparatus, we hope to observe, for the very first time in an atomic beam, the (6s26p2) 3P0 —> 3P1 magnetic dipole (M1) transition. We will eventually lock the 1279 nm laser to the M1 transition and incorporate it in a two-step excitation experiment with the aforementioned E1 transition, leading up to a measurement of the atomic polarizability through the Stark shift.

Optimal Measurements for Bell Inequalities in Arbitrary Number of Dimensions

Mariam Ughrelidze

We have reformulated the Collins, Gisin, Linden, Massar, Popescu (CGLMP) inequality, a general Bell inequality for d-dimensional systems, purely in terms of matrix operators. Using these operators, we have analyzed, via numerical and analytic methods, the optimality of the measurements found in the literature for the Bell type experiments. We numerically demonstrated that these measurements are optimal under general perturbations. We analytically showed optimality under diagonal perturbations. We are working on optimality under off-diagonal perturbations. Our analytic and numerical results help shed light on the structure of the CGLMP inequality and guide future work to detect entanglement in high-dimensional systems.

Psychology

The Song Exploder Effect: When Learning Leads to Love

Marissa Anderson

Research on people's behavior in regards to seeking or avoiding information is inconsistent. Information such as movie spoilers or behind the scenes information are controversial. The current research aims to determine if learning leads to increased liking. Participants completed surveys measuring their intuitions about how learning information would affect their aesthetic experience. Generally people anticipated that learning the information would increase their liking, but a sizable majority said the opposite. Two more studies were conducted that experimentally measured the how information affects liking using a podcast, Song Exploder, where an artist takes apart their song piece by piece and tells the story of how it was made, and measuring how that podcast affected liking of the song it discussed. It was determined that listening to a Song Exploder podcast increased liking of the song discussed in the podcast due to a social connection that the listener felt with the artist. Results could be used to help artists build a stronger following and to help shape advertising techniques. Future research could test how strong the effect is across all songs by the same artist and if the same effect could be produced by a shorter podcast.

Examining Empathy and the Social Transmission of Emotions in Sprague Dawley Rats

Gabriella Bal

Empathy is often defined as one's ability to not only recognize, but to understand another individual's thoughts, feelings, emotions, or psychological state (Steuber, 2013). While this phenomenon can be observed in human beings, recent studies have shown that many other species can also share emotional states in a variety of situations. In several situations involving images of a predator or a non-threatening animal, rhesus macaques and several other non-human primates have been shown to act empathetically towards other individuals in order to alert them to the possible danger (Cheney and Seyfarth, 1990). Moreover, empathetic behaviors have even been observed in birds, such as ravens, who could recognize certain negative facial expressions in pictures of other birds, and proceed to act in a more negative manner than birds who were shown pictures of birds with positive facial expressions (Nakahashi and Ohtsuki, 2018; Adriaense et al., 2019). Recently, a paper was published that detailed a new paradigm that allowed an observer rodent to witness a demonstrator rodent receive several mild electrical foot-shocks, and then record the subsequent behaviors of the observer animal (Carrillo et. al, 2019). Based on their behavioral results, the researchers determined that the observer Sprague Dawley rats were indeed capable of mounting an empathetic response to the shocked demonstrator, in the form of reciprocated freezing behaviors. When rodents are frightened, they often display a defensive behavior in which they freeze. Therefore, the hypothesis was that if the observer was able to mount an empathetic response when witnessing the demonstrator being shocked, then both groups of animals should increase the amount of time that they spent freezing. After finding support for this behavioral phenomenon, the researchers attempted to elucidate the neural mechanisms of empathy, and isolated a specific region of cells in the anterior cingulate cortex (ACC) that may act as mirror neurons, allowing an observing animal to respond to the emotions or behaviors of another animal (Carrillo et al., 2019). Even though the previous study did identify these neurons, much more research is needed to determine whether these cells are necessary and sufficient to produce empathetic behaviors. The current study aimed to confirm the presence of empathy in Sprague Dawley rats. In order to do so, two experiments were performed, the first of which examined the freezing behaviors of 40 rats who were split into observer-demonstrator pair-housed dyads. After one day of habituation, the rats underwent a test trial in which the demonstrators received several mild foot-shocks, and the freezing behaviors of both animals were recorded using AnyMaze tracking technology. The second experiment extended the habituation period to four days, and added a non-shock control group in which the demonstrators did not receive the foot-shocks on the test day. In addition, immunohistochemical testing was done on the brain tissue of the animals from the second experiment in an attempt to identify the neurons that were responsive to this particular experience. Overall, it was determined that the observers did increase their freezing behaviors during the shock period, however, this increase was less significant than the increase seen in the demonstrators, and this increase did not persist through the minutes after the foot-shocks, whereas the demonstrators remained frozen throughout this post-shock period. Therefore, it seems likely that the rats were able to act empathetically to the demonstrators' pain responses, but not to their fear responses. Moreover, the histological data did not reveal any significant correlations between freezing behaviors

and neuronal activity, however, factors outside of the experimenter's control (the Covid-19 pandemic) may have affected these results. Much more research is needed to confirm the presence and nuances of empathy in rodents, especially rats. Further, many other factors including sex differences, conspecific familiarity, previous exposure to foot-shocks, and length of habituation likely play a role in the expression of empathy in these animals, suggesting that many other future studies are necessary to discover the true nature of this fascinating phenomenon. Since empathy is also present in humans, studies like this will likely have major impacts on the development of treatments for humans with disorders characterized by dysfunctional empathetic abilities such as Autism Spectrum Disorder and Antisocial Personality Disorder and Schizophrenia (Lombardo et al., 2007; Henrik, 2003; Haker and Rössler, 2009).

Defining and Predicting Moral Inconsistency

Stephanie Brown

Moral judgments are highly consequential, influencing the way we structure our everyday choices and our societies. Yet, previous research has demonstrated that people's moral judgments can be influenced by a variety of seemingly morally irrelevant factors such as order bias, emotionality of the question, and language in which the question is asked. My goal in the present work was to develop a novel measure of the extent to which people exhibit moral inconsistency in their judgments, either by providing different answers to moral dilemmas that invoke similar moral principles or by providing different answers to the same problem at different time points. In five studies that included the moral judgments over 1672 participants, I had participants complete a set of moral dilemmas and calculated a measure of the extent to which they provided different answers across them, assessing its psychometric properties such as its normality and reliability. I also sought, across these studies, to explore the relationship between this novel measure and a variety of other traits, such as empathy, rationality, and intuition. Although the measure exhibited good psychometric properties, none of the individual differences measures I collected appeared to correlate with the measure, despite their well-established relevance for moral judgment in the literature. I discuss the implications of these findings for theories of moral judgment.

Auditory Hindsight Bias and the Role of Top-Down Processing in Music Perception

Yeojin (Julia) Choi

Previous research on auditory hindsight bias has focused on auditory perception and judgment in the context of speech. In this study, we focused on a more complex auditory stimuli: music. We investigated the participants' perception and recognition of 4 sec song excerpts paired with white noise, chosen for their most highly recognizable parts. Each excerpt was repeated eleven times, and with each repetition, the volume of white noise decreased so that the excerpt gradually became clearer. Participants listened to the excerpts in two phases. During the first phase, they were instructed to press a button when they recognized the song, whereas during the second phase, they were instructed to press a button at the moment when they first recognized the song in the previous phase. Results showed that participants exhibited auditory hindsight bias by believing they had recognized the songs at an earlier time than was actually the case. We propose that participants' outcome knowledge and expectation of the identity of the songs triggered top-down processing that filled in missing auditory cues, leading them to believe they were hearing the songs more clearly. As a result, participants showed hindsight bias, overestimating their naive song identification performance.

Changes in Heart Rate Variability Following Concussion: Assessment of HRV Fingerprinting

Tristan Colaizzi

The present study aims to fill a gap in the growing body of SRC monitoring and diagnostic research by investigating a novel method called heart rate variability (HRV) fingerprinting. HRV fingerprinting is designed to provide objective, non-invasive, and accessible concussion diagnosis and monitoring through the use of a wrist-based heart rate (HR) monitor. By controlling for variables that affect HRV we hypothesized that we would be able to accurately predict HRV in a non-injured individual, that we would overpredict HRV in concussed individuals, and that the difference between predicted HRV and observed HRV would narrow as the individual recovers from concussion in a manner consistent with other clinical measures that are currently used to assess recovery. We found that we were able to successfully generate a model to predict HRV in non-concussed individuals using HRV fingerprinting. We overpredicted HRV in some concussed individuals but not others and were unable to compare the difference between predicted and observed HRV due to a small sample of concussed individuals. Our findings support the hy-

pothesis that HRV fingerprinting may be a promising tool for the objective diagnosis and monitoring of concussion. Further research, focused on collected large amounts of healthy and concussed data in a within-subject design, is needed to confirm this hypothesis.

Racial Bias and Letters of Recommendation: The Effects of Threat and "Little Red Flags"

Sean Fontellio

Racial biases, especially those displayed in more covert ways are certainly still prevalent in our society. Through several studies involving small hedges in letters of recommendation, this paper seeks to analyze the findings regarding individual's rating of participants for a lab position with race and identity threat as the main factors in conjunction with the presence of our "little red flag." Our first study looked at whether or not there was a main effect between the letters of recommendation themselves according to the participants. We needed to ensure that when the subject's identity is threatened and the race of the participant is black, the presence of subtle hedges within a sample letter of recommendation for a research candidate has impactful results on their approval rating. Study 2 examined 8 conditions in hopes of discovering a main effects across all dimensions that were qualified by a three-way interaction between the race of the "applicant," the presence of a few hedges in a letter of recommendation (or lack thereof), and whether or not the participants' identity was threatened through use of a demographic shift article backed by research done by Madera. Both these studies confirmed our assumptions through main effects and a three-way interaction. Further studies are to be explored.

The Implicit Stench of Guilt: The Influence of Visual Cues and Evidence on Implicit Associations of Guilt

Krystal Hahn

The present research aims to explore the role of implicit associations of guilt in mock jurors' decisions. Implicit cognition has been shown to occur spontaneously and unintentionally, potentially capturing what is overlooked in its explicit counterpart. In 4 studies, I investigate the importance of visual cues present in a defendant's facial appearance, such as race or perceived trustworthiness, and evidence presented in a court case that either implicates or exonerates the defendant. Using the Stereotype Misperception Task (SMT), Study 1 establishes that trustworthiness cues influence implicit guilt associations, while race cues surprisingly do not (Study 2). Study 3 replicates these findings, suggesting trustworthiness cues even swamp out race cues. Study 4 confirms the importance of evidence for the formation of explicit guilt judgments, as well as the updating of implicit guilt judgments. I also discuss the implications of these findings, especially in the interest of practical application in the legal system.

Early Adversity and Internalizing Psychopathology: The Moderating Effects of Emotion Regulation Among Young Adult Women

Chloe Kaplan

Theory and research indicate that exposure to early adversity (i.e., early life stress) can affect emotion regulation, a process by which individuals influence what emotions they have, when they have them, and how they experience and express them. When emotion regulation is compromised early in development by exposure to early adversity, research has consistently documented difficulties in the ability to regulate emotions adaptively, making one more vulnerable to the later development of psychopathology. Although prior work has explored many of these links in different ways, multiple indices of emotion regulation, considered separately and together, have yet to be examined as moderators of the relationship between early adversity and different profiles of internalizing psychopathology. The present study sought to address this gap by investigating three types of emotion regulation – cognitive reappraisal, emotion suppression, and emotional reactivity – as potential risk or protective factors for depressive and anxiety symptoms following early adversity. In a one-year longitudinal study, 91 female-identifying college students (M = 20.62 years, SD = .70 years) completed objective contextual early adversity interviews, semi-structured diagnostic interviews, and two self-report measures of emotion regulation: the emotion regulation questionnaire (ERQ; Gross & John, 2003) and the emotional reactivity scale (ERS; Nock & Holmberg, 2008). Results indicated that greater early adversity predicted increases in both depressive and anxiety symptoms at the one-year follow-up (T2). Although only limited associations were found between early adversity and emotion regulation, and between emotion regulation and psychopathology, cognitive reappraisal moderated the relationship between early adversity and T2 depressive symptoms, and emotion suppression and emotional reactivity each moderated the relationship between early adversity and T2 anxiety symptoms. These findings suggest that individual differences in emotion

regulation are essential factors to consider when determining who, and under which circumstances, are most at risk to developing psychopathology. Specifically, for women with a history of early adversity, the results identified suppression and reactivity as risk factors, and reappraisal as a protective factor against depression and anxiety. Future directions for research and clinical implications for early intervention are discussed.

Early Adversity and Internalizing Psychopathology: Investigating the Role of Interpersonal Functioning

Sarah Kelly

Research and theory indicate that experiencing severe forms of early adversity (i.e., early life stress) is related to higher levels of internalizing psychopathology among young adult female-identifying participants. Early adversity has also been associated with maladaptive interpersonal behaviors, specifically excessive reassurance seeking and co-rumination, as seen through attachment theory (e.g. Lam et al., 1996; Cassidy & Shaver, 1999; Mikulincer & Shaver, 2003; Hankin, Stone, & Wright, 2010). However, prior work has not examined whether maladaptive interpersonal behaviors affect the relationship between early adversity and internalizing psychopathology. The present study examined whether interpersonal functions (excessive reassurance seeking and co-rumination) moderated the relationship between early adversity and internalizing psychopathology across three conceptualizations of early adversity: total severity, frequency, and variety. Internalizing psychopathology was also broken down into three metrics: depressive symptoms, anxiety symptoms, and internalizing symptoms. This study was longitudinal and was completed over the course of a year. Participants comprised 91 college-aged women (Mage = 20.62). Multiple hierarchical regression analyses were used to test study predictions. Results indicated that greater co-rumination predicted increases in subsequent depressive, anxiety, and internalizing symptoms, regardless of history of early adversity. Additionally, co-rumination, but not excessive reassurance seeking, was found to significantly moderate the relationship between early adversity and depressive symptoms. Consistent with previous literature, greater variety and a higher frequency of early adversity predicted increases in depressive symptoms (at trend level). These results suggest that co-rumination is a significant risk factor for the development of internalizing psychopathology, both alone and in the face of a history of early adversity. Further examination of the effect of co-rumination on the link between early adversity and depressive, anxiety, and internalizing symptoms across multiple ages and genders is warranted.

Change We Want to Believe In: The Motivated Incorporation and Rejection of Evidence into Implicit Social Impressions

Alexandra Medeiros

Theories of implicit cognition propose that although explicitly (i.e. intentionally) we are influenced by our motivated beliefs, we may not be implicitly (i.e., unintentionally) because this level of cognition does not allow for deliberate processes such as motivation. However, recent work has suggested that believability matters both implicitly and explicitly, so the question is: if believability matters implicitly, then shouldn't motivation to believer matter too? The current work investigates whether motivations to (dis)believe a novel story or scientific evidence can influence whether people view the information as truthful, even at the implicit level. In 6 studies (N=1700+), participants motivated beliefs were manipulated using political partisanship, health-related threats, and personal incentives. Using three different implicit measures, we assessed participants' implicit beliefs and evaluations about the study target. Results indicated that motivated reasoning did not influence implicit beliefs, however these results suggest that attempts at motivation may have been unsuccessful and the novel Truth Misattribution Procedure (TMP) may have been unreliable.

Exploring Liraglutide as a Possible Treatment for Oxycodone Addiction and Relapse

Carl Porto

There are currently few successful interventions for the treatment of opioid abuse disorder and relapse despite a growing understanding of the neurobiological underpinnings to addiction. Similarities in the behavioral and neurobiological mechanisms of drug addiction and obesity suggest that treatments for obesity may be useful in the treatment of substance dependence. For example, glucagon-like peptide-1 (GLP-1) receptor agonists, such as liraglutide, has been shown to reduce both food intake and reduce drug intake. Here, the effect of liraglutide on oxycodone self-administration was examined in male and female Sprague Dawley rats. Eight (n = 3 males; Experiment 1) rats received 50 µg/kg and 250 µg/kg intraperitoneal liraglutide injections while another cohort of fourteen (n = 8 males,

Experiment 2) received 50 µg/kg and 200 µg/kg subcutaneous liraglutide injections to study the effects of low dose liraglutide on acute oxycodone abuse. While none of these doses significantly attenuated daily oxycodone self-administration, they revealed that low-dose liraglutide does not affect food consumption or body weight. Importantly, Experiment 2 rats and a separate cohort of eleven rats (n= 5 males; Experiment 3) underwent relapse testing in the presence of 1000 µg/kg and 500 µg/kg subcutaneous liraglutide injections, respectively, both of which were effective at reducing relapse behavior when compared to results from the same tests without liraglutide exposure (ps < 0.019). At these high doses generalized malaise associated with liraglutide use may have influenced behavior, but activation of a ventral hippocampus to medial prefrontal cortex circuit shown to be stimulated by GLP-1 and to improve impulse control may also play a crucial role. These results provide strong evidence suggesting that liraglutide can treat opioid abuse disorder, and further research should continue to explore the effective doses for attenuating acute drug taking and relapse while avoiding gastrointestinal malaise.

Does language help children invent?

Whitney Sandford

The ability to invent, or produce novel creations to solve problems, is a defining attribute of the human species, and one that has facilitated extensive cultural and technological progress. In addition to inventions often being highly useful, the mental process of inventing is considered valuable because it teaches an individual to recognize problems and generate ideas. Early forms of invention can be seen in children from a young age, as they solve everyday problems and create imaginary scenarios during play. However, empirical studies, which have, until now, typically tasked subjects with bending a pipe cleaner into a hook to retrieve a basket from a narrow tube, indicate that children struggle to invent until they are 8 years old. In response to these findings, we propose that this existing experimental paradigm lacks the generative quality of true invention and, therefore, may fail to capture young children's potential as resourceful inventors. Additionally, we suspect that children's use of metacognitive language may be related to their ability to invent. Invention, which has been termed an "ill-defined problem", requires considerable mental coordination on the part of the child. Metacognitive language may aid children in inventing because it offers a way to organize and evaluate one's thoughts and behaviors. Thus, we hypothesize that priming young children to use metacognitive language may help them become better inventors. In the present study, we designed an open-ended, playful, and narrative-based task in which 4- to 6-year-old subjects were invited to make two inventions to help toy characters cross a river. While working on their first invention, half of all subjects were primed with metacognitive language. The results show that 4- to 6-year-old children are capable of invention, as all subjects successfully completed the task. Further, subjects who were primed with metacognitive language were significantly more likely to use metacognitive language themselves and create stronger inventions during the second portion of the activity. Overall, our findings suggest that children's ability to invent is situationally influenced, and that one can foster young children's invention both by changing the context in which it occurs and by priming children with metacognitive language.

Effects of Moral Credentialing on the Ambiguous Context Task

Daiana Takashima

The current study investigated whether manipulations of moral credentials and self-affirmation could help buffer the anxiety some individuals feel concerning interracial interactions. Specifically, this study extended previous findings by applying these manipulations in an ambiguous negative intergroup context (ACT). Study 1 (N = 193) found that participants who completed the Motivation to Respond Without Prejudice Scale were more likely to recognize race during the ACT. Study 2 (N = 180) did not find a significant effect to rule out a race saliency alternative explanation of the results from Study 1. Study 3 (N = 269) demonstrated that participants who established their moral credentials were more likely to mention race and conflict during the ACT, while also providing evidence against the explanation that priming race was the cause for the increase in acknowledging race in Study 1. Study 4 (N = 366) examined the effects of traditional and new affirmation procedures on the rate of mentioning race in the ACT, and the results were not of significance. These studies extend previous findings to demonstrate for the first time that establishing one's moral credentials can lead to increased acknowledgement of race and conflict in the novel ambiguous intergroup context. Limitations of the current study as well as potential future applications are discussed.

PUBLICATIONS

Astronomy

Measuring Turbulent Motion in Planet-Forming Disks with ALMA

Flaherty, K., Hughes, A.M., Simon, J.B. Qi, C., Bai, X.-N., Bulatek, A., Andrews, S.M., Wilner, D.J., Kóspál, Á.

The Astrophysical Journal, 895, 2, 109

Turbulence is a crucial factor in many models of planet formation, but it has only been directly constrained among a small number of planet-forming disks. Building on the upper limits on turbulence placed in disks around HD 163296 and TW Hya, we present ALMA CO J=2-1 line observations at ~0.3" (20-50 au) resolution and 80 m/s channel spacing of the disks around DM Tau, MWC 480, and V4046 Sgr. Using parametric models of disk structure, we robustly detect nonthermal gas motions around DM Tau of between 0.25cs and 0.33cs, with the range dominated by systematic effects, making this one of the only systems with directly measured nonzero turbulence. Using the same methodology, we place stringent upper limits on the nonthermal gas motion around MWC 480 (<0.08 cs) and V4046 Sgr (<0.12cs). The preponderance of upper limits in this small sample and the modest turbulence levels consistent with dust studies suggest that weak turbulence (α<10-3) may be a common, albeit not universal, feature of planet-forming disks. We explore the particular physical conditions around DM Tau that could lead this system to be more turbulent than the others.

From Scattered-light to Millimeter Emission: A Comprehensive View of the Gigayear-old System of HD 202628 and its Eccentric Debris Ring

Faramaz, V., Krist, J., Stapelfeldt, K.R., Bryden, G., Mamajek, E.E., Matra, L., Booth, M., Flaherty, K., Hales, A.S., Hughes, A.M., Bayo, A., Casassus, S., Cuadra, J., Olofsson, J., Su, K.Y.L., Wilner D.J.

The Astronomical Journal, 2019, 158, 4, 162

We present here new observations of the eccentric debris disk ring surrounding the Gyr-old solar-type star HD 202628: at millimeter wavelengths with ALMA, at far-infrared wavelengths with Herschel, and in scattered light with the Hubble Space Telescope (HST). The ring inner edge is found to be consistent between ALMA and HST data. As radiation pressure affects small grains seen in scattered-light, the ring appears broader at optical than at millimeter wavelengths. The best fit to the ring seen with ALMA has inner and outer edges at 143.1 ± 1.7 au and 165.5 ± 1.4, respectively, and an inclination of 57.4 ± 0.4 from face-on. The offset of the ring center of symmetry from the star allows us to quantify its eccentricity to be e=0.09+0.02-0.01. This eccentric feature is also detected in low resolution Herschel/PACS observations, under the form of a pericenter-glow. Combining the infrared and millimeter photometry, we retrieve a disk grain size distribution index of ~-3.4, and therefore exclude in situ formation of the inferred belt-shaping perturber, for which we provide new dynamical constraints. Finally, ALMA images show four point-like sources that exceed 100 μJy, one of them being just interior to the ring. Although the presence of a background object cannot be excluded, we cannot exclude either that this source is circumplanetary material surrounding the belt-shaper, in which case degeneracies between its mass and orbital parameters could be lifted, allowing us to fully characterize such a distant planet in this mass and age regime for the very first time.

Modeling the Spatial Distribution and Origin of CO gas in Debris Disks

Hales, A.S., Gorti, U., Carpenter, J.M., Hughes, A.M., Flaherty, K.M.

The Astrophysical Journal, 2019, 878, 2, 113

The detection of gas in debris disks raises the question of whether this gas is a remnant from the primordial protoplanetary phase, or released by the collision of secondary bodies. In this paper we reanalyze ALMA observations at 1"-1.5" resolution of three debris disks where the 12CO(2-1) rotational line was detected: HD 131835, HD 138813, and HD 156623. We apply the iterative Lucy-Richardson deconvolution technique to the problem of circumstellar disks to derive disk geometries and surface brightness distributions of the gas. The derived disk parameters are used as input for thermochemical models to test both primordial and cometary scenarios for the origin of the gas.

We favor a secondary origin for the gas in these disks and find that the CO gas masses (~3x10-3 Mearth) require production rates (~5x10-7 Mearth/yr) similar to those estimated for the bona fide gas-rich debris disk beta Pic.

The Semi-forbidden C III] λ1909Å Emission in the Rest-Ultraviolet Spectra of Green Pea Galaxies

Ravindranath, Swara, TalaWanda Monroe, Anne Jaskot, Henry C. Ferguson, and Jason Tumlinson

The Astrophysical Journal, accepted for publication, arXiv:2005.05399, 2020

We used the Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope (HST) to observe the semi-forbidden CIII] emission in Green Pea galaxies at 0.13 < z < 0.3. We detect CIII] emission in 7/10 galaxies with CIII] equivalent widths that range from 2-10Å. The observed CIII] emission line strengths are consistent with the predictions from photoionization models which incorporate the effects of binary stellar evolution with young stellar ages < 3-5 Myrs, and high ionization parameters (logU > -2). The hard ionizing radiation from young massive stars, and high nebular temperatures at low-metallicities can account for the observed high equivalent widths of CIII] and [OIII] emission lines. The Green Pea galaxies do not show a significant correlation between the Lyα and CIII] equivalent widths, and the observed scatter is likely due to the variations in the optical depth of Lyα to the neutral gas. Green Pea galaxies are likely to be density-bounded, and we examined the dependence of CIII] emission on the Lyman continuum optical depth. The potential LyC leaker galaxies in our sample have high CIII] equivalent widths that can only be reproduced by starburst ages as young as < 3 Myrs and harder ionizing spectra than the non-leakers. Among the galaxies with similar metallicities and ionization parameters, the CIII] equivalent width appears to be stronger for those with higher optical depth to LyC, as expected from the photoionization models. Further investigation of a larger sample of CIII]-emitters is necessary to calibrate the dependence of CIII] emission on the escape of LyC radiation, and to enable application of the CIII] diagnostics to galaxies in the reionization epoch.

Chemodynamics of green pea galaxies - I. Outflows and turbulence driving the escape of ionizing photons and chemical enrichment

Hogarth, Lucy, Ricardo Amorín, José M. Vílchez, Guillermo F. Hägele, Monica Cardaci, Enrique Pérez-Montero, Veronica Firpo, Anne Jaskot, and Ricardo Chávez

Monthly Notices of the Royal Astronomical Society, 494, 3541, 2020

We investigate the ionized gas kinematics, physical properties, and chemical abundances of Sloan Digital Sky Survey J142947, a Green Pea galaxy at redshift z~ 0.17 with strong, double-peak Lyα emission and indirect evidence of Lyman continuum (LyC) leakage. Using high-dispersion spectroscopy, we perform a multicomponent analysis of emission-line profiles. Our model consistently fits all lines as a narrow component with intrinsic velocity dispersion σ ~ 40 km s-1, and two broader blue-shifted components with σ ~ 90 and ~ 250 km s-1. We find electron densities and temperatures, ionization conditions, and direct O/H and N/O abundances for each component. A highly ionized, metal-poor, young and compact starburst dominates narrow emission, showing evidence of hard radiation fields and elevated N/O. The blue-shifted broader components are consistent with highly turbulent, possibly clumpy ionized gas at the base of a strong photoionized outflow, which accounts for ≳50 per cent of the integrated emission-line fluxes. The outflow is dense and metal-enriched compared to the H ii regions, with expansion velocities larger than those obtained from UV interstellar absorption lines under standard assumptions. Some of these metals may be able to escape, with outflows loading factors comparable to those found in high-z galaxies of similar SFR/Area. Our findings depict a two-stage starburst picture; hard radiation fields from young star clusters illuminate a turbulent and clumpy ISM that has been eroded by SNe feedback. Whilst UV data suggest an extended Lyα halo with high average H I column density, LyC photons could only escape from SDSS J142947 through low H I density channels or filaments in the ISM approaching density-bounded conditions, traced by outflowing gas.

HST Imaging of the Ionizing Radiation from a Star-forming Galaxy at z = 3.794

Ji, Zhiyuan, Mauro Giavalisco, Eros Vanzella, Brian Siana, Laura Pentericci, Anne Jaskot, Teng Liu, Mario Nonino, Henry C. Ferguson, Marco Castellano, Filippo Mannucci, Daniel Schaerer, Johan Peter Uldall Fynbo, Casey Papovich, Adam C. Carnall, Ricardo Amorín, Raymond C. Simons, Nimish Hathi, Fergus Cullen, and Derek McLeod

The Astrophysical Journal, 888, 109, 2020

We report on the Hubble Space Telescope (HST) detection of the Lyman-continuum (LyC) radiation emitted by

a galaxy at redshift z = 3.794 dubbed Ion1. The LyC from Ion1 is detected at 820−890 Å with HST WFC3/UVIS in the F410M band (m410 = 27.60 ± 0.36 mAB, peak signal-to-noise ratio (S/N) = 4.17 in an r = 0".12 aperture) and 700−830 Å with the Very Large Telescope (VLT)/VIMOS in the U band (mU = 27.84 ± 0.19 mAB, peak S/N = 6.7 with an r = 0".6 aperture). A 20 hr VLT/VIMOS spectrum shows low- and high-ionization interstellar metal absorption lines and the P Cygni profile of C IV and Lyα in absorption. The latter spectral feature differs from what observed in known LyC emitters, which show strong Lyα emission. An HST far-UV color map reveals that the LyC emission escapes from a region of the galaxy that is bluer than the rest. The F410M image shows that the centroid of the LyC emission is offset from the centroid of the nonionizing UV emission by 0".12 ± 0".03, corresponding to 0.85 ± 0.21 kpc, and that its morphology is likely moderately resolved. These morphological characteristics favor a scenario where the LyC photons produced by massive stars escape from low H I column density "cavities" in the interstellar medium. We also collect the VIMOS U-band images of 107 Lyman-break galaxies at 3.40 < zspec < 3.95, i.e., sampling the LyC, and stack them with inverse-variance weights. No LyC emission is detected in the stacked image, resulting in a 32.5 mAB flux limit (1σ) and an upper limit of absolute LyC escape fraction fescabs ≤ 0.63%.

New Insights on Lyα and Lyman Continuum Radiative Transfer in the Greenest Peas

Jaskot, Anne, Tara Dowd, M. S. Oey, Claudia Scarlata, and Jed McKinney

The Astrophysical Journal, 885, 96, 2019

As some of the only Lyman continuum (LyC) emitters at z ~ 0, Green Pea (GP) galaxies are possible analogs of the sources that reionized the universe. We present HST COS spectra of 13 of the most highly ionized GPs, with [O III]/[O II] = 6-35, and investigate correlations between Lyα, galaxy properties, and low-ionization UV lines. Galaxies with high [O III]/[O II] have higher Hα equivalent widths (EWs), and high intrinsic Lyα production may explain the prevalence of high Lyα EWs among GPs. While the Lyα escape fraction is closely linked to low gas covering fractions, implying a clumpy gas geometry, narrow Lyα velocity peak separation (Δ vLyα) correlates with the ionization state, suggesting a density-bounded geometry. We therefore suggest that Δ vLyα may trace the residual transparency of low-column-density pathways. Metallicity is associated with both [O III]/[O II] and Δ vLyα. This trend may result from catastrophic cooling around low-metallicity star clusters, which generates a compact geometry of dense clouds within a low-density inter-clump medium. We find that the relative strength of low-ionization UV emission to absorption correlates with Lyα emission strength and is related to Lyα profile shape. However, as expected for optically thin objects, the GPs with the lowest Δ vLyα show both weak low-ionization emission and weak absorption. The strengths of the low-ionization absorption and emission lines in a stacked spectrum do not correspond to any individual spectrum. Galaxies with high [O III]/[O II] contain a high fraction of LyC emitter candidates, but [O III]/[O II] alone is an insufficient diagnostic of LyC escape.

Biology

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

Heggeseth, B., *Danielle Sim '18, Laura Partida '16*, Maroja, L.S.

BMC Evolutionary Biology 20: 21

Background

The hybridizing field crickets, *Gryllus firmus* and *Gryllus pennsylvanicus* have several barriers that prevent gene flow between species. The behavioral pre-zygotic mating barrier, where males court conspecifics more intensely than heterospecifics, is important because by acting earlier in the life cycle it has the potential to prevent a larger fraction of hybridization. The mechanism behind such male mate preference is unknown. Here we investigate if the female cuticular hydrocarbon (CHC) profile could be the signal behind male courtship.

Results

While males of the two species display nearly identical CHC profiles, females have different, albeit overlapping profiles and some females (between 15 and 45%) of both species display a male-like profile distinct from profiles of typical females. We classified CHC females profile into three categories: *G. firmus*-like (F; including mainly *G. firmus* females), *G. pennsylvanicus*-like (P; including mainly *G. pennsylvanicus* females), and male-like (ML; including females of both species). *Gryllus firmus* males courted ML and F females more often and faster than they courted P females ($p<0.05$). *Gryllus pennsylvanicus* males were slower to court than *G. firmus* males, but courted ML females more often ($p<0.05$) than their own conspecific P females (no difference between P and F). Both males courted heterospecific ML females more often than other heterospecific females ($p<0.05$, significant only for *G. firmus* males).

Conclusions

Our results suggest that male mate preference is at least partially informed by female CHC profile and that ML females elicit high courtship behavior in both species. Since ML females exist in both species and are preferred over other heterospecific females, it is likely that this female type is responsible for most hybrid offspring production.

Eavesdropping on adult vocal interactions does not enhance juvenile song learning: an experiment with wild songbirds

Mennill, D.J., Doucet S.M., Newman, A.E.M., Williams, H., Moran I.G., Thomas, I.P., Woodworth, B.K., Bornais, M.K.M., Norris, D.R.

Animal Behaviour, 155:67-75.

Animals often live within close proximity of multiple conspecific individuals, allowing them to eavesdrop on other animals' signalling interactions to guide their own social behaviours. For a young animal that is learning to vocalize, eavesdropping on vocal interactions between adults may provide a rich source of information: young animals might preferentially learn vocalizations that are commonly heard in interactions between adults or that are heard to be effective for attracting mates or defending resources. We used a multispeaker playback experiment with wild Savannah sparrows, *Passerculus sandwichensis*, to test the hypothesis that vocal learning is guided by eavesdropping. Over a 6-year period, we tutored young Savannah sparrows with experimental tutor songs; half of the tutor songs were broadcast in simulated vocal interactions between two tutors, and the other half were broadcast as noninteractive, stand-alone solo performances. If eavesdropping plays an important role in guiding vocal learning, we predicted that young birds would preferentially learn the vocalizations heard during interactions between tutors. In contrast to our prediction, young Savannah sparrows did not preferentially learn interactive tutor songs; birds were similarly likely to learn songs heard in an interactive context ($N = 13$) and in a noninteractive context ($N = 17$). Analysis of live adult tutors' reactions to the loudspeakers showed that they responded with similar vocal behaviour during interactive and noninteractive treatments, and therefore their vocal behaviour did not compromise the playback simulation. We conclude that eavesdropping on vocal interactions between tutors does not appear to be essential for vocal learning of wild Savannah sparrows.

Diel and seasonal patterns of variation in the singing behaviour of Savannah Sparrows (*Passerculus sandwichensis*)

Moran I.G., Lukianchuk, K.C., Doucet, S.M., Newman, A.E.M., Williams, H., Norris, D.J.M, Mennill, D.J.

Avian Research, 10, doi: 10.1186/s40657-019-0165-6

Background

The vocalizations of birds are dynamic traits that often vary in output with time of day and time of year. By quantifying patterns of diel and seasonal variation in vocal output, we can gain insight into the ecology and evolution of birds and the function of their vocalizations. In this investigation, we quantified diel and seasonal variation in song output by studying a breeding population of Savannah Sparrows (*Passerculus sandwichensis*).

Methods

We used autonomous recorders to collect extensive recordings across the breeding season in a long-term, colour-marked study population of Savannah Sparrows in eastern Canada. We described diel and seasonal variation across five different breeding stages based on recordings of more than 50,000 songs from 34 males.

Results

During the pre-breeding stage, prior to female arrival, males sang a pronounced dawn chorus with a peak in song output during the early morning. During the breeding stage, in contrast, the dawn chorus was diminished and males instead exhibited a pronounced dusk chorus with a peak in song output during the evening. Across the breeding season, the highest levels of song output occurred in late April and early May, soon after males arrived on the breeding grounds, and the lowest levels occurred in August, prior to the departure of birds for the wintering grounds.

Individual differences determine the strength of ecological interactions

Griffiths, J. I., D. Z. Childs, R. D. Bassar, T. Coulson, D. N. Reznick, and M. Rees.

PNAS July 21, 2020 117 (29) 17068-17073; first published July 6, 2020; https://doi.org/10.1073/pnas.2000635117

Biotic interactions are central to both ecological and evolutionary dynamics. In the vast majority of empirical studies, the strength of intraspecific interactions is estimated by using simple measures of population size. Biologists have long known that these are crude metrics, with experiments and theory suggesting that interactions between individuals should depend on traits, such as body size. Despite this, it has been difficult to estimate the impact of traits on competitive ability from ecological field data, and this explains why the strength of biotic interactions has empirically been treated in a simplistic manner. Using long-term observational data from four different populations, we show that large Trinidadian guppies impose a significantly larger competitive pressure on conspecifics than individuals that are smaller; in other words, competition is asymmetric. When we incorporate this asymmetry into integral projection models, the predicted size structure is much closer to what we see in the field compared with models where competition is independent of body size. This difference in size structure translates into a twofold difference in reproductive output. This demonstrates how the nature of ecological interactions drives the size structure, which, in turn, will have important implications for both the ecological and evolutionary dynamics.

Upper thermal limits are repeatable in Trinidadian guppies

Grinder, R. M., R. D. Bassar, and S. K. Auer

Journal of Thermal Biology https://doi.org/10.1016/j.jtherbio.2020.102597

Measurements of thermal tolerance are critical for predicting species vulnerability to climate change. Critical thermal maximum (CTmax) is a measure of an animal's upper thermal tolerance, but there is limited evidence for how repeatable it is within individuals over time. We measured the CTmax of Trinidadian guppies (*Poecilia reticulata*) across six consecutive trials, each a week apart. The repeatability of CTmax over six trials was 0.43 (0.26–0.62). However, CTmax also changed over time, ranging from 39.0 to 39.6 °C and increasing by 0.6 °C across the first four trials before leveling off. This is most likely the effect of heat hardening, indicating that thermal tolerance can increase after repeated exposure to extreme heat events.

Metabolic rate interacts with resource availability to determine individual variation in microhabitat use in the wild

Auer, S. K., R. D. Bassar, D. Turek, G. J. Anderson, S. McKelvey, J. D. Armstrong, K. H. Nislow, H. K. Downie, T. A. J. Morgan, D. McLennan, N. B. Metcalfe

The American Naturalist 196, Number 2 August 2020, pp 132-44

Ecological pressures such as competition can lead individuals within a population to partition resources or habitats, but the underlying intrinsic mechanisms that determine an individual's resource use are not well understood. Here we show that an individual's own energy demand and associated competitive ability influence its resource use, but only when food is more limiting. We tested whether intraspecific variation in metabolic rate leads to microhabitat partitioning among juvenile Atlantic salmon (*Salmo salar*) in natural streams subjected to manipulated nutrient levels and subsequent per capita food availability. We found that individual salmon from families with a higher baseline (standard) metabolic rate (which is associated with greater competitive ability) tended to occupy faster-flowing water, but only in streams with lower per capita food availability. Faster-flowing microhabitats yield more food, but high metabolic rate fish only benefited from faster growth in streams with high food levels, presumably because in low-food environments the cost of a high metabolism offsets the benefits of acquiring a productive microhabitat. The benefits of a given metabolic rate were thus context dependent. These results demonstrate that intraspecific variation in metabolic rate can interact with resource availability to determine the spatial structuring of wild populations.

Environmental change, if unaccounted, prevents detection of cryptic evolution in a wild population

Potter, T., R. D. Bassar, P. Bentzen, E. W. Ruell, J. Torres-Dowdall, C. A. Handelsman, C. K. Ghalambor, J. Travis, D. N. Reznick, and T. Coulson

The American Naturalist, in press

Detecting contemporary evolution requires demonstrating that genetic change has occurred. Mixed-effects models allow estimation of quantitative genetic parameters and are widely used to study evolution in wild populations. However, predictions of evolution based on these parameters frequently fail to match observations. Here, we applied three commonly used quantitative genetic approaches to predict the evolution of size at maturity in a wild population of Trinidadian guppies. Crucially, we tested our predictions against evolutionary change observed in common garden experiments performed on samples from the same population. We show that standard quantitative genetic models underestimated or failed to detect the cryptic evolution of this trait as demonstrated by the common garden experiments. The models failed because: 1) size at maturity and fitness both decreased with increases in population density, 2) offspring experienced higher population densities than their parents, and 3) selection on size was strongest at high densities. When we accounted for environmental change, predictions better matched observations in the common garden experiments, although substantial uncertainty remained. Our results demonstrate that predictions of evolution are unreliable if environmental change is not appropriately captured in models.

Experimental study of species invasion in a natural community: early population dynamics and role of disturbance in invasion success

Reznick, D. N., S. De Bona, A. López-Sepulcre, M. Torres-Mejía, R. D. Bassar, P. Bentzen, and J. Travis.

Ecological Monographs 90 number 3, August 2020, https://doi.org/10.1002/ecm.1413

Much of our understanding of natural invasions is retrospective, based on data acquired after invaders become established. As a consequence, we know little about the characteristics of the early population growth and habitat use of the invaders during establishment. Here we report on experimental introductions of guppies into natural streams in which we conducted monthly censuses of each population. Two of the four introductions were in streams with thinned canopies, which mimic a common form of habitat disturbance. We conducted similar censuses of natural populations to characterize natural population densities and generate a null distribution against which we could test a priori hypotheses about the establishment of the experimental invaders. We constructed a pedigree for one population, which enabled us to quantify lifetime reproductive success. Population simulations predict that the nature of the introduced population's life history, in combination with reduced risk of predation in the introduction sites, will result in explosive population growth; however, populations of introduced invaders instead grew to match densities observed in natural streams with intact canopies. Experimental populations in streams with thinned canopies

grew to densities that often exceeded those of natural streams with intact canopies. High population densities were associated with the increased use of marginal habitat. Adult females and males that moved into marginal habitat suffered no apparent fitness loss, suggesting lower population densities found there compensated for lower habitat quality. Our results suggest that the ecological setting in which invasions occur plays a role at least comparable in importance to that of the invader's inherent characteristics in shaping early population growth and habitat use.

The BAR Domain of the Arf GTPase-activating Protein ASAP1 Directly Binds Actin Filaments

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J Biol Chem. 2020 May. doi: 10.1074/jbc.RA119.009903

ASAP1 regulates F-actin-based structures and functions, including focal adhesions (FAs) and circular dorsal ruffles (CDRs), cell spreading and migration. ASAP1 function requires its N-terminal BAR domain. We discovered that nonmuscle myosin 2A (NM2A) directly bound the BAR-PH tandem of ASAP1 in vitro. ASAP1 and NM2A co-immunoprecipitated and colocalized in cells. Knockdown of ASAP1 reduced colocalization of NM2A and F-actin in cells. Knockdown of ASAP1 or NM2A recapitulated each other's effects on FAs, cell migration, cell spreading, and CDRs. The NM2A-interacting BAR domain contributed to ASAP1 control of cell spreading and CDRs. Exogenous expression of NM2A rescued the effect of ASAP1 knockdown on CDRs but ASAP1 did not rescue NM2A knockdown defect in CDRs. Our results support the hypothesis that ASAP1 is a positive regulator of NM2A. Given other binding partners of ASAP1, ASAP1 may directly link signaling and the mechanical machinery of cell migration.

A major role for noncoding regulatory mutations in the evolution of enzyme activity

Loehlin DW, *Ames JRA '19*, Vaccaro K, Carroll SB

PNAS, DOI: 10.1073/pnas.1904071116

The quantitative evolution of protein activity is a common phenomenon, yet we know little about any general mechanistic tendencies that underlie it. For example, an increase (or decrease) in enzyme activity may evolve from changes in protein sequence that alter specific activity, or from changes in gene expression that alter the amount of protein produced. The latter in turn could arise via mutations that affect gene transcription, posttranscriptional processes, or copy number. Here, to determine the types of genetic changes underlying the quantitative evolution of protein activity, we dissected the basis of ecologically relevant differences in Alcohol dehydrogenase (Adh) enzyme activity between and within several Drosophila species. By using recombinant Adh transgenes to map the functional divergence of ADH enzyme activity in vivo, we find that amino acid substitutions explain only a minority (0 to 25%) of between- and within-species differences in enzyme activity. Instead, noncoding substitutions that occur across many parts of the gene (enhancer, promoter, and 5′ and 3′ untranslated regions) account for the majority of activity differences. Surprisingly, one substitution in a transcriptional Initiator element has occurred in parallel in two species, indicating that core promoters can be an important natural source of the tuning of gene activity. Furthermore, we show that both regulatory and coding substitutions contribute to fitness (resistance to ethanol toxicity). Although qualitative changes in protein specificity necessarily derive from coding mutations, these results suggest that regulatory mutations may be the primary source of quantitative changes in protein activity, a possibility overlooked in most analyses of protein evolution.

Chemistry

A chemically fueled non-enzymatic bistable network

Indrajit Maity, Nathaniel Wagner, Rakesh Mukherjee, Dharm Dev, Enrique Peacock-Lopez, Rivka Cohen-Luria, Gonen Ashkenasy

Nature Communications, 10: 4636, 2019. DOI: 10.1038/s41467-019-12645-0

One of the grand challenges in contemporary systems chemistry research is to mimic life-like functions using simple synthetic molecular networks. This is particularly true for systems that are out of chemical equilibrium and show complex dynamic behaviour, such as multi-stability, oscillations, and chaos. We report here on thiodepsipeptide-based non-enzymatic networks propelled by reversible replication processes out of equilibrium, displaying bistability. Accordingly, we present quantitative analyses of the bistable behaviour, featuring a phase transition from the simple equilibration processes taking place in reversible dynamic chemistry into the bistable region. This behaviour is observed only when the system is continuously fueled by a reducing agent that keeps it far from equilibrium, and only when operating within a specifically defined parameter space. We propose that the development of biomimetic bistable systems will pave the way towards the study of more elaborate functions, such as information transfer and signaling.

Complex Dynamics in a Minimal Model of Protection-Based Mutualism

Samuel Swire '18, *Elizabeth Pasipanodya '09*, Manuel A. Morales, Enrique Peacock-Lopez

Axioms, 9:26, 2020. DOI: 10.3390/axioms9010026

This paper presents the first five variable model of mutualism motivated by the interaction between ants and homopterans. In this mutualism, homopterans benefit both directly through increased feeding rates and indirectly through predator protection. The results of our analyses show oscillatory, complex, and chaotic dynamic behavior. Also, we show that intraspecies interactions are crucial for closing trophic levels and stabilizing the dynamic system from potential "chaotic" behavior.

Influenza hemagglutinin drives viral entry via two sequential intramembrane mechanisms

Pabis, A.; Rawle R. J.; Kasson, P.M.

PNAS 117:7200-7207, 2020. DOI: 10.1073/pnas.1914188117

Enveloped viruses enter cells via a process of membrane fusion between the viral envelope and a cellular membrane. For influenza virus, mutational data have shown that the membrane-inserted portions of the hemagglutinin protein play a critical role in achieving fusion. In contrast to the relatively well-understood ectodomain, a predictive mechanistic understanding of the intramembrane mechanisms by which influenza hemagglutinin drives fusion has been elusive. We used molecular dynamics simulations of fusion between a full-length hemagglutinin proteoliposome and a lipid bilayer to analyze these mechanisms. In our simulations, hemagglutinin first acts within the membrane to increase lipid tail protrusion and promote stalk formation and then acts to engage the distal leaflets of each membrane and promote stalk widening, curvature, and eventual fusion. These two sequential mechanisms, one occurring before stalk formation and one after, are consistent with our experimental measurements of single-virus fusion kinetics to liposomes of different sizes. The resulting model also helps explain and integrate previous mutational and biophysical data, particularly the mutational sensitivity of the fusion peptide N terminus and the length sensitivity of the transmembrane domain. We hypothesize that entry by other enveloped viruses may also use sequential processes of acyl tail exposure, followed by membrane curvature and distal leaflet engagement.

Detecting and controlling dye-effects in single virus fusion experiments

Rawle, R.J.; Villamil Giraldo, A.M.; Boxer, S.G.; Kasson, P.

Biophysical Journal, 117:445-452. DOI: 10.1016/j.bpj.2019.06.022

Fluorescent dye-dequenching assays provide a powerful and versatile means to monitor membrane fusion events. They have been used in bulk assays, for measuring single events in live cells, and for detailed analysis of fusion kinetics for liposomal, viral, and cellular fusion processes; however, the dyes used also have the potential to perturb

membrane fusion. Here, using single-virus measurements of influenza membrane fusion, we show that fluorescent membrane probes can alter both the efficiency and the kinetics of lipid mixing in a dye- and illumination-dependent manner. R18, a dye that is commonly used to monitor lipid mixing between membranes, is particularly prone to these effects, whereas Texas Red is somewhat less sensitive. R18 further undergoes photoconjugation to viral proteins in an illumination-dependent manner that correlates with its inactivation of viral fusion. These results demonstrate how fluorescent probes can perturb measurements of biological activity and provide both data and a method for determining minimally perturbative measurement conditions.

The Middle Stone Age (MSA): Technological Patterns, Innovations and Behavioral Changes at Bed VIA of Mumba Rockshelter, Northern Tanzania

Pastory Magayane Bushozi, Anne Skinner, and Luis de Luque

African Archaeological Review, 37, 2020

Although anatomically modern humans emerged during the MSA, debates have focused on the timing for the development of cognitive thoughts, planning depths, and profound cultural innovations. While some scholars have attributed these qualities to the LSA population, others have proposed that the evolutionary modern human behaviors developed during the MSA. This paper is a contribution to this debate based on new excavations at Mumba site, Tanzania, occupied at different periods from the last Interglacial Maximum about 128,000 BP thorugh the onset of the Holocene ca. 12,000 BP. We use new ESR dates, geochronology of stratigraphic sequences, lithic technology and typological variability in archaeological assemblages to show gradual transformation, steadiness and shared technological traits between the MSA and LSA occupation levels at Mumba. We concluded that there are no fixed boundaries between the late MSA and early LSA regarding cognitive thought and technological transformation in Africa.

Evidence for Pleistocene habitability and occupations in the Western Desert of Egypt, MIS4 through MIS2

Maxine R. Kleindienst, Mary M. A. McDonald, Anne R. Skinner, Bonnie, A. B. Blackwell, and Marcia F. Wiseman

In: *Not Just a Corridor* (ed: Alice Leplongeon), Museum Science Press, 1-31, 2020

Although many have considered that the Western Desert of Egypt, the entire area west of the Nile Valley, was uninhabitable and uninhabited during MIS 4 through MIS 2—the 'Empty Desert Hypothesis'—evidence for the availability of water and, therefore, habitability does exist. Lithic aggregates found during surveys in Dakhleh Oasis (Sheikh Mabruk Unit, 318 Unit) and on the bounding eastern escarpment and plateau above Kharga Oasis depression (Khargan Unit, originally defined by G. Caton-Thompson) likely relate to those times of potential habitability. Such aggregates are assigned to the Terminal Middle Stone Age, and to the Khargan Complex. These are thought to fall between MIS 4 and early MIS 2, most likely in MIS 3. In addition, a few aggregates in Kharga can be considered as Later Stone Age (Aguz Unit), dating sometime in MIS 2.

Computer Science

Smart Homes: From Research to Industry
A. J. Brush '96, J. Albrecht and R. Miller

IEEE Pervasive Computing, vol. 19, no. 2, pp. 69-73, 1 April-June 2020.

Smart home innovations are both a research topic and an industry reality. In this article, we highlight smart home research from the Proceedings of the ACM Journal on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT) presented at the September 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and smart home industry updates from the CES conference in January 2020.

An MS in CS for non-CS Majors: Moving to Increase Diversity of Thought and Demographics in CS
Carla Brodley, Megan Barry, Aidan Connell, Catherine Gill, Ian Gorton, Benjamin Hescott, Bryan Lackaye, Cynthia LuBien, Leena Razzaq, Amit Shesh, Tiffani Williams, and Andrea Danyluk

Proceedings of the ACM SIGCSE Symposium, 2020.

We have created, piloted and are growing the Align program, a Master of Science in Computer Science (MS in CS) for post-secondary graduates who did not major in CS. Our goal is to create a pathway to CS for all students, with particular attention to women and underrepresented minorities. Indeed, women represent 57% and underrepresented minorities represent 25% of all bachelor's recipients in the U.S., but only 19.5% and 12.6% of CS graduates, respectively. If we can fill this opportunity gap, we will satisfy a major economic need and address an issue of social equity and inclusion. In this paper, we present our "Bridge" curriculum, which is a two-semester preparation for students to then join the traditional MS in CS students in master's-level classes. We describe co-curricular activities designed to help students succeed in the program. We present our empirical findings around enrollment, demographics, retention and job outcomes. Among our findings is that Align students outperform our traditional MS in CS students in grade point average. To date we have graduated 137 students and 827 are enrolled.

Evaluating ProDirect Manipulation in Hour of Code
Quan Do, Kiersten Campbell, Emmie Hine, Dzung Pham, Alex Taylor, Iris Howley, and Daniel W. Barowy.

SPLASH-E 2019: Proceedings of the 2019 ACM SIGPLAN Symposium on SPLASH-E. October 2019, pp 25–35. https://doi.org/10.1145/3358711.3361623

We examine whether augmenting traditional coding environments with ProDirect manipulation improves several learning measures. ProDirect manipulation is a novel user interaction model that provides a bidirectional link between code and outputs. Instead of reasoning abstractly about the output a program might produce, users instead directly manipulate outputs (e.g., using a keyboard and mouse). Program text is then updated to reflect the change.

We report the effects on learning using a ProDirect manipulation environment versus a standard development environment for more than one hundred middle school students. To conduct the study, we built SWELL, a programming language with ProDirect manipulation features. We conclude that within the context of an Hour-of-Code course, ProDirect manipulation does not offer a significant advantage. We also make several observations regarding the way students interact with SWELL, which may inform future language design for this age group.

Infrastructor: Flexible, No-Infrastructure Tools for Scaling CS
Daniel W. Barowy and William K. Jannen

SIGCSE '20: Proceedings of the 51st ACM Technical Symposium on Computer Science Education. February 2020, pp 1005–1011. https://doi.org/10.1145/3328778.3366905

Demand for computer science education has skyrocketed in the last decade. Although challenging everywhere, scaling up CS course capacities is especially painful at small, liberal arts colleges (SLACs). SLACs tend to have few instructors, few large-capacity classrooms, and little or no dedicated IT support staff. As CS enrollment growth continues to outpace the ability to hire instructional staff, maintaining the quality of the close, nurturing learning environment that SLACs advertise-and students expect-is a major challenge.

We present Infrastructor, a workflow and collection of course scaling tools that address the needs of resource-strapped CS departments. Infrastructor removes unnecessary administrative burdens so that instructors can focus on teaching and mentoring students. Unlike a traditional learning management system (LMS), which is complex, monolithic, and usually administered by a campus-wide IT staff, instructors deploy Infrastructor themselves and can trivially tailor the software to suit their own needs. Notably, Infrastructor does not require local hardware resources or platform-specific tools. Instead, Infrastructor is built on top of version control systems. This design choice lets instructors host courses on commodity, cloud-based repositories like GitHub. Since developing Infrastructor two years ago, we have successfully deployed it in ten sections of CS courses (323 students), and over the next year, we plan to more than double its use in our CS program.

Adapting Guided Inquiry Learning Worksheets for Emergency Remote Learning

Iris Howley

Journal of Information and Learning Sciences, 17 June 2020

Process-Oriented Guided Inquiry Learning (POGIL) are a series of learning activities building on student prior knowledge guiding them to construct their own understanding of new concepts in collaborative roles. During the switch to emergency remote learning, POGIL worksheets can be adapted for low bandwidth, low-computing environments, to accommodate the largest swathe of learners in higher education. This article discusses an approach to adapting POGIL worksheets for introduction to computer science for students who may not have the necessary digital tools (i.e., programming software, bandwidth for streaming video, etc.).While the context for this article is computer science, POGIL has a deep history in chemistry education and other natural sciences, suggesting an approach that may be adapted for situations where hands-on laboratory experiments may not be possible. The POGIL worksheets in this article scaffold the discovery of new concepts while providing sample computer program output, guiding students to make predictions about the connection between program input and program output. Answers are provided to these questions after completion so that students may check their understanding or look to the answers as worked examples. These POGIL worksheets were used the past two years in an in-person classroom situation with minimal computing resources, replacing 4/5 of a classroom lecture doing POGILs collaboratively. In the midst of emergency remote learning, these worksheets were adapted to complement asynchronous lecture videos, but also serve as lecture replacement as needed.

Assessing Post-hoc Explainability of the BKT Algorithm

Tongyu Zhou '20, Haoyu Sheng '20, & Iris Howley

AAAI/ACM conference on Artificial Intelligence, Ethics, and Society

As machine intelligence is increasingly incorporated into educational technologies, it becomes imperative for instructors and students to understand the potential flaws of the algorithms on which their systems rely. This paper describes the design and implementation of an interactive post-hoc explanation of the Bayesian Knowledge Tracing algorithm which is implemented in learning analytics systems used across the United States. After a user-centered design process to smooth out interaction design difficulties, we ran a con-trolled experiment to evaluate whether the interactive or static version of the explainable led to increased learning. Our results reveal that learning about an algorithm through an explainable depends on users' educational background. For other contexts, designers of post-hoc explainables must consider their users' educational background to best determine how to empower more informed decision-making with AI-enhanced systems.

How to Copy Files

Yang Zhan, Alexander Conway, Yizheng Jiao, Nirjhar Mukherjee, Ian Groombridge, Michael A. Bender, Martin Farach-Colton, William Jannen, Rob Johnson, Donald E. Porter, Jun Yuan

18th USENIX Conference on File and Storage Technologies

Making logical copies, or clones, of files and directories is critical to many real-world applications and workflows, including backups, virtual machines, and containers. An ideal clone implementation meets the following performance goals: (1) creating the clone has low latency; (2) reads are fast in all versions (i.e., spatial locality is always

maintained, even after modifications); (3) writes are fast in all versions; (4) the overall system is space efficient. Implementing a clone operation that realizes all four properties, which we call a nimble clone, is a long-standing open problem.

This paper describes nimble clones in BetrFS, an open-source, full-path-indexed, and write-optimized file system. The key observation behind our work is that standard copy-on-write heuristics can be too coarse to be space efficient, or too fine-grained to preserve locality. On the other hand, a write-optimized key-value store, as used in BetrFS or an LSM-tree, can decouple the logical application of updates from the granularity at which data is physically copied. In our write-optimized clone implementation, data sharing among clones is only broken when a clone has changed enough to warrant making a copy, a policy we call copy-on-abundant-write.

We demonstrate that the algorithmic work needed to batch and amortize the cost of BetrFS clone operations does not erode the performance advantages of baseline BetrFS; BetrFS performance even improves in a few cases. BetrFS cloning is efficient; for example, when using the clone operation for container creation, BetrFS outperforms a simple recursive copy by up to two orders-of-magnitude and outperforms file systems that have specialized LXC backends by 3-4×.

Rounding Meshes in 3D

Devillers, O., Lazard, S. & Lenhart, W.J.

Discrete Comput Geom 64, 37–62 (2020). https://doi.org/10.1007/s00454-020-00202-2

Let P be a set of n polygons in 3 dimensions, each of constant complexity and with pairwise disjoint interiors. We propose a rounding algorithm that maps P to a simplicial complex Q whose vertices have integer coordinates. Every face of P is mapped to a set of faces (or edges or vertices) of Q and the mapping from P to Q can be done through a continuous motion of the faces such that: (i) the Hausdorff distance between a face and its image during the motion is at most 3/2, and (ii) if two points become equal during the motion, they remain equal through the rest of the motion. In the worst case the size of Q is polynomial (of degree 13) in the size of P and the time complexity of the algorithm is polynomial (of degree 15), but, under reasonable assumptions, these complexities decrease to degrees 4.5 and 5, respectively.

Packing Trees into 1-Planar Graphs.

De Luca, F., Di Giacomo, E, Hong, SH., Kobourov, S., Lenhart, W., Liotta, G., Meijer, H., Tappini, A., Wismath, S.

Rahman M., Sadakane K., Sung WK. (eds) *WALCOM: Algorithms and Computation*. WALCOM 2020. Lecture Notes in Computer Science, vol 12049. Springer, Cham

We introduce and study the 1-planar packing problem: Given k graphs with n vertices $G1,\ldots,Gk$, find a 1-planar graph that contains the given graphs as edge-disjoint spanning subgraphs. We mainly focus on the case when each Gi is a tree and k=3. We prove that a triple consisting of three caterpillars or of two caterpillars and a path may not admit a 1-planar packing, while two paths and a special type of caterpillar always have one. We then study 1-planar packings with few crossings and prove that three paths (resp. cycles) admit a 1-planar packing with at most seven (resp. fourteen) crossings. We finally show that a quadruple consisting of three paths and a perfect matching with $n \geq 12$ vertices admits a 1-planar packing, while such a packing does not exist if $n \leq 10$.

Timely Reporting of Heavy Hitters using External Memory

P. Pandey, S. Singh, M. A. Bender, J. W. Berry, M. Farach-Colton, R. Johnson, T. Kroeger, C. Phillips.

ACM International Conference on Management of Data (SIGMOD), June 2020.

The problem of finding heavy-hitters is extensively studied in the database literature. We study a real-time heavy-hitters variant in which an element must be reported shortly after they cross a certain threshold (and hence becomes a heavy hitter). We call this the Timely Event Detection (TED) Problem. The TED problem models the needs of many real-world monitoring systems, which demand accurate (i.e., no false negatives) and timely reporting of all events from large, high-speed streams, and with a low reporting threshold (high sensitivity).

A Scheduling Approach to Incremental Maintenance of Datalog Programs

Shikha Singh, Sergey Madaminov, Michael Bender, Michael Ferdman, Ryan Johnson, Benjamin Moseley, Hung Ngo, Dung Nguyen, Soeren Olesen, Kurt Stirewalt, Geoffrey Washburn. International Parallel and Distributed

Processing Symposium (IPDPS), May 2020.

In this paper, we study the problem of incremental maintenance of Datalog programs and model it as a scheduling problem on DAGs. We design provably good time- and memory-efficient scheduling algorithms for (re)executing a Datalog program where some (but not necessarily all) of the inputs have changed. We prove that our schedulers, called LevelBased and LevelBased with lookahead, have asymptotically improved running time and space efficiency when compared with benchmark algorithms used in production at LogicBlox.

Non-Cooperative Rational Interactive Proofs

J. Chen, S. McCauley, and S. Singh

European Symposium on Algorithms (ESA), September 2019.

Interactive-proof games model the scenario where an honest party interacts with powerful but strategic provers, to elicit from them the correct answer to a computational question. Interactive proofs are increasingly used as a framework to design protocols for computation outsourcing. Existing interactive-proof games largely fall into two categories: either as games of cooperation such as multi-prover interactive proofs and cooperative rational proofs, where the provers work together as a team; or as games of conflict such as refereed games, where the provers directly compete with each other in a zero-sum game. Neither of these extremes truly capture the strategic nature of service providers in outsourcing applications. In this paper, we introduce a mechanism-design approach to define a multi-prover interactive-proof model in which the provers are rational and non-cooperative---they act to maximize their expected utility given others' strategies.

Geosciences

Survival and recovery atrypid fauna following the terminal Ordovician extinction, the Atrypinae: central Oslo Region, Norway

Baarli, B.G.

Historical Biology, 1-38. doi: org/10.1080/08912963.2019.1620228, 2019

The atrypid fauna immediately following the end-Ordovician extinction event is poorly known. Siliciclastic strata of the Solvik Formation in the central Oslo region was deposited during the latest Hirnantian into the Aeronian and contains an uncommonly rich atrypid fauna. The brachiopod subfamily Atrypinae includes three new genera; Askerina, Nottina and Sifella, and six new species; Askerina cymbula, Dihelictera askeriensis, Joviatrypa nakremi, Nottina phalerata, Sifella patera and Zygospiraella nupera. Schachriomonia spiraensis sp. nov. (subfamily Spirigerininae) shows transitional traits to the subfamily Atrypinae. Free-lying, relatively large-shelled genera with many-whorled spiralia and frills like Atrypa developed earlier than previously known with the new genus Askerina occurring in the Ordovician/Silurian boundary layers. A possible gradual evolutionary lineage from Zygospiraella duboisi to Z. nupera sp. nov. is explored. Well-developed fossil assemblages are present from the base of the Solvik Formation. The Formation was deposited at varying depths with deeper shale facies inhabited by Atrypinae like Askerina, Schachriomonia and Protatrypa, shallower calcareous facies showcase Nottina and Dihelictera, whereas the storm-dominated, Aeronian parts of the formation include species of Joviatrypa, Sifella, Zygospiraella and Gotatrypa? Baltica situated in southern tropical to subtropical latitudes had migration of taxa from east to west following the tropical storm track.

Medial to Distal Interactions and Deposits of the Lyttelton Volcanic Complex, South Island, New Zealand

Jared Bathen '20 and Samuel Hampton

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592 doi: 10.1130/abs/2019AM-334562, 2019

Medial to distal interactions and facies can provide insight into volcanic growth processes, mechanisms of lava transport, eruptive processes, and emplacement environments including subaerial versus subaqueous settings. To date, submarine volcanism has yet to be identified in the Lyttelton Volcanic Complex, Banks Peninsula, New Zealand. Detailed field mapping of four sites of the shore platform coupled with photographic analysis was used to characterise the constructional medial to distal flank sequences exposed in the now heavily eroded Lyttelton Volcanic Complex. Deposits along the shore platform include lava flow contacts, brecciated and fragmented zones, channel-like and tube-like flow structures, levee-like structures, zones of reworked ashy sediment, potentially glassy and frothy chilled margins, irregular jointing, and pseudopillow-like structures. Pseudopillow structures and fracture systems, frothy chilled margins, potentially glassy chilled margins, and evidence of aqueous reworking of volcaniclastic and sedimentary materials indicate the occurrence of lava-water interactions during the time of emplacement from approximately 12 to 9.7 mya. We interpret that these interactions are submarine, and that relative paleo sea level during volcanism was within approximately 5m of modern sea level, which correlates with global sea level data. Trends and strike and dips of lava flow features and channels indicate it is unlikely the lava flows and volcanic deposits were sourced from the central vent region of the Lyttelton Volcanic Complex, but from a source to the southwest, in the Mt. Evans area. This sequence / exposure in Camp Bay provides evidence that the Lyttelton Volcanic Complex was an oceanic island, and that eruptions at this evolving volcanic complex interacted with seawater that may have influenced eruptive processes and deposition.

Using seismology to track the timing of sea ice ridging events and shorefast ice stabilization in coastal Alaska

Marshall Borrus '20, Alice Bradley, Kasey Aderhold, and *Lucas Estrada '20*

C13D-1346 presented at AGU fall meeting, San Francisco, CA, 9-13 December 2019

Shorefast sea ice is used for hunting and travel by Iñupiat subsistence hunters and has long been monitored for stability by indigenous ice experts. The highly dynamic nature of shorefast sea ice presents a risk to these community users, with local knowledge and experience challenged by global climate change. The grounding of pressure

ridges protects the protects the landward extent of the shorefast ice from breaking off from breaking off and makes it safer for travel. Pressure ridges form during convergence events, but it is difficult to determine when a ridge is grounded. Our work utilizes cryoseismic data to identify these grounding events as they happen, in an effort to identify the spectral features that can be used to monitor the stability of the shorefast ice. We pair seismic data from coastal EarthScope Transportable Array stations with radar footage of local ice conditions in Utqiaġvik, Alaska to characterise sea ice deformation events by their seismic signature. Our analysis covers three ice seasons (from 2014 to 2017) using feature tracking,day-by-day radar observations, and community records to provide qualitative and quantitative descriptions of the seasonal evolution of nearshore ice. This presentation will cover event classifications with the UAF Utqiaġvik sea ice radar, the analysis of these events' seismic traces, and the potential applicability of this method as a tool for coastal Arctic communities.

The Arctic Observing Summit: Continued Progress towards an Integrated, Multipurpose, International Arctic Observing System

Peter Schlosser, Ravi Sankar, Larry Hinzman, Jen René Larsen, Roberta Pirazzini, Thorsteinn Gunnarsson, Alice Bradley, Hajo Eicken, Eva Kruemmel, Maribeth Murray, Allen Pope, and Peter Pulsifer

PA51E-0933 presented at 2019 AGU fall meeting, San Francisco, CA, 9-13 December

The International Study of Arctic Change (ISAC) is a multidisciplinary Arctic environmental change research program. ISAC engages researchers, community members and others in research planning, implementation, data-sharing and synthesis, and knowledge translation to advance observing and understanding of Arctic change for improved decision making. The biennial Arctic Observing Summit (AOS) is a SAON (Sustaining Arctic Observing Network) led by ISAC and is critical for implementation of the observing component of the ISAC Science Plan. The AOS facilitates community-driven, science-based guidance for the design, implementation, coordination and sustained operation of an international pan-Arctic observing system. It serves as a forum for planning and priority-setting that links diverse needs for information with observing system design, data accessibility, and timely and relevant products useful for decision making.

During the most recent Summit (2018) progress was made on developing the business case for a pan-Arctic observing system. There was consensus from delegates that in order to build an Arctic Observing System that is comprehensive, coordinated and sustainable, all existing assets and activities, including Indigenous knowledge must be leveraged to the greatest extent. Such a system needs to span the full range of spatial and temporal observation scales. This is achievable by combining multiple observational methods and technologies, including Indigenous knowledge, in situ observations, satellite remote sensing, community-based monitoring and citizen science, and by linking all relevant data systems.

AOS 2020 will be held in Akureyri, Iceland (March 31- April 2) in conjunction with Arctic Science Summit Week, and other activities. Work is underway to ensure that many of the needs and issues identified during prior summits are addressed in 2020. AOS 2020 themes under development include: Design, Optimization and Implementation of the Observing System; Observing in Support of Adaptation and Mitigation; Observing in Support of Indigenous Food Security and Related Needs; Data Interoperability and Federated Search; Arctic Observations in the context of Global Observing initiatives; Arctic Observing in Support of Global Actions.

Observed relationship between freeze-up and melt timing supports inter-annual feedbacks in first-year Arctic sea ice volume

Alice Bradley and *William Downs '20*

C43E-1532 presented at 2019 AGU fall meeting, San Francisco, CA, 9-13 December

As the Arctic transitions to a regime of predominantly first-year sea ice, inter-annual feedbacks will depend on what happens over the winter growth season. Ice that freezes up earlier in the season has more time over which to grow, and presumably grows thicker before the onset of the ice melt season. Thicker ice then takes longer to melt through in the spring. The earlier in the fall ice freezes then, the later in the following melt season we would expect ice to melt out, barring complicating factors like snow cover, deformation, and feedbacks with local weather. Using 40 years of SSMI passive microwave ice concentration data, we have determined initial and final freeze up and melt dates for every pixel over the last several decades. Accounting for patterns of ice motion by binning years according

to North Atlantic Oscillation (NAO) and Arctic Oscillation indices, we see high negative correlations between a regional mean freeze up date and the melt dates for a region offset by the winter's typical ice motion. Particularly during years of positive NAO, we see a significant negative (late freeze up leading to early melt) relationship across the Siberian Arctic, with weaker relationships on the Alaskan/Canadian side.

Travel support requirements for internationally diverse early career participation in polar science workshops

Alice Bradley, Juan Hofer, and Clare Eayrs

ED33A-09 presented at 2019 AGU fall meeting, San Francisco, CA, 9-13 December

The Association of Polar Early Career Scientists is an international organization with membership representing 70 countries. Members are mostly graduate students and post-docs, though 29% are early career professionals in other polar-related career tracks. A survey was sent in summer 2019 to APECS members and polar science community members asking about travel support needs and how respondents' recent travel was funded. Participants described the perceived availability of different types and sources of travel funding. Availability of travel awards and the expectation that early career researchers would pay for their meeting-related travel out of personal funds varies widely between countries and institutions. Early results suggest that substantially higher travel support is often needed to support participants from countries outside the US, Canada, and Northern Europe because of both the higher cost of traveling to typical meeting destinations coupled with lower availability of supplemental travel support. This presentation will cover the international patterns in early career travel funding, the utility of partial support, and the lessons learned from this community survey.

Inter-Annual Variability in the Timing of Arctic Sea Ice Freeze-Up Depends on Summer and Fall Arctic Storm Activity

William Downs '20 and Alice Bradley

A53K-3028 AGU presented at 2019 AGU fall meeting, San Francisco, CA, 9-13 December

The timing of fall Arctic sea ice freeze-up determines the length of the over-winter growth season and by extension the first-year ice thickness the following spring. Arctic storms affect sea surface temperatures and mechanically disrupt formative sea ice, leading to later freeze-up. We calculate an annual record of sea ice freeze-up dates and storm activity across the Arctic from 1979-2016 using passive microwave sea ice concentration data and atmospheric reanalysis products (MERRA-2, NCEP/NCAR Reanalysis, ERA-Interim). We observe notable positive correlations (more storms correspond to later freeze-up) between storm activity in the fall and freeze-up dates of sea ice in the Arctic Ocean, in regions where climatological freeze-up lies between late September and November. Storm activity in the summer also affects freeze-up timing in the Arctic, but this relationship requires accounting for surface currents between the time of a storm and freeze-up. The strongest correlations between storm activity and freeze-up timing are observed in geographically enclosed areas like Hudson Bay where water advection is restricted.

Characterizing Sea Ice Modulations of Seismic Noise using the Alaska Transportable Array

Lucas Estrada '20, Kasey Aderhold, Richard Aster, Alice Bradley, Michael Baker, and *Marshall Borrus '20*

S23D-0660 presented at 2019 AGU fall Meeting, San Francisco, CA, 9-13 December

The microseism background seismic wavefield is globally visible across the ≈5-30 s period range. Microseisms are primarily associated with ocean wave energy conversion into globally observable Rayleigh and other wave types within the longer portion of this period range. However, near-coastal ocean and large lake wave processes excite prominent regional shorter-period (≈1-5 Hz) seismic signals that are regionally notable. In polar regions, sea ice prominently modulates microseism power by attenuating ocean wave energy near coastlines across the microseism spectrum (e.g., Aster et al., 2008; Tsai and McNamara, 2011), with particularly strong effects at regionally observed shorter periods.

Using seismic data collected by the Alaska Transportable Array from 2013-2019 and daily sea ice concentration estimated from the Defense Meteorological Satellite Program's SSM/Is and SSMIS passive microwave data, we study the influence of sea ice concentration on seismic noise in northern Alaska, including quantifying and modeling sea ice modulation for stations at various distances from the coast.

We document a very strong anticorrelation between sea ice concentration and daily background noise power be-

tween 0.5 and 1 Hz. This frequency is more consistent with studies observing seismic noise in lakes and suggests modifications to traditional ocean microseism theory associated with much shorter period waves and their interactions with shallow water. This characterization and understanding of the mechanism controlling sea ice modulation could provide applications for ground-based remote monitoring of sea ice strength, concentration, stability, and wave energy impacting polar coastal regions.

Impact of the length of the sea ice-free summer season on Alaskan Arctic coastal erosion rates

Matthew Wiseman '20 and Alice Bradley

C13D-1345 presented at 2019 AGU fall meeting, San Francisco, CA, 9-13 December

Erosion along the Arctic Alaskan coastline poses a major threat to local communities and their way of life. While erosional processes are far from new, erosion rates seem to be increasing in response to a changing Arctic climate. In the Arctic, factors such as permafrost degradation, storms, and decreases in sea ice cover all play a large role in determining the severity of the coastal erosion. For this project, we are specifically looking into the effects of the changing length of the sea ice-free summer season and how it is impacting coastal erosion. Coastal erosion rates are measured for study sites along the Alaskan Coastline by analyzing Planet Labs satellite imagery over the 2009-2019 period. The number of ice free days per summer for the area surrounding each of these locations is calculated from SSMI-derived passive microwave ice concentration products. Together, we use the coastal erosion rates and annual sea ice-free day counts to investigate the relationship between the length of the ice-free season and coastal erosion over this period. Historical erosion rates sourced from USGS reports provide additional comparisons in a changing Arctic climate. We expect to find that a warming climate causes the ice free season to lengthen, leaving the shoreline exposed to storms and coastal processes for a greater period of time, leading to an increase in coastal erosion rates. This presentation will cover recent variability in coastal erosion in the Alaskan Arctic and the influence that sea ice-free summers have on the shoreline.

Oldest fossil ciliates from the Cryogenian glacial interlude reinterpreted as possible red algal spores

Cohen, Phoebe A., *Vizcaíno, Maoli '17*, and Anderson, Ross

Palaeontology, doi: 10.1111/pala.12497, 2020

The Cryogenian Period experienced two long lived global glaciations known as Snowball Earths. While these events were dramatic, eukaryotic life persisted through them, and fossil evidence shows that eukaryotes thrived during the c. 30-million-year interlude between the glaciations. Carbonate successions have become an important taphonomic window for this interval. One of the most notable examples is the c. 662–635 Ma Taishir Formation (Tsagaan Olom Group, Zavkhan Terrane, Mongolia) which has yielded a number of eukaryotic fossil taxa. Here, we examine more closely the morphology and taxonomic affinity of some of these Taishir fossils previously interpreted as remains of ciliate tintinnid loricae (purportedly the oldest fossil ciliates). New morphological and ultrastructural analyses indicate that these fossils are not ciliate tintinnids. Instead, we propose a new interpretation: that they are algal reproductive structures related to coeval macroscopic organic warty sheets described as putative red algae. We report the first occurrence of these fossils in the earliest Ediacaran Ol Formation, indicating that this taxon persisted through the Marinoan Snowball Earth. A new interpretation of these fossils as putative red algal spores has broad implications for our understanding of biodiversity in the Neo-proterozoic Era, specifically during the Cryogenian Period, and for the antiquity of ciliates.

The triple oxygen isotope composition of Precambrian chert

Liljestrand, F.L., Knoll, A.H., Tosca N.J., Cohen, P.A., Macdonald F.A., Peng, Y., Johnston, D.

Earth and Planetary Science Letters.1;537:116167. doi: 10.1016/j.epsl.2020.116167, 2020

The temperature and chemistry of early seawater have both been inferred from the isotopic composition of Precambrian chert (SiO_2), a precipitated mineral formed on or within marine sediments. The $\delta^{18}O$ of chert shows a robust quasi-linear increase through time - a signal that has been interpreted in a number of conflicting ways. For example, changing $\delta^{18}O$ has been hypothesized to reflect the product of cooling surface ocean temperatures, a signature of evolving seawater $\delta^{18}O$ composition, or the product of later stage diagenesis (where measured $\delta^{18}O$ reflects the composition of diagenetic fluids). We suggest this uncertainty can be resolved through the additional measurement and interpretation of the minor oxygen isotope ^{17}O (noted as $\Delta'^{17}O$) in conjunction with $\delta^{18}O$. In this study, we present a

suite of triple oxygen isotope data on stratigraphically constrained Precambrian chert (both peritidal chert nodules in carbonates and iron formation silica). These mineralogically well-defined data allow for the first stratigraphic tests of the fidelity of ^{17}O in SiO_2. We then apply a Monte Carlo resampling technique to test the features of the competing hypotheses noted above, here now including critical constraints from ^{17}O. The most parsimonious interpretation of these data suggests that secondary alteration with higher-temperature, meteoric-derived groundwater has skewed an original geochemical signature. This treatment can allow for some change in the oxygen isotope composition of seawater itself, however this does not appear to be the most statistically defensible single solution - clearly, some combination of multiple mechanisms is always possible and even likely. What is definitively the case is an equitable, modern-like Archean surface ocean temperature.

Institute for the Quantitative Study of Inclusion, Diversity, and Equity (QSIDE)

Topaz, C.M., Ciocanel, V., Cohen, P., Ott, M., Rodriguez, N.

Notices Amer Math Soc. 2020 Feb 1;67(02):1–6.

Consider the following vital questions: Are Black and Latinx artists represented proportionally in US museums? Why are some professional fields dominated by men and others by women? How can judges achieve equitable outcomes for defendants? The mathematical sciences have the potential to address these questions at a level of detail undreamt of a decade ago. The Institute for the Quantitative Study of Inclusion, Diversity, and Equity, Inc. (QSIDE) brings quantitative expertise together with expertise from the social sciences, humanities, and arts to discover the impact and scope of injustices, and to build solutions to remedy them. Established as an independent nonprofit 501(c)3 corporation in 2019, QSIDE is a multi-institutional network of scholars and practitioners. Our vision is inspired by civil rights leaders such as educator and investigative journalist Ida B. Wells, who said that "the way to right wrongs is to shine the light of truth upon them." For QSIDE, quantitative methods are one form of this light of truth. QSIDE has a four-pronged approach to achieving our vision. First, we incubate and conduct cross-disciplinary research that leverages quantitative tools. Second, we partner with people and organizations empowered to use our discoveries. Third, we build community among researchers and practitioners working on social justice issues through virtual and in-person networking and events. Finally, we increase capacity for work aligned with our vision by equipping those researchers and practitioners with appropriate methodologies and tools. With this communication, we are reaching out to the mathematical sciences community. Our goal is to emphasize the need for social justice research and to highlight ways in which our community is uniquely positioned to contribute to this work. To motivate the QSIDE research agenda, we begin by introducing our framework for the concepts of inclusion, diversity, and equity, and by discussing the need for quantitative approaches to social justice.

A Gender Analysis of the Paleontological Society: Trends, Gaps, and a Way Forward

Cohen, Phoebe A., Alycia Stigal land Chad Topaz

Geological Society of America Annual Meeting, Vol. 51, No. 5, ISSN 0016-7592 doi: 10.1130/abs/2019AM-338938, 2019

Gender disparities still exist in many STEM fields, including paleontology, despite decades of efforts to attract and retain women into STEM fields. These disparities are often more pronounced at the level of senior researchers. One way to identify both progress and continuing problems is by looking at trends in data. This study focuses on gender, inferred using the GenderizeR.io database from first names of Paleontological Society (PS) members, authors, awardees, grant recipients, officers, and committee members focusing on the years 2000-2018.

Our results show that the proportion of PS members with female-gendered names has remained relatively constant over our time interval of analysis. There has been a significant lag in PS awards to women, despite a constant pool of potential women awardees. We also find a notable increase in the proportion of PS committee and officer participation by women over the study interval.

PS is doing a good job at gender equity at the student level, but equity declines with career progression. Service burdens are falling disproportionately to women, whereas executive leadership roles and prestige awards are male dominated. We discuss the many factors leading to this trend including over-burdening of service for the relatively small number of senior women. Overall, there have been positive changes in gender equity in publications and awards in the last 5-10 years. However, these improvements are not necessarily self-sustaining and more work is

needed to continue to improve inclusion and equity.

These data show important areas where the society is doing well (mainly at the student level) and areas that need improvement (mainly at the mid and late career level). This study does not address the persistent under-representation of people of color, LGBTQ people, and other dimensions of identity, but we hope that it serves as a focal point for future conversations within the discipline and the society.

Session No. 195--Booth# 186

Implications of the modifiable unit problem for wildfire analyses

Nagle-McNaughton, T. '18, Gong, X., Constantine, J.A.

Advances in Biology & Earth Sciences, v. 4, p. 150-175, 2019

Wildfires pose a danger to both ecologies and communities. To this end, many large-scale analyses of wildfire patterns and behavior rely on the aggregation of point data to polygons, typically those based on distinct disparate ecological areas. However, the sizes, shapes, and orientations of the polygons to which data are aggregated are not neutral factors in the resulting analysis. The influence of the aggregation polygons on calculated results is known as the modifiable areal unit problem (MAUP), which is well-documented in the spatial statistics literature. Despite the documentation of the MAUP, relatively few wildfire studies consider the effects of the MAUP on their results. Here, wildfire data from the Western United States are aggregated to twenty-five different sets of polygons. Variation by fishnet polygon area and shape are measured via summary statistics and a spatio-temporal trend analysis. Variation is also quantified between well-established hierarchical nested ecoregion polygons via summary statistics. Lastly, best practices for mitigating the effects of the MAUP on future wildfire studies are recommended.

Effect of channel tributaries on the evolution of submarine channel confluences (Espírito Santo Basin, SE Brazil)

Qin, Y., Alves, T.M., Constantine, J.A., Gamboa, D., Wu, S.

Geological Society of America Bulletin, v. 132, p. 263-272, 2020

Confluences are geomorphologic features fed by distinct channel tributaries that record the contribution of multiple sediment sources. They are key features of both fluvial and submarine channels in geomorphologic and sedimentologic terms. Here, we use high-quality three-dimensional seismic data from SE Brazil to document the response of a submarine channel confluence to turbidity currents originating from a tributary. The studied channel system consists of a west tributary, an east tributary, and a postconfluence channel, with the last two comprising the main channel at present. Downstream from the confluence, changes in planform morphology and architecture were found due to the effect of turbidity currents sourced from the west tributary channel. A channel bend in the main channel curved toward the west when it was first formed but later curved toward the east, and so remains until the present day. This process led to the migration of the confluence point ~500 m to the east, and changed the bed morphology from discordant (where the beds of tributaries and main channels meet at an unequal depth) to concordant (where the beds of tributaries and main channels meet at approximately the same depth). In addition to the channel bend near the confluence, two other bends further downstream recorded significant changes with time, increasing channel sinuosity from 1.11 to 1.72. These three channel bends near the confluence accumulated a large volume of sediment at their inner banks, generating depositional bars. Multiple channel forms within the depositional bars indicate the occurrence of large-scale lateral migration near the confluence. Hence, turbidity currents from the west tributary are shown to influence the submarine channel by promoting lateral channel migration, confluence migration, increases in channel sinuosity, and the formation of large depositional bars. These variations near the confluence reveal a change in tributary activity and a shift in sediment sources from east to west on the continental shelf. Such a shift suggests variations in sedimentary processes on the continental shelf probably due to avulsions on Doce River Delta.

Responses of soil erosion to climate change across three British catchments

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Science of The Total Environment Volume 749, 20 December 2020, 141657

Simulations of 21st century climate change for Great Britain predict increased seasonal precipitation that may lead to widespread soil loss by increasing surface runoff. Land use and different vegetation cover can respond differently

to this scenario, mitigating or enhancing soil erosion. Here, by means of a sensitivity analysis of the PESERA soil erosion model, we test the potential for climate and vegetation to impact soil loss by surface-runoff mechanisms to three differentiated British catchments. First, to understand general behaviours, we modelled soil erosion adopting regular increments for rainfall and temperature from the baseline values (1961-1990). We then tested future scenarios using climatic projections from UKCP09 under the IPCC-defined medium-emissions scenario SRES-A1B at the horizons 2010-39, 2040-69 and 2070-99. Our results indicate that the model reacts to the changes of the climatic parameters and the three catchments respond differently depending on their land use arrangement. Increases in rainfall produce a rise in soil erosion while higher temperatures tend to lower the process because of the mitigating action of the vegetation. 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, under a global balance and for specific land uses, the increase in air temperature associated with climate change can modify the rainfall thresholds required to generate soil loss, and rates of soil erosion could decline by up to about 30% from 2070-2099. We deduce that enhanced primary productivity due to climate change can introduce a negative-feedback mechanism limiting 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 could provide an adaptation strategy to reduce climate-driven soil loss.

MARINE20: The Marine Radiocarbon Age Calibration Curve (0 to 55,000 cal BP)

Heaton, T.J., P. Kohler, M. Butzin, E. Bard, R.W. Reimer, W.E.N. Austin, C.B. Ramsey, P.M. Grootes, K.A. Hughen, B. Kromer, P.J. Reimer, J. Adkins, A. Burke, M.S. Cook, J. OLsen, L.C. Skinner

Radiocarbon. https://doi.org/10.1017/RDC.2020.68

The concentration of radiocarbon (^{14}C) differs between ocean and atmosphere. Radiocarbon determinations from samples which obtained their ^{14}C in the marine environment therefore need a marine-specific calibration curve and cannot be calibrated directly against the atmospheric-based IntCal20 curve. This paper presents Marine20, an update to the internationally-agreed marine radiocarbon age calibration curve that provides a non-polar global-average marine record of radiocarbon from 0 – 55 cal kBP and serves as a baseline for regional oceanic variation. Marine20 is intended for calibration of marine radiocarbon samples from non-polar regions; it is not suitable for calibration in polar regions where variability in sea ice extent, ocean upwelling and air-sea gas exchange may have caused larger changes to concentrations of marine radiocarbon. The Marine20 curve is based upon 500 simulations with an ocean/atmosphere/biosphere box-model of the global carbon cycle that has been forced by posterior realisations of our Northern Hemispheric atmospheric IntCal20 ^{14}C curve and reconstructed changes in CO_2 obtained from ice core data. These forcings enable us to incorporate carbon cycle dynamics and temporal changes in the atmospheric ^{14}C level. The box-model simulations of the global-average marine radiocarbon reservoir age are similar to those of a more complex three-dimensional ocean general circulation model. However, simplicity and speed of the box model allow us to use a Monte Carlo approach to rigorously propagate the uncertainty in both the historic concentration of atmospheric ^{14}C and other key parameters of the carbon cycle through to our final Marine20 calibration curve. This robust propagation of uncertainty is fundamental to providing reliable precision for the radiocarbon age calibration of marine based samples. We make a first step towards deconvolving the contributions of different processes to the total uncertainty; discuss the main differences of Marine20 from the previous age calibration curve Marine13; and identify the limitations of our approach together with key areas for further work. The updated values for ΔR, the regional marine radiocarbon reservoir age corrections required to calibrate against Marine20, can be found at the data base http://calib.org/marine/.

Maximal heights of nearshore storm waves and resultant onshore flow velocities

Bujan, N. and Cox, R.

Frontiers in Marine Science. 10.3389/fmars.2020.00309, 2020

Storm waves, after breaking or overtopping, generate strong onshore flows that do significant mechanical work, including eroding and transporting large boulders. The waves can be amplified on approach, and the flows themselves may be further intensified by local topographic effects. These processes are currently poorly parameterised, but are of great importance for understanding the interactions between waves and coasts. We present a highly gen-

eralised equation for estimating maximal coastal wave heights and consequent onshore flow velocities. Although very approximate, this method contains no embedded assumptions, and thus provides a more realistic first-order check of storm wave capabilities than previous approaches. Initial analysis suggests that exceptional wave impacts may generate onshore flow velocities up to six times greater than expected from previous approaches. Although the probability of occurrence in any given storm is very low, the possibility of such extreme values cannot be ignored, especially when interpreting ancient deposits of large boulders. The equations presented here can be used as a first-order test for coastal boulder deposits currently interpreted as tsunami deposits, to evaluate whether a storm-wave origin should be reconsidered. This approach could also be employed at coasts in general, to evaluate long-term probabilities of damaging flows, as a component of coastal risk analysis.

Megagravel deposits on the west coast of Ireland show the impacts of severe storms

Cox, Rónadh

Weather, v. 75, issue 3, 10.1002/wea.3677, 2020

At steep rocky coasts with open-ocean exposure, as on the Atlantic-facing sides of the Aran Islands (Ireland), wave energy arrives with minimal attenuation. These are the kind of sites where coastal boulder deposits accumulate. Boulder ridges—which are stacked, sorted, coast-parallel accumulations (Williams and Hall, 2004; Cox et al., 2012)—are the classic occurrence, but deposits may also take the form of disorganised piles of a few boulders, or isolated larger blocks. Some occur on top of sea cliffs (up to 50 m above high water). Others are quite far above the intertidal zone, at the back of coastal bedrock platforms (the most distal we measured were about 220 m inland of the high tide mark). Many include enormous megagravel1 blocks weighing tens of tonnes, even up to several hundred tonnes in some cases. There is a wide range of settings and morphologies, but what they all have in common is that they sit above high water, and that between the boulders and the ocean is a wave-scoured bedrock surface, bare of sediment and vegetation (Figure 1). Coastal boulder deposits are of particular interest because they represent a direct sedimentary response to extreme wave events.

Systematic review shows that work done by storm waves can be misinterpreted as tsunami-related because commonly used hydrodynamic equations are flawed

Cox, R., Ardhuin, F., Dias, F., Autret, R., Beisiegel, N., Earlie, C.S., Herterich, J.G., Kennedy, A., Paris, R., Raby, A., Schmitt, P., Weiss, R.

Frontiers in Marine Science, 10.3389/fmars.2020.00004 , 2020

Coastal boulder deposits (CBD), transported by waves at elevations above sea level and substantial distances inland, are markers for marine incursions. Whether they are tsunami or storm deposits can be difficult to determine, but this is of critical importance because of the role that CBD play in coastal hazard analysis. Equations from seminal work by Nott (1997), here referred to as the Nott Approach, are commonly employed to calculate nominal wave heights from boulder masses as a means to discriminate between emplacement mechanisms. Systematic review shows that this approach is based on assumptions that are not securely founded and that direct relationships cannot be established between boulder measurements and wave heights. A test using an unprecedented dataset of boulders moved by storm waves (with associated sea-state data) shows a lack of agreement between calculations and actual wave heights. The equations return unrealistically large heights, many of which greatly exceed sea states occurring during the boulder-moving storms. This underscores the finding that Nott-Approach wave-height calculations are unreliable. The result is general, because although the field data come from one region (the Aran Islands, Ireland), they represent a wide range of boulder masses and topographic settings and present a valid test of hydrodynamic equations. This analysis demonstrates that Nott Approach equations are incapable of distinguishing storm waves from tsunami transport and that wave heights hindcast from boulder masses are not meaningful. Current hydrodynamic understanding does not permit reliable computation of wave height from boulder measurements. A combination of field, numerical, and experimental approaches is required to quantify relationships between wave power and mass transport onshore. Many CBD interpreted as tsunami deposits based on Nott-Approach analysis may in fact have been emplaced during storms and should therefore be re-evaluated. This is especially important for CBD that have been incorporated into long-term coastal risk assessments, which are compromised if the CBD are misinterpreted. CBD dynamics can be better determined from a combination of detailed field measurements, modeling, and experiments. A clearer understanding of emplacement mechanisms will result in more reliable hazard analysis.

Measuring change using quantitative differencing of repeat structure-from-motion photogrammetry: the effect of storms on coastal boulder deposits

'18 Nagle-McNaughton, T.P., and Cox, R.

Remote Sensing, v. 12, 42; 10.3390/rs12010042, 2020

Repeat photogrammetry is increasingly the go-too tool for long-term geomorphic monitoring, but quantifying the differences between structure-from-motion (SfM) models is a developing field. Volumetric differencing software (such as the open-source package CloudCompare) provides an efficient mechanism for quantifying change in landscapes. In this case study, we apply this methodology to coastal boulder deposits on Inishmore, Ireland. Storm waves are known to move these rocks, but boulder transportation and evolution of the deposits are not well documented. We used two disparate SfM data sets for this analysis. The first model was built from imagery captured in 2015 using a GoPro Hero 3+ camera (fisheye lens) and the second used 2017 imagery from a DJI FC300X camera (standard digital single-lens reflex (DSLR) camera); and we used CloudCompare to measure the differences between them. This study produced two noteworthy findings: First, volumetric differencing reveals that short-term changes in boulder deposits can be larger than expected, and that frequent monitoring can reveal not only the scale but the complexities of boulder transport in this setting. This is a valuable addition to our growing understanding of coastal boulder deposits. Second, SfM models generated by different imaging hardware can be successfully compared at sub-decimeter resolution, even when one of the camera systems has substantial lens distortion. This means that older image sets, which might not otherwise be considered of appropriate quality for co-analysis with more recent data, should not be ignored as data sources in long-term monitoring studies.

From fine sand to boulders: examining the relationship between beach-face slope and sediment size

Bujan, N. Cox, R., Masselink, G.

Marine Geology, 10.1016/j.margeo.2019.106012 , 2019

It is a long-standing maxim that coarser sediment sizes are associated with steeper beach-face slopes; but because most work has focused on sandy beaches, few data are available for the pebble, cobble, or boulder size ranges. Little is known, therefore, about how beach morphology and grain size relate at the coarser size grades. We compiled data from the literature—2144 measurements of beach-face slope with associated grain sizes—covering the range from very fine sand to boulders. This meta-analysis shows that beach faces do tend to steepen as average grain size increases, at least up to the cobble size range; but the trend is not simple. Although previous studies suggested a simple power-law relationship between grain size and beach-face slope, in fact the data distribution is best fit by a curve that is steep at the finer grain sizes but is much more gentle as grain size coarsens (and may trend downward for boulders). Fine and medium sands have the greatest range of reported slopes and the data support the importance of effective-weight modification and boundary layer dynamics as primary controls on beach-face steepness at these fine size grades. Around the very coarse sand size grade, a plateau marks a shift in beach dynamics: as hydraulic conductivity increases, beaches switch to being infiltration-dominated. The trend toward steeper slopes continues, but at a lower and steady rate, from granules through cobbles. There appears to be a falloff in slope for the coarsest boulder deposits (but we note that this is based on very few locations, so should be considered preliminary). The overall data distribution is described by a power-law function. The broadness of each transition zone also shows that a range of factors, other than grain size, governs where that tipping point occurs. In the cobble and boulder size ranges there are two deposit categories: boulder beaches, and supratidal boulder ridges. Although not commonly thought of as beaches, boulder ridges record long-term storm deposition and reworking on the highest energy coasts. Supratidal ridges and boulder beaches seem to show different slope/grain-size relationships, with the steepest slopes occurring in boulder ridges, and with boulder beaches showing more gentle gradients than other coarse clastic beaches; but our data set reveals how little quantitative information exists about the coarsest end of the beach spectrum, and invites further work to investigate the sedimentology of cobble- and boulder-dominated systems.

Imbricated coastal boulder deposits are formed by storm waves, and can preserve a long-term storminess record

Cox, R., O'Boyle, L., and '18 Cytrynbaum, J.

Scientific Reports, v. 9 (article 10784). 10.1038/s41598-019-47254-w, 2019

Coastal boulder deposits (CBD) are archives of extreme wave events. They are emplaced well above high tide, and may include megagravel clasts weighing tens or even hundreds of tonnes. But do they represent storms or tsunami?

Many are interpreted as tsunami deposits based simply on clast size and inferences about transport, despite the fact that there are no direct observations documenting formation of these inbricated boulder clusters and ridges. In this study, we use force-balanced, dynamically scaled wave-tank experiments to model storm wave interactions with boulders, and show that storm waves can produce all the features of imbricated CBD. This means that CBD, even when containing megagravel, cannot be used as de facto tsunami indicators. On the contrary, CBD should be evaluated for inclusion in long-term storminess analysis.

Hybrid Approaches to Coastal Protection as a Sustainable Alternative to Built Solutions

Kyrien Edwards '17, Tetsuya Hiraishi, and Rónadh Cox

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592 doi: 10.1130/abs/2019AM-333754, 2019

Catalyzed by disasters such as the Indian Ocean Tsunami in 2004 and Hurricane Katrina in 2005, interest in techniques to protect coastlines from inundation has risen rapidly. It is well known that marshes, oyster reefs, mangroves, and other coastal ecosystems provide natural protection from storm surge. Whether natural or engineered, these are referred to as green solutions, and they use the innate wave attenuating properties of dynamic ecosystems. However, communities increasingly rely on built solutions (also referred to as grey or hard infrastructure), including levees, sea walls, and rip-rap revetments; but these structures can be detrimental, in many cases effectively removing natural protective systems. A third option—which receives less attention but has much potential—is the hybrid approach, which integrates both grey and green approaches, aiming to maximize coastal protection while reducing ecosystem damage.

Research on Superstorm Sandy's effects on coastal communities in New Jersey shows that salt marshes alone are insufficient in preventing damage, highlighting the necessity for a synergistic approach that includes built infrastructure. Initiatives aimed at natural and hybrid approaches like "Rebuild By Design" and "Designing With Water" in New York and Boston respectively are gaining traction, but one of the barriers is a lack of data on the long term benefits. Other challenges associated with hybrid systems include development timescales and policy barriers, so that built solutions often seem more tractable.

Successful adoption therefore requires substantial community buy-in. Education and awareness building— teaching the public that these ecosystems have inherent value above and beyond their protective functions—are therefore important. Coastal resiliency projects might gain more traction if marketed with a focus on ecosystem services rather than simply storm surge protection. Some of these might include increased tourism, species diversity, fishery stability, and extended life cycles for built infrastructure. We contend that hybrid strategies, incorporating natural and grey infrastructure, should be a strong focus of future studies.

Megagravel: A Youtube Movie Showcasing Coastal Boulder Deposits, the Scientists Working on Them, and the People Living Next to Them

Ava Palmo '19 and Rónadh Cox

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592, doi: 10.1130/abs/2019AM-331729, 2019

MEGAGRAVEL is a short documentary film introducing coastal boulder deposits (CBD) to a general audience. CBD accumulate above high tide on certain rocky coasts. Some are on tops of tall cliffs, others are found up to a quarter of a kilometer inland; and they can include clasts weighing 10s or 100s of tonnes. Because they occur in remote areas prone to extreme waves, few people are aware of them. But CBD can help us understand the upper limits of storm waves power at coastlines.

Devised as part of the Broader Impacts component of an NSF-funded research project investigating CBD and storm waves, the documentary is designed to give people a sense of wonder about CBD, to put a human face on the scientists, and to place CBD in the societal context of the people who live next to them. The video, which is just under 10 minutes long, is posted at https://www.youtube.com/watch?v=u9PuDY7QyBo.

The documentary combines interviews (filmed on location as well as on campus), field footage, and still images. A narrative voice-over by the first author, placing the research project in the context of her personal involvement,

draws the viewer in by piquing their interest in the human experience of the location and its people. Information about the CBD is conveyed mostly through short interviews with the scientists involved, contextualized via field footage and interviews with local people. The video concludes with clips showcasing the scientists' visceral responses and awe in the face of nature.

Response to the video has been very positive. Many people to whom the link was sent as part of project reporting protocols actually watched the whole thing (!!), and gave unsolicited feedback. We have incorporated links to the video in educational materials developed as additional parts of the project's Broader Impacts, and will continue to include it in other kinds of research output.

Coastal Land Loss in Louisiana Disproportionately Affects Native American Tribal Groups

Devon Parfait '21, Williams Downs '20, Rónadh Cox, Shirell Parfait-Dardar, José Constantine

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592, doi: 10.1130/abs/2019AM-336906, 2019

Land loss is a growing threat for all coastal communities, but risks and impacts are unequally distributed. The Biloxi-Chitimacha-Choctaw Confederation of Muskogees is an alliance of three ancestrally related but independent state-recognized tribes that are located in Terrebonne and Lafourche Parishes, marginalized—quite literally—at the southern fringes of Louisiana. Displaced by European settlers, these people have lived in the delta swamplands for generations. Now their homelands are again being taken, this time by land loss. Tribal cemeteries, as well as pre-historic Native American sites and artifacts, are being engulfed as sea level rises and land subsides. Woodlands where adult tribe members ran as children are now replaced by open water. Driveways and yards flood during high tides, even in fair weather. With education levels and median income well below national and state averages, these communities are also at risk socio-economically, with no income safety net to deal with the threat of inundation, or its costs.

Land loss is pervasive in southern Louisiana, but GIS analysis of tribal lands reveals that they are turning to water at rates greater than the average. For example, the area of Terrebonne Parish occupied by the Grand Caillou/Dulac Band of Billoxi-Chitimacha-Choctaw comprises 295 km^2. Topographic maps from the 1940s show this area as marshland, drained by numerous bayous, with three distinct lakes (Boudreaux, Gero, and Quitman) By the 1980s, the lakes had expanded and merged to form a single water body; numerous artificial channels (including the 30-mile Houma Navigation Canal) had been dredged; and land loss rates were on the increase. Landsat images spanning 1996 to 2017 show that in 1996 the tribal area was 88% land and 12% water. By 2017 that had changed to 81% land and 19% water. Computed slightly differently, 9% of the 1996 land area had turned to water by 2017. USGS data for the same time period (Couvillon et al. 2017, SIM 3381) show that for Terrebonne Parish as a whole, 3.1% of the land had turned to water; and for the entire coastal Louisiana region, the loss over that time period was 2.8%. Thus the rate of loss of this tribal group's land in the past two decades is about 3 times higher than the background rate. This underscores the extreme vulnerability of indigenous groups in the delta.

Storm-wave movement of megagravel, and formation of imbricated boulder ridges: evidence from Froude-scaled wave-tank experiments

Cox, R., O'Boyle, L., Dias, F. and *Cytrynbaum, J. '18*

20th Congress of the International Union for Quaternary Research

Coastal boulder deposits (CBD) are supratidal clastic deposits that include isolated boulders, small clusters, and extensive ridge systems built of stacked, imbricated clasts. Individual boulders can weigh many 10s to 100s of tonnes. They are emplaced by waves along steep rocky coasts. Some are on cliffs as high as 50m above high water, and others are found at the back of shallowly dipping coastal ramps, up to 250m inland of the tide line. They occur worldwide, but some of the best examples occur on the west coast of Ireland. An outstanding question about these deposits is whether storm waves can produce the structured and imbricated boulder ridges that are characteristic of CBD, or whether they are the signatures of tsunami.

We carried out Froude-scaled 1:100 wave tank experiments, using a JONSWAP spectrum to simulate realistic storm conditions, with Hs ranging from 10-14m (scaled equivalent). Model boulders (441-1075t scaled equivalent) were situated on a cliff-top platform (10m a.s.l. scaled equivalent), and we examined both the movement of individual

blocks and the formation of boulder clusters and ridges on the platform. We ran multiple tests, varying boulder size and configuration. Wave gauges at several locations in the tank recorded water surface elevation, and video footage captured wave parameters and wave-boulder interactions that are difficult to measure at full scale.

Overtopping waves did not disperse cliff-top boulders, but tended to deposit them in clumps and ridges, with imbrication and geometry matching coastal boulder deposits, indicating that storm waves can and do form imbricated boulder ridges. The majority of boulder displacements were caused by a small subset of the incident waves, the key to boulder transport being development of a high velocity bore. The largest waves are not necessarily the most effective: instead, wave-front steepness just before cliff impact seems to control the strength of post-collapse cross-platform flow. Waves that approached the cliff unbroken, had a front slope angle in the range 15°-25°, and were taller than the cliff, generated the most powerful bores. These waves moved very large boulders with masses in excess of those predicted by existing hydrodynamic equations.

¡Cuba! River Water Chemistry Reveals Rapid Chemical Weathering, the Echo of Uplift, and the Promise of More Sustainable Agriculture

Bierman, Paul, Hernández, Rita Yvelice Sibello, Schmidt, Amanda H., Aguila, Héctor Alejandro Cartas, Alvarez, Yoelvis Bolaños, Arruebarrena, Aniel Guillén, Campbell, Mae Kate, Dethier, David, Dix, Monica, Massey-Bierman, Marika, Moya, Alejandro García, Perdrial, Julia l., Racela, Jason, Alonso-Hernández, Carlos

GSA Today, v. 30, https://doi.org/10.1130/GSATG419A.1, 2020

For the first time in more than half a cen¬tury, a joint Cuban/American science team has worked together to quantify the impacts of chemical weathering and sustainable agri¬culture on river water quality in Cuba—the largest and most populous Caribbean island. Such data are critical as the world strives to meet sustainable development goals and for understanding rates of landscape change in the tropics, an understudied region. To char¬acterize the landscape, we collected and ana¬lyzed water samples from 25 rivers in central Cuba where upstream land use varies from forested to agricultural.

Cuban river waters bear the fingerprint of the diverse rocks underlying the island, and many carry exceptionally high dis¬solved loads. Chemical denudation rates are among the top 15% globally and are similar to those measured in other Caribbean islands. High rates of solute export and the distinct composition of the waters in spe¬cific basins suggest flow paths that bring river source waters into contact with fresh, weatherable rock—unusual in a warm, wet, tropical climate where weathering should extend deep below the surface. Tectonically driven uplift likely maintains the supply of weatherable material, leads to channel inci¬sion and thus to the exposure of bedrock in river many river channels.

Despite centuries of agriculture, the impact on these rivers' biogeochemistry is limited. Although river water in many cen¬tral Cuban rivers has high levels of E. coli bacteria, likely sourced from livestock, concentrations of nitrate are far lower than other areas where intensive agriculture is practiced, such as the Mississippi River Basin. This suggests the benefits of Cuba's shift to conservation agriculture after 1990 and provides a model for more sustainable agriculture worldwide.

Features of seafloor hydrothermal alteration in metabasalts of mid-ocean ridge origin from the Chrystalls Beach Complex

Caroline Hung '19, Lisa A. Gilbert, Damon A.H. Teagle, Dave Craw, and Reinhard A. Wobus

New Zealand Journal of Geology & Geophysics, submitted November 2019, revised June 2020

The Taieri Mouth locale of the Chrystalls Beach Complex (CBC) in the South Island of New Zealand includes well preserved to strongly deformed and sheared pillow lavas and flattened veins of epidote, quartz and chlorite intercalated with basalt flows and volcanoclastic breccias. The tectonic affinity for the rare igneous portion of the predominantly sedimentary CBC has not been well established in the context of its regional metamorphic geology. New field, petrographic, geochemical and isotopic observations suggest a mid-ocean ridge origin for the Taieri metabasalts. Further, paleo-vertical to sub-vertical networks of epidote-quartz-chlorite veins and cross-cutting faults are characteristic of an oceanic hydrothermal origin. Altered pillows and epidote separates have $\delta^{18}O$ isotope values ranging from 9.3 to 13.1‰. This indicates slightly enriched $\delta^{18}O$ fractionation resulting from seafloor weathering near-axis low-temperature (<250°C) exchange between seawater and hydrothermal fluids in basaltic fractures.

Age-corrected $^{87}Sr/^{86}Sr$ ratios of range from 0.704135 and 0.70624 show low temperature fluid-rock interactions where the altered pillows and veins did no succumb to major mineralogic changes or isotopic re-equilibration after formation. In contrast, compressed s-fold epidote and coarse quartz veins near metasediments are suggestive of the elevated temperatures and pressures during accretion. We provide a detailed study to differentiate between episodic seafloor venting and accretional wedge-related alteration recorded within these metabasalts.

Teaching Geoscience Tools For Addressing Societal Grand Challenges: A Unique Study-Away Experience During COVID19

Lisa A. Gilbert

Science Education and Civic Engagement: An International Journal, 12(2) (in press)

During the COVID-19 switch to remote learning Spring 2020 semester, I used the final 6 weeks of my oceanography course to teach specific topics and skills that would support students' ability to address complex, relevant problems. Students evaluated hazard and risk, worked with a variety of data, and learned the fundamentals of systems thinking. Much of the curricular material was based on published and peer-reviewed InTeGrate models, which were originally designed to be societally relevant. I introduced many of the examples and case studies originally planned related to hurricanes, oil spills, and climate. Although I did not teach public health, human biology, or other topics more closely related to the global pandemic, students reported that the course was exceptionally relevant. They had the opportunity to apply knowledge and skills learned, but not all chose to. Assignments were tailored to give students choice, and while some students had a great desire to process the health crisis, many had limited tolerance for discussions of COVID-19 and saw class as one of their only breaks from news and household discussions.

A New Vision of Sustainability in Earth Science Education

Lisa A. Gilbert, Rachel Teasdale, and Cathryn A. Manduca

EOS, 101, 2020

How can we structure our societies to live and prosper within the boundaries that ecological limits impose? The geosciences can—and should—play a strong role in studying, communicating, and finding solutions to modern societal challenges, not the least of which is building sustainable societies. Human demands on the Earth system—through natural resource use and urbanization, for example—have put at risk our ability to live sustainably on our planet, while Earth hazards like storms and earthquakes exacerbate societal inequities. A public that is geoscience literate and a geoscience workforce that can provide scientific knowledge, systems thinking, and skill in interdisciplinary problem solving are of paramount importance for addressing societal grand challenges in environmental sustainability. Thus, it is vital that Earth scientists and educators collaborate to ensure a steady supply of geoscientists [e.g., Wilson, 2018] and Earth-literate graduates, to improve upon the lack of diversity within the geoscience workforce [e.g., Bernard and Cooperdeck, 2018], and to prepare scientists to collaborate with a variety of community groups and institutions that help educate the public at large.

Evidence for Seafloor Hydrothermal Alteration in Delaminated MOR-Type Metabasalts of the Chrystalls Beach Complex, South Island, New Zealand

Caroline Hung '19, Lisa A. Gilbert, Damon A.H. Teagle, Dave Craw, and Reinhard A. Wobus

American Geophysical Union Fall Meeting, Abstracts with Program, San Francisco, CA, 2019

Evidence from the Chrystalls Beach Complex (CBC), an accretionary mélange of the Triassic-Jurassic age, are integral to our understanding of the origin and metamorphic history of the Otago Schist, an extensive belt of low grade metamorphosed Mesozoic sediments and basalts on the South Island of New Zealand. However, previous studies note the tectonic affinity and age of the CBC are not well-defined within its own boundaries- nor with the neighboring terranes. In an attempt to reinterpret the geologic history and emplacement of the CBC, we focus on the Taieri Mouth locale, which includes well-preserved to deformed and sheared pillow lavas and volcaniclastic breccias with prominent veins of epidote, quartz and chlorite. New field, petrographic, geochemical and isotopic observations suggest a mid-ocean ridge origin for the volcanic rocks and contradict previous notions of subduction-related metamorphism as the predominant source of alteration. Restored relative to paleohorizontal, vertical to sub-vertical arrays of epidote-filled veins and thrust faults indicate the presence of concentrated on-axis hydrothermal fluid upflow. Cross-cutting veins show the episodic stages of fracture genesis and fluid flow specific to ridge

settings. Analyses show strong enrichments of fluid-mobile alkali (K, Rb, and Cs) and alkali earth elements (Ba, Sr). Differing hydrothermal fluid dynamics from near- to off- axis generate a gradation of epidote compositions of Fe (III):Al. Pillows, secondary and sulphide mineral veins are relict of hydrothermal alteration, with $\delta^{18}O$ ranging from 9.0 to 13.1‰ and $^{87}Sr/^{86}Sr$ ratio from 0.7042 to 0.7061, comparable to those values of other well-studied ophiolites of Troodos and Semail. Multiple events of seafloor hydrothermal alteration due to faulting on- or near- axis may yield changes in overall porosity of the complex that have broader implications for the preservation (obduction) and delamination of rare MORB-type ophiolites.

Supporting and Assessing Systems Thinking Skills Development in Undergraduates

Lisa A. Gilbert, Ellen A.R. Iverson, Kim A. Kastens, & Cathryn Allen Manduca

American Geophysical Union Fall Meeting, Abstracts with Program, San Francisco, CA, 2019

Many grand societal challenges including access to clean drinking water and resilience to natural hazards involve the complex interaction of natural and human systems in ways that are often counterintuitive and nonlinear. To prepare a citizenry to address such complexity, the Interdisciplinary Teaching about Earth for a Sustainable Future (InTeGrate) project had as one of its major goals to improve systems thinking in undergraduates. As a National Science Foundation STEP Center, InTeGrate addressed students' ability to use systems thinking skills through development and implementation of innovative curricular materials that incorporated instruction in systems thinking. Systems thinking was then assessed with student answers to a multi-part essay, an instrument which is publicly available. The essay prompts students to give an example of a real-world system and describe its parts, explain how parts of the system interact using systems concepts (e.g., feedback loops, equilibrium), and discuss how an effect in one part of that system can be influenced by multiple causal factors.

More than 100,000 undergraduate students have taken courses with InTeGrate materials since 2012 and a subset of essay answers from those students (n=360) was scored and compared to essay answers from a control group without systems thinking instruction (n=173). Students in the InTeGrate group scored significantly higher on the systems thinking essay than the control group despite similar demographics and institution types, Earth literacy (measured by the Geoscience Literacy Exam), and essay writing skills. In the InTeGrate group, 82% of students scored 50% or higher on the instrument while in the control group only 11% of students scored 50% or higher. Although the systems thinking instruction in InTeGrate was fairly basic -- using systems vocabulary, making or evaluating systems diagrams or causal loop diagrams, and, in a few of the modules, testing or generating models -- the data presented here demonstrate significant mastery of systems thinking skills by the InTeGrate group as compared to the control group.

Impact of InTeGrate Teaching Materials on Student Geoscience Interests, Literacy and Learning Outcomes at Historically Black Colleges and Universities

Richard D.S. Gragg, III, Ellen Iverson, Helen Brethauer-Gay, John Warford, Lisa A. Gilbert, Kathyrn Sheriff, and Cathryn A. Manduca

Earth Educators' Rendezvous, Nashville, TN, 2019

An interdisciplinary research team from Carleton College and Florida A&M University is investigating the impacts of geoscience materials on faculty teaching practices and student learning outcomes at Historically Black Colleges and Universities (HBCU). As part of the work of the InTeGrate-HBCU Geosciences Working Group, 14 HBCU faculty taught 24 courses using geoscience materials from the InTeGrate, open source, online platform (see https://serc.carleton.edu/integrate/teaching_materials/itg_materials_dev.html). The courses included a wide breadth of disciplines including environmental science, geography, mathematical teacher preparation, sociology, criminal justice, politics, engineering, marine science, and earth science. From the 24 course enactments, assessment data from over 530 enrolled students was collected. Participating faculty administered before and after course instruction, the Integrate Attitudinal Instrument (IAI) and the Geoscience Literacy Exam (GLE) surveys. In addition, the InTeGrate interdisciplinary problem solving and systems thinking essay questions were administered at the end of each course to assess student responses. Five members of the research team used a rubric (0 to 4 total score possible), to score a representative sample of 135 essays, with each essay being independently scored by two of the team members. This presentation will provide results of preliminary analyses on the student data, including the impact of InTeGrate materials and design concepts on HBCU student interest in the environment, further pursuit of geoscience education,

geoscience related careers, and action to enhance human sustainability on the planet and the higher order thinking related to interdisciplinary problem solving and systems thinking.

Geoscience Literacy and Career Interest Improve Among Two-Year College Students with InTeGrate Materials

Elizabeth Nagy-Shadman and Lisa A. Gilbert

Earth Educators' Rendezvous, Nashville, TN, 2019

InTeGrate classroom materials are designed to strengthen earth science literacy of undergraduate students as well as increase the number of earth science majors who can address critical environmental and resource challenges. Two assessment instruments used to measure the success of these goals were each given to students pre- and post-instruction in classes where instructors used the InTeGrate materials, as well as with control groups that were not instructed with InTeGrate materials. The Geoscience Literacy Exam (GLE), based on the four Geoscience Literacy Documents, is designed to measure gains in content knowledge over one semester. The InTeGrate Attitudinal Instrument (IAI) examines interests in earth science careers and motivation related to solving grand challenges in earth science such as environmental sustainability and resource depletion. This study separated and compared GLE and IAI data from two-year colleges (2YCs) and four-year colleges (4YCs) to examine literacy and interest gains. Paired GLE results (i.e., pre- and post-semester results for a given student) show that the InTeGrate materials enhanced geoscience literacy for both 2YC (n=568) and 4YC (n=3739) students, but that the 2YC gains are significantly higher. By the end of the course, the 2YC students no longer lag behind 4YC students in geoscience literacy. The 2YC students also show a greater increase in geoscience-related career interests from pre- to post-semester (43%) compared to 4YC students (32%) and a control group (32%). One interpretation of these results is that InTeGrate materials are providing a disproportionate benefit to 2YC students in terms of geoscience literacy and attitudes. According to American Geoscience Institute reports 25% of students holding bachelor's degrees in the geosciences attended a 2YC for at least one semester before transferring to a 4YC. This study suggests that InTeGrate materials may be particularly effective in recruiting even more 2YC students into the geosciences.

Holocene hurricane deposits eroded as a coastal barrier from andesite sea cliffs at Puerto Escondido (Baja California Sur, Mexico)

Johnson, M.E., Johnson, E.M., Guardado-France, R., and Ledesma-Vázquez, J.

Journal of Marine Science and Engineering, 8, 75; doi: 10.3390/jmse8020075, 2020

Previous studies on the role of hurricanes in Mexico's Gulf of California examined coastal boulder deposits (CBDs) eroded from limestone and rhyolite sea cliffs. Sedimentary and volcanic in origin, these lithotypes are less extensively expressed as rocky shores than others in the overall distribution of gulf shores. Andesite that accumulated as serial volcanic flows during the Miocene constitutes by far the region's most pervasive rocky l\shores. Here, we define a subgroup of structures called barrier boulder deposits (BBDs) that close off lagoons as a result of lateral transport from adjacent rocky shores subject to recurrent storm erosion. Hidden Harbor (Puerto Escondido) is the most famous natural harbor in all of Baja California. Accessed from a single narrow entrance, it is commodious in size (2.3 km^2) and fully sheltered by outer andesite hills linked by two natural barriers. The average weight of embedded boulders in a succession of six samples tallied over a combined distance of 710 m ranges between 74 and 197 kg calculated on the basis of bolder volume and the specific gravity of andesite. A mathematical formula is utilized to estimate the wave height necessary to transport large boulders from their source. Average wave height interpreted by this method varies between 4.1 and 4.6 m. Input from fossil deposits and physical geology related to fault trends is applied to reconstruct coastal evolution from a more open coastal scenario during the late Pleistocene 125,000 years ago to lagoon closure in Holocene time.

Comparison of modern and Pleistocene (MIS 5e) coastal boulder deposits from Santa Maria Island (Azores Archipelago NE Atlantic Ocean)

Ávila, S.P., Johnson, M.E., Rebelo, A.C., Baptista, L, and Melo, C.S.

Journal of Marine Science and Engineering, 8, 386; doi: 10.3390/jmse8060386, 2020

Modern and palaeo-shores from Pleistocene Marine Isotope Substage 5e (MIS 5e) featuring prominent cobble/boulder deposits from three locations on the southern and eastern coast of Santa Maria Island in the Azores Archipelago,

were compared, in order to test the idea of higher storminess during the Last Interglacial. A total of 175 basalt clasts from seven transects were measured manually in three dimensions perpendicular to one another. Boulders that exceeded the minimum definitional diameter of 25cm contributed to 45% of the clasts, with the remainder falling into the category of large cobbles. These were sorted for variations in shape, size, and weight pertinent to the application of two mathematical formulas to estimate wave heights necessary for traction. Both equations were based on the "Nott-approach", one of them being sensitive to the longest axis, the other to the shortest axis. The preponderance of data derived from the Pleistocene deposits which included an intertidal invertebrate fauna for accurate dating. The island's east coast at Ponta do Cedro lacked modern boulder beds due to steep rocky shores, whereas raised Pleistocene palaeo-shores along the same coast reflect surges from an average wave height of 5.6m and 6.5m. Direct comparison between modern and Pleistocene deposits at Ponta do Castelo to the southeast and Prahina on the island's south shore produced contrasting results, with higher wave heights during MIS 5e at Ponta do Castelo and higher wave heights for the modern bolder beach at Prahina. Thus, our results did not yield a clear conclusion about higher storminess during the Last Interglacial compared to the present day. Historical meteorological records pit the seasonal activity of winter storms arriving from the WNW-NW against the scant record of hurricanes arriving from the ESE-SE. The disparity in the width of the marine shelf around Santa Maria Island with broad shelves to the north and narrow shelves to the south and east suggested that periodic winter storms had a more regular role in coastal erosion, whereas the rare episodic recurrence of hurricanes had a greater impact on southern and southeastern rocky shores where the studied coastal boulder deposits were located.

Multiphase storm deposits eroded from andesite sea cliffs on Isla Sn Luis Gonzaga (northern Gulf of California)

Guardado-France, R., Johnson, M.E., Ledesma-Vázquez, J., Santa Rosa-del Rio, M.A., and Herrera-Gutiérrez, A.R.

Journal of Marine Science and Engineering, 8, 525; doi: 10.3390/jmse8070525, 2020

The 450-m long spit that extends westward from the northwest corner of Isla San Luis Gonzaga is one of the largest and most complex constructions of unconsolidated cobbles and boulders found anywhere in Mexico's Gulf of California. The material source derives from episodic but intense storm erosion along the island's andesitic cliff face with steep northern exposures. A well-defined marine terrace from the late Pleistocene cuts across the same corner of the island and provides a marker for the subsequent development of the spit that post-dates tectonic-eustatic adjustments. A total of 660 individual andesite clasts from seven transects across the spit were measured for analyses of change in shape and size. These data are pertinent to the application of mathematical formulas elaborated after Nott (2003) and subsequent refinements to estimate individual wave heights necessary for lift from parent sea cliffs and subsequent traction. Although the ratio of boulders to clasts diminishes from the proximal to distal end of the structure, relatively large boulders populate all transects and the average wave height required for the release of joint-bound blocks at the rocky shore amounts to 5m. Based on the region's historical record of hurricanes, such storms tend to decrease in intensity as they migrate northward through the Gulf of California's 1100-km length. However, the size and complexity of the San Luis Gonzaga spit suggests that a multitude of extreme storm events impacted the island in the upper gulf area through the Holocene time, yielding a possible average growth rate between 7 and 8 m/century over the last 10,000 years. In anticipation of future storms, a system to track the movement of sample boulders should be emplaced on the San Luis Gonzaga spit and similar localities with major coastal boulder deposits.

Neogene marine sediments and biota encapsulated between lava flows on Santa Maria Island (Azores, north-east Atlantic): An interplay between sedimentary, erosional and volcanic processes

Uchman, A., Johnson, M.E., Ramalho R.S., Quartau, R., Berning, B., Hipólito, A., Melo, C.S., Rebelo, A.C., Cordeiros, R., and Ávila, S.P.

Sedimentology, doi: 10.1111/sed.12763, 2020

Sedimentary rocks are rarely preserved on reefless volcanic oceanic islands because their sediments are mostly exported from coastal areas towards the deep sea and such islands typically undergo subsidence. In contrast, the exceptional geological record of the uplifted Santa Maria Island (Azores) provides a unique opportunity to gain insight on such coastal systems. This study focuses on a locality at Ponta do Cedro (eastern Santa Maria Island), which features a series of marine fossiliferous sediments wedged between steep lava deltas. As demonstrated by local structure, these sediments correspond to clinoforms deposited on the steep submarine slope of an active volcanic

island, implying transport from shallow waters to greater depths and subsequent colonization by benthic communities. Rapid volcanic progradation eventually sealed the deposits, allowing for their preservation and providing a rare snapshot of the ecology during those intervals, in addition to insights on sedimentary dynamics along submarine island slopes. This study reveals spatial relationships between wedges of sedimentary bodies encapsulated by lavas in the Ponta do Cedro section, and interprets depositional processes preserved in those strata based on sedimentological and palaeontological data. The dynamics of the environment are mostly related to relative sea-level changes, intense volcanic activity and regional uplift during the Neogene.

Do topographic barriers prevent hinterland detritus from reaching foreland basins? Two examples from the Taconic and Acadian orogenies in the northern Appalachians

Karabinos, Paul, Crowley, James L., and Macdonald, Francis A.

Geological Society of America Abstracts with Programs. Vol. 51, No. 5 doi: 10.1130/abs/2019AM-332695, 2019

Detrital zircon studies provide constraints on the depositional age and provenance of Early Paleozoic foreland and hinterland basins in the northern Appalachians. Collision of Gondwanan-derived terranes with Laurentia occurred during both the Ordovician Taconic and Devonian Acadian orogenies. Detrital zircon populations from Early Ordovician to Early Devonian units in hinterland basins in New England indicate that both Laurentia and Gondwanan-derived terranes contributed sediment. In contrast, Early Ordovician to Late Devonian rocks deposited in foreland basins on the Laurentian margin contain only Laurentian-derived detritus, with the exception of some Late Devonian units from the Catskill basin, which contain only a minor component of Gondwanan-derived sediment. Previous studies have noted that foreland basin deposits lack detritus derived from accreted terranes in the hinterland, but commonly explain the absence by invoking tectonic burial of Gondwanan-derived terranes. The ubiquitous presence of mixed Laurentian and Gondwanan-derived detrital zircons in hinterland basins indicates that tectonic burial cannot explain the absence of detrital zircons derived from accreted terranes in foreland basins. Ordovician and Devonian airfall tephras preserved in Laurentian foreland basins record explosive hinterland arc and slab break-off volcanism. Ordovician slates from the Giddings Brook thrust sheet in the Taconic range record a shift in εNd from -12 to -8, toward more juvenile values, at approximately 466 Ma, which is interpreted to reflect the weathering of Ordovician arc rocks proximal to the Laurentian margin. This suggests that fine-grained mud was transported from the hinterland to foreland even though coarse-grained detritus was not. We suggest that foreland-directed thrusting of the rifted margin of Laurentian created topographic barriers that prevented coarse-grained hinterland detritus from reaching the foreland basins and that erosion of the thrust sheets recycled Laurentian detritus into the foreland basins. The intensity of crustal shortening in the hinterland may still have affected the rate of sedimentation in the foreland basin, but it was modulated by the reactivation of thrusts along the Laurentian margin whenever a critical taper was reestablished.

Fantastic maps and where to find them: Creating a new generation of geologic maps for teaching structural analysis and cross-section construction

Karabinos, Paul, and Allmendinger, Richard W.

Geological Society of America Abstracts with Programs. Vol. 51, No. 5 doi: 10.1130/abs/2019AM-334364, 2019

Traditional methods for teaching students how to analyze structures in geologic maps and to construct cross-sections rely on paper maps with topographic contours and standard drafting tools. This approach helps students learn how to visualize structures on maps, but it does not introduce them to digital maps and, more importantly, to computer programs that incorporate elevation data for map analysis. For example, GeolMapDataExtractor (GMDE) (Allmendinger, 2019) is a versatile program that can use digital geologic maps to perform 3-point problems, calculate stratigraphic thicknesses, project contacts across topography, and construct topographic profiles. Orientation data can also be entered manually based on measurements recorded on the map. Elevation data can be entered manually from topographic contours, obtained from web-based elevation servers, or read from user-provided DEMs for offline use. Some published geologic maps are suitable for teaching purposes, but even the simplest maps may be too complex for beginning students. A suite of simple to complex synthetic geologic maps, illustrating specific geometries, can be used to bridge the gap between traditional paper map exercises and computer-based map analysis for teaching purposes. A DEM from a real region with suitable topography is imported into Trimble SketchUP (SU) where topographic contours are added. A cross-section illustrating stratigraphic contacts, folds, and faults is

constructed on a vertical plane in SU and projected with the push-pull tool into the DEM. The intersection of the projected cross-section with the DEM is used to create the geologic contacts. If desired, the maps can be printed for use in traditional map exercises. The same maps can also be used in GMDE to show students how to determine the orientation of contacts, to estimate the stratigraphic thickness of map units, to project contacts across topography, and to begin cross-section construction. Because the DEMs are based on actual topography, elevations can be obtained from web-based servers or read from the DEMs for offline use. By using SU it is possible to generate a large number of geometrically consistent synthetic geologic maps of increasing complexity in a reasonable amount of time. These maps can help introduce students to some of the methods of modern structural geology.

Improving geologic mapping with computational field geology

Allmendinger, Richard W. and Karabinos, Paul

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Computers are faster at calculating and more accurate at plotting precise geometries than a human field geologist. If the field geologist can do a complex calculation in the field, the result of the calculation can be tested immediately. For example, we many want to calculate the complex trace of a planar contact across topography, fit a plane to the vertices of a digitized contact, calculate an orientation based on three points, rapidly calculate a map thickness of a unit, calculate a piercing point, or calculate mean vectors or cylindrical best fits. Most of these calculations require the X, Y, AND Z components of digitized points but, unfortunately, most mobile device mapping programs only record X and Y.

GMDE Mobile and desktop apps, written by the senior author, enable the field geologist to load a digital elevation model (DEM) for offline use and can carry out all of the above calculations. The Mesozoic stratigraphy of the Idaho Wyoming thrust belt presents an ideal test case because of the combination of good exposure and distinctive units. We have used these technologies for mapping and structural analysis in the Poker Peak Quadrangle. We have also used these programs with DEMs based on LiDAR data in high grade metasedimentary rocks in the Berkshires, to map fractures in Grenville basement of the Adirondacks, and map earthquake fault ruptures.

Allowing the computer to project a planar contact across topography not only results in more accurate contacts that bridge areas of no exposure but also aids significantly in identifying fault offsets by showing where a projections suddenly fails to match the geology. Map scale strike and dips from 3-point calculations are more consistent and display considerably less scatter than orientations measured by the geologist on the outcrop. An iterative approach, where the geologist first draws a contact segment by hand, best-fits a plane to that segment, and then has the iPad calculate the contact using the best-fitting orientation can help identify local geological anomalies.

More accurate contacts and more consistent orientations mean better cross sections and down-plunge projections. Outcrop scale noise, introduced either by poor measurement technique or by stochastic variations of the outcrop itself can be reduced by these computational field methods.

The laser's edge: pushing detrital zircon geochronology to the limit to study complex rocks in the Pelham dome, northern Appalachians

Crowley, James L., Karabinos, Paul M., and Macdonald, Francis A.

Geological Society of America Abstracts with Programs. Vol. 51, No. 5 doi: 10.1130/abs/2019AM-337680, 2019

Detrital zircon geochronology in rocks with complex tectono-thermal histories is challenging. Metamorphism affects the U-Pb systematics of detrital zircon through recrystallization and Pb loss, resulting in dates that are too young. Also problematic is intrusion of granitoids followed by intense deformation because that adds post-depositional zircon that can be difficult to distinguish from the detrital zircon based on composition and age. Studies that combine high spatial resolution (SIMS or LA-ICPMS) with high age precision (CA-TIMS) are often necessary to ensure accurate detrital ages.

The Pelham dome in central MA is one of 21 domes in the Ordovician Bronson Hill composite arc (BHCA) and the only that has Neoproterozoic rocks of the Dry Hill Gneiss (DHG) in its core. The DHG was interpreted as metavolcanic based, in part, on its intercalation with the metasedimentary Poplar Mountain Gneiss (PMG), which was also considered Neoproterozoic. Our goal was to determine if Paleozoic dates (~330, 390, 420, and 470 Ma) obtained

from 18 grains (7%) from one PMG lithology are accurate detrital ages or too young. Creation of 30-40 mm thick zircon wafers polished on both sides allowed for 3-8 LA-ICPMS dates per grain and two CA-TIMS dates per grain from fragments that were cut out with a laser. Within-grain age agreement suggests all dates are accurate; there is no mixing with ubiquitous ~290 Ma rims that are clearly metamorphic. Compositions of the ~330-470 Ma grains show they did not grow during metamorphism or pegmatite crystallization, but instead are likely from arc magmas. To test whether these grains were added to the PMG as inherited cores in zircon from pegmatite that was sheared into the PMG, a pegmatite-rich rock was analyzed. It has 330 Ma zircon, but lacks 390-470 Ma grains, making an inherited origin for them unlikely. We conclude that parts of the PMG were deposited after 390 Ma, possibly after 330 Ma, thereby providing evidence for a Carboniferous extensional or transtensional basin on a Gondwanan-derived accreted terrane and Alleghenian underthrusting of it under the BHCA.

Tectonic synthesis of the Taconic orogeny from New England to Newfoundland

Macdonald, Francis A., Hodgin, Eben Blake, Crowley, Jim L., and Karabinos, Paul

Geological Society of America Abstracts with Programs. Vol. 51, No. 5 doi: 10.1130/abs/2019AM-340493, 2019

A detailed synthesis of the Ordovician Taconic orogeny in the northern Appalachians has been hindered by along strike variations in Laurentian, Gondwanan-derived, and arc-generated tectonic elements. In particular, it is not clear which variations reflect primary differences in plate tectonic geometry, differential erosion, or post-Taconic strike-slip faulting. Here we present new geochronologic data from the Corner Brook Lake block (CBLB) and the Dashwood terrane of Newfoundland and compare them with data from New England. New Grenvillian magmatic and metamorphic dates from the CBLB constitute piercing points with the Indian Head Range across the Humber River Fault. Metasediments on the Dashwoods terrane, previously correlated with the Fleur de Lys Supergroup (FDLS) on the Laurentian margin, are bracketed in age by Early to Middle Ordovician detrital zircon and Middle Ordovician intrusions and metamorphism. These data demonstrate that the CBLB is not far travelled and that the Lush's Bight and Dashwoods metasediments were deposited in a syncollisional basin postdating the deposition of the FDLS. The Middle to Late Cambrian (?) Twillingate Granite and Little Port Trondhjemite are the only pre-Ordovician basement present in the Dashwoods terrane. We have found neither Laurentian basement nor Gondwanan-derived Moretown terrane equivalent underlying Dashwoods. Dashwoods may be an Early Paleozoic juvenile arc terrane or an intra-arc basin and potentially equivalent to the Hawley Formation in New England.

Geochronological evidence for Salinic thrusting and Acadian reactivation of external basement massifs in western New England and overprinting of the Ordovician Taconic thrust belt

Webb, Laura E., Karabinos, Paul, and Klepeis, Keith A.

Geological Society of America Abstracts with Programs, Vol. 51, No. 5 doi: 10.1130/abs/2019AM-334274, 2019

We present new data from 40Ar/39Ar geochronology of samples from two exposures of the Rattlesnake Fault, the western frontal thrust of the Green Mountain massif near its southern end in Pownal, Vermont. At exposure 1, the Cambrian Cheshire Quartzite lies structurally above a graphitic phyllite interpreted as either the Ordovician Walloomsac or Cambrian Nassau Fm. At exposure 2, the Neoproterozoic to Cambrian Dalton Fm. is in the hanging wall above a similar phyllite. Samples of the Cheshire Quartzite in the fault zone record evidence of quartz deformation via subgrain rotation recrystallization and grain boundary migration. Small feldspars display core and mantle structures. Together these observations suggest temperatures of deformation at c. 500°C. White mica is present as fine grains along foliation planes and as small crenulated masses in thin seams. Step heating of white mica from the Cheshire Quartzite within the fault zone yielded a plateau age of 414.3 ± 3.6 Ma (2σ). Based on the lack of grain boundary area reduction and static recovery of quartz, we interpret the age to approximate the timing of deformation. Oblique grain-shape foliations defined by quartz in the dated sample suggest a top-to-the-W transport of the hanging wall. The Dalton Fm. records similar deformation mechanisms and kinematics as described above. A phyllite sample immediately below the Dalton Fm. at the fault contact displays C'-S fabric consistent with a top-to-the-W shear sense. The C' shear bands cut an S2 foliation in which microlithons locally preserve a crenulated S1 foliation. White mica from this sample yielded a plateau age of 417.9 ± 3.8 Ma. An additional sample of the phyllite was collected from a lower structural level. Compared to the phyllite at the fault contact with the Dalton Fm., foliations at the lower level are generally more chaotic, quartz microlithons show greater grain size reduction, and the thin section is crosscut by microfaults. White mica from this sample yielded a weighted mean age of 398.7

± 4.6 Ma. Although the footwall and hanging wall lithologies are similar to those at the Champlain Thrust, which is inferred to have formed during the Taconic orogeny, our new dates suggest that the Rattlesnake Fault is a late Silurian to Early Devonian Salinic thrust that may have been reactivated at c. 400 Ma during the Acadian orogeny.

The early rifting record of Laurentia in the New England and Quebec Appalachians and the generation of peri-Laurentian microcontinents

Karabinos, Paul, Crowley, James L., Jaret, Steven J., Hodgin, E.B., and Macdonald, Francis A.

Geological Society of America, Abstracts with Programs, Vol. 52, No. 1, doi: 10.1130/abs/2020SE-344705, 2020

The Ediacaran breakup of Rodinia created the Laurentian margin and set the stage for the Paleozoic accretion of terranes during the Appalachian orogenic cycle. Cawood et al. (2001) proposed two pulses of rifting in the northern Appalachians at ca 570 and 540 Ma and suggested that the first separated Laurentia from Gondwanan cratons and that the second created Laurentian microcontinents. The Argentine Precordillera (Astini et al., 1995) is a far-travelled Laurentian-derived microcontinent. Waldron and van Staal (2001) suggested that the Dashwoods block in Newfoundland is a peri-Laurentian fragment that was reaccreted during the Taconic orogeny.

Dated rift volcanic rocks in the New England and Québec Appalachians include a 571 ± 5 Ma felsite from the Pinney Hollow Fm in Vermont (Walsh and Aleinikoff, 1999) and a 554 +4/-2 Ma felsite from the Tibbit Hill Fm in Québec (Kumparapeli et al., 1989). We used CA-IDTIMS to date 7 zircon grains from the Pinney Hollow Formation. Our revised date is 562.37 +/- 0.14 Ma. We also used LA-ICPMS to date detrital zircon from undated basal rift clastic rocks and discovered that the detritus was locally derived from subjacent basement rocks in isolated rift graben in the Hoosac Range in northwestern MA and in the Chester dome in southeastern VT. In contrast, the Rowe Schist in MA, correlative with the Pinney Hollow Fm in VT, contains detrital zircon derived from many different sources in Laurentia, suggesting deposition by long-shore currents on an ocean-facing continental margin.

Our data suggest that deposition in deep water on a (hyper-?) extended continental margin was under way by 562 Ma and that rifted blocks were never far removed from the Laurentian margin. Relict oceanic crust and obducted mantle occur outboard of the Pinney Hollow/Rowe belt along the contact with the Gondwanan-derived Moretown Fm. Evidence for reaccreted peri-Laurentian crust can be reinterpreted as Ordovician deposits in intra-arc or syn-collisional basins.

SKS splitting beneath Connecticut: constraints from the SEISCONN array

Lopes, Ethan '18, Long, Maureen D., Karabinos, Paul, and Aragon, John C.

Geological Society of America, Abstracts with Programs, Vol. 52, No. 1, doi: 10.1130/abs/2020SE-344369, 2020

The crustal structure of eastern North America was created during two supercontinent cycles over the past 1.35 billion years. The Mesoproterozoic Grenville orogenic cycle culminated in the supercontinent Rodinia. Neoproterozoic rifting of Rodinia created a passive eastern Laurentian margin. The Paleozoic Appalachian orogenic cycle ended with the supercontinent Pangea. Mesozoic rifting formed the present eastern North American passive margin. The present structure of the crust and mantle lithosphere beneath eastern North America preserves evidence of this complicated tectonic history, and new geophysical datasets are shedding light on this structure. The Seismic Experiment for Imaging Structure beneath Connecticut (SEISConn) consisted of 15 broadband seismometers deployed (between 2015 and 2019) across northern Connecticut at ~10-15 km station spacing. Here we present preliminary results from the analysis of SKS splitting using data from SEISConn stations. Shear wave splitting results from seismic anisotropy in the upper mantle, which in turn reflects the deformation of the lithosphere during past tectonic processes.

Evidence for Salinic and Acadian reactivation of Taconic thrusts along the western Green Mountain front

Webb, Laura E., Karabinos, Paul, and Klepeis, Keith A.

Geological Society of America, Abstracts with Programs, Vol. 52, No. 1, doi: 10.1130/abs/2020SE-344590, 2020

Taconic thrust faults in Vermont have long been suspected to record multiple slip events, however, data revealing the timing of these postulated reactivations are largely lacking. We present the initial findings of a study seeking to constrain the timing of such events through integrated 40Ar/39Ar geochronology and microstructural analysis. We sampled two localities from the Rattlesnake Fault, the western frontal thrust of the Green Mountain massif

near its southern end in Pownal, Vermont, where the fault places 1) Cambrian Cheshire Quartzite and 2) Neoproterozoic–Cambrian Dalton Fm. arenite on graphitic phyllite interpreted as either the Ordovician Walloomsac or Cambrian Nassau Fm. Upper plate rocks preserve S2 mylonitic foliations in which asymmetric lozenges, mantled feldspar porphyroclasts and quartz oblique grain-shape fabrics indicate top-to-the-W shearing. Mica domains locally preserve evidence for an older S1 foliation. Well-preserved D2 quartz and feldspar microstructures suggest rapid cooling following temperatures of deformation in the range of 500–400°C. Evidence for overprinting by lower-T deformation is variable and includes subtle S3 crenulation cleavage development, as well as Fe-rich fractures parallel to and cross-cutting S2. Phyllite sampled in the lower plate directly below the Dalton Fm. has C'-S shear bands (S2; top-to-the-W). The S1 foliation is preserved locally as crenulations within S2 microlithons and Fe-rich fractures are also observed. These observations integrated with the results of 40Ar/39Ar step-heating experiments on white mica and K-feldspar are consistent with a polyphase deformation history. Plateau and weighted mean ages of white mica from the Cheshire Quartzite and phyllite range from c. 419¬–409 Ma and are interpreted to reflect the timing of D2 top-to-the-W thrusting. These samples preserve age gradients that suggest Latest Devonian–Early Carboniferous partial resetting. Similar age gradients (c. 421–362 Ma) have been obtained from mylonitic Cheshire Quartzite in the hanging wall of the Hinesburg Thrust. In comparison, white mica and K-feldspar from the Dalton Fm. immediately above the thrust contact are completely reset with plateau-like segments at c. 356 and 350 Ma, respectively, and age gradients that suggest additional resetting at c. 250 Ma.

Stratigraphic and structural evidence for a fault contact between Ordovician arc rocks and the Connecticut Valley - Gaspé basin sequence in Vermont

Karabinos, Paul, Westerman, D.S., Crowley, J.L., and Macdonald, F.A.

Field Guide: in Koteas, C. ed., New England Intercollegiate Geologic Conference, Northfield, Vermont, p. C3-1 – C1-32, 2019

U-Pb dates on magmatic and detrital zircon from samples collected in the Connecticut Valley-Gaspé basin (CVGB) in Vermont and Massachusetts indicate that the Waits River, Gile Mountain, Northfield, and Goshen Formations are Early Devonian in age, and that they were deposited over a 10 million-year interval (Karabinos and Crowley, 2019). Early Devonian (c. 407 Ma) felsic volcanic beds have recently been dated in the Goshen Formation in Massachusetts by Karabinos and Crowley (2019) (equivalent to the Northfield Formation in Vermont) and in the Meetinghouse House Slate Member of the Gile Mountain Formation by Rankin and Tucker (2009). These are the youngest rocks preserved in the basin, and they are located at the west and east margin of the basin, respectively. The age of the oldest Early Devonian unit in the basin, the Waits River Formation, is bracketed by the youngest detrital zircon from a quartz-rich bed dated by SHRIMP at 415 ± 2 Ma (McWilliams et al, 2010) and a CA-IDTIMS date on a dike cutting the Standing Pond Volcanic Member of the Waits River Formation near Springfield, Vermont of 413.5 ± 0.11 Ma (Karabinos and Crowley, 2019). Hatch (1988a) used graded beds as evidence that the Northfield Formation stratigraphically overlies the Waits River Formation along the western margin of the basin. However, the apparent age gap between the Northfield and Waits River Formations, as determined by isotopic dating, suggests that the Northfield does not conformably overlie that Waits River Formation. Recently acquired LA-ICPMS for crystallization zircons in trondhjemitic dikes and tonalites in a swarm less than 2 km west of the CVGB border provide dates of 412.7 ± 4 and 409.7 ± 8 Ma., perhaps recording the extension associated with filling of the basin (Westerman, 2019; Trip B-2 this volume).

The Shaw Mountain (Vermont) and Russell Mountain (Massachusetts) Formations are commonly correlated with each other and assigned a Silurian age. This age assignment is based on scarce fossil evidence and correlation of the Shaw Mountain and Russell Mountain Formations with the Clough Quartzite to the east in New Hampshire and Massachusetts and the Shawangunk Conglomerate to the west in New York, which have been confidently assigned Silurian ages based on well-preserved fossils. Detrital zircon dates from the Russell Mountain Formation support a Silurian depositional age for the quartz-pebble conglomerate in Massachusetts (Karabinos and Crowley, 2019). Although detrital zircon dates from the Shaw Mountain Formation in Vermont only constrain the maximum depositional age to Ordovician, rare fossils are consistent with a Silurian age.

The eastern border of the CVGB, near the New Hampshire border, is the Monroe fault (Hatch, 1988a, 1988b). The western border of the CVGB is also characterized by faulting, first recognized by Westerman (1985, 1987, 1994) and called the Dog River fault zone (DRFZ) in the vicinity of Northfield, Vermont. The pre-Silurian rocks west of

the CVGB are various members of the Missisquoi Formation of Doll et al. (1961) in Vermont and the Hawley Formation in Massachusetts. Fault-bounded lenses of the Shaw Mountain (VT) or Russell Mountain (MA) Formation are exposed along this important fault zone, just east of the Missisquoi and Hawley Formations. East of the pre-Silurian rocks, or the lenses of quartz-pebble conglomerate, where present, is a belt of dark gray to black phyllite to schist of the Northfield (VT) or Goshen (MA) Formation. This belt of distinctive graphitic schist is noteworthy because it is always present east of the fault zone and is typically about 0.5 km in outcrop width. The apparent lack of truncation of this unit along the more than 350-kilometer-long fault zone in Vermont and Massachusetts warrants an explanation, which we cannot provide at this time.

There is no sedimentological or stratigraphic continuity between the quartz-pebble conglomerate of the Shaw Mountain Formation and the graphitic schist of the Northfield Formation. The Silurian quartz-pebble conglomerate and interbedded fossiliferous white calcareous arenite must have formed in shallow high-energy water near shore, whereas the turbiditic Early Devonian graphitic schist probably formed as distal deposits in deep quiet water.

Following the filling of the CVGB, the compressional conditions of the Acadian orogeny arrived from the east and migrated across Vermont, shortening the basin into large-scale structures reflected by the Vermont Geologic map pattern (Hatch, 1988a), with superimposed high-amplitude (100s of meters) isoclinal folds with wavelengths of 10s of meters (Westerman and Coish, 2009). The western margin of the basin, sensu stricto, is a surface, separating pre-Silurian units from Silurian and Devonian units of the CVGB. This surface, which Hatch and others (1982) referred to as the Taconian Line, and informally called the Richardson Memorial contact (RMC), is a tectonostratigraphic surface that in central Vermont occurs within a zone of faulting, the DRFZ.

The style of deformation along the DRFZ is quite variable, apparently due to significant lithologic contrasts that led to strong strain localization. High-strain fault surfaces occur in a braided pattern wrapping around low strain lozenges. Rocks in the high-strain zones include contorted schists and ultramylonites, as well as breccias. Because the DRFZ does not appear to be overprinted by Acadian deformation recorded by rocks in the CVGB, it is likely that it developed during the waning stages of the Acadian orogeny, perhaps coeval with intrusion of the Devonian New Hampshire series plutons.

Stratigraphic, Textural, and Geochemical Analysis of a Pyroclastic Density Current Deposit in the Akaroa Volcanic Complex, New Zealand

Kate Pippenger '20, Samuel Hampton, and Darren Gravely

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592 doi: 10.1130/abs/2019AM-340315, 2019

Pyroclastic density current (PDC) deposits are classically associated with intermediate to silicic explosive volcanism, though associations with basaltic end members are increasingly common. Exposed on the outer flanks of the Akaroa Volcanic Complex (AVC) of Banks Peninsula, New Zealand, is a 30 metre thick, ashy, lithified deposit similar to PDC deposits. The late-Miocene AVC is primarily composed of basaltic to trachytic lava flows, intrusives, and localized scoria deposits. Here we present the first identification of a geochemically and stratigraphically distinct ignimbrite in the AVC.

This study investigates the stratigraphic, textural, geomechanical, and geochemical properties of the lithified deposit. The exposure is massively bedded and trachytic in composition, and contains at least four ignimbrite packages distinguished by variation in lithology, chemistry, and welding. All packages are composed of a crystal-rich groundmass, K-feldspar phenocrysts, and high-temperature alteration minerals. Three of the ignimbrite packages display Si-enrichment trends indicating upwards evolution. Degree of welding was interpreted using geomechanical (density, permeability, porosity) and textural (groundmass orientation, pumice clast collapse) properties. At least two packages were extensively welded by very high temperatures during emplacement, indicating a deeper or more volatile magma source.

The four ignimbrite packages represent different pulses of PDC eruption. They are interbedded with two airfall ash deposits that serve as eruptive time breaks and indicate at least two distinct eruption events. The deposit may represent co-eval glass-rich ashfall and crystal-rich ignimbrites with eruptive mechanisms involving either the segregation of a dilute turbulent flow into a PDC and vitric-enhanced turbulent cloud or the escape of glassy material

during eruption column collapse.

This is the first recognition of a PDC deposit in the AVC, changing our understanding of the eruption dynamics, volcanic products, and magma sources associated with the AVC during its eruptive lifespan. The AVC could produce PDCs in addition to its typical basaltic and trachytic lava flows, which has implications for eruptive styles and hazard management in similar, modern lava-flow-dominated volcanic complexes.

Geomorphic Mapping and Subsurface Characterization of a Debris Flow Complex in Banks Peninsula, New Zealand

Matthew Wiseman '20, Josh Borella, and Harry Jol

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592 doi: 10.1130/abs/2019AM-335174, 2019

Debris flows represent a significant geologic hazard in hilly and mountainous regions throughout the world, and may pose a threat to human life and property. Here we use a multi-technique approach to investigate a debris flow complex in Purau, Banks Peninsula (BP). Geomorphic mapping, ground penetrating radar (GPR), and stratigraphic studies reveal a debris flow complex composed of at least two temporally distinct events - based on differences in texture, degree of induration, and the presence of bounding soil horizons. The source drainage catchment has a Melton R value of ~0.65 and watershed length equal to ~1.5 km, indicating a catchment prone to debris flows. The resolution of the GPR is limited to the upper 2 meters, but appears to capture a potential debris flow contact and the location for several buried boulders. The studied debris flows demonstrate the ability to raft large volcanic boulders (max. volume = ~15-25 m 3) from the source area and highlight the potential hazard to a nearby and recently built residential home, as well as any future development. We propose that any new development in the study catchment (or nearby catchment areas) should design hazard mitigation strategies assuming future events of similar magnitude will occur. Our findings suggest the potential debris flow hazard in BP should be given a high priority as building and improvements to infrastructure continues. While these results indicate past debris flows have occurred in the studied catchment, the timing of the debris flows remains unknown. Although we were unable to find organic material for radiocarbon dating, surface exposure dating of rafted boulders and/or OSL (optically stimulated luminescence) dating of loess-colluvial sediments could prove successful and should be considered.

Evidence for Seafloor Hydrothermal Alteration in Delaminated MOR-Type Metabasalts of the Chrystalls Beach Complex, South Island, New Zealand

Caroline Hung '19, Lisa Gilbert, Dave Craw, Damon Teagle, R.A. Wobus

American Geophysical Union Fall Meeting, Abstracts with Program, San Francisco, CA, 2

Evidence from the Chrystalls Beach Complex (CBC), an accretionary mélange of the Triassic-Jurassic age, are integral to our understanding of the origin and metamorphic history of the Otago Schist, an extensive belt of low grade metamorphosed Mesozoic sediments and basalts on the South Island of New Zealand. However, previous studies note the tectonic affinity and age of the CBC are not well-defined within its own boundaries- nor with the neighboring terranes. In an attempt to reinterpret the geologic history and emplacement of the CBC, we focus on the Taieri Mouth locale, which includes well-preserved to deformed and sheared pillow lavas and volcaniclastic breccias with prominent veins of epidote, quartz and chlorite. New field, petrographic, geochemical and isotopic observations suggest a mid-ocean ridge origin for the volcanic rocks and contradict previous notions of subduction-related metamorphism as the predominant source of alteration. Restored relative to paleohorizontal, vertical to sub-vertical arrays of epidote-filled veins and thrust faults indicate the presence of concentrated on-axis hydrothermal fluid upflow. Cross-cutting veins show the episodic stages of fracture genesis and fluid flow specific to ridge settings. Analyses show strong enrichments of fluid-mobile alkali (K, Rb, and Cs) and alkali earth elements (Ba, Sr). Differing hydrothermal fluid dynamics from near- to off- axis generate a gradation of epidote compositions of Fe (III):Al. Pillows, secondary and sulphide mineral veins are relict of hydrothermal alteration, with δ18O ranging from 9.0 to 13.1‰ and 87Sr/86Sr ratio from 0.7042 to 0.7061, comparable to those values of other well-studied ophiolites of Troodos and Semail. Multiple events of seafloor hydrothermal alteration due to faulting on- or near- axis may yield changes in overall porosity of the complex that have broader implications for the preservation (obduction) and delamination of rare MORB-type ophiolites.

Geomorphology and Tectonism in Colorado's Southern Front Range: Implications of Boulder and Volcanic Deposits on the Late Eocene Erosion Surface

Olson, Erikka R. '19 and R.A. Wobus

Geological Society of America Abstracts with Programs, Vol. 51, No. 5, ISSN 0016-7592 doi: 10.1130/abs/2019AM-331776, 2019

One of the most prominent geologic features of central Colorado is the Late Eocene Erosion Surface (LEES), a widespread area of gentle topography stretching across the frontal ranges of the Southern Rocky Mountains at an average elevation of ~2600 m. While extensive research has been done to characterize the origin and history of the LEES, this study provides a new approach, focusing on an E - W transect of the surface across its widest point at approximately 39◦ north. We use prominent deposits of rounded boulders (some up to 5 m in diameter) and pyroclastic flow remnants that rest directly upon the surface to better understand the evolution of its topography, drainage networks, and tectonic modification. Determining the provenance of the boulders provides an approximation of their transport distance, raising the question of how these massive boulders were moved over a surface of allegedly low relief. New analyses of boulder chemistry indicate lithologic sources up to 15 km from the deposits, primarily to the northwest. Given the size of the boulders and the lack of fluvial sedimentary structures, we propose debris flows along channels as a potential transport mechanism from source to deposit. Uplift of the Puma Hills (10 - 15 km to the west), temporally constrained by new correlations of the 37 Ma Wall Mountain Tuff mantling the surface on both sides, is proposed as a potential stimulus for elevated slopes necessary for debris flow inception.

Mathematics and Statistics

Triple Crossing Number and Moves on Triple-Crossing Link Diagrams
Colin Adams, J. Hoste, M. Palmer

Journal of Knot Theory and its Ramifications, Vol. 28, No. 11, 1940001, 2019

This paper extends the well-known Reidemeister moves for projections of knots and links with the usual crossings to knots and links in triple crossing projections.

TG-Hyperbolicity of Virtual Links
Colin Adams, O. Eisenberg, *J. Greenberg '19*, K. Kapoor, Z. Liang, K. O'Connor, N. Pacheco-Tallaj, Y. Wang

Journal of Knot Theory and Its Ramifications, 1950080 (26 pages) 2019

In this paper, we extend hyperbolicity of knots and links and the associated hyperbolic volume to virtual knots ad links, including a determination of the volumes of all virtual knots of four or fewer crossings.

Five Dollars, Living Proof: Stories of Resilience Along the Mathematical Journey
Colin Adams

Mathematical Association of America, 2019

The story of mathematical failure and ultimate success in a volume about overcoming mathematical adversity.

Why Do We Teach?
Colin Adams

Notices of the AMS, Vol 66, No. 7, 1045-1047, 2019

Why do we teach, and how should we decide what works best for us and for our students?

Spanning Surfaces for Hyperbolic Knots in the 3-Sphere
Colin Adams

Low-Dimensional Topology and Applications, Knots in Hellas, Springer, 2019

A compendium of results about spanning surfaces of hyperbolic knots and their possible geometries.

Do Androids Dream of Symmetric Sheaves
Colin Adams

*Mathematical Intelligence*r, Volume 41, Issue 2, 57-59, 2019

A future where all math is controlled by androids.
Cylindra Ella, Colin Adams

Mathematical Intelligencer, Volume 41, Issue 3, 41-43, 2019

The cinderella story as told to math children.

GUI
Colin Adams

Mathematical Intelligencer, Volume 41, Issue 4, 35-36, 2019

Grading Under the Influence…

Prime Suspect
Colin Adams

Mathematical Intelligencer, Volume 42, Issue 1, 47-48, 2020

What happens when 9 is murdered and 7 is the prime suspect?

Identifying Research Needs to Inform White-Nose Syndrome Management Decisions

RF Bernard, JD Reichard, JTH Coleman, JC Blackwood, ML Verant, JL Segers, JM Lorch, JP White, MS Moore, AL Russell, RA Katz, DL Linder, RS Toomey, GG Turner, WF Frick, MJ Vonhof, CKR Willis, and EHC Grant

Conservation Science and Practice, e220, 2020

Ecological understanding of host–pathogen dynamics is the basis for managing wildlife diseases. Since 2008, federal, state, and provincial agencies and tribal and private organizations have collaborated on bat and white-nose syndrome (WNS) surveillance and monitoring, research, and management programs. Accordingly, scientists and managers have learned a lot about the hosts, pathogen, and dynamics of WNS. However, effective mitigation measures to combat WNS remain elusive. Host–pathogen systems are complex, and identifying ecological research priorities to improve management, choosing among various actions, and deciding when to implement those actions can be challenging. Through a cross-disciplinary approach, a group of diverse subject matter experts created an influence diagram used to identify uncertainties and prioritize research needs for WNS management. Critical knowledge gaps were identified, particularly with respect to how WNS dynamics and impacts may differ among bat species. We highlight critical uncertainties and identify targets for WNS research. This tool can be used to maximize the likelihood of achieving bat conservation goals within the context and limitations of specific real-world scenarios.

Comparison of Methods for Handling Covariate Missingness in Propensity Score Estimation With a Binary Exposure

Coffman, D. L., Zhou, J., and Cai, X.

BMC Medical Research Methodology, 20(1): 1-14. doi: 10.1186/s12874-020-01053-4, 2020

Causal effect estimation with observational data is subject to bias due to confounding, which is often controlled for using propensity scores. One unresolved issue in propensity score estimation is how to handle missing values in covariates. In this paper, we compared several existing proposals for handling covariate missingness, as well as several other potential useful approaches which have not been evaluated. By the simulation studies, we are able to evaluate and compare the biasness and efficiency of these methods.

Challenges and Opportunities in Collecting and Modeling Ambulatory Electrodermal Activity Data Exposure

Coffman, D., Cai, X., Li, R., Leonard, NR.

JMIR Biomedical Engineering. 5(1): e17106, 2020

Ambulatory assessment of electrodermal activity (EDA) is an emerging technique for capturing individuals' autonomic responses to real-life events. There is currently little guidance available for processing and analyzing such data in an ambulatory setting. This paper is aimed to describe and implement several methods for preprocessing and constructing features for use in modeling ambulatory EDA data, particularly for measuring stress. We developed algorithms to analyze data from a study examining the effects of stressful tasks on EDA of adolescent mothers (AMs), which can be used by other researchers to study stress and anxiety.

Counting Peaks on Graphs

Alexander Diaz-Lopez, Lucas Everham, Pamela E. Harris, Erik Insko, Vincent Marcantonio, and Mohamed Omar

Australasian Journal of Combinatorics Volume 75, 174-189, 2019

Given a graph G with n vertices and a bijective labeling of the vertices using the integers 1,2,...,n, we say G has a peak at vertex v if the degree of v is greater than or equal to 2, and if the label on v is larger than the label of all its neighbors. Fix a set $S \subset V(G)$. We want to determine the number of distinct bijective labelings of the vertices of G, such that the vertices in S are precisely the peaks of G. The set S is called the peak set of the graph G, and the set of all labelings with peak set S is denoted by P (S; G). This definition generalizes the study of peak sets of permutations, as that work is the special case of G being the path graph on n vertices. In this paper, we present an algorithm for constructing all of the bijective labelings in P (S; G) for any $S \subseteq V(G)$. We also use combinatorial methods to explore peak sets in certain well-studied families of graphs.

Generalizations of the Feline and Texas Chainsaw Josephus Problems

David Ariyibi '19, Kevin Chang '19, and Pamela E. Harris,

Open Journal of Discrete Mathematics, Vol. 9 No. 4, October 2019.

We define and study the Extended Feline Josephus Game, a game in which n players, each with l lives, stand in a circle. The game proceeds by alternating between hitting k consecutive players -- each of whom will consequently lose a life -- and skipping s consecutive players. This cycle continues until every player except one loses all of their lives. Given the nonnegative integer parameters n, k, s and l, the goal of the game is to identify the surviving player. In this paper, we show how the defining parameters n, k, s, and l affect the survivor of games with specific constraints on those parameters and our main results provide new closed formulas to determine the survivor of these Extended Feline Josephus Games. Moreover, for cases where these formulas do not apply, we provide recursive formulas for reducing the initial game to other games with smaller parameter values. For the interested reader, we present a variety of directions for future work in this area, including an extension which considers players lying on a general graph, rather than on a circle.

When is the q-multiplicity of a Weight Equal to a Power of q?

Pamela E. Harris, Margaret Rahmoeller, Lisa Schneider, and *Anthony Simpson '19*

Electronic Journal of Combinatorics 26(4) #P4.17, 2019

Berenshtein and Zelevinskii provided an exhaustive list of pairs of weights (λ,μ) of simple Lie algebras g (up to Dynkin diagram isomorphism) for which the multiplicity of the weight μ in the representation of g with highest weight Λ is equal to one. Using Kostant's weight multiplicity formula we describe and enumerate the contributing terms to the multiplicity for subsets of these pairs of weights and show that, in these cases, the cardinality of these contributing sets is enumerated by (multiples of) Fibonacci numbers. We conclude by using these results to compute the associated q-multiplicity for the pairs of weights considered, and conjecture that in all cases the q-multiplicity of such pairs of weights is given by a power of q.

A Generalization of Parking Functions With Backward Movement

Alex Christensen, Pamela E. Harris, Zakiya Jones, Marissa Loving, Andrews Ramos Rodriguez, Joseph Rennie, and Gordon Rojas Kirby

The Electronic Journal of Combinatorics 27(1) #P1.33, 2020

Classical parking functions are defined as the parking preferences for n cars driving (from west to east) down a one-way street containing parking spaces labeled from 1 to n (from west to east). Cars drive down the street toward their preferred spot and park there if the spot is available. Otherwise, the car continues driving down the street and takes the first available parking space, if such a space exists. If all cars can park using this parking rule, we call the n-tuple containing the cars' parking preferences a parking function.

In this paper, we introduce a generalization of the parking rule allowing cars whose preferred space is taken to first proceed up to k spaces west of their preferred spot to park before proceeding east if all of those k spaces are occupied. We call parking preferences which allow all cars to park under this new parking rule k-Naples parking functions of length n.

This generalization gives a natural interpolation between classical parking functions, the case when k=0, and all n-tuples of positive integers 1 to n, the case when k>= n-1. Our main result provides a recursive formula for counting k-Naples parking functions of length n. We also give a characterization for the k=1 case by introducing a new function that maps 1-Naples parking functions to classical parking functions, i.e. 0-Naples parking functions. Lastly, we present a bijection between k-Naples parking functions of length n whose entries are in weakly decreasing order and a family of signature Dyck paths.

Efficient (tr) Broadcast Dominating Sets of the Triangular Lattice

Pamela E. Harris, *Dalia Luque '18, Claudia Reyes '18,* and *Nohemi Sepulveda '18*

Discrete Applied Mathematics Volume 277, 30, 180-192, April 2020

Blessing, Insko, Johnson and Mauretour gave a generalization of the domination number of a graph G called the (t,r) broadcast domination number which depends on the positive integer parameters t and r. In this setting, a v in V is a broadcast vertex of transmission strength t if it transmits a signal of strength t-d(u,v) to every vertex u in V with d(u,v) <t. Given a set of broadcast vertices S subset or equal to V, the reception at vertex u is the sum of the transmissions from the broadcast vertices in S.

The set S \subseteq V is called a (t,r) broadcast dominating set if every vertex u in V has a reception strength r(u) greater than or equal to r and for a finite graph G the cardinality of a smallest broadcast dominating set is called the (t,r) broadcast domination number of G. In this paper, we consider the infinite triangular grid graph and define efficient (t,r) broadcast dominating sets as those broadcasts that minimize signal waste. Our main result constructs efficient (t,r) broadcasts on the infinite triangular grid graph for all t>=r>= 1. Using these broadcasts, we then provide upper bounds for the (t,r) broadcast domination numbers for triangular matchstick graphs when (t,r) in {(2,1) ,(3,1),(3,2),(4,1),(4,2),(4,3),(t,t)}.

Completely Controlling the Dimensions of Formal Fiber Rings at Prime Ideals of Small Height

S. Fleming '18, L. Ji, S. Loepp*, P. McDonald '16, N. Pande '17*, and D. Schwein

Journal of Commutative Algebra, 11, no. 3, 363-388 (2019)

Let T be a complete equicharacteristic local (Noetherian) UFD of dimension 3 or greater. Assuming that |T| = |T/m|, where m is the maximal ideal of T, we construct a local UFD A whose completion is T and whose formal fibers at height one prime ideals have prescribed dimension between zero and the dimension of the generic formal fiber. If, in addition, T is regular and has characteristic zero, we can construct A to be excellent.

Maximal Chains of Prime Ideals of Different Lengths in Unique Factorization Domains

S. Loepp and *A. Semendinger '18*

Rocky Mountain Journal of Mathematics, 49, no. 3, 849-865 (2019)

We show that, given integers n1, n2, …, nk with 2 < n1 < n2 < ··· < nk, there exists a local (Noetherian) unique factorization domain that has maximal chains of prime ideals of lengths n1, n2, …, nk which are disjoint except at their minimal and maximal elements. In addition, we demonstrate that unique factorization domains can have other unusual prime ideal structures.

Uncountable n-Dimensional Excellent Regular Local Rings with Countable Spectra

S. Loepp and *A. Michaelsen '19*

Transactions of the American Mathematical Society, 373, 479-490, 2019

We prove that, for any n ≥ 0, there exists an uncountable, n-dimensional, excellent, regular local ring with countable spectrum.

Almost Excellent Unique Factorization Domains

S. Loepp and *S. Fleming '18*

Involve, 13, no. 1, 165-180, 2019

Let T be a complete local (Noetherian) domain with maximal ideal m such that depthT > 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 local unique factorization domain A such that the completion of A is T and such that there exist uncountably many height one prime ideals q of A such that (T/(q ∩ A)T)q is a field. Furthermore, in the case where T is a normal domain, we can make A "close" to excellent in the following sense: the formal fiber at every prime ideal of A of height not equal to one is geometrically regular, and uncountably many height one prime ideals of A have geometrically regular formal fibers.

Generalizations of a Curious Family of MSTD Sets Hidden By Interior Blocks
Steven Miller with Hung Chu, Noah Luntzlara and Lily Shao

Integers 20A, #A5, 2020

A set A is MSTD (more-sum-than-difference) or sum-dominant if $|A+A|>|A-A|$, and is RSD (restricted-sum dominant) if $|A+^A|>|A-A|$, where $A+^A$ is the set of sums of distinct elements in A. We study an interesting family of MSTD sets that have appeared many times in the literature (see the works of Hegarty, Martin and O'Bryant, and Penman and Wells). While these sets seem at first glance to be ad hoc, looking at them in the right way reveals a nice common structure. In particular, instead of viewing them as explicitly written sets, we write them in terms of differences between two consecutive numbers in increasing order. We denote this family by F and investigate many of its properties. Using F, we are able to generate many sets A with high value of $\log|A+A|/\log|A-A|$, construct sets A with a fixed $|A+A|-|A-A|$ more economically than previous authors, and improve the lower bound on the proportion of RSD subsets of $\{0,1,2,\ldots,n-1\}$ to about 10^{-25} (the previous best bound was 10^{-37}). Lastly, by exhaustive computer search, we find six RSD sets with cardinality 15, which is one lower than the smallest cardinality found to date, and find that 30 is the smallest diameter of RSD sets.

Infinite Families of Partitions into MSTD Subsets
Steven Miller with Hung Chu, Noah Luntzlara and Lily Shao

Integers 19 #A60, 20 pages, http://math.colgate.edu/~integers/t60/t60.pdf , 2019

A set A is MSTD (more-sum-than-difference) if $|A+A|>|A-A|$. Though MSTD sets are rare, Martin and O'Bryant proved that there exists a positive constant lower bound for the proportion of MSTD subsets of $\{1,2,\ldots,r\}$ as $r\to\infty$. Later, Asada et al. showed that there exists a positive constant lower bound for the proportion of decompositions of $\{1,2,\ldots,r\}$ into two MSTD subsets as $r\to\infty$. However, the method is probabilistic and does not give explicit decompositions.

Continuing this work, we provide an efficient method to partition $\{1,2,\ldots,r\}$ (for r sufficiently large) into $k\geq 2$ MSTD subsets, positively answering a question raised by Asada et al. as to whether this is possible for all such k. Next, let R(k) be the smallest integer such that for all $r\geq R(k)$, $\{1,2,\ldots,r\}$ can be k-decomposed into MSTD subsets. We establish rough lower and upper bounds for R(k). Lastly, we provide a sufficient condition on when there exists a positive constant lower bound for the proportion of decompositions of $\{1,2,\ldots,r\}$ into k MSTD subsets as $r\to\infty$.

The Generalized Zeckendorf Game
Steven Miller with Paul Baird-Smith, *Alyssa Epstein'18* and Kristen Flint

The Fibonacci Quarterly (Proceedings of the 18th Conference) 57, no. 55, 1-15, 2019

Zeckendorf proved that every positive integer n can be written uniquely as the sum of non-adjacent Fibonacci numbers; a similar result, though with a different notion of a legal decomposition, holds for many other sequences. We use these decompositions to construct a two-player game, which can be completely analyzed for linear recurrence relations of the form $G_n=\sum_{i=1}^{k} c\, G_{n-i}$ for a fixed positive integer c ($c=k-1=1$ gives the Fibonaccis). Given a fixed integer n and an initial decomposition of $n=n_{G1}$, the two players alternate by using moves related to the recurrence relation, and whomever moves last wins. The game always terminates in the Zeckendorf decomposition, though depending on the choice of moves the length of the game and the winner can vary. We find upper and lower bounds on the number of moves possible; for the Fibonacci game the upper bound is on the order of $n\log n$, and for other games we obtain a bound growing linearly with n. For the Fibonacci game, Player 2 has the winning strategy for all $n>2$. If Player 2 makes a mistake on his first move, however, Player 1 has the winning strategy instead. Interestingly, the proof of both of these claims is non-constructive.

Benford's Law Beyond Independence: Tracking Benford Behavior in Copula Models
Steven Miller with Becky Durst

Involve 12, no. 7, 1193—1218, 2019

Benford's law describes a common phenomenon among many naturally occurring data sets and distributions in which the leading digits of the data are distributed with the probability of a first digit of d base B being $\log_B((d+1)/d)$. As it often successfully detects fraud in medical trials, voting, science and finance, significant effort

has been made to understand when and how distributions exhibit Benford behavior. Most of the previous work has been restricted to cases of independent variables, and little is known about situations involving dependence. We use copulas to investigate the Benford behavior of the product of n dependent random variables. We develop a method for approximating the Benford behavior of a product of n dependent random variables modeled by a copula distribution C and quantify and bound a copula distribution's distance from Benford behavior. We then investigate the Benford behavior of various copulas under varying dependence parameters and number of marginals. Our investigations show that the convergence to Benford behavior seen with independent random variables as the number of variables in the product increases is not necessarily preserved when the variables are dependent and modeled by a copula. Furthermore, there is strong indication that the preservation of Benford behavior of the product of dependent random variables may be linked more to the structure of the copula than to the Benford behavior of the marginal distributions.

Upper Level Mathematics and Statistics Courses Shared Across Campuses

Steven Miller with Stephan Garcia and Jingchen (Monika) Hu)

contributed chapter in: *Teaching and Learning Mathematics Online*, James P. Howard II and John F. Beyers (editors), Chapman and Hall/CRC, Boca Raton, Florida, https://doi.org/10.1201/9781351245586,2020

For undergraduate students of advanced mathematics and statistics, the liberal arts model offers a deep level of engagement in learning with faculty and peers. Due to practical limitations, small colleges cannot usually offer the breadth of courses available at large institutions with graduate programs. To explore collaborative models that may help enrich curricular offerings, faculty and technologists from several leading liberal arts colleges are experimenting with a consortial hybrid/online course-sharing model. The goal of this chapter is to report on what we learned from teaching three different courses in this context.

On Near Perfect Numbers

Steven Miller with Peter Cohen, Katherine Cordwell, *Alyssa Epstein '18*, Chung-Hang Kwan and Adam Lott

Acta Arithmetica 194, no. 4, 341—366, 2020

The study of perfect numbers (numbers which equal the sum of their proper divisors) goes back to antiquity, and is responsible for some of the oldest and most popular conjectures in number theory. We investigate a generalization introduced by Pollack and Shevelev: k-near-perfect numbers. These are examples to the well-known pseudoperfect numbers first defined by Sierpiński, and are numbers such that the sum of all but at most k of its proper divisors equals the number. We establish their asymptotic order for all integers $k \geq 4$, as well as some properties of related quantitie

A Refined Conjecture for the Variance of Gaussian Primes Across Sectors

Steven Miller with Ryan C. Chen, Yujin H. Kim, Jared D. Lichtman, *Alina Shubina '19*, Shannon Sweitzer, Ezra Waxman, Eric Winsor, Jianing Yang

Experimental Mathematics, https://doi.org/10.1080/10586458.2020.1753598 , published online 2020

We derive a refined conjecture for the variance of Gaussian primes across sectors, with a power saving error term, by applying the L-functions Ratios Conjecture. We observe a bifurcation point in the main term, consistent with the Random Matrix Theory (RMT) heuristic previously proposed by Rudnick and Waxman. Our model also identifies a second bifurcation point, undetected by the RMT model, that emerges upon taking into account lower order terms. For sufficiently small sectors, we moreover prove an unconditional result that is consistent with our conjecture down to lower order terms.

The Pi Mu Epsilon Centennial Problems

Steven Miller with Stephan Garcia

American Mathematical Society, 2019.

This book is an outgrowth of a collection of 100 problems chosen to celebrate the 100th anniversary of the undergraduate math honor society Pi Mu Epsilon. Each chapter describes a problem or event, the progress made, and

connections to entries from other years or other parts of mathematics. In places, some knowledge of analysis or algebra, number theory or probability will be helpful. Put together, these problems will be appealing and accessible to energetic and enthusiastic math majors and aficionados of all stripes.

A List of Open Problems in Differential Geometry
Frank Morgan and Pierre Pansu, ed.
São Paulo Journal of Mathematical Sciences, 2019

Open problems assembled at the 2018 conference "Modern Trends in Differential Geometry," University of São Paulo.

My Undercover Mission to Find Cairo Tilings
Frank Morgan

Math Intelligencer, 41 (3) 19–22, 2019

I went to Cairo, Egypt, to find sidewalk examples of the Cairo tiling, which we had proved minimizes perimeter among convex pentagonal tilings.

The Least-Area Tetrahedral Tile of Space
Eliot Bongiovanni, Alejandro Diaz, *Arjun Kakkar '18*, Nat Sothanaphan

Geometriae Dedicata, 2019

My 2017 undergraduate research Geometry Group identifies the "best" tetrahedral tile. (The regular tetrahedron does not tile.)

Isoperimetric Regions on the Line With Density |x|p
Ruiyu Roy Huang, Yiheng Willa Pan, Xinkai Oliver Qian, Mulei Lily Xu, Lu Sarah Wang, Junfei Jefferson

Rose-Hulman Und. Res. J., 20, 2019

My research seminar in differential geometry for a select group of high school students in Shanghai, China, proves a new isoperimetric theorem.

Our First Slam
Max Everett '21, Jihoon Kim '22, Geoffrey Lu '20, Robert Nielsen '23, Alex Simons '21, Miranda Wang '21

ACBL Bulletin, 36–37, April 2020

My 2020 Tournament Bridge Winter Study reports on their adventures.

The Smallest Art Gallery Not Guarded by Every Third Vertex
Ralph Morrison

Geombinatorics 29, no. 1, 24-32, 2019

Given an art gallery with straight walls, you can guard all points in it by placing guards at one-third of the corners. However, the natural strategy of placing a guard at every third vertex does not always work. In this paper we find the smallest counterexample displaying this phenomenon, and prove that it is optimal.

Treewidth and Gonality of Glued Grid Graphs
Ralph Morrison with Ivan Aidun, *Frances Dean '19, Teresa Yu '20*, and Julie Yuan

Discrete Applied Mathematics, 279, 1—11, 2020

The treewidth of a graph or a network measures how close it is to being a tree, which is a network with no cycles in it. In this paper we determine the treewidth of graphs that look like grids with additional edges "gluing" sides together, and apply our results to study chip-firing games on graphs.

Nullstellenfont

Ralph Morrison with *Ben Logsdon '20* and *Anya Michaelsen '19*

Math Horizons, 27:4, 5-7, 2020

The authors develop a typographical font built out of algebraic curves, which are defined by polynomial equations.

Tropical Geometry

Ralph Morrison, In P. Harris, E. Inkso, & A. Wootton (eds.)

A Project-Based Guide to Undergraduate Research in Mathematics: Starting and Sustaining Accessible Undergraduate Research, Birkhäuser Basel, 63-105, 2020

This chapter presents an accessible introduction to tropical geometry, along with more than a dozen possible research projects suitable for undergraduates.

Tropical Hyperelliptic Curves in the Plane

Ralph Morrison

Journal of Algebraic Combinatorics, https://doi.org/10.1007/s10801-019-00933-3, 2020

In tropical geometry we study piecewise-linear versions of algebraic curves. In this paper we classify the tropical version of what are classical known as "hyperelliptic" plane curves.

Accurate Regional Influenza Epidemics Tracking Using Internet Search Data

Shaoyang Ning, S. Yang, S.C. Kou

Scientific Report, 9, 5238, 2019

Accurate, high-resolution tracking of influenza epidemics at the regional level helps public health agencies make informed and proactive decisions, especially in the face of outbreaks. Internet users' online searches offer great potential for the regional tracking of influenza. However, due to the complex data structure and reduced quality of Internet data at the regional level, few established methods provide satisfactory performance. In this article, we propose a novel method named ARGO2 (2-step Augmented Regression with Google data) that efficiently combines publicly available Google search data at different resolutions (national and regional) with traditional influenza surveillance data from the Centers for Disease Control and Prevention (CDC) for accurate, real-time regional tracking of influenza. ARGO2 gives very competitive performance across all US regions compared with available Internet-data-based regional influenza tracking methods, and it has achieved 30% error reduction over the best alternative method that we numerically tested for the period of March 2009 to March 2018. ARGO2 is reliable and robust, with the flexibility to incorporate additional information from other sources and resolutions, making it a powerful tool for regional influenza tracking, and potentially for tracking other social, economic, or public health events at the regional or local level.

Accurate Regional Influenza Epidemics Tracking Using Internet Search Data

H. Li, Shaoyang Ning, M. Ghandi, G. V. Kryukov, S. Gopal, A. Deik, A. Souza, K. Pierce et al.

Citation: Li, H., Ning, S., Ghandi, M. et al. The Landscape of Cancer Cell Line Metabolism. *Nature Medicine* 25, 850–860, 2019

Despite considerable efforts to identify cancer metabolic alterations that might unveil druggable vulnerabilities, systematic characterizations of metabolism as it relates to functional genomic features and associated dependencies remain uncommon. To further understand the metabolic diversity of cancer, we profiled 225 metabolites in 928 cell lines from more than 20 cancer types in the Cancer Cell Line Encyclopedia (CCLE) using liquid chromatography–mass spectrometry (LC-MS). This resource enables unbiased association analysis linking the cancer metabolome to genetic alterations, epigenetic features and gene dependencies. Additionally, by screening barcoded cell lines, we demonstrated that aberrant ASNS hypermethylation sensitizes subsets of gastric and hepatic cancers to asparaginase therapy. Finally, our analysis revealed distinct synthesis and secretion patterns of kynurenine, an immune-suppressive metabolite, in model cancer cell lines. Together, these findings and related methodology provide comprehensive resources that will help clarify the landscape of cancer metabolism.

Vaginal and Extra-Vaginal Bacterial Colonization and Risk for Incident Bacterial Vaginosis in a Population of Women who Have Sex with Men

Fredricks DN, Plantinga A, Srinivasan S, Oot A, Wiser A, Fiedler TL, Proll S, Wu MC, Marrazzo JM

Genetic Epidemiology 42.8, 772-782, 2018

Background: Bacterial vaginosis (BV) is a common cause of vaginal discharge and associated with vaginal acquisition of BV-associated bacteria (BVAB).

Methods: We used quantitative polymerase chain reaction assays to determine whether presence or concentrations of BVAB in the mouth, anus, vagina, or labia before BV predict risk of incident BV in 72 women who have sex with men.

Results: Baseline vaginal and extra-vaginal colonization with Gardnerella spp, Megasphaera spp, Sneathia spp, BVAB-2, Dialister sp type 2, and other BVAB was more common among subjects with incident BV.

Conclusions: Prior colonization with BVAB is a consistent risk for BV.

Effect of Stevia on the Gut Microbiota and Glucose Tolerance in a Murine Model of Diet-Induced Obesity

Becker SL, Chiang E, Plantinga A, Carey HV, Suen G, Swoap SJ

FEMS Microbiology Ecology 96.6, fiaa079, 2020

Artificial sweeteners have been shown to induce glucose intolerance by altering the gut microbiota; however, little is known about the effect of stevia. Here, we investigate whether stevia supplementation induces glucose intolerance by altering the gut microbiota in mice, hypothesizing that stevia would correct high fat diet-induced glucose intolerance and alter the gut microbiota. Mice were split into four treatment groups: low fat, high fat, high fat + saccharin and high fat + stevia. After 10 weeks of treatment, mice consuming a high fat diet (60% kcal from fat) developed glucose intolerance and gained more weight than mice consuming a low fat diet. Stevia supplementation did not impact body weight or glucose intolerance. Differences in species richness and relative abundances of several phyla were observed in low fat groups compared to high fat, stevia and saccharin. We identified two operational taxonomic groups that contributed to differences in beta-diversity between the stevia and saccharin groups: Lactococcus and Akkermansia in females and Lactococcus in males. Our results demonstrate that stevia does not rescue high fat diet-induced changes in glucose tolerance or the microbiota, and that stevia results in similar alterations to the gut microbiota as saccharin when administered in concordance with a high fat diet.

Demographic Study of Signatories to Public Letters on Diversity in the Mathematical Sciences

C.M. Topaz, J. Cart, C. Diaz Eaton, A. Hanson Shrout, J.A. Higdon, K. Ince, B. Katz, D. Lewis, J. Libertini, C.M. Smith

PLOS One 15 (4), e0232075, 2020

In its December 2019 edition, the Notices of the American Mathematical Society published an essay critical of the use of diversity statements in academic hiring. The publication of this essay prompted many responses, including three public letters circulated within the mathematical sciences community. Each letter was signed by hundreds of people and was published online, also by the American Mathematical Society. We report on a study of the signatories' demographics and find that most individuals opposed to the use of diversity statements are tenured white men.

Spatiotemporal Chaos and Quasipatterns in Coupled Reaction-Diffusion Systems

D.J. Ratliff, A.M. Rucklidge, P. Subramanian, C.M. Topaz

Physica D (409), 132475, 2020

We investigate the role of three-wave interactions in the multi-layer Brusselator system, a canonical example of a chemical pattern-forming system. These systems can produce spatially complex but steady patterns as well as time varying states such as spatiotemporal chaos. Our analysis shows how formation of these various states can be encouraged, as we confirm through extensive numerical simulation. Our arguments allow us to predict when spatiotemporal chaos might be found.

Institute for the Quantitative Study of Inclusion, Diversity, and Equity
C.M. Topaz, M.-V. Ciocanel, P. Cohen, M. Ott, N. Rodriguez

Notices of the AMS, 67 (2) 2020

We report on the formation, goals, and outcomes of the Institute for the Quantitative Study of Inclusion, Diversity, and Equity (QSIDE) a nonprofit organization co-founded and directed by Chad Topaz. QSIDE brings the vanguard of quantitative methods together with expertise from the social sciences, humanities, and arts to discover the impact and scope of injustices, and to build solutions to remedy them.

Analyzing Collective Motion with Machine Learning and Topology
D. Bhaskar, A. Manhart, J. Milzman, J.T. Nardini, K. Storey, C.M. Topaz, L. Ziegelmeier

Chaos, 29 (12) 123125, 2019

A fundamental goal in the study of complex, nonlinear systems is to understand the link between local rules and collective behaviors. We examine such links by bringing together tools from applied topology and machine learning to study a seminal model of collective motion that replicates behavior observed in biological swarming, flocking, and milling. More specifically, we study an inverse problem: given observed data, what model parameters could have produced it?

Model Reconstruction from Temporal Data for Coupled Oscillator Networks
M.J. Panaggio, M.-V. Ciocanel, L. Lazarus, C.M. Topaz, B. Xu

Chaos, 29 (10) 103116, 2019

Many complex systems in nature, science, and society can be modeled as a network of coupled oscillators. Often, it is possible to observe the behavior of individual oscillators, but not to directly determine their intrinsic properties or the structural connections between them. We consider the problem of reconstructing the structural interaction network, the functional form of the coupling, and the oscillator dynamics from time series data.

One Size Does Not Fit All: Customizing MCMC Methods for Hierarchical Models Using NIMBLE
Lauren C. Ponisio, Perry de Valpine, Nicholas Michaud and Daniel Turek

Ecology and Evolution, 10(5): 2385-2416, 2020

Developing customized MCMC sampling strategies for certain common hierarchical model structures, and an evaluation of the relative performance of strategies.

Diversity of Artists in Major U.S. Museums
Chad M. Topaz, Bernhard Klingenberg, Daniel Turek, Brianna Heggeseth, Pamela E. Harris, Julie C. Blackwood, C. Ondine Chavoya, Steven Nelson and Kevin M. Murphy

PLoS ONE, 14(3): e0212852, 2019

A data-driven study and statistical analysis of the diversity which exists in artist representation at major US art museums.

Peer Influence of Injection Drug Use Cessation Among Dyads in Rural Eastern Kentucky
Rudolph AE, Upton E, McDonald MJ, Young AM, Havens JR.

International Journal of Drug Policy, 102604, 2019

The analysis aims to assess whether injection drug use cessation among peers predicts injection drug use cessation among individuals and explores whether this association varies by relationship type and strength. Our findings suggest that in this rural community, closer, more supportive relationships, may be more influential for modeling injection cessation; however, relationship-types were not mutually exclusive so differences in effect size across strata may not be statistically significant. In this setting, social support through the recovery process (including cessation attempts with peers) may increase likelihood of injection cessation.

Physics

Part-per-billion measurement of the 42S1/2 → 32D5/2 electric quadrupole transition isotope shifts between 42,44,48Ca+ and 40Ca+

Knollmann, Felix W. '19, Patel, Ashay N. '18, and Doret, S. Charles

Phy. Rev. A, 100, 022514 (2019)

We report a precise measurement of the isotope shifts in the $4^2S_{1/2} \rightarrow 3^2D_{5/2}$ electric-quadrupole transition at 729 nm in $^{40-42,44,48}Ca^+$. The measurement has been made via high-resolution laser spectroscopy of co-trapped ions, finding measured shifts of 2,771,872,467.6(7.6), 5,340,887,394.6(7.8), and 9,990,381,870.0(6.3) Hz between $^{42,44,48}Ca^+$ and $^{40}Ca^+$, respectively. By exciting the two isotopes simultaneously using frequency sidebands derived from a single laser systematic uncertainties resulting from laser frequency drifts are eliminated. This permits far greater precision than similar previously published measurements in other alkaline-earth systems. The resulting measurement precision provides a benchmark for tests of theoretical isotope shift calculations, and also offers a step towards probing new physics via isotope shift spectroscopy.

Search for trinucleon decay in the MAJORANA DEMONSTRATOR

G. K. Giovanetti and others

Physical Review D, 99 (7), 2019

The MAJORANA DEMONSTRATOR is an ultra low-background experiment searching for neutrinoless double-beta decay in ^{76}Ge. The heavily shielded array of germanium detectors, placed nearly a mile underground at the Sanford Underground Research Facility in Lead, South Dakota, also allows searches for new exotic physics. We present the first limits for tri-nucleon decay-specific modes and invisible decay modes for Ge isotopes. We find a half-life limit of 4.9×10^{25} yr for the decay $^{76}Ge(ppn)\rightarrow^{73}Zn$ e+π+ and 4.7×10^{25} yr for the decay $^{76}Ge(ppp)\rightarrow^{73}Cu$ e+π+π+. The half-life limit for the invisible tri-proton decay mode of ^{76}Ge was found to be 7.5×10^{24} yr.

Multisite event discrimination for the MAJORANA DEMONSTRATOR

G. K. Giovanetti and others

Physical Review C, 99 (6), 2019

The MAJORANA DEMONSTRATOR is searching for neutrinoless double-beta decay in ^{76}Ge using arrays of point-contact germanium detectors operating at the Sanford Underground Research Facility. Background results in the neutrinoless double-beta decay region of interest from data taken during construction, commissioning, and the start of full operations have been recently published. A pulse shape analysis cut applied to achieve this result, named AvsE, is described in this paper. This cut is developed to remove events whose waveforms are typical of multi-site energy deposits while retaining (90 +/- 3.5)% of single-site events. This pulse shape discrimination is based on the relationship between the maximum current and energy, and tuned using ^{228}Th calibration source data. The efficiency uncertainty accounts for variation across detectors, energy, and time, as well as for the position distribution difference between calibration and 0νββ events, established using simulations.

Search for neutrinoless double-beta decay in ^{76}Ge with 26 kg yr of exposure from the MAJORANA DEMONSTRATOR

G. K. Giovanetti and others

Physical Review C, 100 (2), 2019

The MAJORANA Collaboration is operating an array of high purity Ge detectors to search for the neutrinoless double-beta decay of ^{76}Ge. The MAJORANA DEMONSTRATOR consists of 44.1 kg of Ge detectors (29.7 kg enriched to 88% in ^{76}Ge) split between two modules constructed from ultra-clean materials. Both modules are contained in a low-background shield at the Sanford Underground Research Facility in Lead, South Dakota. We present updated results on the search for neutrinoless double-beta decay in ^{76}Ge with 26.0±0.5 kg-yr of enriched exposure. With the DEMONSTRATOR's unprecedented energy resolution of 2.53 keV FWHM at Qββ, we observe one event in the region of interest with 0.65 events expected from the estimated background, resulting in a lower limit on the ^{76}Ge

neutrinoless double-beta decay half-life of 2.7×10^{25} yr (90% CL) with a median sensitivity of 4.8×10^{25} yr (90% CL). Depending on the matrix elements used, a 90% CL upper limit on the effective Majorana neutrino mass in the range of 200-433 meV is obtained. The measured background in the low-background configurations is 11.9±2.0 counts/(FWHM t yr).

Measurement of the ion fraction and mobility of 218Po produced in 222Rn decays in liquid argon
G. K. Giovanetti and others

Journal of Instrumentation, 14 (11), 2019

We report measurements of the charged daughter fraction of ^{218}Po as a result of the ^{222}Rn alpha decay, and the mobility of $^{218}Po^{+}$ ions, using radon-polonium coincidences from the ^{238}U chain identified in 532 live-days of DarkSide-50 WIMP-search data. The fraction of ^{218}Po that is charged is found to be 0.37 ± 0.03 and the mobility of $^{218}Po^{+}$ is (8.6 ± 0.1) x 10-4 cm^2/Vs.

Design and construction of a new detector to measure ultra-low radioactive-isotope contamination of argon
G. K. Giovanetti and others

Journal of Instrumentation, 15 (2), 2020

Large liquid argon detectors offer one of the best avenues for the detection of galactic weakly interacting massive particles (WIMPs) via their scattering on atomic nuclei. The liquid argon target allows exquisite discrimination between nuclear and electron recoil signals via pulse-shape discrimination of the scintillation signals. Atmospheric argon (AAr), however, has a naturally occurring radioactive isotope, ^{39}Ar, a β emitter of cosmogenic origin. For large detectors, the atmospheric ^{39}Ar activity poses pile-up concerns. The use of argon extracted from underground wells, deprived of ^{39}Ar, is key to the physics potential of these experiments. The DarkSide-20k dark matter search experiment will operate a dual-phase time projection chamber with 50 tonnes of radio-pure underground argon (UAr), that was shown to be depleted of ^{39}Ar with respect to AAr by a factor larger than 1400. Assessing the ^{39}Ar content of the UAr during extraction is crucial for the success of DarkSide-20k, as well as for future experiments of the Global Argon Dark Matter Collaboration (GADMC). This will be carried out by the DArT in ArDM experiment, a small chamber made with extremely radio-pure materials that will be placed at the centre of the ArDM detector, in the Canfranc Underground Laboratory (LSC) in Spain. The ArDM LAr volume acts as an active veto for background radioactivity, mostly γ-rays from the ArDM detector materials and the surrounding rock. This article describes the DArT in ArDM project, including the chamber design and construction, and reviews the background required to achieve the expected performance of the detector.

Twin-beam intensity-difference squeezing below 10 Hz
Kevin Jones and others

Optics Express 27 (4), 4769 - 4780 (2019)

We report the generation of strong, bright-beam intensity-difference squeezing down to measurement frequencies below 10 Hz. We generate two-mode squeezing in a four-wave mixing (4WM) process in Rb vapor, where the single-pass-gain nonlinear process does not require cavity locking and only relies on passive stability. We use diode laser technology and several techniques, including dual seeding, to remove the noise introduced by seeding the 4WM process as well as the background noise. Twin-beam intensity-difference squeezing down to frequencies limited only by the mechanical and atmospheric stability of the lab is achieved. These results should enable important low-frequency applications such as direct intensity-difference imaging with bright beams on integrating detectors.

Signal advance and delay due to an optical phase-sensitive amplifier
Kevin Jones and others

Optics Express 28 (10), 14573 - 14579 (2020)

Fast and slow light media exploit a steep frequency dependence in their index of refraction in order to advance or delay a modulated signal. Here we observe a qualitatively similar advance and delay from an optical phase-sensitive amplifier (PSA). Unlike in the case of slow and fast light, this effect is due to a redistribution of power between

imbalanced signal sidebands, and the advance or delay is dependent on the optical phase of the input. The PSA adds energy and also changes the frequency spectrum of the input. We show that the advances and delays observed in a PSA implemented using four-wave mixing in a warm rubidium vapor are consistent with the expected behavior of an ideal PSA.

High-precision measurement and *ab initio* calculation of the $(6s^26p^2)3P0 \rightarrow 3P^2$ electric- quadrupole-transition amplitude in 208Pb

D.L. Maser, *Eli Hoenig '17, Bingyi Wang '18*, P.M. Rupasinghe, S.G. Porsev, M.S. Safronova, and P.K. Majumder

Phys. Rev. A 100, 052506 (2019)

We have completed a measurement of the $(6s^26p^2)3P0 \rightarrow 3P^2$ 939 nm electric quadrupole (E2) transition amplitude in atomic lead. Using a Faraday rotation spectroscopy technique and a sensitive polarimeter, we have measured this very weak E2 transition, and determined its amplitude to be $<3P2||Q||3P0> = 8.91(9)$ a.u.. We also present an *ab initio* theoretical calculation of this matrix element, determining its value to be 8.88(5) a.u., in excellent agreement with the experimental result. We heat a quartz vapor cell containing ^{208}Pb to between 800 and 940 ◦C, apply a ~10G longitudinal magnetic field, and use polarization modulation and lock-in detection to measure optical rotation amplitudes of order 1 mrad with noise near 1 μrad. We compare the Faraday rotation amplitude of the E2 transition to that of the $^3P_0$ - $^3P_1$ 1279 nm magnetic dipole (M1) transition under identical sample conditions.

Baryogenesis and dark matter from freeze-in

Brian Shuve and David Tucker-Smith

Phys. Rev. D 101, 115023 (2020)

We propose a simple model in which the baryon asymmetry and dark matter are created via the decays and inverse decays of QCD-triplet scalars, at least one of which must be in the TeV mass range. Singlet fermions produced in these decays constitute the dark matter. The singlets never reach equilibrium, and their coherent production, propagation, and annihilation generates a baryon asymmetry. We find that the out-of-equilibrium condition and the dark matter density constraint typically require the lightest scalar to be long-lived, giving good prospects for detection or exclusion in current and upcoming colliders. In generalizing the leptogenesis mechanism of Akhmedov, Rubakov and Smirnov, our model expands the phenomenological possibilities for low-scale baryogenesis.

Psychology Abstracts

The Long-Term Effects of New Evidence on Implicit Impressions of Others

J. Cone, *K. Flaharty '18*, & M.J. Ferguson

Psychological Science, in press.

Implicit impressions are often assumed to be difficult to update in light of new information. Even when an intervention appears to successfully change implicit evaluations, the effects have been found to be fleeting, reverting back to baseline just hours or days later. Recent findings, however, show that two properties of new evidence—diagnosticity and believability—can result in very rapid implicit updating. In the current studies, we assessed the long-term effects of evidence possessing these two properties on implicit updating over periods of days, weeks, and months. Three studies assessed the malleability of implicit evaluations after memory consolidation (Study 1; N=396), as well as the longer-term trajectories of implicit responses after exposure to new evidence about novel targets (Study 2; N=375) and familiar ones (Study 3; N=341). In contrast with recent work, our findings suggest that implicit impressions can exhibit both flexibility after consolidation and durability weeks or months later.

Type I Error Is Inflated In The Two-Phase Reverse Correlation Procedure

J. Cone, J. Brown-Iannuzzi, R. Lei, & R. Dotsch

Social Psychological & Personality Science, https://doi.org/10.1177/1948550620938616

Mental images of social categories are highly consequential: They can reveal biases and help elucidate the factors that contribute to those biases. One strategy frequently used to evaluate the properties of mental images is reverse correlation, which is a data-driven method that allows researchers to visualize a person's mental representation of individuals or groups. In social psychology, this technique often employs a unique two-phase structure. This approach, however, has not yet been carefully validated, and its structure may alter the properties of the statistical tests used to evaluate differences between conditions. Using computer simulations to evaluate the Type I error rate in a typical two-phase reverse correlation procedure, we find that it is inflated in a nontrivial set of circumstances.

Opposing Contributions of Psychologically Distinct Components of Empathy to Empathic Accuracy

A. Mayukha '17, I. Andrade '18, & J. Cone

J. Exp Psychol Gen. 2020; 149(11):2186

What is it that provides us an accurate window into the thoughts and feelings of others? Although, intuitively, it might seem as though trait empathy would enhance this ability, research has produced decidedly mixed results, ultimately failing to uncover robust, systematic relationships between the two. Recent research has suggested, however, that different facets of empathy—emotional contagion, on the one hand, and empathic concern, on the other—are psychologically distinct and result in different behavioral tendencies (Jordan, Amir, & Bloom, 2016). In 5 preregistered studies involving nearly 2,600 participants, we assessed the opposing contributions of these distinct facets of empathy to empathic accuracy. We found that whereas trait concern is beneficial to empathic accuracy, trait contagion is, paradoxically, detrimental. These patterns emerged across 4 different measures of empathic accuracy that involve emotional and mental states communicated through the eyes (Study 1), paralinguistic cues in the voice (Study 2), facial expressions (Studies 2 and 4), and cues presented during a mock interview (Study 3). Moreover, in Study 4, we identified rational thinking style as a mechanism for these opposing effects. Whereas those who exhibit contagion tend to be less rational, those who exhibit concern tend to be more rational. These differences in cognitive style mediate the opposing relationships of contagion and concern with interpersonal accuracy. Our studies thus highlight the value of empirically separating psychologically distinct facets of empathy to more accurately characterize their independent contributions to interpersonal processes.

A Process Dissociation Model of Implicit Rapid Revision In Response to Diagnostic Revelations.
J. Cone & J. Calanchini

Personality and Social Psychology Bulletin, https://doi.org/10.1177/0146167220919208

Previous research has demonstrated that implicit evaluations can be reversed with exposure to a single impression-inconsistent behavior. But what exactly is changing when perceivers encounter diagnostic revelations about someone? One possibility is that rapid changes are occurring in the extent to which perceivers view the person positively or negatively. Another possibility is that they override the expression of initial evaluations through control-oriented processes. We conducted three studies (one preregistered) that used multinomial process trees to distinguish between these possibilities. We find consistent support across two different implicit measures that diagnostic behaviors result in rapid changes in evaluative processes. We obtained only inconsistent evidence for effects on more control-oriented processes. These findings thus help to reveal the cognitive processes underlying rapid implicit revision. Implications for theoretical perspectives on implicit attitudes are discussed.

How Do We Reduce Implicit Bias Toward Outgroups?
M.J. Ferguson, X. Shen, J. Cone, & T.C. Mann

In J.A. Krosnick, T.H. Stark, & A.L. Scott (Eds.), *The Cambridge Handbook of Implicit Bias and Racism*. Cambridge, England: Cambridge University Press (in press).

Implicit impressions are often assumed to be difficult to update in light of new information. Even when an intervention appears to successfully change implicit evaluations, the effects have been found to be fleeting, reverting back to baseline just hours or days later. Recent findings, however, show that two properties of new evidence—diagnosticity and believability—can result in very rapid implicit updating. In the current studies, we assessed the long-term effects of evidence possessing these two properties on implicit updating over periods of days, weeks, and months. Three studies assessed the malleability of implicit evaluations after memory consolidation (Study 1; N=396), as well as the longer-term trajectories of implicit responses after exposure to new evidence about novel targets (Study 2; N=375) and familiar ones (Study 3; N=341). In contrast with recent work, our findings suggest that implicit impressions can exhibit both flexibility after consolidation and durability weeks or months later.

Perceptual Salience Influences Food Choices Independent of Health and Taste Preference.
J. Dai '17, J. Cone, & J. Moher

Cognitive Research: Principles and Implications, 5(2), 1-13, https://doi.org/10.1186/s41235-019-0203-2, 2020.

Making decisions about food is a critical part of everyday life and a principal concern for a number of public health issues. Yet, the mechanisms involved in how people decide what to eat are not yet fully understood. Here, we examined the role of visual attention in healthy eating intentions and choices. We conducted two-alternative forced choice tests of competing food stimuli that paired healthy and unhealthy foods that varied in taste preference. We manipulated their perceptual salience such that, in some cases, one food item was more perceptually salient than the other. In addition, we manipulated the cognitive load and time pressure to test the generalizability of the salience effect.

Is She a Good Teacher? Children Learn to use Meaningful Gesture as a Marker of a Good Informant
E.M. Wakefield, E.L. Congdon, M.A. Novack, & L.H. Howard

Proceedings of the 42nd Annual Conference of the Cognitive Science Society, Virtual Meeting: Cognitive Science Society, 2020.

To learn from others, children rely on cues (e.g., familiarity) to infer who will provide useful information. We extend this research to ask whether children will use an informant's inclination to gesture as a marker of whether they are a good person to learn from. Children (N=459, ages 4-12 years) watched videos in which actresses made statements accompanied by meaningful iconic gestures, beat gestures, or no gestures. After each trial, children were asked "Who do you think would be a good teacher?" (good teacher- experimental condition) or "Who do you think would be a good friend?" (good friend-control condition). Results show children do believe that someone who produces iconic gesture would make a good teacher over someone who does not, but this is only later in childhood and only if a child has the propensity to see gesture as meaningful. The same effects were not found in the good-friend condition.

Gesture and Communication Across Development
E.L. Congdon & M.N. Novack

In J.B. Benson (ed.), *The Encyclopedia of Infant and Early Childhood Development* (pp. 48-54). Netherlands: Elsevier Science (2020)

Learning Math by Hand: The Neural Effects of Gesture-Based Instruction in 8-Year-Old Children
E. Wakefield, E.L. Congdon, M.A. Novack, S. Goldin-Meadow, & K.H. James

Attention, Perception & Psychophysics (pp. 1-11), doi: 10.3758/s13414-019-01755-y, 2019

Producing gesture can be a powerful tool for facilitating learning. This effect has been replicated across a variety of academic domains, including algebra, chemistry, geometry, and word learning. Yet the mechanisms underlying the effect are poorly understood. Here we address this gap using functional magnetic resonance imaging (fMRI). We examine the neural correlates underlying how children solve mathematical equivalence problems learned with the help of either a speech + gesture strategy, or a speech-alone strategy. Children who learned through a speech + gesture were more likely to recruit motor regions when subsequently solving problems during a scan than children who learned through speech alone. This suggests that gesture promotes learning, at least in part, because it is a type of action. In an exploratory analysis, we also found that children who learned through speech + gesture showed subthreshold activation in regions outside the typical action-learning network, corroborating behavioral findings suggesting that the mechanisms supporting learning through gesture and action are not identical. This study is one of the first to explore the neural mechanisms of learning through gesture.

Narcissism and Attachment: The Importance of Early Parenting
Phebe Cramer

Journal of Nervous and Mental Disease, 207, 69-75, 2019.

Research often shows that narcissism and attachment style are related. The present research examines the question of whether early parenting style contributes to adult attachment style, beyond the relation between narcissism and attachment. Parents reported on their parenting style at age 3, and offspring were assessed for attachment style and narcissism at age 23. The results indicated that early parenting style was not directly related to narcissism, but along with narcissism added to the prediction of attachment style. In combination with vulnerable narcissism, authoritarian parenting was positively related to secure attachment, and negatively related to preoccupied attachment, whereas permissive and responsive parenting were negatively related to secure attachment and positively related to preoccupied attachment.

What has Happened to Hysteria?
Phebe Cramer

Journal of Nervous and Mental Disease, 207, 705–706, 2019.

This article traces the history of the diagnosis of hysteria from the earliest medical formulations in the 17th century to the present, including the presence of this diagnosis in the five iterations of the Diagnostic Statistical Manual (DSM) of the American Psychiatric Association. Several different types of hysteria are discussed, with alternative causal explanations. Research focusing on this disorder is summarized.

Externalizing/Projection; Internalizing/Identification: An Examination
Phebe Cramer

Psychoanalytic Psychology, 37, 207-211, 2020.

The psychological mechanisms of externalizing and internalizing are compared with those of the defenses of projection and identification, in a sample of 91 young adults. The results indicate that externalizing and projection are positively correlated for males, but not for females. Internalizing and identification were found to be negatively related for both males and females. This unexpected finding is discussed.

The Welch Emotional Connection Screen: Validation of a Brief Mother Infant Relational Health Screen

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Acta Paediatr, 108(4), 615-625, doi:10.1111/apa.14483, 2019.

The Welch Emotional Connection Screen (WECS), assesses mother-infant Emotional Connection in clinical settings. It includes: Attraction, Vocal Communication, Facial Communication, Sensitivity/Reciprocity and clinical decision of Emotional Connection (yes/no). We tested concurrent and construct validity of the WECS and associations with behavioural and physiological measures in preterm infants. Videos from 76 mothers-infants (gestational age 36 weeks) during an in-NICU caregiving paradigm were coded for maternal caregiving behaviour. Videos of mothers-infants were also obtained at 4 months during 10 minutes of face-to-face play (coded with WECS and for maternal positivity and infant social engagement) and the still-face paradigm (coded for infant behavioural approach towards mother; infant electrocardiogram acquired in vivo). WECS maternal scores were positively associated with maternal sensitivity and quality of vocal contact at 36 weeks (caregiving) and maternal positivity at 4 months (face-to-face). WECS infant scores positively correlated with infant social engagement and maternal positivity during face-to-face interactions at 4 months. Infants from emotionally not connected dyads (vs. emotionally connected dyads) displayed autonomic dysregulation and less approach-seeking behaviour towards mother during interactive/play sessions of the still-face paradigm. This preliminary evidence supports the WECS as a valid screen for rating mother-preterm infant emotional connection associated with healthier infant biobehavioural stress responding.

The Practical Utility of the Welch Emotional Connection Screen for Rating Parent–Infant Relational Health

M.A. Fagan, C.A. Frosch, W. Middlemiss, J.N. LaCoursiere, M.T. Owen, A.A. Hane, & M.G. Welch

Infancy, doi:10.1111/infa.12311, 2019.

Emotional Connection (EC) measured by the Welch Emotional Connection Screen (WECS) was related to the Parent–Infant Interaction Rating System (PIIRS), a 5-point adaptation of the rating system developed for the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development (e.g., NICHD Early Child Care Research Network, 1999, Developmental Psychology, 35, 1399). Parent–infant dyads (n = 49 mothers; 43 fathers) were videotaped during face-to-face interaction at infant age 6 months; interactions were coded with both the WECS and PIIRS. At age 3, mothers completed the Child Behavior Checklist. WECS ratings of EC were associated with PIIRS rating items for both mother–infant and father–infant dyads. Mother–infant EC related positively to maternal sensitivity and positive regard for child, child positive mood and sustained attention, and dyadic mutuality, and negatively with maternal intrusiveness. Father–infant EC related positively to fathers' positive regard for child, child positive mood and sustained attention, and dyadic mutuality. Mother–infant EC predicted child behavior problems at age 3 better than mother–infant PIIRS ratings of dyadic mutuality. With fathers, neither EC nor dyadic mutuality ratings predicted mother-reported child behavior problems. Findings highlight the practical utility of the WECS for identifying potentially at-risk dyads and supporting early relational health.

Investigation of a Developmental Pathway from Infant Anger Reactivity to Childhood Inhibitory Control and ADHD Symptoms: Interactive Effects of Early Maternal Caregiving

N.V. Miller, A.A. Hane, K.A. Degnan, N.A. Fox, & A.J. Chronis-Tuscano

Journal of Child Psychology and Psychiatry, doi:10.1111/jcpp.13047, 2019.

ADHD is a neurodevelopmental disorder with a complex pathogenesis. Individual differences in temperamental reactivity - in particular, anger reactivity - are predictive of ADHD. The goal of this study was to examine the moderating (maternal caregiving behaviors; MCB) and mediating (inhibitory control) variables of reactivity using a 9-year multimethod prospective longitudinal design. Participants included 291 children (135 male; 156 female) who participated in a larger study of temperament and social-emotional development. Anger reactivity was assessed by observation of facial anger during an arm restraint task, and MCB were observed during a series of semi-structured mother-infant tasks, both at 9 months of age. Inhibitory control was assessed by performance on a go/no-go task at 5 years of age. ADHD symptoms were assessed by parent and teacher report questionnaires at 7 and 9 years, respectively. Anger reactivity and poor inhibitory control were predictive of later ADHD symptoms. Results supported a moderated mediation model, in which the indirect effects of anger reactivity on ADHD symptoms through inhibitory control were conditional on quality of early MCB. Inhibitory control mediated the effect of anger reac-

tivity on ADHD symptoms, but only among children exposed to lower-quality MCB. Infant anger reactivity exerts a direct effect on later ADHD from infancy, suggesting anger reactivity as a very early indicator of ADHD risk. Higher-quality caregiving did not buffer against the direct risk of anger reactivity on ADHD but did buffer against the indirect risk by reducing the negative effect of anger reactivity on inhibitory control. Thus, in the developmental pathway from anger reactivity to ADHD, more sensitive, less intrusive parenting supports the development of protective mechanisms (i.e. inhibitory control) to remediate ADHD risk.

Autonomic Regulation of Preterm Infants is Enhanced by Family Nurture Intervention

S.W. Porges, M.I. Davila, G.F. Lewis, J. Kolacz, S. Okonmah-Obazee, A.A. Hane, M.G. Welch

Developmental Psychobiology, doi:10.1002/dev.21841, 2019.

Preterm infants have maturational delays in several neurobehavioral systems. This study assesses the impact of the Family Nurture Intervention (FNI) in the neonatal intensive care unit (NICU) on the maturation of autonomic regulation of preterm infants. Preterm infants born at 26–34 weeks postmenstrual age (PMA) were assigned to groups receiving either standard care (SC) or SC plus FNI, using a randomized controlled trial design. At two collection time points, approximately 35 weeks and 41 weeks PMA, electrocardiograms (ECG) were monitored for approximately 1 hour during sleep. Heart rate and respiratory sinus arrhythmia (RSA) were quantified from the ECG. Across the two time points, the FNI group exhibited greater increases in RSA (Cohen's d = 0.35) and slope between RSA and heart rate, as a measure of vagal efficiency (Cohen's d = 0.62). These results document that FNI resulted in enhanced autonomic regulation consistent with greater maturation of cardiac function. These and previous findings strongly suggest that facilitating early nurturing interactions and emotional connection between preterm infants and their mothers is a practicable and effective means of optimizing postnatal development in preterm infants. Interpretation of these autonomic function results also enriches our understanding of the potential long-term beneficial outcomes of FNI by drawing upon polyvagal theory, which explains how autonomic state provides a neurophysiological platform for optimal co-regulation between infant and caregiver, and by drawing upon calming cycle theory, which provides a model for understanding how repeated mother/infant calming interactions positively condition autonomic state and reinforce approach, prosocial behaviors.

Validation Study Showed that Ratings on the Welch Emotional Connection Screen at Infant Age Six Months are Associated with Child Behavioural Problems at Age Three Years

C.A. Frosch, M.A. Fagan, M.A. Lopez, W. Middlemiss, M. Chang, A.A. Hane, & M.G. Welch

Acta Paediatr, 108(5), 889-895, doi:10.1111/apa.14731, 2019.

The emotional connection between mothers and infants born preterm has been associated with positive behaviour. The aim of this study was to examine the longitudinal association between emotional connection at six months of age and behavioural problems at three years. This study was carried out by the University of North Texas, USA and comprised 49 mothers and infants from a longitudinal investigation of family interaction and infant development conducted in 1994–1997. Face-to-face interaction and toy-based play were videotaped and coded at six months of age using the Welch Emotional Connection Screen (WECS), a brief screening tool for relational health. When the children were three years of age, the mothers reported on child behavioural problems. The children from dyads that were rated as emotionally connected at six months of age had fewer externalising and internalising behavioural problems at the age of three. No links were found between emotional connection during toy-based play at six months and later child behavioural problems. We showed that when the WECS was used at six months of age it was a promising and valid relational screening tool for infants at risk of adverse behavioural outcomes at the age of three.

Balancing Alliances with Couples and Families: A Primer

L. Heatherington, M.L. Friedlander, & V. Escudero

Psychotherapy Bulletin, 54 (3), 21-24, 2019.

Many therapists in training, and even experienced therapists, anticipate working with couples and families with trepidation. As family therapists and researchers, we understand that trepidation, and indeed, sometimes find ourselves experiencing these same feelings! However, we know that understanding systemic interactions really helps in learning to work with couples and families; thus, we offer some evidence-based information to demystify this work.

We hope it inspires readers who have not received training in couple and family therapy (CFT) to consider doing so, given the abundant evidence of its effectiveness across a range of relational problems and diagnoses.

Neurobehavioral Effects of Neonatal Opioid Exposure in Mice: Influence of the OPRM1 SNP

S.A. Robinson, A.D. Jones, J. Brynildsen, M.E. Ehrlich, & J.A. Blendy

Addiction Biology, 2019;e12806, 2019.

Opioid use among pregnant women is a growing public health concern in the United States. Infants exposed to opioids in utero are at risk of exhibiting neonatal opioid withdrawal syndrome (NOWS). The biological mechanisms underlying short and long -term consequences of in utero opioid exposure and NOWS are unknown. A potential genetic factor is a single-nucleotide polymorphism (SNP) in the mu-opioid receptor gene (OPRM1 A118G). Opioid exposed infants with the G-allele spend less time in hospitals after birth. To determine whether this SNP modulates the neurobehavioral effects of neonatal opioid exposure and withdrawal, we used mice possessing the equivalent Oprm1 SNP (A112G). Pups were treated chronically with saline or morphine from postnatal days (PNDs) 1 to 14, a developmental period equivalent to the third trimester of a human pregnancy and a sensitive period for opioid exposure in rodents. Morphine treatment produced significant developmental delays regardless of genotype and increased total ultrasonic vocalizations in males during spontaneous withdrawal. Animals were aged and tested for anxiety and drug response during adolescence and adulthood, respectively. AA morphine-treated animals showed reduced activity in the marble burying task compared with saline controls; however, this effect was absent in AG and GG animals. As adults, AA males exposed to morphine from PNDs 1 to 14 exhibited enhanced development of locomotor sensitization to morphine, whereas females showed reduced locomotor sensitization. These data suggest the involvement of the Oprm1 SNP for certain outcomes of neonatal opioid exposure and highlight the importance of considering sex and genetic variability for the prognosis of NOWS.

An Exploratory Mixed Methods Approach to Implicit and Explicit Identification with Non-Suicidal Self-Injury

S. Jarvi Steele, K. Furbish, T. Bjorgvinsson, & L.P. Swenson

Journal of Behavior Therapy and Experimental Psychiatry, https://doi.org/10.1016/j.jbtep.2020.101594

Identification with non-suicidal self-injury (NSSI) is uniquely related to NSSI behavior and predicts future NSSI. This exploratory, mixed methods study used implicit and explicit approaches to further understanding of NSSI identity. Methods: Participants included 15 treatment-seeking adults (60% female, 87% Caucasian) with lifetime NSSI. Participant age ranged from 19 to 38 years (M = 25.33, SD = 6.10). Implicit tasks were completed at two time points in a test-retest design, followed by a qualitative interview.

Does he Unified Protocol Really Treat Neuroticism? Results from a Randomized-Controlled Trial

S. Sauer-Zavala, J. Fournier, S. Jarvi Steele, B.K. Woods, M. Wang, T.J. Farchione, & D.H. Barlow

Psychological Medicine, DOI: https://doi.org/10.1017/S0033291720000975

Neuroticism is associated with the onset and maintenance of a number of mental health conditions, as well as a number of deleterious outcomes (e.g. physical health problems, higher divorce rates, lost productivity, and increased treatment seeking); thus, the consideration of whether this trait can be addressed in treatment is warranted. To date, outcome research has yielded mixed results regarding neuroticism's responsiveness to treatment, perhaps due to the fact that study interventions are typically designed to target disorder symptoms rather than neuroticism itself. The purpose of the current study was to explore whether a course of treatment with the unified protocol (UP), a transdiagnostic intervention that was explicitly developed to target neuroticism, results in greater reductions in neuroticism compared to gold-standard, symptom focused cognitive behavioral therapy (CBT) protocols and a waitlist (WL) control condition. Patients with principal anxiety disorders (N = 223) were included in this study. They completed a validated self-report measure of neuroticism, as well as clinician-rated measures of psychological symptoms. At week 16, participants in the UP condition exhibited significantly lower levels of neuroticism than participants in the symptom-focused CBT ($t(218) = -2.17$, $p = 0.03$, $d = -0.32$) and WL conditions($t(207) = -2.33$, $p = 0.02$, $d = -0.43$), and these group differences remained after controlling for simultaneous fluctuations in depression and anxiety symptoms. Treatment effects on neuroticism may be most robust when this trait is explicitly targeted.

Treating Depression with the Unified Protocol: Results from a Randomized-Controlled Trial
S. Sauer-Zavala, K.H. Bentley, S. Jarvi Steele, J. Wilner Tirpak, A.A. Ametaj, M. Nauphal, N. Cardona, M. Wang, T.J. Farchione, & D.H. Barlow

Journal of Affective Disorders, 264, 438-445, https://doi.org/10.1016/j.jad.2019.11.072, 2020.

This study aims to examine the efficacy of the Unified Protocol for Transdiagnostic Treatment of Emotional Disorders (UP) for individuals diagnosed with a depressive disorder. Participants included 44 adults who met criteria for major depressive disorder, persistent depressive disorder, or another specified depressive disorder according to the Anxiety Disorder Interview Schedule (ADIS). These individuals represent a subset of patients from a larger clinical trial comparing the UP to single-disorder protocols (SDPs) for discrete anxiety disorders and a waitlist control (WLC) condition (Barlow et al., 2017); inclusion criteria for the parent study required participants to have a principal anxiety disorder. Significant reductions in depressive symptoms were observed within the UP condition across clinician-rated and self-report measures of depression from baseline to post-treatment, as well as to the 12-month follow-up assessment. Compared to the WLC group, individuals in the UP condition demonstrated significantly lower levels on our continuous, clinician-rated measure of depressive symptoms at post-treatment. There were no differences between the UP and SDP conditions on depressive symptoms at post-treatment or at the 12-month follow-up timepoint. In this exploratory set of analyses, the UP evidenced efficacy for reduction of depressive symptoms, adding to the growing support for its utility in treating depression.

From Urges to Action: Negative Urgency and Nonsuicidal Self-Injury in an Acute Transdiagnostic Sample
A.D. Peckham, H. Jordan, A.L. Silverman, S. Jarvi Steele, T. Bjorgvinsson, & C. Beard

Archives of Suicide Research, doi: 10.1080/13811118.2019.1625831, 2019.

This study aims to examine the efficacy of the Unified Protocol for Transdiagnostic Treatment of Emotional Disorders (UP) for individuals diagnosed with a depressive disorder. Participants included 44 adults who met criteria for major depressive disorder, persistent depressive disorder, or another specified depressive disorder according to the Anxiety Disorder Interview Schedule (ADIS). These individuals represent a subset of patients from a larger clinical trial comparing the UP to single-disorder protocols (SDPs) for discrete anxiety disorders and a waitlist control (WLC) condition (Barlow et al., 2017); inclusion criteria for the parent study required participants to have a principal anxiety disorder. Significant reductions in depressive symptoms were observed within the UP condition across clinician-rated and self-report measures of depression from baseline to post-treatment, as well as to the 12-month follow-up assessment. Compared to the WLC group, individuals in the UP condition demonstrated significantly lower levels on our continuous, clinician-rated measure of depressive symptoms at post-treatment. There were no differences between the UP and SDP conditions on depressive symptoms at post-treatment or at the 12-month follow-up timepoint. In this exploratory set of analyses, the UP evidenced efficacy for reduction of depressive symptoms, adding to the growing support for its utility in treating depression.

Unified Protocol: A Transdiagnostic CBT Approach.
T.J. Farchione, S. Jarvi Steele, B.K. Woods, A.J. Curreri, M. Wang, & D.H. Barlow

In N.M. Simon, E. Hollander, B.O. Rothbaum, & D.J. Stein (Eds.), *APA Textbook of Anxiety, Trauma, and OCD Related Disorders* (pp. 113- 122). Washington, D.C.: APA Publishing (2020).

Serotonergic Multilocus Genetic Variation Moderates the Association Between Major Interpersonal Stress and Adolescent Depression: Replication and Candidate Environment Specification
L.R. Starr, S. Vrshek-Schallhorn, & C.B. Stroud

Journal of Psychiatric Research, 117:55-61, doi: 10.1016/j.jpsychires.2019.06.020, 2019.

Serotonin-linked genetic risk and stressful life event (SLE) interaction research has been criticized for using single genetic variants with inconsistent replicability. A recent study showed that a multilocus genetic profile score (MGPS) capturing additive risk from five serotonin-linked polymorphisms moderated the association between major interpersonal SLEs and depression, but no subsequent replication attempts have been reported. Moreover, major interpersonal SLEs have been suggested as "candidate environments" for this MGPS, but it has never been demonstrated that gene-environment interactions (G × Es) for major interpersonal SLEs are significantly stronger than

for other contexts. Adolescents (N = 241) completed contextual-threat life stress interviews and clinical interviews assessing depressive symptoms, and provided DNA. MGPS intensified the major interpersonal stress-depression association; the interaction accounted for 4% of depressive symptom variance. Genetic moderation was statistically unique to major interpersonal stress versus other environments. Extending previous findings, results support an MGPS approach and underscore the cruciality of the G × E candidate environment.

The Cortisol Awakening Response (CAR) Interacts with Acute Interpersonal Stress to Prospectively Predict Depressive Symptom Among Early Adolescent Girls

C.B. Stroud, S. Vrshek-Schallhorn, *E.M. Norkett '14*, & L.D. Doane

Psychoneuroendocrinology, 107:9-18, doi: 10.1016/j.psyneuen.2019.04.017, 2019.

The cortisol awakening response (CAR) has been shown to prospectively predict depression, but it remains unresolved whether a greater CAR predicts risk independently of subsequent acute stress, or whether greater CAR indicates increased vulnerability to subsequent acute stress. Further, no prior work has evaluated whether the CAR increases vulnerability to certain types of acute stress, but not others, in predicting depression. To address these gaps, we investigated whether the CAR predicted depressive symptoms alone and in interaction with acute interpersonal stress in a one-year longitudinal study of 86 early adolescent girls with no history of diagnosable depression. To index the CAR, adolescents collected saliva at waking and 30-minutes past waking for 3 days; compliance with the sampling protocol was electronically monitored. Diagnostic and objective contextual stress interviews were used to quantify acute stress in the 2-months prior to worst depressive symptom onset during the follow-up. Supporting hypotheses, results indicated that greater CAR predicted greater depressive symptoms, and interacted with acute interpersonal stress in predicting depressive symptoms. Further, the CAR interacted with acute dependent (i.e., at least partially arising from the person's behavior) interpersonal stress in predicting depressive symptoms. In contrast, the CAR did not interact with acute non-interpersonal stress nor acute interpersonal independent (i.e., fateful) stress in predicting depressive symptoms. These results further refine circumstances in which the CAR is predictive of depressive symptoms among early adolescent girls, and highlight the importance of focusing on etiologically relevant stress when testing interactions between physiological stress indicators and environmental stress.

Cortisol Awakening Response and Additive Serotonergic Genetic Risk Interactively Predict Depression in Two Samples: The 2019 Donald F. Klein Early Career Investigator Award Paper

S. Vrshek-Schallhorn, C.B. Stroud, L.D. Doane, S. Mineka, R. Zinbarg, M.G. Craske, & E.K. Adam

Depression & Anxiety, 36, 480-489, 2019.

Background: The serotonin system and hypothalamic pituitary-adrenal (HPA)-axis are each implicated in the pathway to depression; human and animal research support these systems' cross-talk. Our work implicates a 5-variant additive serotoninergic multilocus genetic profile score (MGPS) and separately the cortisol awakening response (CAR) in the prospective prediction of depression; other work has shown that the serotonin transporter polymorphism 5HTTLPR predicts CAR and interacts with the CAR to predict depression.

Methods: We tested the hypothesis that a 6-variant MGPS (original plus 5HTTLPR) would interact with CAR to predict prospective depressive episode onsets in 201 emerging adults using four annual follow-up interviews. We also tested whether MGPS predicted CAR. We attempted replication of significant findings in a sample of 77 early adolescents predicting depression symptoms.

Results: In sample 1, MGPS did not significantly predict CAR. MGPS interacted with CAR to predict depressive episodes; CAR slopes for depression steepened as MGPS increased, for risk or protection. No single variant accounted for results, though CAR's interactions with 5HTTLPR and the original MGPS were both significant. In sample 2, the 6-variant MGPS significantly interacted with CAR to predict depression symptoms.

Conclusions: Higher serotonergic MGPS appears to sensitize individuals to CAR level—for better and worse—in predicting depression.

Selection on Ultrasonic Call Rate in Neonatal Rats Affects Low Frequency, but Not Ultrasonic, Vocalizations In Adults

R. Lesch, *A. Orozco '21, M. Shilling '18*, B. Zimmerberg, & W.T. Fitch (2020)

Ethology, https://doi.org/10.1111/eth.13075, 2020.

In this experiment, we studied a rodent model selected over 57 generations for high or low rates of ultrasonic vocalizations (USVs) during maternal separation as pups. We investigated the influence of this breeding on the adult animals' subsequent vocal output, comparing acoustic variables across developmental stages. We hypothesized that selection on pup USV rate would impact adult USV production without affecting lower frequency calls. Contrary to this hypothesis, we found neither number of USV calls or other acoustic variables to differ among selected adult lines. Instead, we found that pup USV selection mainly affected adults' low-frequency (human-audible) calls. Furthermore, low-frequency vocalizations did not fully fit a predicted correlation between body weight and fundamental frequency: high line males, although the heaviest on average, did not produce the lowest fundamental frequencies. Our findings suggest that selection for early ultrasonic vocal behaviour pleiotropically results in changes in anatomical production mechanisms and/or neural control affecting low-frequency calls.