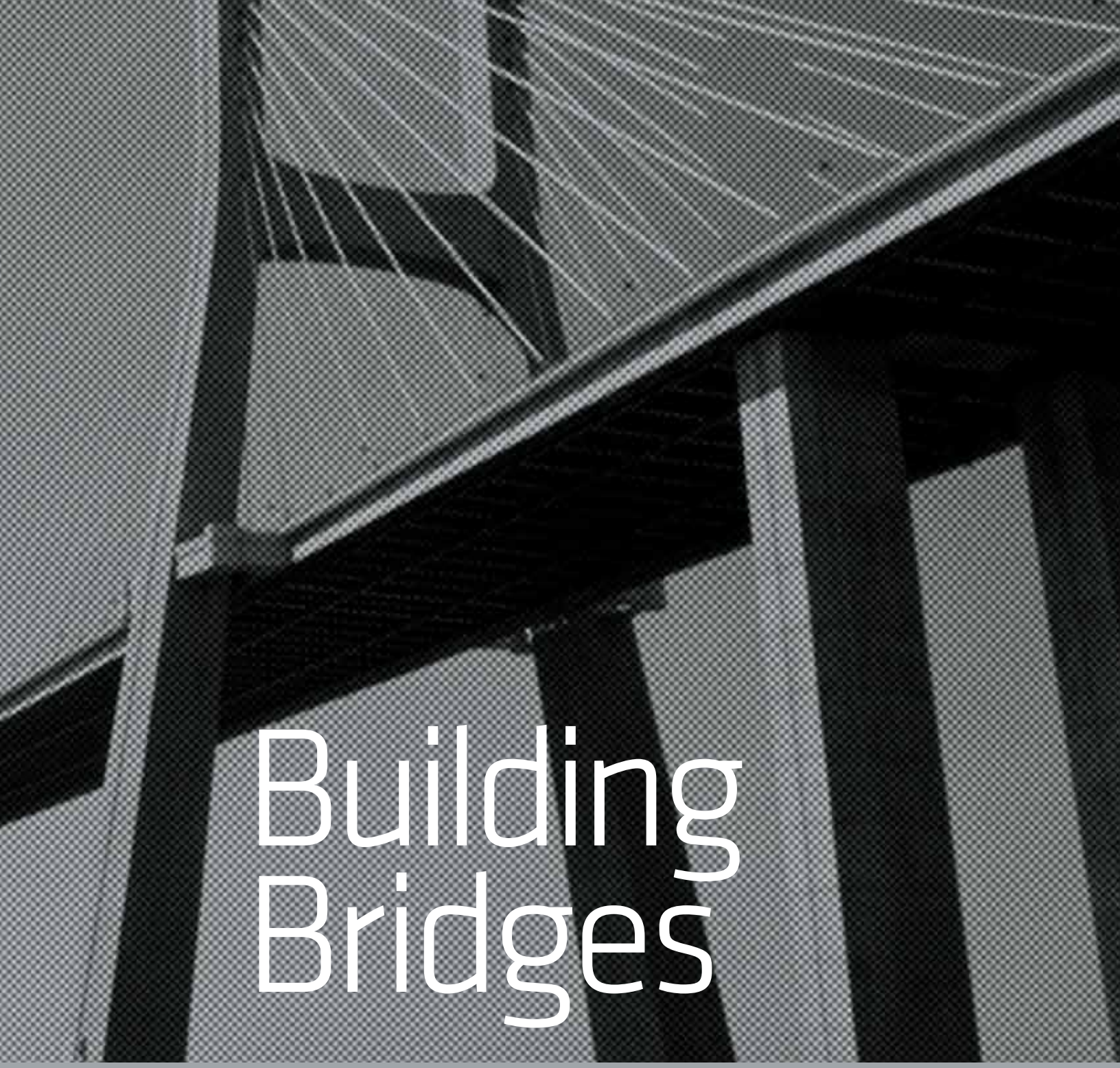

Building Bridges

The 22nd Annual Cottrell Scholar Conference
July 13-15. 2016 at Westin La Paloma

COTTRELL SCHOLARS COLLABORATIVE

RESEARCH CORPORATION *for* SCIENCE ADVANCEMENT

2016 Conference Planning Committee

Penny Beuning, Chair
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University of Massachusetts, Amherst

Zachary Schultz
Department of Chemistry and Biochemistry
University of Notre Dame

Silvia Ronco
Senior Program Director
Research Corporation for Science Advancement

From the President

The theme for this year's Cottrell Scholars conference is "building bridges." It reflects the fact that teacher/scholars are somewhat isolated in numerous ways by the traditional structure of the academy and many long-standing practices.

First, by the highly specialized nature of their scientific knowledge and research interests; second, by the arbitrary distinctions between faculty at research institutions in contrast to faculty at primarily undergraduate institutions; third, by various social boundaries such as national identity, and by real or imagined differences among professors and students, professors and administrators, academia and government interests, academic values and nonacademic priorities, scientist and nonscientist.

It's all rather daunting, really; but the Cottrell Scholar program was founded on the belief that the superlative teacher/scholar relishes the bridge-building opportunities these barriers present.

Traditionally, Scholars are dedicated to bridging the gap between excellence in research and excellence in teaching. Certainly the two keynote speakers at this year's conference, Catherine Drennan and Eric Mazur, have achieved that goal, as has attending TREE awardee Rigoberto Hernandez. Not only are these three individuals superb investigators, but they are also master communicators and educators.

In addition to benefiting from the wisdom these accomplished scientists will impart over the next two-and-a-half days, many Scholars would surely benefit from attending the Academic Leadership Training (ALT) Workshop to be held early next year at the American Chemical Society headquarters in Washington, DC. It was created by members of the Cottrell Scholars Collaborative and features multiple sessions to help sharpen the academic leadership skills of an interdisciplinary group of faculty from research universities and primarily undergraduate institutions. An intensive course in bridge building.

To help Scholars further hone those skills, we have now made five TREE awards and one LEAD award. We are currently reviewing a number of superlative applications for SEED and FRED awards. For more on these competitive, career-building opportunities available exclusively to Cottrell Scholars visit *www.rescorp.org*.

Returning to the immediate business at hand, not only is this year's conference the largest on record, with more than 90 attendees, including our initial two Cottrell-Fulbright Scholars from Germany– chemist Olalla Vázquez, University of Marburg, and physicist Sebastian Slama, University of Tübingen – we also welcome the largest cohort of newly minted Scholars – 24 – who come from both research universities and PUIs. As always, I urge you to take advantage of this superb opportunity to get to know your fellow attendees, make new friends and develop great collaborations.

Sincerely,

Robert N. Shelton
President
Research Corporation for Science Advancement

From the Program Chairs

Welcome to the 2016 Cottrell Scholar Conference!

Diversity and relevance – these are two increasingly vital factors in STEM education that we hope will become major topics of discussion during this conference and beyond.

Catherine Drennan and Eric Mazur, our dynamic keynote speakers, will each address one of these factors in practical terms from their unique individual viewpoints. Your task as a conference participant is to further the discussion by speaking up in the Q&A sessions, during the official breakout sessions, and in as many one-on-one and small-group conversations as you can during the next two-and-a-half days.

TREE award winners, early career faculty, post-tenured faculty, foundation officers and representatives of professional organizations – we've all come together to make this 22nd-annual conference our largest and most diverse since the start of the program in 1994. As we build bridges between these communities, we are likely to see this potent mix of accomplished people come up with major new ideas and top-quality projects during this precious and limited time.

Another main goal of the conference is to welcome the new class of Cottrell Scholars (2016), including two Cottrell-Fulbright Scholars from a new RCSA partnership with the German-American Fulbright Program. Our advice to these newcomers is the same as our advice to old hands: The more you interact with colleagues, the more you will benefit from the conference program. So don't be shy – mingle!

Of course, a real added value for early career Scholars is participation in the Cottrell Scholars Collaborative. A cross-disciplinary network begun in 2011, CSC's overarching goal is to improve undergraduate and graduate science education at colleges and universities across the country through projects with potential high impact. In the process, CSC participants are also developing their academic leadership skills.

We hope you find this event well worthwhile. Please contact us with advice on how to make both the CS program and the conference even better!

Penny Beuning
Associate Professor of Chemistry
Northeastern University

Silvia Ronco
Senior Program Director
Research Corporation for Science Advancement

Conference Objectives

To empower scholars to build bridges across different environments, participants will:

- → Discuss successful activities and approaches for engaging with students, colleagues, and administrators at different types of institutions.
- → Learn how to work with colleagues and administrators to engender buy-in for educational change.
- → Explore partnerships engaging diverse constituents.
- → Become familiar with ongoing activities aimed at transforming STEM education at the national level.
- → Identify tactics that enable collective action.
- → Have the opportunity to form teams and become involved in educational projects of national impact.
- → Engage in collaborative work that will continue throughout the year.

2016 Cottrell Scholar Conference Agenda

Building Bridges
Westin La Paloma

Wednesday, July 13, 2016

2:00 - 6:00 pm	**Registration**	Retail Foyer
3:00 - 4:00 pm	**Opening Reception** Drinks and Light Hors d'Oeuvres	Murphey Patio
4:00 - 5:00 pm	**Welcome and Introductions** Conference Overview and Goals Robert Shelton, Silvia Ronco, Penny Beuning **Introduction of Scholars**	Murphey
5:00 - 7:00 pm	**Presentations by 2016 Cottrell Scholars**	Murphey
7:00 - 9:00 pm	**Dinner** **Cottrell Scholar Trophy Ceremony**	Sonoran I

2016 Cottrell Scholar Conference Agenda

Building Bridges
Westin La Paloma

Thursday, July 14, 2016

7:00 am	**Registration**	Finger Rock Foyer
7:00 - 8:00 am	**Breakfast**	Murphey Patio
8:00 - 10:00 am	**2016 Cottrell Scholar and Cottrell-Fulbright Scholar Presentations**	Murphey
10:00 - 10:30 am	**Morning Break**	Finger Rock Foyer
10:30 am - 12:00 pm	**Breakout Session I** *PUI and Research Intensive Institutions: Working Together to Transform Science Education* **Regroup to Discuss**	Finger Rock I, II, III & Lantana
12:00 - 1:00 pm	**Lunch**	Sonoran I
1:00 - 2:30 pm	**Keynote Presentation** *What Every Teacher and Mentor Should Know: A Guide to Identifying and Reducing Stereotype Threat to Maximize Student Performance* Catherine Drennan, HHMI Professor and Investigator, Chemistry and Biology, MIT **Discussion / Q&A**	Murphey
2:30 - 3:00 pm	**Afternoon Break**	Finger Rock Foyer
3:00 - 4:30 pm	**Breakout Session II** *Understanding Academic Leadership* **Regroup to Discuss**	Finger Rock I, II, III & Lantana
4:30 - 6:00 pm	**Pool Time** Swimming & Informal Discussion	
6:00 - 7:00 pm	**Reception Honoring New Scholars** Poster Session with Drinks & Light Hors d'Oeuvres	Sonoran
7:00 - 9:30 pm	**Dinner** **2016 TREE Award Presentation** Rigoberto Hernandez, Chemistry, Johns Hopkins University Poster Session with Dessert & Drinks	Sonoran

2016 Cottrell Scholar Conference Agenda Continued

Friday, July 15, 2016

7:00 - 8:00 am	**Breakfast**	Murphey Patio
8:00 - 10:00 am	**Cottrell Scholar Collaborative Presentations**	Murphey
10:00 - 10:30 am	**Morning Break**	Finger Rock Foyer
10:30 am - 12:00 pm	**Breakout Session III** *Cottrell Scholars Working Together* **Regroup to Discuss**	Finger Rock I, II, III & Lantana
12:00 - 1:00 pm	**Lunch**	Sonoran I
1:00 - 2:30 pm	**Keynote Presentation** *Assessment: The Silent Killer of Learning* Eric Mazur, Professor of Physics, Harvard University **Discussion / Q&A**	Murphey
2:30 - 3:00 pm	**Afternoon Break**	Finger Rock Foyer
3:00 - 4:30 pm	**Breakout Session IV** Unstructured Time to Work on Educational and/or Research Collaborations	Finger Rock I, II, III & Lantana
4:30 - 5:00 pm	**Conference Survey**	Murphey
5:00 - 6:00 pm	**Pool Time** Swimming & Informal Discussion	
6:00 - 7:00 pm	**Reception** Drinks & Light Hors d'Oeuvres	Terrace Level Foyer
7:00 - 9:30 pm	**Dinner** All Guests are Invited to Join	Terrace Level Patio

Keynote Speaker

What Every Teacher and Mentor Should Know: A Guide to Identifying and Reducing Stereotype Threat to Maximize Student Performance

Catherine L. Drennan
HHMI Professor and Investigator, Professor of Chemistry and Biology, Massachusetts Institute of Technology

Abstract: My aha moment concerning diversity-training occurred when I asked an underrepresented minority (URM) undergraduate student why he left his STEM major, and he said, "I never had a TA who believed in me." I was stunned by the response, since my experience with our graduate student TAs was so positive. I asked him to recall what these graduate student TAs had said, and, after careful thought, he replied, "it is not what my TAs said, it is what they didn't say." In that moment, I realized the importance of diversity-training to teacher training and also to mentor training. When a TA or mentor says nothing, different students take away very different messages; with one student interpreting silence as an indication that everything is perfect and another student interpreting that silence as an indication that failure is assured. In this talk, I will describe the development and evaluation of diversity-training material that can be used to train both researchers and educators on issues of unconscious bias and stereotype threat. The goal of this training is to help educators and mentors create the type of environment in their classrooms and/or laboratories in which all young scientists can reach their full potential. The training program that will be described is freely available to anyone who would like to adopt it at his or her home institution. *http://drennan.mit.edu/education/education-interests/teacher-and-mentor-training/#Diversity-Training*

Bio: Catherine L. Drennan is a Professor of Chemistry and Biology at the Massachusetts Institute of Technology, and a professor and investigator with the Howard Hughes Medical Institute. She received an AB in chemistry from Vassar College, working in the laboratory of Professor Miriam Rossi, and a Ph.D. in biological chemistry from the University of Michigan, working in the laboratory of the late Professor Martha L. Ludwig. She was also a postdoctoral fellow with Professor Douglas C. Rees at the California Institute of Technology. In 1999, she joined the faculty at the Massachusetts Institute of Technology. Dedicated to both research and teaching, Drennan's educational initiatives include creating free resources for educators that help students recognize the underlying chemical principles in biology and medicine, and that train graduate student teaching assistants and mentors to be effective teacher–scholars. Her primary research interest is the use of X–ray crystallography to study the structure and mechanism of metalloproteins.

Keynote Speaker

Assessment: The Silent Killer of Learning

Eric Mazur
Area Dean of Applied Physics and Balkanski Professor of Physics and Applied Physics, Harvard University

Abstract: Why is it that stellar students sometimes fail in the workplace while dropouts succeed? One reason is that most, if not all, of our current assessment practices are inauthentic. Just as the lecture focuses on the delivery of information to students, so does assessment often focus on having students regurgitate that same information back to the instructor. Consequently, assessment fails to focus on the skills that are relevant in life in the 21st century.

Assessment has been called the "hidden curriculum" as it is an important driver of students' study habits. Unless we rethink our approach to assessment, it will be very difficult to produce a meaningful change in education.

Bio: Eric Mazur is the Balkanski Professor of Physics and Applied Physics at Harvard University and Area Dean of Applied Physics. He leads a vigorous research program in optical physics and supervises one of the largest research groups in the Physics Department at Harvard University. He has made important contributions to spectroscopy, light scattering, the interaction of ultrashort laser pulses with materials, and nanophotonics. In addition to his work in optical physics, Mazur has been very active in education. In 1990 he began developing Peer Instruction, a method for teaching large lecture classes interactively. He is the author of *Peer Instruction: A User's Manual* (Prentice Hall, 1997), a book that explains how to teach large lecture classes interactively. In 2006 he helped produce the award-winning DVD *Interactive Teaching*. Mazur's teaching method has developed a large following, both nationally and internationally, and has been adopted across many disciplines.

2016 TREE Awards

Started in 2015, the TREE Award (Transformational Research and Excellence in Education) honors the outstanding research and education accomplishments of the community of Cottrell Scholars. Additionally, the award encourages the improvement of science education and raises the national profile of the Cottrell Scholar community.

Rigoberto Hernandez

Department of Chemistry, Johns Hopkins University
Cottrell Scholar 1999

Rigoberto Hernandez is a Professor in the Department of Chemistry at the Johns Hopkins University as of July 1, 2016, and remains as the Director of the Open Chemistry Collaborative in Diversity Equity (OXIDE) since 2011. Before Hopkins, he was a Professor in the School of Chemistry and Biochemistry at Georgia Tech, and Co-Director of the Center for Computational Molecular Science and Technology of which he co-founded. He holds a B.S.E. in Chemical Engineering and Mathematics from Princeton University (1989), and a Ph.D. in Chemistry from the University of California, Berkeley (1993). His research area can be broadly classified as the theoretical and computational chemistry of systems far from equilibrium. This includes a focus on microscopic reaction dynamics and their effects on macroscopic chemical reaction rates in arbitrary solvent environments. Hernandez is the recipient of a National Science Foundation (NSF) CAREER Award (1997), Research Corporation Cottrell Scholar Award (1999), the Alfred P. Sloan Fellow Award (2000), a Humboldt Research Fellowship (2006-07), the ACS Award for Encouraging Disadvantaged Students into Careers in the Chemical Sciences (2014), the CCR Diversity Award (2015), and the RCSA Transformational Research and Excellence in Education (TREE) Award (2016). He is a Fellow of the American Association for the Advancement of Science (AAAS, 2004), the American Chemical Society (ACS, 2010), and the American Physical Society (APS, 2011).

Vincent Rotello

Department of Chemistry, University of Massachusetts Amherst
Cottrell Scholar 1996

Vincent Rotello is the Charles A. Goessmann Professor of Chemistry and a University Distinguished Professor at the University of Massachusetts at Amherst. He received his B.S. in Chemistry in 1985 from the Illinois Institute of Technology, and his Ph.D. in 1990 in Chemistry from Yale University. He was an NSF postdoctoral fellow at Massachusetts Institute of Technology from 1990-1993, and joined the faculty at the University of Massachusetts in 1993. He has been the recipient of the NSF CAREER and Cottrell Scholar awards, as well as the Camille Dreyfus Teacher-Scholar, the Sloan Fellowship, and the Langmuir Lectureship, and is a Fellow of the American Association for the Advancement of Science (AAAS) and of the Royal Society of Chemistry (U.K.). He was also recognized in 2014 and 2015 by Thomson Reuters as one of the "Most Influential Scientific Minds." Rotello is currently the Editor-in-Chief of Bioconjugate Chemistry, and is on the Editorial Board of 14 other journals. His research program focuses on using synthetic organic chemistry to engineer the interface between hard and soft materials, and spans the areas of devices, polymers, and nanotechnology/bionanotechnology, with over 460 peer-reviewed papers published to date.

Presentations by Cottrell Scholars and Cottrell-Fulbright Scholars

2015 Cottrell Scholars

Gary Baker	Chemistry, University of Missouri-Columbia
Catherine Grimes	Chemistry and Biochemistry, University of Delaware

2016 Cottrell Scholars

John Antos	Chemistry, Western Washington University
Tamara Bogdanovic	Physics, Georgia Institute of Technology
Jahan Dawlaty	Chemistry, University of Southern California
Rafael Fernandes	Physics, University of Minnesota
Sergey Frolov	Physics, University of Pittsburgh
Sharon Gerbode	Physics, Harvey Mudd College
Kathryn Haas	Chemistry, Saint Mary's College
Eliza Kempton	Astronomy, Grinnell College
Dušan Kereš	Astronomy, University of California, San Diego
Dmytro Kosenkov	Chemistry, Monmouth University
Aaron Leconte	Chemistry, Claremont McKenna, Pitzer, and Scripps Colleges
Thomas Maimone	Chemistry, University of California, Berkeley
Brent Melot	Chemistry, University of Southern California
William Pomerantz	Chemistry, University of Minnesota
Aaron Romanowsky	Astronomy, San José State University
Michael Rose	Chemistry, The University of Texas at Austin
Scott Shaw	Chemistry, The University of Iowa
Levi Stanley	Chemistry, Iowa State University
Lauren Waters	Chemistry, University of Wisconsin Oshkosh
Di Xiao	Physics, Carnegie Mellon University
Yan Yu	Chemistry, Indiana University

2016 Cottrell-Fulbright Scholars

Sebastian Slama	Physics, University of Tübingen
Olalla Vázquez	Chemistry, University of Marburg

Presentations by Cottrell Scholars Collaborative Teams

Talks

Exploring a Community-Based Entrepreneurial Approach to STEM Education

Mats Selen, Physics, University of Illinois at Urbana-Champaign

Cottrell Scholar Collaborative New Faculty Workshop

Andrew Feig, Chemistry, Wayne State University

Rory Waterman, Chemistry, University of Vermont

3D-MoChI: Three Dimensional Models for Chemistry Instruction

Ognjen Miljanic, Chemistry, University of Houston

National Collegiate Scholastic Association

Jennifer Ross, Physics, University of Massachusetts Amherst

Academic Leadership Training

Rigoberto Hernandez, Chemistry, Johns Hopkins University

Poster

Getting a Job at a Research Intensive PUI

Gina MacDonald, Chemistry, James Madison University

Cottrell Scholars Collaborative Proposal Writing Rules

Successful proposals should have the potential to positively impact undergraduate and/or graduate science education in the classroom, at the departmental level or at the national level.

- → Up to four $25,000 awards will be given to teams of Cottrell Scholars working collaboratively.
- → Two-year awards made to a team formed at this conference.
- → Members of the team are active or past Cottrell Scholars.
- → Award could be for a new project that will expand the impact of existing funded collaborative projects. New collaborative projects are also welcome.
- → Proposal should briefly explain an innovative approach for projects with potentially broad impact.
- → Two-page proposal must submitted electronically to Silvia Ronco (sronco@rescorp.org) and Richard Wiener (rwiener@rescorp.org) by midnight (PDT) on July 29, 2016.
- → Awards will be announced within a month of submission.

Conference Evaluation Survey

An online conference survey will be available on Friday, July 15, 2016. To access and complete the survey, please go to: *http://www.surveymonkey.com/r/2016CSconferencesurvey*

2016 Cottrell Scholars

Nandini Ananth

Department of Chemistry and Chemical Biology, Cornell University

Quantum Dynamic Investigations of Photo-induced Electron Transfer Catalyzed by Transition Metal Complexes

The search for renewable energy resources has intensified in the last decade and the role of researchers in chemistry has grown increasingly important in our efforts to design novel materials that efficiently harvest abundant natural resources such as sunlight and water to produce energy. In this proposal we will investigate the mechanisms of multi-electron transfer in transition metal catalysts with the goal of designing efficient water splitting catalysts. We will draw our inspiration from natural systems such as the Oxygen evolving complex of Photosystem II where a multi-electron (and proton) redox reaction is involved in the generation of hydrogen and oxygen from water. Although experimental efforts have had some success designing a handful of catalysts that split water, we propose to design and employ accurate theoretical simulation methods to understand charge transfer reaction mechanisms at the atomic and sub-atomic levels and on sub-femtosecond timescales. We will develop and employ electronic structure techniques to accurately describe excited states in metal complexes and we will employ approximate yet accurate quantum dynamic simulation methods that employ classical molecular dynamics trajectories to capture quantum reaction mechanisms. Building this uniquely powerful approach will allow us to (i) uncover general guidelines to design more efficient TM complexes as catalysts and (ii) generate a toolbox of transferable techniques that can be employed in the study of other renewable energy materials including organic photovoltaics.

My educational plan involves a multi-pronged strategy to provide a strong, foundational baseline of mathematics for the physical sciences at the undergraduate level with a specific initial focus on Chemistry majors.

John M. Antos

Department of Chemistry, Western Washington University

Maximizing the Utility of Bacterial Sortases for Protein Modification and Undergraduate Education

Bacterial sortases have emerged as remarkably versatile tools for the chemoenzymatic derivatization of proteins and peptides. The research component of this proposal seeks to enhance the potential of sortases through two projects focused on addressing fundamental limitations of sortase methodology. First, we will increase the efficiency of sortase-mediated ligations by blocking reaction reversibility using metal-binding peptides. Through the use of peptide and protein models, we will systematically optimize key reaction components, and explore the compatibility of this strategy with multiple protein substrates. Second, with the goal of expanding the scope of sortase-based methodology beyond the termini of polypeptide targets, we will develop a selective strategy for forming isopeptide bonds that exploits the unique reactivity of natural sortase homologs. Peptides will be used to elucidate structure-function relationships that influence isopeptide bond formation. Ultimately, this approach will be applied to the selective modification of lysine side chains in a full size protein.

In addition to research aims, we will leverage the therapeutic potential of sortase inhibitors to develop a discovery-driven laboratory experiment for an undergraduate organic laboratory course. Students will participate in a multi-week drug discovery exercise that includes computer modeling, organic synthesis, and *in vitro* enzyme activity studies to design small molecule sortase inhibitors with applications in the treatment of tooth decay. We will complement this lab module by piloting the use of a flipped classroom strategy to boost student engagement and create more opportunities for active learning in the associated organic chemistry lab lecture.

2016 Cottrell Scholars Continued

Tamara Bogdanovic
Department of Physics, Georgia Institute of Technology

Shedding Light on Supermassive Black Hole Binaries

Gravitationally bound supermassive black hole binaries (SBHBs) are thought to be a natural product of galactic mergers and growth of the large scale structure in the universe. They remain observationally elusive, thus raising a question about the characteristic observational signatures associated with these systems. Large amount of effort and resources invested in observational searches for SBHBs makes development of a new generation of theoretical models worthwhile. More specifically, models that will account for interaction of matter and radiation represent an essential step in understanding the physical properties and observational signatures of SBHBs. In this context, I propose a program of research based on the high-resolution, radiation-magnetohydrodynamic simulations of sub-parsec scale SBHBs which will for the first time investigate the impact of radiative feedback from the two accretion powered active nuclei on the properties of these systems.

There is a compelling body of evidence, drawn from research on how people learn science and engineering, that shows that student-centered methods of teaching and learning are more effective than a traditional, passive approach. In this proposal I describe the plan to implement research-based teaching methods that put emphasis on active student participation and collaborative learning. I also discuss how online resources can be used to further enhance the student learning experience and my plan to remain engaged in education research through continued training and development.

Eva-Maria Schoetz Collins
Department of Physics, University of California, San Diego

Unraveling the Role of Mechanics for Tissue Self-Organization *in Vivo*

This experimental project addresses fundamental questions regarding the role of mechanical interactions for pattern formation in development. It has two aims: (1) to determine the role of mechanical properties for cell behaviors during tissue organization and body axis formation and (2) to obtain *in vivo* measurements of the forces individual cells experience and their connection to cell signaling during these patterning processes. We choose *Hydra* regeneration from cell aggregates as a model system to answer these questions, because these aggregates are structurally simple, consisting of two epithelial tissues and extracellular matrix, which enables quantitative measurements of forces and material properties as well as controlled perturbations. Simultaneously, aggregates develop into a functional animal in less than one week; thus, the system provides a biologically relevant *in vivo* context. Finally, we have genetic and molecular tools for molecular manipulation and real-time gene expression analysis to correlate physical properties and cell signaling. By using a multiscale approach from the molecular to the organismal level, this study will provide insight into how macroscopic organism-level patterning emerges from physicochemical interactions on the microscopic scale.

The educational plan is centered on training students to become effective teacher-scholars in biological physics. It is indispensable to engage them in research and in mentoring/teaching activities as early as possible. Therefore, I will create specific activities (a novel research-based lab class, a new STEM mentoring program, and research opportunities in my group) especially for younger students to practice these skills. Focus is long-term engagement and interdisciplinary research approaches and mentoring.

2016 Cottrell Scholars Continued

Jahan Dawlaty

Department of Chemistry, University of Southern California

A New Handle in Solar-to-Fuel Light Harvesting: Creating Protons Where They are Most Needed

Electrons and protons are two essential ingredients of redox reaction needed for converting solar light to fuel. Significant research is focused on exciting electrons and holes with light to drive such reactions. Protons are just as important in these reactions and high flux sources and sinks of protons near the active site of a catalyst is essential for its efficiency. The proposed work aims to understand and engineer such proton sinks and sources near catalytic interfaces. In particular light will be used to "activate" protons in photoacids and thus drive proton-requiring redox reactions that are otherwise kinetically unfeasible. Two implementations will be pursued. First, photoacids will be tethered near electrode surfaces, right where protons are needed. Second, proton conducting polymers will be doped with photoacids as means of proton delivery in analogy to photovoltaics. We have already taken preliminary steps in each one of these fronts.

The proposed educational work is centered on modernizing the pedagogy of thermodynamics and kinetics from its 19th century mold to fit the challenges of this century. I hypothesize that the current perception of thermodynamics as abstract and unpalatable is due to the pedagogical structure that was built in response to the 19th century technological challenges, such as improving the efficiency of steam engines. In response, I propose two sets of tools, insertable modules and collaborative concept-maps, that will connect the classical concepts to contemporary challenges and technologies for example solar light harvesting, drinking water, global climate change, and nanoscience.

Rafael M. Fernandes

School of Physics and Astronomy, University of Minnesota

A Tale of Two States: Interplay Between Magnetism and Superconductivity in Quantum Materials

Quantum materials host a variety of electronic states with remarkable potential for technological applications. Among those, high-temperature superconductors have attracted both fundamental and applied scientists for their ability to carry currents without dissipation above the liquid nitrogen boiling temperature. Because most quantum materials displaying this unconventional state also show a nearby antiferromagnetic phase, elucidating the interplay between these two states has become a key challenge to understand and possibly design new superconductors. In this proposal, the intertwining between superconductivity and antiferromagnetism will be explored via a novel Quantum Monte Carlo approach. Two complementary problems will be investigated. In the first, a systematic comparison of the magnetically promoted enhancements of the pairing susceptibilities of copper- and iron-based superconductors will be conducted. In the second, the phase diagram showing how these states depend on the strength of electronic interactions will be determined by solving a microscopic electronic model that treats antiferromagnetism and superconductivity on equal footing. Completion of this work will shed new light on the rich interplay between magnetism and superconductivity and will establish this novel Quantum Monte Carlo approach as a viable tool to study quantum materials.

The educational component of this proposal involves implementing active learning in upper-division undergraduate physics classes. The goals are to foster the development of skills appealing to students interested in non-academic STEM careers and to enhance the students' performance and interest. Rigorous and thorough assessments will be implemented to attest the viability and efficacy of this approach to improve the teaching of undergraduate physics.

2016 Cottrell Scholars Continued

Sergey Frolov

Department of Physics and Astronomy, University of Pittsburgh

Experimental Investigation of One-Dimensional Topological Phases

We will investigate two kinds of one-dimensional topological phases, namely the spin helical liquid and topological superconductivity. Helical liquid is a state in which spin-up electrons only move to the right, while spin-down only move to the left. Topological superconductivity is notorious because Majorana quasiparticles, which are their own antiparticles, should appear at its boundaries. Nanoscale electronic devices based on semiconductor nanowires will be fabricated and investigated at low temperatures. Uniquely to this proposal, we shall explore the valence band which, compared to the conduction band, offers a much stronger spin-orbit interaction, the key component in both topological phases. The ultimate evidence of new phases is the observation of an energy gap in the electronic spectrum. The studies of the gap will bring fundamental understanding of topological phases. The realization of helical and Majorana states in a robust form will have implications for spintronics and quantum computing.

The education goal of this proposal is to create a laboratory course in which the facilities of the Pittsburgh Quantum Institute and Petersen Institute of Nanoscience and Engineering will be used for inquiry-based training in the state of the art of nanofabrication, nanocharacterization, quantum transport and optics studies of novel materials such as graphene, nanowires and nanotubes. Students will receive a first impression of how research projects proceed, get introduced to the latest research and learn valuable technical, modelling and communication skills. Online component of the course will include a platform for discussing fresh scientific preprints as online lecture videos on the topics of modern quantum science.

Sharon Gerbode

Department of Physics, Harvey Mudd College

Interactions Between Impurities and Dislocations in Small Colloidal Crystals

If you buy a silicon wafer, you might expect the crystal to be pure and perfectly ordered. Yet, it is probably riddled with impurities—e.g. aluminum atoms replacing silicon atoms. How these move within crystals is a fundamental topic in condensed matter physics that is central to numerous technological processes. The motion of impurities is thought to be influenced by dislocations, localized patches of disorder that dominate the crystal's materials properties. However, while existing theories of dislocation and impurity motion are accurate for very large, effectively continuum crystals, they can fail for smaller, technologically relevant systems such as nanocrystals. Using an optical trap to induce disorder in colloidal crystals, we will experimentally measure the interactions between dislocations and impurities. By perturbing crystals of various sizes, ultimately we will discover how these interactions change in the technologically relevant regime of very small crystals.

Recently, Harvey Mudd College has emerged as a leader in recruiting and retaining women and other underrepresented groups to STEM. Our most notable achievement in this context has been in the Department of Computer Science (CS), where the fraction of female CS majors has increased from 12% to 40% in just the past five years—a direct result of their nationally recognized revision of "CS5", the introductory CS programming course. I propose to work with the creators of CS5 to develop a broadly appealing mechanics animations course in which students encode interactive animations of mechanics problems using the programming skills learned in CS5 to illuminate challenging physics topics.

2016 Cottrell Scholars Continued

Kathryn L. Haas

Department of Chemistry and Physics, Saint Mary's College

Transporting Cu(I) as Cargo and Using Cu(III) as a Killer Cofactor: Histidine-rich Motifs in Ctr1 and Histatin 5 Control Cu Oxidation State and Reactivity

The human cellular copper transporter (Ctr1) protects against Cu redox cycling during Cu transport while the salivary antimicrobial peptide, Histatin 5 (Hist5) leverages Cu-catalyzed reactive oxygen species as a weapon against fungal pathogens. Ctr1 and Hist5 serve different biological roles, but have interesting parallels in their use of similar histidine-rich coordination motifs in controlling Cu reactivity. Our undergraduate research group will characterize the sequence-dependent structures and redox activity of model peptides based on the soluble, histidine-rich regions of Ctr1 and Hist5. This program will uncover new knowledge about the chemical mechanisms by which Ctr1 traffics vital Cu cargo, and by which Hist5 uses Cu as a cofactor to kill pathogenic fungi.

As the chemistry curriculum at Saint Mary's College is transitioned to a more flexible, integrated program, audience preparation diversity becomes a fundamental issue in upper-division chemistry laboratory courses. This proposal calls for creation of a "Video Web" to enable student self-preparation and to help students integrate concepts between courses. The Video Web will consist of videos that introduce each experiment (designated "Pro-Lab Videos"), as well as "Concept Videos" that teach foundational concepts and theories. Pro-Lab Videos and Concept Videos will be posted publicly on YouTube and will be linked to each other using the YouTube Annotations feature. The Video Web will address the issue of preparation diversity in upper-division laboratory courses and will empower students to take control of their education and integrate discipline-specific concepts into their open-ended, interdisciplinary laboratory projects.

Eliza Kempton

Department of Physics, Grinnell College

Atmospheric Structure and Emission Spectrum Calculations for Extrasolar Super-Earths: Looking Toward JWST and Beyond

One of the most significant findings of NASA's Kepler mission has been the ubiquity of so-called super-Earth exoplanets—planets with masses and sizes intermediate between Earth and Neptune. The bulk densities of these objects reveal a highly diverse population of planets. Additionally, the recent observations of the *atmospheres* of two super-Earths, GJ 1214b and HD 97658b, reveal atmospheres that do not appear to resemble any of the planets of our solar system (Kreidberg et al. 2014, Knutson et al., 2014). It is this issue of atmospheric diversity that I propose to investigate here. The first part of this proposal is to complete the development of a robust radiative transfer (RT) suite that can calculate atmospheric structure (temperature-pressure profiles), as well as emission spectra, and transmission spectra for exoplanets of arbitrary atmospheric composition. The computational tools will then be applied to investigate a compositionally diverse set of super-Earths that have not previously been studied in detail. The scientific agenda of this proposal is set to coincide with observational studies of super-Earth atmospheres using JWST and eventually 30-meter class ELTs.

I will additionally develop two programs aimed at improving diversity amongst STEM majors at Grinnell College. The first is a spatial reasoning course for students with a low level of STEM preparation, and the second is a peer-mentoring program for STEM students from traditionally underrepresented groups. This two-pronged approach will address key issues of preparedness and community building for first-year science students.

2016 Cottrell Scholars Continued

Dušan Kereš
Department of Physics, University of California, San Diego

Using Cosmological Hydrodynamic Simulations to Constrain Evolution of Galaxies and Their Gaseous Halos

I propose to develop and use state-of-the-art cosmological hydrodynamical simulations with the explicit stellar feedback model to study the evolution of galaxies and their surrounding gaseous halos. The halo gas in so-called "circum-galactic medium" is a crucial reservoir in which gas infall and outflow processes interact and shape the galaxy evolution. My study will answer questions such as: What is the phase structure of gas infall and outflows? How do infall and outflows interact? How can we use observations of halo gas to constrain theoretical models? How does the star formation driven feedback affect the distribution of dark matter within galaxies? Simulations will also help me interpret current observations and provide predictions for the future observations of gas around galaxies. Furthermore, I will use the same simulations to characterize the distribution of dark matter within galaxies and test the currently favored cold dark matter model.

Galaxies and computational astrophysics are an integral part of my educational plan. I propose to re-shape the introductory astronomy course on galaxies and cosmology into a student-centered flipped classroom. Furthermore, I propose to use my local computing cluster and existing simulations to enable research-like experience for astrophysics students at the University of California, San Diego. For my upper-level undergraduate and graduate courses, I will develop project based assignments that will help students gain experience in effective use of data and models while teaching them about physical properties of galaxies such as the contribution of different matter components to the rotation curves of galaxies.

Dmytro V. Kosenkov
Department of Chemistry and Physics, Monmouth University

Exciton Energy Transfer in Light Harvesting Proteins with Covalently Bound Pigments: The Role of Molecular Vibrations

Advancement in the development of organic photovoltaic devices may be accomplished by mimicking natural light harvesting complexes (LHCs). It has been suggested that exciton energy transfer is amplified by vibrationally-assisted quantum coherence effects in LHCs. The proposed project focuses on revealing the role of molecular vibrations in exciton energy transfer in phycoerythrin – an LHC with covalently bound pigments (e.g. phycocyanobilins). Novel computational methodologies based on a combination of quantum mechanics, fragmentation techniques, and molecular mechanics will be employed to obtain the detailed atomistic description of the key mechanisms of exciton energy transfer in LHCs. Our preliminary results suggest that C=C stretching vibrations in the tertrapyrrole system of phycocyanobilin are coupled to its lowest singlet excited state. The vibrations satisfy the quasi-resonance conditions by bridging the gap in excitation energies of the pigments. It has also been found that exciton energy transfer occurs due to quantum coherence rather than linear correlation of atomic motions in the phycoerythrin.

The educational proposal is designed to revamp physical chemistry laboratory courses at Monmouth University by embedding original research projects into the curriculum. The proposal aims to encourage critical thinking by students, build problem-solving skills, and promote deeper understanding of chemical phenomena. The proposal includes the following laboratory units: transient UV-Vis spectroscopy of *cis-trans* conformational transitions in diazo-dyes; solvatochromism of organic dyes; determination of the rate constant of a chemical reaction using titration; modeling ligand binding to DNA. The proposed project will serve as a model for revising other laboratory courses within the department.

2016 Cottrell Scholars Continued

Aaron Leconte

Department of Chemistry, Keck Science Center, Claremont McKenna, Pitzer and Scripps Colleges

Biochemical Characterization and Engineering of Luciferases Through Statistical Coupling Analysis

Luciferase Bioluminescence Imaging (BLI) is a non-invasive method for monitoring diverse processes in living systems. BLI couples *in vitro* and *in vivo* biological events to the bioluminescent output of the enzyme luciferase. BLI is constrained by the limitations of the luciferase enzyme—primarily insufficient emissions, limited emission colors, and thermal and pH instability. To date, efforts to biochemically characterize and/or engineer luciferase have imparted notable improvements to the luciferase enzyme; however, the improvements in one biochemical property (*e.g.* red-shifted emission) are typically accompanied by concomitant deterioration of other properties (*e.g.* decreased light output or decreased affinity for substrate). Thus, optimization of luciferase is still necessary. Here, we propose to develop techniques that will maximize the potential of finding new, advantageous properties while minimizing the possibility of diminishing other, biochemically important properties. We propose to apply a powerful, evolution-based heuristic method Statistical Coupling Analysis (SCA) to guide both biochemical characterization and engineering efforts for luciferase.

As our education proposal, we propose to incorporate the biochemical characterization of SCA-identified amino acid residues into an introductory chemistry course, enabling a large population of students to experience research as well as developing a potentially novel long-term strategy to incorporate research into introductory courses. In the research proposal, we propose to engineer these enzymes; by using SCA coupled to a screen that focuses on identifying mutants that have multiple beneficial properties, we hope to create novel luciferase enzymes with biotechnologically useful properties as well as increase our biochemical understanding of this important enzyme.

Thomas Maimone

Department of Chemistry, University of California, Berkeley

Redesigning Natural Products for the Treatment of Human Disease

Despite our power as synthetic chemists to produce nearly any small molecule conceivable to the human mind, we are still largely limited in our ability to design and efficiently synthesize small molecules with desired function. By using highly evolved natural products as inspiration, and the tools of rational design, medicinal chemistry, and total synthesis, we hope to pave the way forward to new classes of molecules that are not accessible by other means, and that possess greater relevance to problems in human health than the ones nature has already afforded to us. We believe that rationally designed etoposide derivatives can become next generation anti- cancer agents and we plan to prepare and study such compounds in collaboration with experts in oncology.

Training the next generation of synthetic chemists requires a multi-faceted approach starting with getting children interested in science and chemistry, "refreshing" traditional organic chemistry classes, and finally, getting students interested in research. The educational program developed herein introduces new undergraduate curriculum, new research opportunities for both UC-Berkeley students and community college transfer students, and seeks to develop interest in the sciences at an elementary level.

2016 Cottrell Scholars Continued

Brent C. Melot

Department of Chemistry, University of Southern California

Design of Safe and Sustainable Materials to Enable Large-Scale Energy Storage

Safer and more sustainable ways to store energy are desperately needed. Li-ion batteries have come to dominate the consumer product market, but fail to meet the more stringent demands of large-scale applications like grid storage. The clearest way to address issues of cost is to move away from Li-based technology and towards intercalation chemistry based on sodium. This work will seek to answer several essential and fundamental questions for developing the next generation of Na-ion batteries. The development of environmentally sustainable methods for portable energy storage is an area of critical interest, since the development of high-performance Na-ion electrodes that meet or exceed the properties of Li-ion cells will drastically reduce the cost per kilowatt hour for batteries and make them more commercially viable.

The fields of science, technology, engineering, and mathematics (STEM) struggle to recruit and retain underrepresented minorities. I plan to address this problem in two major ways: (1) by creating an outreach program to promote American Indian participation in STEM and (2) helping to modernize the undergraduate curriculum to improve Chemistry major retention. The American Indian population in Los Angeles is underserved. I plan to build bridges and work to engage these communities once they reach the university. In parallel, I will develop a first year seminar class that will build a sense of community amongst Chemistry majors – an issue that has proven to be critical in retaining underrepresented students in STEM fields – and modernize the laboratory curriculum to better engage students in the learning process.

Maiken H. Mikkelsen

Department of Physics, Duke University

Exploring the Interplay Between Nanoscale Design and Optical Properties of Materials: A Research and Educational Approach

This proposal explores the interplay between nanoscale design and optical properties of materials in both research and education. The grand challenge of the research project is to understand how to design and perfect atom- and energy-efficient synthesis of revolutionary new forms of matter with tailored properties. I seek to understand, design, and dynamically control optical processes and light-matter interactions occurring in nanoscale materials with sub-10 nm dimensions while exploiting chemical assembly techniques. This will advance our insight into fundamental physical behavior and phenomena arising between extreme optical fields and emitters embedded in structured materials approaching the molecular scale. Gaining insight into nanomaterials-by-design may contribute to the foundation for new energy-efficient technologies, which could be the key to addressing global energy and environmental challenges.

The proposed educational project aims to create new and interactive teaching techniques in undergraduate courses, to enhance diversity in physics, and through these initiatives, to address the shrinking pipeline of students choosing careers in the sciences. In particular, I will create opportunities for undergraduate students to develop creative and independent thinking through a new interactive undergraduate course on "Physics of Semiconductor Nanostructures", new modules for the introductory "Quantum Mechanics" course, and independent research opportunities. Significant outreach and diversity activities are proposed centered around visualizing the nanoworld and optics to excite more students from all backgrounds and encourage them to choose science careers. In these ways, the educational plan aims to use experimental research breakthroughs to reinvigorate undergraduate physics education and science recruitment.

2016 Cottrell Scholars Continued

William Pomerantz

Department of Chemistry, University of Minnesota

Fluorinated Peptides and Proteins for ^{19}F MRI and Integrated Research Experiences in an Organic Chemistry Lab Course

This proposal addresses learning gains in a discovery-based research experience in an organic chemistry laboratory in collaboration between the University of Minnesota and Gustavus Adolphus College, and a research plan for developing high signal ^{19}F magnetic resonance imaging (MRI) probes using fluorinated peptides. My laboratory has developed a ^{19}F NMR approach for characterizing protein-small molecule interactions. The data acquisition is rapid and the molecules which bind to the protein are made by short multi-step organic syntheses. The proposed curricular change targets first and second year undergraduates, aimed at retaining students in STEM fields and addresses a scalable problem of providing research experiences to a majority of undergraduates within their major field of study. Pilot studies through a winter and summer research experience enrolled twenty students, providing training in organic chemistry, biomolecular NMR, and molecular design which is well-aligned with the new American Chemical Society degree guidelines.

A new research direction is also being undertaken for chemical synthesis of sequence-defined and sequence-random fluorinated polypeptides. Fluorine is found in trace amounts in biological systems, and can thus make a powerful MRI probe. The central hypothesis is that unstructured peptides can override the environmental sensitivity of fluorine resulting in highly overlapping and intense fluorine signal for ^{19}F MRI. Sequence, size and physicochemical properties will be investigated to develop high signal ^{19}F MRI agents in aqueous media. Due to environmental persistence and bioaccumulation, chemically synthesized fluorinated biopolymers offer a tunable scaffold as a more environmentally friendly and sustainable alternative to replace perfluorocarbons.

Aaron Romanowsky

Department of Physics and Astronomy, San José State University

The Nature and Nurture of Galaxies: Dynamics, Dark Matter, and Data Mining

This project will analyze the outer regions of galaxies in order to understand their mass distributions and their assembly histories. It will chart out the dark matter distributions across the full range of galaxy types, focusing on the ellipticals as a crucial gap in our knowledge. There will also be a new survey of substructures (accreted streams and shells) along with detailed dynamical analysis, and accompanying searches for compact stellar systems and X-ray flares. The research will be carried out in the context of a large, teaching-focused university in an urban environment, with a diverse student population: San José State University (SJSU).

The computational program in the SJSU Department of Physics and Astronomy will be developed through new undergraduate and masters courses that cover data science, numerical astrophysics, and visualization—providing students with practical and transferable skills for careers both in academia and in industry. Students will be closely mentored in cutting-edge astronomy research that includes a special focus on open-access databases and software, along with opportunities to participate in observations with the world's largest telescopes, as well as in outreach that leverages their experiences in order to inspire others in their community to consider STEM careers. Students will also have the chance to engage in intensive, mentored summer computational research and training alongside talented students from other colleges. The SJSU program could serve as a regional or national model for involving students in research, for equipping them with transferable skills, and for enhancing the success of underrepresented populations.

2016 Cottrell Scholars Continued

Michael J. Rose

Department of Chemistry, The University of Texas at Austin

Imparting Precious Metal Properties to First-Row Metals with Heavy Atom Ligands, and Connecting and Encouraging Undergraduates for Outreach Activities via 'Undergraduate Outreach Corps'

The high cost of precious metals motivates the search for C–H activation catalysts derived from earth abundant elements. Heavy metals possess certain properties—most notably, high spin-orbit coupling (SOC) constants—that facilitate C–H bond reactivity. We propose using inexpensive, main group, heavy elements such as antimony and bismuth (Sb, Bi: ~$1-10/oz) coordinated to first row metals to 'mimic' the reactivity of precious metals (~$2000/oz). We will synthesize heavy atom chelates of general formula $[(Y3L)M(X)_n]$, (where Y = P→Bi; M = Mn→Cu). The heavy atom effect will be investigated using C–H activation reagents (cyclohexadiene, norborene, etc); magnetic studies (SQUID, μ_{eff}); and spectroscopy (EPR, XPS).

There is a growing emphasis on providing information and motivation to young learners regarding STEM careers. This proposal highlights one readily available resource to increase the impact of university outreach: And that resource is undergraduates. Many undergraduates seek short-term opportunities to build their CVs and applications for graduate school. This pool of educated and motivated volunteers represents an un-tapped resource. Such students can make meaningful contributions in 1 semester, 1 day, even 1 hour. We will develop a volunteer 'Undergraduate Outreach Corps' that will engage, recruit and maintain an active pool of students eager to participate in outreach. This proposal is unique because the purpose of the 'Outreach Corps' is not to develop a *single* outreach program, but rather to provide a replicable paradigm for catalyzing the *systematic* improvement and expansion of department-wide or college-wide outreach programs.

Scott K. Shaw

Department of Chemistry, The University of Iowa

Chemical Measurements in Confined Liquid Films: Defining and Controlling the Transition from Bulk to Interface

In this research proposal, I will examine liquid films of varying thicknesses (from single nanometer to several micrometers) to create unique perspectives on the creation, behavior, and control of the chemical interface. Our preliminary data and early reports show the utility in examining fluid films' stimulating interfacial behaviors. Fluid films are created by an innovative *dynamic wetting* technique which allows continuous examination of a film's properties as its thickness is systematically varied between 'bulk' and 'interfacial' phases. Existing theories permit the prediction of film thicknesses within these two phases which provides helpful benchmarking of experimental data. Judicious selection of specific fluid-fluid and fluid-substrate pairings allows us to quantify varying classes and strengths of chemical and physical forces that control interfacial to bulk transitions. Our results will aid in identification of the key factors involved in the formation and maintenance of interfacial regions.

My educational plans center on enhancing advanced educational and research experiences for rural students, including a focus on public conversations and *science service* events in their home towns. With support from University Honors and Admissions, this program's scope serves several purposes: young, rural scientists are supported early in their development; scientific ideas, discussions, and role models are planted inside of rural, underserved communities; and relationships with otherwise isolated science educators are forged. By recruiting additional rural students to the sciences, simultaneously improving the research experiences of undergraduates, and providing mentoring experience for graduate students, this program couples directly with ongoing educational priorities in my home department and university.

2016 Cottrell Scholars Continued

Levi Stanley

Department of Chemistry, Iowa State University

Catalyst Design and Development to Unlock the Synthetic Potential of Olefin Hydroacylation Reactions

The discovery and development of new catalysts has established olefin hydroacylation reactions as an attractive strategy to construct new chemical architectures. However, fundamental challenges remain to be addressed before the full synthetic potential of catalytic olefin hydroacylation can be realized. The studies outlined in this proposal aim to overcome challenges associated with the reactivity of higher-order alkenes in hydroacylation reactions, the regioselectivity of olefin hydroacylation reactions, and the synthetic value of ketones prepared from olefin hydroacylation reactions. We propose to develop catalysts to enable enantioselective hydroacylations of substrates containing 1,2-disubstituted and trisubstituted alkenes, formal Markovnikov-selective hydroacylations of terminal alkynes, and sequential alkene hydroacylations and α- arylations to generate novel heterocycles with quaternary stereogenic centers that will be valuable building blocks and structures for synthetic and medicinal chemists.

In addition to the research plans summarized above, this proposal includes an educational plan to drive retention and achievement of chemistry majors and STEM students at Iowa State University. The educational plan is comprised of three initiatives including: 1) the establishment of a Freshman Research Initiative in the Chemistry Learning Community; 2) the introduction of an authentic research experience into our undergraduate organic chemistry laboratory curriculum; and 3) the development of new programming to improve engagement of upper-level and international students in our Chemistry Learning Community.

Lauren Waters

Department of Chemistry, University of Wisconsin Oshkosh

Manganese Homeostasis in Bacteria: Characterization of a Mn-Regulated Small Protein and Identification of Novel Mn Exporters

Manganese (Mn) is an essential trace nutrient, but in excess it is toxic. Mn protects cells against oxidative stress and catalyzes diverse chemical reactions, with important medical and ecological consequences. For example, pathogenic and symbiotic bacteria require Mn to survive in eukaryotic host tissues. Yet many aspects of the role of Mn in bacteria are not well understood. Recently, two new *Escherichia coli* proteins involved in Mn homeostasis were identified: MntS, a putative Mn chaperone, and MntP, a Mn exporter. We propose to investigate the function and mechanism of MntS by testing the hypothesis that it binds Mn and helps activate Mn-using proteins. In Aim I, we will determine the proteins that interact with MntS *in vivo*. In Aim II, we will identify the essential amino acids for MntS function and investigate the evolution of MntS from an ancestral signal peptide sequence. In Aim III, we will use bioinformatics to identify novel Mn exporters in diverse species of bacteria. We will then carry out structure-function studies on the MntP protein and the new Mn exporters to identify critical amino acids for their function and determine their membrane topology.

UW Oshkosh has a large number of first-generation college and non-traditional students. New pedagogical strategies that aim to improve learning in this population should also benefit traditional students. I propose to alter upper-level biochemistry courses to incorporate active learning approaches, facilitate application of knowledge to higher levels of learning (analysis and evaluation), and provide more genuine lab experiences.

2016 Cottrell Scholars Continued

Di Xiao

Department of Physics, Carnegie Mellon University

Topological Excitonics in Gapped Dirac Materials

The research plan of this proposal focuses on the theoretical study of topological excitonic effects in gapped Dirac materials. These novel materials feature a topological band gap with the low/energy charge carriers behaving like massive Dirac fermions. Examples include gapped topological surface states, biased graphene bilayers, and monolayers of semiconducting transition metal dichalcogenides. The unique band structure of these materials sets them apart from conventional semiconductors and holds promise for new quantum optoelectronics. I plan to investigate how band topology affects the formation of excitons as well as their dynamics, and explore the exciting possibility of realizing topological excitonic states, which would then allow dissipationless exciton transport. The new physics uncovered in this proposal may lead to next-generation topological excitonics that utilizes the Berry curvature and band topology as a handle.

My education plan aims at promoting hypothesis-driven learning process through computer simulation and, at the same time, integrating advanced research-oriented topics into undergraduate education. Specifically, building upon existing efforts, I will develop a comprehensive, simple-to-use simulation toolbox for the teaching of *Solid State Physics*. It will be first implemented at CMU, then distributed freely through the internet to achieve maximal impact of this project. The designed plan is expected to stimulate students' interest in science and technology.

Yan Yu

Department of Chemistry, Indiana University

Exploiting Nanomaterials to Unravel Trafficking Inside Cells

Trafficking of vesicles and other cargos inside cells is a vital process in cellular decision-making, but our understanding of intracellular trafficking is limited by the methods available to quantify dynamics and interactions during this process. In this research project, we propose to develop a new quantitative imaging method that measures dynamics of single cargos in living cells with unprecedented spatiotemporal resolutions. By taking advantage of novel surface chemistry of particles, we will design two-faced particles as intracellular probes that allow us to measure simultaneously rotational and translational movements of intracellular cargos. This imaging approach will be combined with automated single-particle tracking algorithms to reveal single cargo dynamics that are inaccessible to conventional methods. We will also reveal the correlation between cargo rotation and the 3-dimensional structure of microtubules in cells, providing new insights into the understanding of intracellular trafficking mechanisms.

The concept of this proposed research will be integrated into teaching innovations that aim to foster critical thinking in introductory undergraduate courses. I propose to bring art into chemistry teaching to create an engaging learning environment. Two teaching strategies will be established: an "X-factor of Chemistry" in-class project that uses short artistic presentations to enhance students' conceptual understanding, and a "Chemistry in Art" seminar course that fosters critical reading of scientific literature in freshmen and sophomores. The artistic platform will provoke inquiry, creativity, and thinking in chemistry learning. The proposed teaching approaches will also be easily adaptable into teaching in different disciplines.

2016 Cottrell-Fulbright Scholars

Sebastian Slama

Department of Physics, University of Tübingen

Dipole-Dipole Interactions of Rubidium Atoms Close to Nanofiber Tips in Home-built Vapor Cells

The ability to generate single photons on demand is one of the fundamental challenges of light-matter interactions. While many approaches are being pursued, an ideal single photon source has not been demonstrated so far. The proposed research project investigates a new system that is based on a metallic nanofiber tip inside a thermal gas of atoms. The tip is attached to a glass fiber which leads out of a home-built vapor cell. If an atom is at a sub-wavelength distance from the tip, the tip can collect photons that are emitted by the atom with high probability. The photons are guided via the glass fiber to a single-photon counter where we detect them. We will investigate the role of dipole-dipole interactions between atoms at the tip on the emitted light. These can lead to super- and subradiant states and have an impact on the photon statistics. We will test this approach for its use as single photon source.

The technologies that are developed within the project will be transferred to an existing practical course on laser physics with the goal of increasing the possibilities of a research-based explorative learning. As the success of the practical course is based on its direct connection with research it will greatly profit from interaction with the PhD student working on the research project. The participating students will build their own vapor cells and do time-resolved spectroscopy with them, thereby developing qualifications that are important both for a career at the university and in industry.

Olalla Vázquez

Department of Chemistry, University of Marburg

EpiTools: Chemical Tools for Unravelling Molecular Epigenetic Mechanisms

Chemistry is firmly understood as the connecting language to interrelate different disciplines; particularly, it has a key role in the intersection of chemistry and biology. The specific approach of studying biological systems at molecular level, chemical biology, is turned into a powerful strategy to finish with the reductionism and to interrogate biology satisfactorily. This is exactly the perspective that epigenetics needs. Epigenetics studies chromatin-based post-translational protein and DNA modifications that dynamically regulate gene expression without altering DNA sequence. Misregulation of these systems has been linked to many illnesses. Despite remarkable progress, our understanding of epigenetic mechanisms at the molecular level is in its infancy. Therefore, chemists, with their preference towards thinking about problems in terms of structure, thermodynamics, and kinetics, will provide the appropriate tools to acquire the detailed mechanistic knowledge needed to comprehend and develop rational epigenetic therapies.

In this context, we propose an indivisible research and teaching project to contribute to solve this problem at the same time that we cope with the still remaining difference between how we do research and how we teach. We will exploit the unique structural features of the nucleosome and the extensive knowledge about DNA binders to design specific nucleosome sensors while we introduce an interdisciplinary, active learning course in which the students will learn how to produce chemicals that directly interfere in epigenetic phenomena and examine their effects in the laboratory. Such compounds represent powerful tools for uncovering and controlling the chromatin events. The outcomes will have both scientific and educational impact.

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