Sustaining the Change You Make

The 21st Annual Cottrell Scholar Conference
July 8-10, 2015 at Westin La Paloma

COTTRELL SCHOLARS COLLABORATIVE

RESEARCH CORPORATION *for* SCIENCE ADVANCEMENT

2015 Conference Planning Committee

Adam Leibovich, Chair
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University of Pittsburgh

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Northeastern University

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University of Massachusetts, Amherst

Silvia Ronco
Program Director
Research Corporation for Science Advancement

From the President

This Cottrell Scholar Conference marks a new era in the program by bringing together the very best early career scientists from major research universities as well as their equally qualified colleagues from primarily undergraduate institutions. The overarching goal, meanwhile, remains essentially unchanged: The Cottrell Scholar program seeks to nurture an interdisciplinary community of outstanding scientific/academic leaders committed to research and teaching at the highest levels.

By opening CS eligibility to PUI scientists earlier this year, RCSA acknowledged several realities:

→ Scientific collaboration in today's academic culture is not necessarily determined by the nature of one's institution, but by community of interest;

→ America's top PUIs are doing a wonderful job of producing graduates in the physical sciences who matriculate to advanced degree programs at research universities;

→ The decline in federal and corporate funding for basic research in recent decades, when contextualized against increasingly severe and complex global challenges, compels reasonable minds to conclude that it is more important than ever to build a strong, interconnected community of scientific leaders in academia who will work to ensure a bright future for all.

In other words, we at RCSA believe we're all in this together, and what you do—and with whom—is vitally important.

This annual conference is designed to give you ample opportunities to share insights and expertise; and the Cottrell Scholars Collaborative exists to facilitate action on common problems or opportunities you identify. In addition, the CS program has been bolstered by several additional levels of competitive funding in the form of career advancement awards:

→ **TREE** Transformational Research and Excellence in Education

→ **LEAD** Leadership Enrichment and Development

→ **SEED** Singular Exceptional Endeavors of Discovery

We urge you to take advantage of these awards. For more information, please see www.rcsa.org.

For more than two decades, the Cottrell Scholar program has sought to contribute to fundamental scientific knowledge even as it has also promoted excellence in science education. The most recent modifications to the program further these aims. But the program's ultimate successes, and they have been numerous of late, are dependent upon the individual's dedication to the cause and his or her willingness to join with like-minded peers to change the world for the better.

Thus this first conference of the new era represents a renewed opportunity to accomplish great things. The first step in doing so, of course, is to get to know your fellow attendees and make new friends. I hope you have a stimulating and enjoyable conference.

Sincerely,

Robert N. Shelton
President
Research Corporation for Science Advancement

From the Program Chairs

Welcome to the 2015 Cottrell Scholar Conference!

Once again, we were able to put together an impressive program with a rich array of keynote speakers, TREE award winners, early career faculty, post-tenured faculty, foundation officers and representatives of professional organizations. This diversity of participants is the heart and soul of the CS conference, enriching conversations with shared experiences and innovative ideas. We hope our interactive program motivates numerous thought-provoking discussions and generates top-quality projects for individuals and teams.

A main goal of the conference is to welcome the new class of Cottrell Scholars (2015) and introduce them to the increasingly impactful activities of the CS Collaborative. And, because of recent program expansions, this year we are also welcoming a group of outstanding Cottrell Scholars from primarily undergraduate institutions! In this task of getting acquainted we all have an equally vital part. So don't be shy – mingle! The more you interact with new colleagues, the more you will benefit from the conference program.

It is our belief that if our work is to have long-lasting impact, we must seek support from a wide array of stakeholders. To transform education, faculty must engage students in their classrooms while also working effectively with colleagues, department chairs and university administrators. All of this requires engagement and steady commitment, but how do you get buy-in from colleagues and administrators? And most importantly, how do we sustain the positive changes we make?

Here's a small hint: John F. Kennedy once said, "Change is the law of life. And those who look only to the past or present are certain to miss the future." Fundamentally, Cottrell Scholars are all about building a better future, both in research and education. If we manage to do it better than it has been done before, there will be no going back.

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!

Adam Leibovich
Professor of Physics
University of Pittsburgh

Silvia Ronco
Program Director
Research Corporation for Science Advancement

Conference Objectives

To empower scholars to sustain departmental and institutional changes, participants will:

- Share successful activities and approaches for engaging with students, colleagues, administrators and the general public.
- Learn how to work with skeptical colleagues to engender buy-in for educational initiatives.
- Become familiar with ongoing activities aimed at transforming STEM education at the national level.
- Have the opportunity to form teams and become involved in educational projects of national impact.
- Identify tactics that enable collective action.
- Engage in collaborative work that will continue throughout the year.

2015 Cottrell Scholar Conference Program

Westin La Paloma
Tucson, Arizona

Wednesday, July 8, 2015

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, Adam Leibovich **Introduction of Scholars**	Murphey
5:00 - 6:00 pm	**Cottrell Scholars Collaborative Presentations**	Murphey
6:00 - 7:00 pm	**Presentations by 2014 Cottrell Scholars**	Murphey
7:00 - 9:00 pm	**Dinner** **TREE Award Presentation** Mats Selen **Cottrell Scholar Trophy Ceremony**	Sonoran I

2015 Cottrell Scholar Conference Program

Westin La Paloma
Tucson, Arizona

Thursday, July 9, 2015

7:00 am	**Registration**	Finger Rock Foyer
7:00 - 8:00 am	**Breakfast**	Murphey Patio
8:00 - 10:00 am	**2015 Cottrell 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*	Finger Rock I, II, III & Lantana
12:00 - 1:00 pm	**Lunch**	Sonoran I
1:00 - 2:30 pm	**Keynote Presentation** Melanie Cooper *Transforming How We Teach Is Good,* *But Transforming What We Expect Students to Learn is Better* **Discussion / Q&A**	Murphey
2:30 - 3:00 pm	**Afternoon Break**	Finger Rock Foyer
3:00 - 3:30 pm	**Informal Discussion**	Murphey
3:30 - 5:00 pm	**Breakout Session II** *How to Not Be a Hero: Why Change Is Hard?*	Finger Rock I, II, III & Lantana
5:00 - 6:00 pm	**Pool Time** Swimming & Informal Discussion	
6:00 - 7:00 pm	**Reception and Poster Session** Welcoming New Scholars Drinks & Light Hors d'Oeuvres	Sonoran
7:00 - 9:30 pm	**Dinner** **TREE Award Presentations** Cathy Murphy Keivan Stassun	Sonoran

2015 Cottrell Scholar Conference Program Continued

Friday, July 10, 2015

7:00 - 8:00 am	**Breakfast**	Murphey Patio
8:00 - 10:00 am	**2015 Cottrell Scholar Presentations**	Murphey
10:00 - 10:30 am	**Morning Break**	Finger Rock Foyer
10:30 am - 12:00 pm	**Breakout Session III** *Obtaining Buy-in and Support*	Finger Rock I, II, III & Lantana
12:00 - 1:00 pm	**Lunch**	Café Patio
1:00 - 2:30 pm	**Keynote Presentation** G. Peter Lepage *Academic Innovation and Sustainability–The View from a Dean's Office* **Discussion / Q&A**	Murphey
2:30 - 3:00 pm	**Afternoon Break**	Finger Rock Foyer
3:00 - 4:30 pm	**Breakout Session IV** *Bring Home Message*	Finger Rock I, II, III & Lantana
4:30 - 5:00 pm	**Conference Survey**	Murphey
5:00 - 6:30 pm	**Pool Time** Swimming & Informal Discussions	
6:30 - 7:30 pm	**Reception** Drinks & Light Hors d'Oeuvres	Terrace Level Foyer
7:30 - 9:30 pm	**Conference Banquet** Participant Guests are Invited to Join	Terrace Level Patio

Keynote Speaker

Transforming How We Teach is Good, But Transforming What We Expect Students to Learn is Better

Melanie Cooper
Lappan-Phillips Professor of Science Education, Chemistry Department and CREATE for STEM Institute, Michigan State University

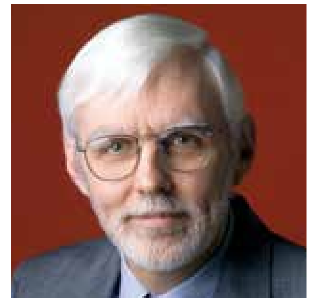
Abstract: The transformation of introductory college-level STEM courses has been highlighted as a national priority. While there are many efforts that target such transformations, most of them are focused on the introduction of student-centered pedagogies. However, it is becoming apparent that equally, if not more important, is the need to change the expectations we have for students to help them develop deep, robust, and useful knowledge. At Michigan State University we are using an approach based on A Framework for K-12 Science Education, in which we engage faculty to identify the core ideas of the discipline, the concepts that cross disciplines, and the ways in which we use these ideas. This three-dimensional approach to teaching and learning will necessarily change the way we teach our classes and assess student learning. In this presentation I will highlight some of the changes we are making and provide examples and evidence from our transformed general chemistry course, Chemistry, Life the Universe and Everything (CLUE).

Bio: Melanie Cooper is the Lappan-Phillips Professor of Science Education at Michigan State University. Before joining MSU in 2012, she was the Alumni Distinguished Professor of Chemistry at Clemson University. At MSU she is jointly appointed in the Department of Chemistry, the College of Education, and the CREATE for STEM Institute.

Cooper received her B.S., M.S. and Ph.D. in chemistry from the University of Manchester, England. She carried out postdoctoral work in organic chemistry before turning to chemical education. Her research interests involve development and assessment of evidence-based curricula to improve the teaching and learning of chemistry within large-enrollment undergraduate chemistry courses.

Keynote Speaker

Academic Innovation and Sustainability—The View from a Dean's Office



G. Peter Lepage
Professor of Physics and former Dean of the College of
Arts and Science, Cornell University

Abstract: There is a striking disconnect between the extent of the (impressive) research arguing for new approaches to classroom teaching of college-level STEM subjects, and the very low rate of adoption of these new ideas. While there is a broad consensus that some sort of institutional change is needed within universities to enable such changes, there is little practical advice about what changes might actually work or who should be responsible for implementing them. Very little has been written about how to structure and launch institution-wide changes in pedagogy, and almost nothing about how to sustain such change in the long run. This talk will discuss how these issues appear to a (former) college dean.

Bio: G. Peter Lepage is a physics professor at Cornell University. Born in Canada, Lepage earned his B.Sc. in physics at McGill University, an M.A.St. in theoretical physics at the University of Cambridge, and his Ph.D. in physics at Stanford University. After graduating from Stanford, he moved to Cornell as a postdoc, becoming a professor, then chair of the Physics Department, and, eventually the Harold Tanner Dean of Cornell's College of Arts and Sciences, a post he held for a decade, from 2003 to 2013. He is currently a member of the National Science Board.

Lepage's research has focused on the application of techniques drawn from quantum field theory and particle physics to novel problems in particle physics, computational quantum field theory, high-precision atomic physics and QED, condensed matter physics, and nuclear physics.

2015 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 undergraduate science education and raises the national profile of the Cottrell Scholar community.

Catherine J. Murphy

Department of Chemistry, University of Illinois, Urbana-Champaign
Cottrell Scholar 1996

In the mid-1990s Catherine Murphy was among the first inorganic chemists to start a program in the synthesis, functionalization, and utilization of inorganic nanomaterials. Her early work on unpassivated II-VI semiconductor "quantum dots" as chemical sensors was well ahead of its time. This work is still highly cited and influential today. According to Google Scholar, Murphy's work has been cited nearly 30,000 times overall, with an overall h index of 76. Her groundbreaking paper on anisotropic metal nanoparticles (J. Phys. Chem. B, 2005) has been cited almost 1,800 times. Thompson Reuters identifies her as 10th among the 100 most frequently cited material scientists in the world for the first decade of the 21st century. In addition she is a champion of undergraduate research and a long-time contributing author to the most widely used introductory general chemistry textbook, *Chemistry: The Central Science*. Murphy is also one of the few tenured faculty members who regularly teaches Illinois' first-year general chemistry course. In 2015, Cathy Murphy was elected to the National Academy of Sciences.

Mats Selen

Department of Physics, University of Illinois, Urbana-Champaign
Cottrell Scholar 1996

A fellow of the American Physical Society, Mats Selen is widely recognized for his critical contributions to the development of CLEO, a general-purpose particle detector at the Cornell Electron Storage Ring (CESR), and his work to advance the understanding of charm hadronic decays and excited states. A few years ago he turned his research focus toward astrophysics, joining the Dark Energy Survey collaboration and working on problems in the field of supernova physics. Most recently, his focus has turned to the field of Physics Education Research. He and his colleagues received the APS Excellence in Physics Education Award for their creation of "smartPhysics," an innovative approach to teaching that does away with the traditional textbook. As a result, the fraction of students who find classroom lectures useful, with the same people teaching, has gone from 40 percent to 80 percent. Selen has also created an electronic/mechanical learning tool, basically a wireless hand-held physics lab, to be incorporated in "smartPhysics" classes. In addition to teaching Physics 211, a calculus-based introductory mechanics course for physics majors and engineers that averages roughly 1,000 students each semester, Selen is also a local celebrity, spreading the gospel of physics to Champaign's morning TV news audience as "the Whys Guy" in a 10-minute weekly segment.

Keivan Stassun

Department of Physics and Astronomy, Vanderbilt University
Cottrell Scholar 2006

One of the rarest events in astronomy is the discovery of an entirely new class of objects. Keivan Stassun and his collaborators made such a discovery in 2007 with the first detection of a brown dwarf eclipsing binary system. In a second outstanding research achievement, Stassun and a graduate student discovered the correlation between stellar "flicker" and the surface gravity of the corresponding star. These measurements promise to better constrain the properties of stars themselves, but they are also leading to better constraints on the properties of extrasolar planets. Meanwhile, in the field of education, Stassun is the prime architect of the highly successful Fisk-Vanderbilt Master's-to-Ph.D. Bridge Program. It has triggered a revolution in the way science doctoral programs at research institutions deal with potential candidates among underrepresented minorities. Stassun's bridge program is now being emulated at the University of Michigan, Columbia University, MIT and Harvard. National Public Radio reports that since it began with a three-student cohort in 2004, "the Fisk-Vanderbilt Master's-to-Ph.D. Bridge Program has accepted 68 students, 55 of whom came from underrepresented minority backgrounds (namely African-American, Hispanic and Native American) and 46 percent of the students have been women." The program has a retention rate of 92 percent, with 100 percent job placement for those who complete the program. According to Stassun, as the program was starting up it greatly benefited from the visibility and imprimatur provided by RCSA as a respected national organization for advancing the physical sciences.

Presentations by Cottrell Scholars

2014 Cottrell Scholars

Mircea Dincă	Chemistry, Massachusetts Institute of Technology
Carla Frohlich	Physics, North Carolina State University
Tyrel McQueen	Chemistry, Johns Hopkins University
Cindy Regal	Physics, University of Colorado Boulder

2015 Cottrell Scholars

Timothy Atherton	Physics, Tufts University
Emily Balskus	Chemistry, Harvard University
Jeffery Byers	Chemistry, Boston College
James Cahoon	Chemistry, University of North Carolina at Chapel Hill
Luis Campos	Chemistry, Columbia University
Aaron Esser-Kahn	Chemistry, University of California, Irvine
Kai-Mei Fu	Physics, University of Washington
Jennifer Heemstra	Chemistry, University of Utah
M. Lisa Manning	Physics, Syracuse University
Thomas Markland	Chemistry, Stanford University
Jill Millstone	Chemistry, University of Pittsburgh
Stefan Stoll	Chemistry, University of Washington
Eric Toberer	Physics, Colorado School of Mines

Presentations by Cottrell Scholars Collaborative Teams

Cottrell Scholars Collaborative New Faculty Workshop

Andrew Feig, Chemistry, Wayne State University

Mobilizing the Forgotten Army: Equipping TAs with Inquiry-Based Instruction Methods

Marilyne Stains, Chemistry, University of Nebraska, Lincoln

Assessing Innovations in Science Education

Lynmarie Posey, Chemistry, Michigan State University

Academic Leadership Training

Rigoberto Hernandez, Chemistry, Georgia Institute of Technology

Peter Dorhout, Dean, College of Science, Kansas State 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 on July 24, 2015.

→ Awards will be announced within a month of submission.

Conference Evaluation Survey

An online conference survey will be available on Friday, July 10, 2015. To access and complete the survey, please go to: http://www.surveymonkey.com/s/2015CSconferencesurvey

2015 Cottrell Scholars

Timothy J. Atherton

Department of Physics and Astronomy, Tufts University

Predicting the Stability of Pickering Emulsions through Computer Simulations

Emulsions are mixtures of immiscible fluids, one of which is dispersed as droplets throughout the second. In a Pickering emulsion, the mixture is stabilized by the presence of colloidal particles adsorbed on the fluid interface; these include many materials important to society such as crude oil and food products. The scientific objective of this proposal is to use computer simulations to identify the most significant physical factors affecting the stability of Pickering emulsions. In some applications, such as foods, stability is desirable, in others, such as separating water from crude oil to prevent corrosion of refining apparatus, a lack of stability would be useful. An understanding how the constituents affect the stability help to characterize, troubleshoot, and optimize very complex commercial materials and industrial processes that exploit these effects but presently lack a rational design basis.

Computation is of key importance to physics disciplinary practice for simulations, visualization and fitting complex models as well as a powerful pedagogical tool. Despite the increasing use of these methods in research, computation is rarely integrated into the undergraduate curriculum. The educational objective of this proposal is therefore to create an integrated approach to undergraduate computational physics education at Tufts through: 1) a new project-based Computational Physics course, 2) integration of computation into Introductory Electromagnetism classes and 3) by providing research experiences for a larger number of undergraduates by establishing a mentoring community.

Gary A. Baker

Department of Chemistry, University of Missouri-Columbia

Tailoring Bacterial Cellulose Ionogels for Diverse Chemical Tasks

We propose an entirely new class of highly tunable advanced functional materials called “bacterial cellulose ionogels” that marry the chemical versatility of ionic liquids with the superlative mechanical properties and sorbent nature of bacterial cellulose. The facility of incorporating virtually any desired ionic liquid phase within a transparent, flexible, and porous host membrane opens up a wealth of potential for solving diverse functional tasks including applications in chemical separation and extraction, drug delivery, oil cleanup, and incorporation as an electrolyte layer within devices (*e.g.,* batteries, fuel cells, electrochromic windows). Initial studies suggest that entrapment within bacterial cellulose results in fundamental and unanticipated improvements in the stability, phase behavior, transport, and dynamics of the ionic liquid phase. The proposed research effort builds upon highly promising preliminary results showing the clear potential of these ionogels in gas separations and optical sensing and seeks to understand how the dynamics, accessibility, transport behavior, and local microenvironment are impacted by confinement of the ionic liquid within this emergent family of soft materials. The educational component of this submission offers a forward-looking response to the “pipeline problem” in STEM education, proposing a holistic solution to bridging this gap by encouraging the entry and retention of greater numbers of underrepresented students in science. This program integrates curricular reform (flip classroom), focused recruiting of disadvantaged and first-generation groups, an expansion of our current Women in Training for Science (WITS) mentoring program, extensive undergraduate training, and promotion of a scientifically literate public via a non-technical lecture series “Food for Thought.”

2015 Cottrell Scholars Continued

Emily P. Balskus
Department of Chemistry and Chemical Biology, Harvard University

Chemically Guided Enzyme Discovery: An Approach to Identifying New Biological Reactions and a Tool for Inspiring Future Scientists

Microorganisms, Earth's most abundant form of life, perform chemical reactions that are unprecedented in organic synthesis. The recent revolution in DNA sequencing represents both an enormous opportunity for chemical discovery as well as a challenge: with nearly unlimited access to genome sequencing data, how do we rapidly link DNA sequences to important biochemical functions? This proposal's research plan describes a novel chemically guided approach to discover new enzymatic chemistry in microbial genomes. Initial application of this strategy has focused on understanding the intriguing C–C bond-forming reactions involved in the biosynthesis of the cyclindrocyclophanes, a family of dimeric, paracyclophane-containing natural products. Discovering new C–C bond forming enzymes will not only enhance knowledge of natural product biosynthesis, but also provide new tools for use in biocatalysis and synthetic biology.

As part of a broader program aimed at fostering and sustaining a passion for science in a diverse student population through teaching, research, and outreach, this proposal's education plan details the creation of a new freshman laboratory course entitled "Discovering Chemistry From the Human Microbiota." Students will work with members of my lab to screen a metagenomic library constructed from gut microbial DNA for new genes that give rise to biochemical functions related to the microbiota's impact on human health (*e.g.*, food and drug metabolism). This course is designed to promote careers in science by introducing first-year undergraduates to the thrill of research at a critical time in their academic training.

Jeffery A. Byers
Department of Chemistry, Boston College

Redox Switchable Iron Catalysts for the Synthesis of Biodegradable Polymers

Iron catalysts bearing bis(imino)pyridine ligands will be developed for the synthesis of new or underdeveloped biodegradable polymers. The functional group tolerance and redox switching capabilities of the new catalysts will be utilized to polymerize morpholine-2,6-diones and for the ternary copolymerization reactions between lactide, carbon dioxide, and epoxides. The successful synthesis of these polymers are expected to result in new biodegradable polymers with improved mechanical properties. Additionally, application of a redox switch to control polymerization reactions has little precedent, and its successful implementation here will serve as one of the first examples of this new polymerization strategy.

To complement the scientific proposal, an educational plan is proposed to improve curriculum in undergraduate courses. New software for electronic tablets will be developed to aid students with spatial recognition skills. New demonstrations and "clicker" questions will be developed that incorporate discrepant events as a primary teaching tool. These teaching aids will be introduced into introductory organic and inorganic courses to encourage active learning without compromising the dissemination of information. Finally, a unique undergraduate-led outreach program is designed to encourage high school students to pursue careers in science.

James F. Cahoon
Department of Chemistry, University of North Carolina at Chapel Hill

Designing Photocathode Materials for Solar Fuel Photoelectrosynthesis: From the Lab to the Classroom

Solar fuel devices are a potential solution to growing worldwide energy consumption. The devices directly couple a renewable energy source, sunlight, with long-term energy storage in the form of chemical bonds. Dye-sensitized solar fuel devices are a low-cost option that use molecules for absorption and catalysis and semiconductors for surface area and charge carrier transport. These devices require a photoanode/photocathode pair to operate. However, high-performance photocathode materials have yet to be developed. Here, we describe a plan to synthesize and evaluate new types of photocathodes using three key strategies: (1) rational design of nanomaterial morphology to simultaneously enable high surface area and efficient carrier transport, *e.g.,* with quasi two-dimensional platelets; (2) development of unexplored materials such as spinel Co_2MO_4 (M = Ni; Zn); and (3) creation of core/shell structures composed of two materials that enable charge carrier separation at the semiconductor surface. These photocathode systems will be integrated into solar fuel devices for evaluation.

Complementary to these efforts, we will develop the technical knowledge for 3D printing of crystals and molecules using open-access 3D printers at UNC-Chapel Hill. The technology to print accurate representations of complex extended crystals is readily accessible but has yet to be applied as a general tool for undergraduate instruction. Through web tutorials and workshops demonstrating 3D printing, we will disseminate this capability throughout the undergraduate curriculum. In addition, we will develop problem-set modules and work with instructors to build sets of 3D crystals and molecules that can be used for in-class instruction.

Luis M. Campos
Department of Chemistry, Columbia University

Development of Polymers for Next-Generation Singlet Fission Solar Cells

Developing materials for next-generation solar cells have the potential to revolutionize the renewable energy landscape, reducing the cost of power generation with highly efficient devices. The third generation is based on materials that take advantage of non-conventional photophysical processes, such as multiexciton generation (MEG) where one photon can yield multiple excitons. The ability to advance our understanding of MEG in organic materials has been dwarfed by the limited number of materials capable of singlet fission. A particular challenge is the development of materials that undergo efficient intramolecular fission, such that local order and strong nearest neighbor coupling is no longer a design constraint. Here it is proposed to address these challenges by demonstrating and studying the mechanistic features of a new materials design of organic materials capable of intramolecular singlet fission (iSF), where one photon can form two triplet states within each polymer in remarkably high yields.

Lectures are failing our students. This transmittal model whereby a professor talks while students listen is an ineffective method of developing conceptual knowledge. The situation is particularly troubling in undergraduate Organic Chemistry courses, where comparatively little is being done to assess or improve teaching. Thus, to both provoke and guide change, an Organic Concept Inventory (OCI) is proposed—an Organic Chemistry analog of the highly successful Force Concept Inventory (FCI) developed in the 1990's. The OCI will be coupled with other process-oriented, guided-inquiry learning (POGIL) strategies. The successful active-learning activities will be implemented in core chemistry classes at Columbia.

2015 Cottrell Scholars Continued

Aaron P. Esser-Kahn
Department of Chemistry, University of California, Irvine

Activation of the Innate Immune System with Light: A Chemical Biology Approach to Improving Vaccination

We want to make better vaccines by understanding how immune signaling works. To do this, we develop light-activated small molecules to probe innate immune signaling. Every day, our innate immune system protects us. It decides if more than a hundred billion molecular entities are self or not self. To decide, single cells must weigh and examine unique chemical signals processed by more than 20 different receptors. These receptors interact and "synergize." However, these synergies are not understood at a cellular level. Immune synergies represent a new molecular code, one with little genetic or pre-existing physical basis. To understand how this molecular code functions within a cell, we will design photo-activated agonists of two receptors—Toll-Like Receptors (TLRs) - that synergize in potent vaccines. Our research will address the following goals and answer the following questions: (1) Synthesize photoactivated agonists of TLR7; (2) Synthesize photo-activated agonists of TLR2; (3) Study how TLR2 and TLR7 coordinate at a sub-cellular level to increase activation of innate immune signaling; and (4) Study how location and time affect signaling of Toll-Like receptors through photo-activated signaling.

Our educational component focuses on developing guided inquiry methods for undergraduate learning. These include a hybrid "flipped classroom" for introductory organic chemistry, guiding undergraduate learning through "challenge sets" and finally the "gamification" of chirality. My aim is to create a "selfguided" funnel in undergraduate education. We start with sophomore level education making learning "addictive" through game play, making classroom learning engaging through flipped classrooms. We then move students to guided inquiry in senior-level classes with "challenge sets"—open-ended questions for resistance training of idea generation.

Kai-Mei C. Fu
Department of Physics, University of Washington

Zinc Oxide Impurity-Bound Electrons for Optics-Based Quantum Information

Despite theoretical promise for quantum information applications, the quantum properties of single electrons bound to donor atoms in zinc oxide (ZnO) have not been experimentally determined. This proposal aims to optically isolate and study ZnO donor-bound electrons in high-purity nanowires. The high spectral quality of the nanowires will facilitate all optical probing of the fundamental electron properties with the aim of determining the electron quantum information memory time. If successful, this material system could significantly outperform all current quantum bit candidates for photon-mediated quantum information platforms.

Targeted teaching strategies with potential long-term impact to the UW physics curriculum are proposed. The use of peer and self-evaluations, administrated online, will be evaluated in large, introductory classes to motivate and facilitate practice of long-answer physics problems. A laboratory class which formally introduces the use of computers for control, acquisition, and analysis will be upgraded to include experiments that probe the quantum world. Finally, advanced undergraduates will have the opportunity conduct independent research in the PI's own teaching laboratory in a supportive learning environment.

2015 Cottrell Scholars Continued

Catherine L. Grimes
Department of Chemistry and Biochemistry, University of Delaware

Remodeling Bacterial Cell Walls and Biochemistry Laboratory Curriculum

I am passionate about bacterial cell walls. As a graduate student, I designed and studied antibiotics to target the destruction of this material. Now, my laboratory is interested in understanding how organisms sense and respond to this polymer at the molecular level. Our lab uses techniques from synthetic organic chemistry, molecular biology, immunology, biochemistry and microbiology to probe this important signaling pathway. In order for a cell to efficiently process and sense the bacterial cell wall, we hypothesize that four events must take place: (1) degradation of the bacterial cell wall to form immune responsive fragments; (2) delivery of the fragments to the proper cellular compartment; (3) fragments engagement by a cellular receptor; and (4) relay of the bacterial molecular signal by the cell to generate response.

This proposal is designed to learn how to manipulate the bacteria's cell wall biosynthetic pathway to install bio-orthogonal probes and then use these probes to determine how the human innate immune system breaks down this polymer to generate an immune response. In addition to remodeling bacterial cell walls, I will also remodel the sophomore organic, biochemistry and nursing laboratories to infuse my passion for bioorganic chemistry. My approach will modernize the curriculum by developing collaborative techniques from organic chemistry, biochemistry and molecular biology. I have shown that my excitement for my research is able to inspire both undergraduate and graduate students; as part of this proposal I plan to share my enthusiasm for science, forging networks among a diverse group of students.

Jennifer M. Heemstra
Department of Chemistry, University of Utah

Fluorescent Biomolecular Labeling to Image RNA Localization and Promote Independent Learning

Covalent labeling of biomolecules with small-molecule fluorophores is a powerful technique to interrogate function both in vitro and in living cells. The proposed activities are aimed at developing new labeling approaches to study cellular RNA localization and utilizing biomolecular labeling reactions as a platform for a cohort-based research experience.

mRNA labeling using self-alkylating ribozymes. Asymmetrical localization and specific protein binding patterns of mRNA play key roles in many cellular processes, creating a need for methods to fluorescently label and visualize specific RNAs in living cells. A number of elegant approaches have been reported, but still suffer from challenges including high background fluorescence and the propensity to disrupt native RNA structure or function. We propose a novel approach to RNA labeling in which a ribozyme is fused to an RNA of interest and catalyzes self-labeling with a reactive small-molecule fluorophore.

Cohort-based research experience in chemical biology. My overarching educational goal is to equip students with the critical thinking and independent learning skills they will need to successfully approach their future careers. The centerpiece of my proposal is a new Advanced Chemical Biology Lab course in which students carry out systematic investigations of reaction kinetics for the labeling of DNA and proteins using strain-promoted azide-alkyne cycloaddition. Beyond the development of this specific course, I am broadly involved in promoting interdisciplinary education and new pedagogical approaches at the University of Utah.

Together, these activities are anticipated to advance fundamental research in chemical biology and promote retention and learning outcomes for undergraduate science students.

2015 Cottrell Scholars Continued

M. Lisa Manning
Department of Physics, Syracuse University

Using Single-Cell Mechanical Properties to Predict Pattern Formation and Mechanical Response in Biological Tissues

For important biological functions such as wound healing, embryonic development, and cancer tumorogenesis, cells must initially rearrange and move over relatively large distances, like a liquid. Subsequently, these tissues must undergo buckling and support shear stresses, like a solid. Our recent work suggests that biological tissues can accommodate these disparate requirements because the tissues are close to glass or jamming transition, meaning that small changes to single-cell parameters can greatly alter the mechanical response of the tissue. I will develop a theoretical framework that describes the exact nature of this transition as well as how it depends on single-cell properties, potentially identifying new biomolecular targets for healing tissues or preventing disease. I will study the competition between this glassy kinematic arrest and tissue surface tension in cancer cell aggregates, probing how cancer tissue boundaries are mechanically regulated. I will also study how cell activity and cell polarization (identified by Golgi body orientation relative to the nucleus) influences the dynamic response of dense cell aggregates.

My complementary educational proposal will increase diversity and retention in large introductory undergraduate physics courses by targeting some common barriers to persistence and diversity in STEM education, specifically: lack of core math skills and lack of student engagement in large gatekeeper classes. I will develop an online math assessment and tutorial targeted specifically to problems in introductory physics courses, biophysics modules that relate cutting-edge research to topics from introductory physics, and improve graduate assistant and learning assistant training via a newly developed course.

Thomas E. Markland
Department of Chemistry, Stanford University

Unraveling Quantum Fluctuations in Charge and Energy Transport

The research component of this proposal will develop approaches to efficiently include nuclear quantum effects in simulations of condensed phase systems. These methods will be applied to address scientific questions regarding the quantum nature of light particles, and how this changes their behavior in systems ranging from enzyme catalysis, atmospheric isotope separation, and proton transfer at catalytic interfaces.

The educational component of this proposal will extend our existing success of utilizing molecular visualization and simulation in undergraduate and graduate teaching at Stanford, including their further development and extension to freshman courses. The approach will center on the development of flexible MATLAB-based simulation learning tools that can be used at all levels ranging from freshman to senior. This will allow students to benefit from visualizing molecular structure and dynamics early in their undergraduate experience in chemistry, and allow students who are enthused to delve deeper into the underlying science.

Jill E. Millstone
Department of Chemistry, University of Pittsburgh

Using Metal-Ligand Chemistry to Understand, Form, and Tailor Nanoscale Alloys

Throughout history, alloys have been some of the most transformative and most thoroughly studied materials, and scientific descriptions of bulk alloy formation are now well-established. Yet these rules break down when the dimensions of the material are reduced to the nanoscale. This disconnect may be attributed to two primary factors: surface energy and solid-state atom diffusion which are negligible factors in the bulk, but become crucial for materials with large surface-to-volume atom ratios. Indeed, a large body of theoretical and surface science research has shown that energetics at metal surfaces dictate their formation, structure, and catalytic behavior. We have demonstrated that these energetics, at least in part, translate to the behavior of alloyed nanoparticles, and that the chemistry of a particle ligand shell is a powerful way to generate previously inaccessible nanoscale alloyed materials with unique, composition tunable physical properties such as magnetic susceptibility and photoluminescence.

This realization has far-reaching impacts, including overcoming barriers to alloy formation at the nanoscale as well as forming alloys that have never been observed at any length scale. By generating alloys at new lengths scales and new alloys for any length scale, we generate a potentially crucial library of materials for the next generation of technological innovation. The foundation of these innovations is elucidating fundamental principles that govern nanoparticle formation. Our overarching objective is to establish the use and versatility of metal-ligand chemistry to control nanoparticle composition and elucidate this process using a unique combination of molecular and materials characterization techniques.

The overarching goal of the educational plan is to develop materials chemistry curriculum resources that can be used in a variety of undergraduate settings including full materials chemistry courses, as well as supplements in existing courses. All curricula will have two key components: a fundamental scientific concept to be taught and a connection to broader technology challenges. An example of this type of curriculum module is based on creation or editing of Wikipedia pages.

2015 Cottrell Scholars Continued

Stefan Stoll
Department of Chemistry, University of Washington

Quantifying the Conformational Landscape of Maltose Binding Protein

The proposed research plan aims at developing and benchmarking accurate biostructural methods for quantifying protein conformational distributions and change. Conformational change accompanies and drives enzyme catalysis, signal transduction and transport. Elucidating these conformational changes is therefore crucial for our understanding of the chemistry of life processes. We will use maltose binding protein (MBP) as a model to develop and validate accurate methods for conformational quantification based on double electron-electron resonance (DEER) spectroscopy. Our first aim is to use a series of different spin labels to determine the underlying protein conformational distributions. Our second aim is to map the conformational transition and equilibrium upon substrate binding by measuring distance distributions at various substrate loading ratios. The results of this project will produce methods and insight that can be used for the conformational studies in more complex protein systems.

The educational proposal aims to design and produce a full series of micro lecture videos, a set of tutorial videos, and an online open-access textbook for undergraduate Physical Chemistry and integrate it into the course series at the University of Washington. The goal is to enhance student engagement and increase learning outcomes through the digital media. The project's success will be assessed using online analytics, exam performance and student surveys. All materials will be publicly available, and the methodology will be disseminated.

Eric S. Toberer
Department of Chemistry, Colorado School of Mines

Embracing Asymmetry – Designing Materials for Thermoelectric Power Conversion

We have previously shown that asymmetry in the electronic band structure can yield significant improvements in thermoelectric performance. Similar enhancements have been predicted, but not realized, for the engineering of charge carrier scattering. Creating high *asymmetry* in the energy dependent scattering tensor can dramatically enhance the Seebeck coefficient. Here, we propose to develop approaches to scattering engineering for ultimately incorporation with our on-going NSF thermoelectric project. Single crystals of SnSe and related alloys will serve as a model system to test a new algorithm for scattering engineering; this code will efficiently handle chemically complex systems. Spectroscopic and transport measurements will be used to validate this code. These efforts will dramatically increase the predictive power of high throughput searches, enable data mining of scattering phenomena, and yield disruptive thermoelectric materials.

Over the last two years, I have pioneered active-learning approaches in upper division solid state physics. These efforts have led to a largely flipped curriculum, where short screencasts provide much of the course content and in-class time is devoted to discussion of the concepts and activities. These efforts have led to presentations to the CSM faculty and AAPT, improved student course feedback, and an international screencast audience (>40,000 views). Moving forward, we will continue to expand this project, focusing on (i) developing and disseminating active-learning activities and out-of-class content; (ii) working with ComPADRE to seed a community of solid state physics educators; and (iii) developing the first concept inventory and associated assessment strategies for solid state physics.

Cottrell Scholars from Primarily Undergraduate Institutions

In 2015, 51 outstanding teacher-scholars from primarily undergraduate institutions were named Cottrell Scholars. All of them are former recipients of Cottrell College Science Awards and have received additional national recognition from federal and private foundations and/or professional organizations.

Mario Affatigato CS 1996
Physics, Coe College

Katherine Aidala CS 2009
Physics, Mount Holyoke College

Karin Akerfeldt CS 1995
Chemistry, Haverford College

Rae Anderson CS 2010
Physics, University of San Diego

Lauren Benz CS 2011
Chemistry, University of San Diego

Scott Brewer CS 2007
Chemistry, Franklin and Marshall College

Michael Brown CS 1995
Physics, Swarthmore College

Mark Bussell CS 1994
Chemistry, Western Washington University

Bert Chandler CS 2001
Chemistry, Trinity University

Tim Clark CS 2007
Chemistry, University of San Diego

Myriam Cotten CS 2004
Chemistry, Hamilton College

Sean Decatur CS 1996
President, Kenyon College

Julio de Paula CS 1994
Chemistry, Lewis and Clark College

Kelling Donald CS 2008
Chemistry, University of Richmond

Jonathan Friedman CS 2002
Physics, Amherst College

Amelia Fuller CS 2010
Chemistry, Santa Clara University

John Gilbertson CS 2009
Chemistry, Western Washington University

Jason Gilmore CS 2006
Chemistry, Hope College

Rainer Grobe CS 1996
Physics, Illinois State

David Hall CS 2001
Physics, Amherst College

Michelle Hamm CS 2002
Chemistry, University of Richmond

David Hanneke CS 2012
Physics, Amherst College

Robert Hinkle CS 1998
Chemistry, College of William and Mary

Peter Iovine CS 2004
Chemistry, University of San Diego

Jeff Johnson CS 2008
Chemistry, Hope College

Jeff Katz CS 2004
Chemistry, Colby College

Istvan Kiss CS 2008
Chemistry, Saint Louis University

Moses Lee CS 1994
M.J. Murdock Trust (formerly at Hope College)

Janelle Leger CS 2009
Physics, Western Washington University

Hai Lin CS 2006
Chemistry, University of Colorado, Denver

Andrea Lommen CS 2005
Astronomy, Franklin and Marshall College

Casey Londergan CS 2008
Chemistry, Haverford College

Peter Love CS 2007
Physics, Haverford College

Gina MacDonald CS 1997
Chemistry, James Madison University

Manish Mehta CS 1999
Chemistry, Oberlin College

Ken Mills CS 2003
Chemistry, College of Holy Cross

Reshmi Mukherjee CS 1998
Astronomy, Barnard College

Greg O'Neil CS 2008
Chemistry, Western Washington University

David Patrick CS 1997
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Kate Plass CS 2008
Chemistry, Franklin and Marshall College

John Poutsma CS 2002
Chemistry, College of William and Mary

Alex Punnoose CS 2003
Physics, Boise State University

Kate Queeney CS 2003
Chemistry, Smith College

Lea Santos CS 2009
Physics, Yeshiva University

George Shields CS 1994
Chemistry, Bucknell University

Josh Smith CS 2010
Physics, California State University, Fullerton

Tom Solomon CS 1995
Physics, Bucknell University

Eileen Spain CS 1995
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