The 20th Annual
Cottrell Scholar Conference

July 9-11, 2014

Westin La Paloma Resort
3800 East Sunrise Drive
Tucson, Arizona 85718

Leading Change

Engaging Your Students, Your Colleagues and the Public to Transform STEM Education

RESEARCH CORPORATION *for* SCIENCE ADVANCEMENT
A foundation dedicated to science since 1912.

COTTRELL SCHOLARS COLLABORATIVE
Integrating Discovery and Education to Advance Science

2014 Conference Planning Committee

Andrew Feig, Chair
Department of Chemistry
Wayne State University

Seth Cohen
Department of Chemistry and Biochemistry
University of California, San Diego

Karen Bjorkman
Department of Physics and Astronomy
University of Toledo

Penny Beuning
Department of Chemistry and Chemical Biology
Northeastern University

Adam Leibovich
Department of Physics
University of Pittsburgh

Sarah Reisman
Department of Chemistry and Chemical Engineering
California Institute of Technology

Silvia Ronco
Program Director
Research Corporation for Science Advancement

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FROM THE PRESIDENT

Welcome to the 20th Annual Cottrell Scholar Conference. Your presence here for the next two-and-a half days evinces a laudable commitment to high-quality, effective undergraduate teaching at your research universities. Short of coming up with the next great disruptive discovery in the physical sciences, there is no more powerful and long-lasting accomplishment in American academic science than encouraging and nurturing the next generation of researchers.

Throughout my academic career as experimental physicist, department chair, vice provost for research and university president, I have held the Cottrell Scholars program in high esteem. For two decades now, Scholars across America have been working tirelessly and wisely to promote great teaching in their departments. Not only have these efforts paid immense dividends for individual students and directly contributed incalculable value to our nation’s scientific enterprise, lately they have been paying off on the administrative level: Currently scholars are having a direct impact on the Association of American Universities’ efforts to improve undergraduate science education among its 60 US member institutions. Your colleagues are also spreading the word about quality teaching in the recently launched New Faculty Workshop organized by members of the Cottrell Scholars Collaborative and sponsored by ACS and RCSA.

These efforts are vitally important because the global lead in science and technology the United States has enjoyed for the past 60 years is rapidly diminishing; other nations are making great strides improving their scientific infrastructures. Meanwhile, the collective values as well as the practical, department-by-department educational accomplishments of Cottrell Scholars are doing much to ensure that American universities remain first among the world’s rapidly growing number of equals in research and science education.

RCSA is delighted and proud to be associated with teacher-scholars who are changing the world for the better; this conference is designed to help you facilitate that change. It is my wish, and the wish of RCSA program directors Silvia Ronco and Richard Wiener, that you will take some time between keynote speeches and dialog sessions to provide us with suggestions about how to improve our service to you and to the great cause of science advancement in America.

Also, for those of you attending your first CS conference, please familiarize yourselves with the independent Cottrell Scholars Collaborative, its goals and objectives. This is your organization, after all, and one we believe has immense potential to champion innovation and maintain best practices in university science instruction.

Ultimately, the purpose of the Collaborative, as well as the CS conferences generally, is to encourage the development of a vibrant national community of great researchers who are also passionate about teaching. To that end, I encourage all of you to take full advantage of your time here by making a sincere effort to get to know one another, both professionally and personally. By doing so you will be empowering yourselves, and those who come later, to create and maintain the scientific and educational excellence our nation requires for the future.

Robert N. Shelton
President/CEO
Research Corporation for Science Advancement

FROM THE PROGRAM CHAIRS

Welcome to the 2014 Cottrell Scholar Conference! This is a very special event – the 20th anniversary of the Cottrell Scholar program; we are honored to have several members of the first class of scholars attending this year.

We also have an impressive array of keynote speakers, early career faculty, post-tenured faculty, foundation officers and professional representatives. This diversity of participants is the heart and soul of the 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.

An additional goal of the conference, of course, is to welcome the new class of Cottrell Scholars (2014) and introduce them to the increasingly notable activities of the CS Collaborative. In this task of getting acquainted we all have an equally vital part – so don't be shy!

It is our belief that if our work is to have long-lasting impact, we must seek steady 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. To change the public perception of science, educators must reach out to the general public in a way that makes science appreciated for the immense value that it brings to society.

All of this requires engagement, the theme of this year's conference.

We see engagement as a powerful tool Scholars wield, both individually and collectively, in the process of community building as well as in the constant renewal required of the very best teacher-scholars in a highly competitive world.

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!

Andrew Feig
Professor of Chemistry
Wayne State University

Silvia Ronco
Program Director
RCSA

CONFERENCE OBJECTIVES

To empower scholars to lead change within and outside their institutions, participants will:

- Share successful activities and approaches for engaging with students, colleagues 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 become involved in educational projects of national impact.
- Identify tactics that enable collective action.
- Engage in collaborative work that will continue throughout the year.

AGENDA

2014 COTTRELL SCHOLAR CONFERENCE PROGRAM

Leading Change: Engaging Your Students, Your Colleagues

and the Public to Transform STEM Education

Westin La Paloma

July 9-11, 2014

WEDNESDAY, JULY 9

2:00 – 6:00 pm	Registration	Retail Lobby
3:30 – 4:30 pm	Opening Reception	Murphey Patio
4:30 – 6:00 pm	Welcome and Introductions	Murphey
	Conference Goals	
	Robert Shelton, Silvia Ronco, Andrew Feig	
6:00 – 7:30 pm	Cottrell Scholar Collaborative Presentations	Murphey
7:30 – 9:30 pm	Dinner	Sonoran I
	Keynote Lecture: Mats Selen *“You Can’t Finish If You Don’t Start”*	
	Cottrell Scholar Trophy Ceremony	

THURSDAY, JULY 10

7:00 am	Registration	Murphey Lobby
7:30 – 8:30 am	Breakfast	Murphey Patio
8:30 – 10:00 am	Presentations by 2014 Cottrell Scholars	Murphey
10:00 – 10:30 am	AM Break	Murphey Patio
10:30 – 12:00 pm	Keynote Lecture: Cathy Middlecamp *"Learning Science by Making Connections: Energy, Food and Trash"*	Murphey
	Discussion / Q&A	
12:00 – 1:30 pm	Lunch	Sonoran I
1:30 – 3:00 pm	Breakout Session 1: Engaging the Public	Finger Rock I, II, III, & Primrose
	Regroup and Discuss	Murphey
3:00 – 3:30 pm	PM Break	Murphey Patio
3:30 – 5:00 pm	Breakout Session 2: Engaging Your Students	Finger Rock I, II, III, & Primrose
	Regroup and Discuss	Murphey
5:00 – 6:00 pm	Free Time	
6:00 – 7:30 pm	Reception and Poster Session	Sonoran
7:30 – 9:30 pm	Dinner	Sonoran

FRIDAY, JULY 11

7:00 – 8:00 am	Breakfast	Murphey Patio
8:15 – 10:00 am	Presentations by 2014 Cottrell Scholars	Finger Rock
10:00 – 10:30 am	AM Break	Murphey Patio
10:30 – 12:00 pm	Breakout Session 3: Engaging Your Colleagues	Aster I, II, Lantana & Primrose
	Regroup and Discuss	Finger Rock
12:00 – 1:30 pm	Lunch	Sonoran I
1:30 – 3:00 pm	Keynote Lecture: Robert Shelton *“Faculty Influence Academic Priorities”*	Finger Rock
	Discussion / Q&A	
3:00 – 3:30 pm	PM Break	Murphey Patio
3:30 – 5:00 pm	Breakout Session 4: Engaging with the Cottrell Scholar Collaborative	Aster I, II, Lantana & Primrose
	Regroup and Discuss	Finger Rock
5:00 – 5:15 pm	Conference Survey	Finger Rock
5:15 – 6:30pm	Free Time	
6:30 – 7:30 pm	Reception	Terrace Level Foyer
7:30 – 9:30 pm	Banquet and Entertainment (Participants and Guests)	Terrace Level Patio

CONFERENCE KEYNOTE SPEAKERS

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

"You Can't Finish If You Don't Start"

In this brief presentation I will describe some really cool projects happening at the University of Illinois Department of Physics: The Physics Van shows the fun of science to elementary school kids; Physics 123 is a hands-on physics course for elementary education students; smartPhysics is a tool used to flip intro physics classes all over North America, and OLab is a gadget that could change the way we approach hands-on activities in these courses as well as fostering communities of citizen scientists. All of these projects have as their focus the engagement of people with each other and with science. The mere existence of each one is, in hindsight, incredibly serendipitous, and they have all evolved in ways that we could never have anticipated in advance.

Mats Selen, a 1996 Cottrell Scholar, earned B.S. ('82) and M.S.('83) degrees in physics at the University of Guelph, and M.A.('85) and Ph.D.('89) degrees in particle physics at Princeton University. After a four year postdoc at the Cornell Electron Storage Ring, he joined the faculty at the University of Illinois in 1993, where he has been ever since. After 25 years of studying elementary particles, Mats is shifting his research focus to understanding and improving the way students learn physics. With Illinois colleagues he developed the i-clicker classroom response system, the smart-Physics learning framework, and most recently IOLabs. On Wednesday mornings he brings science to central Illinois viewers as the WCIA "WhysGuy." In 2013, Mats and his colleagues Gary Gladding and Tim Stelzer received the American Physical Society Excellence in Education Award, in recognition of their sustained commitment to excellence in physics education. Mats Selen became a fellow of the American Physical Society in 2006.

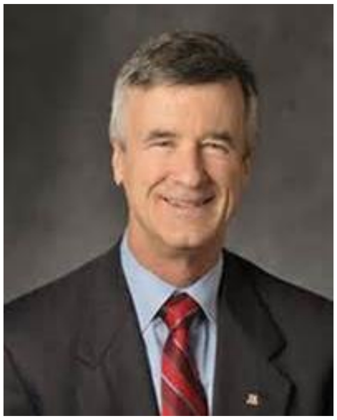
Cathy Middlecamp, Professor, Chemistry Department, University of Wisconsin, Madison

"Learning Science by Making Connections: Energy, Food and Trash"

We and our students need to "connect the dots" not only in the sub-microscopic world but also in the larger world in which we live. Just as our students experience difficulty in imagining atoms, nuclei, electrons and the forces that govern these, they may have trouble imagining how real-world events connect across time and space. For example, consider the connection between turning on a light switch and the natural gas or coal that is burned at an electric utility plant. Or consider the connection between a plastic beverage bottle and what happens after it is discarded. "Connecting the dots" is a high level thinking skill, utilizing both powers of the intellect and powers of the imagination. By making connections, we and our students can learn to better "see" the principles of science at work in many places in our local, regional, and global communities. If we and our students understand the connections, the stage is set for transforming the way we think and learn, possibly even seeing the consequences of our actions and inactions.

Cathy Middlecamp is a professor in the Nelson Institute for Environmental Studies at the University of Wisconsin-Madison. Her scholarship lies at the intersection of science, people, and the planet; she holds joint appointments in the Integrated Liberal Studies Program and the Chemistry Department. Cathy's teaching responsibilities include Environmental Studies 126, a foundational course in the new campus-wide sustainability certificate program. In addition, she is the editor-in-chief for the 7th and 8th editions of the ACS-sponsored *"Chemistry in Context,"* a 25-year national curriculum project that engages undergraduates in learning chemistry in the context of real-world issues. Cathy graduated Phi Beta Kappa from Cornell University in 1972. She was awarded a Danforth Fellowship and earned her doctorate in chemistry from the University of Wisconsin-Madison in 1976. She also has an M.S. in counseling from the School of Education and is a Fellow of the Association for Women in Science (2003), AAAS (2004), and the American Chemical Society (2009).

Robert Shelton, President, Research Corporation for Science Advancement



"Faculty Influence Academic Priorities"

By their intrinsic nature, successful faculty are highly focused and attracted to new intellectual challenges. From the time they begin their independent research, they are driven by the stimulation of discovery. They are always posing the next question and seeking to extend their knowledge. Their rewards come in the excitement of original discovery, of seeing the world from a new perspective and with insight that had been elusive. They are eager to share this knowledge and to have their new understanding challenged and debated. This intellectual reward among peers stands in stark contrast to the broader challenge presented in influencing department-wide or institution-level academic priorities. These venues are often seen as forbidding with high barriers and little promise of achieving one's goals. Yet, it is precisely at these higher levels of institutional leadership that faculty can, and I would argue <u>must</u> engage. The very same abilities to turn information (from research) into insight (leading to action) that manifest success for faculty in their research world are the characteristics in greatest need in leading our universities. In this presentation, I offer examples of faculty engagement and leadership that yielded significant, practical enhancement of the research climate at universities. Following these examples, I conclude with reference to Research Corporation for Science Advancement and the current need for input from Cottrell Scholars as RCSA sets forth its mission for the decade ahead. Audience participation is required!

Robert Shelton, an experimental condensed matter physicist, has spent much of his career in public education, with interests in research funding, intellectual property, higher education and the interface between research and teaching, the role of universities in economic development, and fostering multi-disciplinary/multi-institutional research. He served as the 19th president of the University of Arizona, from 2006 to 2011. During Shelton's tenure, UA set records for applications, enrollments, fundraising, research expenditures, student diversity and the academic strength of incoming classes. Robert was educated at Stanford University (B.S., 1970) and the University of California, San Diego (M.S., 1973; Ph.D., 1975). He began his academic career at UCSD as an assistant research physicist and moved to Iowa State University in 1978, where he was promoted to associate professor in 1981 and professor in 1984. He returned to California as chair of the Department of Physics at UC Davis in 1987, and in 1990 was named vice chancellor for research. In 1996 he joined the President's Office at the University of California as vice provost for research. Before heading the University of Arizona, Shelton was executive vice chancellor and provost at the University of North Carolina at Chapel Hill for five years.

PRESENTATIONS BY COTTRELL SCHOLARS

Theodor Agapie	Department of Chemistry, California Institute of Technology, CS 2013
Shannon Boettcher	Department of Chemistry, University of Oregon, CS 2014
Andrew Boydston	Department of Chemistry, University of Washington, CS 2014
Rebecca Butcher	Department of Chemistry, University of Florida, CS 2014
Dinah Loerke	Department of Physics, University of Denver, CS 2014
Andriy Nevidomskyy	Department of Physics, Rice University, CS 2014
Jennifer Prescher	Department of Chemistry, University of California, Irvine, CS 2014
Joseph Subotnik	Department of Chemistry, University of Pennsylvania, CS 2014
Xiaodong Xu	Department of Physics, University of Washington, CS 2014

PRESENTATIONS BY COLLABORATIVE AWARD TEAMS

"Effective Practices in Learning and Pedagogy from Cottrell Scholars: A High Impact Text for Educational Leadership in the 21st Century," Penny Beuning (Chemistry, Northeastern University) and Scott Snyder (Chemistry, Scripps Research Institute)

"Cottrell Scholar Collaborative New Faculty Workshop," Andrew Feig (Chemistry, Wayne State University)

"Effective Evaluation of Teaching and Learning (EETL) – Searching for New Approaches to R1 STEM Teaching Evaluation," Adam Leibovich (Physics, University of Pittsburgh)

"Mobilizing the Forgotten Army: Equipping TAs with Inquiry-Based Instruction Methods," Sara Skrabalak (Chemistry, Indiana University Bloomington)

"Cottrell Repository for Effective Science Teaching (CREST)," Geoff Hutchison (Chemistry, University of Pittsburgh) and Michael Hildreth (Physics, University of Notre Dame)

"Cottrell Comic Challenge Project (CCCP): A Pilot Program for Attracting and Developing Graphic Talent for a Novel Outreach Project," Sarbajit Banerjee (Chemistry, University at Buffalo)

COTTRELL SCHOLAR COLLABORATIVE PROPOSAL WRITING RULES

Successful proposals should have the potential to positively impact undergraduate 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.
- 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.
- Two-page proposal submitted within two weeks after the conference ends with a deadline of July 25, 2014.
- Proposal should briefly explain an innovative approach for projects with potential broad impact.
- RCSA panel members will review projects within four weeks of the Conference.

CONFERENCE EVALUATION SURVEY

An online conference survey will be available on Friday, July 11. To access and complete the survey, please go to: http://www.surveymonkey.com/s/2014CSconferencesurvey

Shannon W. Boettcher
Department of Chemistry, University of Oregon, OR

"Materials for Solar Water Splitting: Advancing Undergraduate Research and Controlling Chemistry and Charge Transport at Interfaces"

The research goal is to learn to control the transfer of photo-excited carriers from a semiconducting sunlight-absorber such as Si or GaAs to a heterogeneous electrocatalyst driving water-splitting reactions, while also preventing the oxidation/degradation of the semiconductor absorber. We will accomplish this by synthesizing and studying new chemically-stable inorganic oxide films that incorporate defect levels at precise and tunable energies to selectively mediate either hole or electron-tunneling. We will use electrical/electrochemical measurements coupled with computer simulations to understand the dynamic energetics of the semiconductor-oxide-catalyst interface. This fundamental research will facilitate the design of solar water-splitting cells, which integrate solar-energy conversion with chemical-energy storage in a plausibly low-cost platform, as well as provide new routes to control interfacial charge transfer, separation, and injection in light-emitting diodes, transistors, and solar cells.

The education goal is to develop, implement, and evaluate a scalable team-based framework to integrate freshman/sophomore undergraduates into research. The effort utilizes near-peer mentoring; graduate students and/or senior undergraduates lead teams of freshman/sophomores to address research questions. This allows for undergraduates to participate in research at an earlier stage and increases the numbers that are able to participate. The undergraduates also contribute to integrated high-impact outreach efforts in local schools.

Andrew J. Boydston
Department of Chemistry, University of Washington, WA

"Quantitative Assessment of Flex Activation in Polymer Mechanochemistry"

The proposed research plan aims to develop and evaluate the ability to control bond bending motions as a method of functional group activation in polymer mechanochemistry. Computational and experimental approaches will be used to study the relative contributions of bond stretching and bending motions in the activation of isomeric mechanophores. Mechanophore designs will be guided by computer modeling of the effects of mechanical force by using the CoGEF (Constrained Geometries Simulate External Force) method, and regiochemical influences on mechanochemical transduction will be elucidated through experimental mechanochemistry in solution and solid state. The results of the proposed program are expected to enhance our understanding of how fundamental conformational changes in polymers under load can influence reactivity, and expand the capabilities for designing materials that respond autonomously to physical force.

The objective of the educational plan is to restructure my introductory organic chemistry course to allow for faculty-student time to be devoted to applications of concepts and problem-solving strategies. By moving to a hybrid online/in-class format, introductory topics are introduced via online tools, and built upon during lecture discussions. The live discussions will involve in-depth examples, demonstration of strategies for approaching problems, and discussion of the origins of the concepts; I want to teach students how to think like a chemist, not just draw like one!

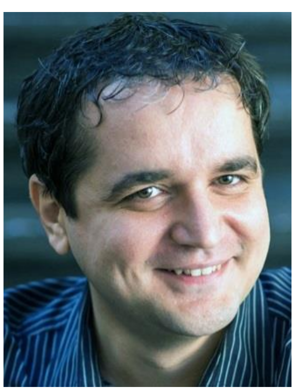
Rebecca A. Butcher
Department of Chemistry, University of Florida, FL

"Chemical Communication in C. elegans and Incorporation of Natural Products Discovery into the Classroom"

The nematode *Caenorhabditis elegans* secretes ascarosides, structurally diverse derivatives of the dideoxysugar ascarylose, as chemical signals to control its development and behavior. At high nematode population densities, specific ascarosides, which are together known as the dauer pheromone, trigger entry into the stress-resistant, dauer larval stage. Specific ascarosides can also influence complex behaviors, such as mating attraction and aggregation. In this proposal, we will use a multi-disciplinary approach, including metabolomics, *in vitro* enzyme assays, chemical synthesis of biosynthetic intermediates, X-ray crystallography, and RNAi-based screens, to investigate the biosynthetic steps that control the production of the dauer pheromone ascarosides. Our preliminary work suggests that *C. elegans* co-opts pathways in primary metabolism for the biosynthesis of ascaroside secondary metabolites and thereby enables pheromone composition to change in response to environmental conditions, such as nutrient availability. As many nematode species, including parasitic ones, modulate their development and/or behavior in response to specific ascarosides, our work will open new avenues for interfering with chemical communication in these species in order to reduce their survival.

The educational objective of this proposal is to develop a laboratory course in natural products discovery that will enable students to participate in real science in a classroom setting.

Mircea Dinca
Department of Chemistry, Massachusetts Institute of Technology, MA



"Teaching Sponges New Tricks: Self-Assembly, Charge Transport, and Electric Conductivity in Microporous Metal-Organic Frameworks"

The research objective of this proposal is to utilize fundamental principles of charge transport in molecular materials to impart electric conductivity to metal-organic frameworks (MOFs). MOFs are crystalline, porous materials synthesized modularly from inorganic and organic building blocks. Known for their extraordinary porosity and internal surface area, which renders them useful particularly for gas storage and separation, MOFs are also notorious insulators. The possibility of increasing the electrical conductivity of these materials would enable a host of new applications including alternative architectures for organic-based photovoltaics, new battery materials, and future platforms for electrocatalysis and potential-swing gas separations. We have shown that by applying fundamental principles of electronic structure and molecular symmetry, we can design and synthesize MOFs with charge mobility values that rival or exceed those of common organic semiconductors.

With the support of the Cottrell Scholar program, we will aim to: (1) Extend the π-stacking and infinite one-dimensional chain charge transport formalisms for creating new MOFs with high charge mobility; (2) Investigate the photoconductive properties in both π-stacked and infinite one-dimensional anisotropic conductive MOFs; (3) Develop single crystal transistor devices – a first demonstration of the utility of conductive MOFs.

The educational plan is aimed at producing short video modules for transitioning the inorganic chemistry curriculum at MIT to an online platform. This will help integrate MIT's curriculum to the MITx platform. At the same time, the curriculum content will be modified to address some of the more modern applications of inorganic chemistry and to integrate it with the newly established Minor degree in Energy Studies at MIT.

Carla Frohlich
Department of Physics, North Carolina State University, NC

"The Origin of the Heaviest Nuclei in the Universe"

The origin of the chemical elements is one of the fundamental questions about our origins and the cosmos around us. In particular, the origin of the elements from iron to uranium is a long-standing puzzle. The most promising process to synthesize these elements is the r-process (rapid neutron-capture process). While we know the conditions required for the r-process to proceed, we do not know the site. That is, we do not know where these conditions occur in nature. In this project, we address the puzzle of the site of the r-process through simulations of element synthesis in neutron-star mergers and accretion disk. The aims of this project are to test in detail the element synthesis in mergers and to prepare for the next generation of numerical simulations.

The educational component of this project tackles the urgent need for effective computational problem solving skills and communication skills among physics graduates. The goal is to prepare the students in all aspects of a science career. The two aims of the project are to (1) develop computational projects for use in upper-level physics classes and (2) to prepare resource modules on effective science communication (writing, posters, and oral presentations).

Dinah Loerke
Department of Physics, University of Denver, CO

"Towards a Mechanistic Understanding of Cell Intercalation in Germ-Band Extension"

It has been a key question in biophysics how we can elucidate a biological mechanism from the observation of spatiotemporal dynamics of proteins at different time and length scales; in particular, we want to know how motion or interaction at the microscopic scale creates a certain macroscopic outcome. This principle is of central importance in embryonic development, which relies on tight regulation of a complex process of local cell interactions to ensure very reproducible outcomes (i.e. it typically produces only minor 'architectural' variations between individuals). My research proposal investigates the question how local asymmetric regulation of cell-cell interaction guides cell intercalation during the initial elongation of the body axis (germ-band extension or GBE). Our working hypothesis is that the driving mechanism for directed cell interface remodeling for germ-band extension in *Drosophila* is not anisotropic *tension* as currently believed, but anisotropic *adhesiveness*.

In my educational proposal, I propose to investigate the relationship between local interaction and system behavior in the 'model system' of player trajectories and player-interaction in ballgames, which provides intuitive research questions and experiential learning experiences for undergraduate students.

Tyrel M. McQueen
Department of Chemistry, Johns Hopkins University, MD

"Superconductivity: From Discovery to Rational Design"

Materials by design in emergent systems is one of the most challenging, but at the same time possibly most transformative endeavors. We seek to develop rational design principles for new and improved superconductors, materials that carry a DC electrical current with zero loss. The springboard to accomplish this is to synthesize and characterize new materials that test the predictive capabilities of two new theories for the origin of high temperature superconductivity.

The educational plan is centered on exposing students of all levels to hands-on experimentation. This includes research in the PI's laboratory and a new integrated lecture and laboratory course, *Chemical Structure and Bonding*, for second semester freshmen. The course is intended to develop students' laboratory skills – particularly the ability to take concepts from 'bookwork' and apply them in the laboratory. The 'lecture' component will move the introduction of concepts and initial 'routine' assessment to 'prelectures,' allowing class time to be better leveraged in understanding the implications of the material. Combined with the existing one semester advanced general chemistry course, the planned course will offer advanced students a coherent year-long sequence in chemical science, encouraging pursuit of science and engineering careers as well as providing a foundation for pre-medical students.

Andriy Nevidomskyy
Department of Physics, Rice University, TX

"Superconductivity in Strange Metals: Some Like It Hot"

This proposal concerns the field of *strongly correlated electron systems*, which has been a major focus of condensed matter physics in the past several decades. Because of strong interactions between electrons, electric current travels differently through such materials, compelling researchers to call them "strange metals," whose nature is not fully understood. Most intriguingly, exotic quantum phases, such as high-temperature superconductivity, can emerge out of the "strange" metallic state. We will investigate theoretically how this emergence occurs using a combination of the state-of-the-art analytical and numerical techniques.

The educational part of this proposal is centered around developing active learning techniques for the upper division undergraduate classes (specifically, Quantum Mechanics), and engaging undergraduate students in research and broad public outreach. The objectives include (a) to help undergraduate students grasp the highly unintuitive aspects of quantum mechanics; (b) to actively involve undergraduates in research in theoretical aspects of magnetism and superconductivity of "strange" metals; (c) to engage undergraduate students in performing digital visualizations of quantum phenomena to be used in Rice University's Masters program for in-service high school teachers and in a full-dome planetarium show aimed at a very broad audience to raise the general public's awareness of the importance of fundamental research.

Jennifer A. Prescher
Department of Chemistry, University of California, Irvine, CA

"Expanding the Bioluminescent Toolbox for Visualizing Metastatic Disease"

Optical imaging technologies have revolutionized our understanding of cancer progression by enabling researchers to "peer" into cells and tissues and visualize biological features in real time. While powerful, current imaging techniques are restricted in their ability to analyze cellular motility and interactions over extended time and length scales—processes crucial to metastatic disease. This application proposes the development of new imaging probes for visualizing tumor spread *in vivo*. We will generate bioluminescent tools that produce light only when two distinct cell types come into close proximity (e.g., when tumor cells infiltrate distant tissues). These tools will enable global surveys of cancer spread and will provide some of the first noninvasive, macroscopic views of metastases in preclinical models.

The UCI Chemistry Department is developing a new major in Chemical Biology to prepare students for modern research and career opportunities at the chemistry-biology interface. I am playing an active role in this endeavor by expanding our introductory chemical biology lecture course. I am also developing cross-disciplinary experiments for the undergraduate laboratories. Lastly, I am launching an innovative seminar series to expose students to career paths for interdisciplinary scientists.

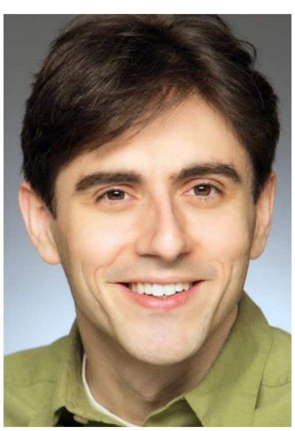
Cindy Regal
Department of Physics, University of Colorado Boulder, CO

"Measuring Micromechanical Motion at Quantum Limits and Identifying Successful Attributes of Undergraduate Research in Large Physics Departments"

In continuously monitoring the position of an object with an interferometer at high precision, one must ultimately confront the effect of quantum backaction. The need to balance the measurement imprecision and backaction results in a limit known as the standard quantum limit (SQL). However, despite many years of theoretical study in quantum optics, an interferometer at the SQL has never been realized. My proposed research will explore micromechanical devices for realizing and surpassing the SQL and hence will prepare us for a rapidly-approaching time when practical detectors will be confronted by the SQL.

This work has been a great way to involve undergraduates in my research. However, large physics departments such as ours at CU face a significant challenge: We struggle to provide an adequate number of undergraduate research experiences (URE). This proposal will study an idea to improve this situation. Aided by the strong Physical Education Research group at CU, I will identify successful attributes of URE project design in physics laboratories like my own. By providing information about features of successful UREs, the hypothesis is that this will make the job of undergraduate research mentoring less challenging and hence expand availability of UREs.

Joseph E. Subotnik
Department of Chemistry, University of Pennsylvania, PA

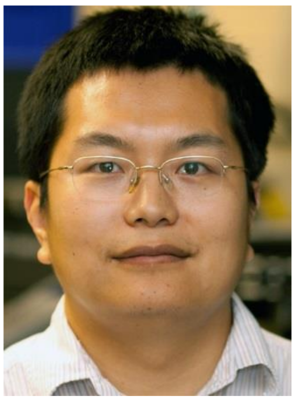


"What Every Undergraduate Should Learn About Electronic Relaxation"

The details of electronic relaxation are messy. After an electron is photo-excited, there are so many avenues for relaxation that an exact calculation is often impractical. As a result, undergraduate physics majors usually avoid the subject entirely and study only atomic emission of photons. Chemistry majors learn that electrons can relax through heat, but the concept is usually vague and never quantitative. The focus of my research program and this grant proposal is to fill in the gaps between these two extreme cases. On the research side, we will employ start-of-the-art techniques from chemical dynamics to model nonadiabatic relaxation through the prism of surface hopping. We will investigate how accurate quasi-classical trajectories can be computed that capture the essence of electronic relaxation and the role of decoherence.

On the education side, we will continue to incorporate computational modeling into the undergraduate curriculum, quickly building up a course on computational chemistry. The latter will introduce students to *ab initio* electronic structure theory, molecular dynamics simulations, and free energy calculations, ending with a discussion of electronic relaxation in time-resolved spectroscopy. We will also continue our collaboration with the MERCURY program with the goal of exposing undergraduates to method development in quantum chemistry.

Xiaodong Xu
Department of Physics, University of Washington, WA



"Valley Quantum Optoelectronics of Monolayer Semiconductors"

The objective of this proposal is to exploit a new class of quantum optoelectronics based on atomically thin transition metal dichalcogenides (TMDs), including MoS_2, $MoSe_2$ and WSe_2. The unique electronic structures of TMDs set them apart from conventional electronic systems and hold promise for new quantum electronics and nano-photonics operating by different principles or employing new degrees of freedom. Monolayer TMDs are the first kind of truly 2D semiconductors, with atoms arranged in a honeycomb lattice like graphene, yet possessing an electronic bandgap in the visible as well as strong spin-orbit coupling. We aim to investigate the fundamental and technical aspects of these 2D systems based on their extraordinary physical properties. Specific projects include: (1) investigation of fundamental physical properties of valley pseudo-spins, such as magnetic moment *m* and valley dynamics; (2) demonstration of the valley and spin Hall effects through both polarization dependent optoelectronic measurements and Kerr rotation spectroscopy; (3) investigation of many-body interaction effects including exciton-exciton, exciton-free carrier, and exchange interactions using ultrafast nonlinear optical spectroscopy and momentum resolved photoluminescence spectroscopy. The obtained physical understanding of 2D materials beyond graphene may push this rapidly growing field for new device technologies and applications.

The education plan focuses on introducing undergraduate experiments that couple nanoscale device physics with novel materials and measurements of interest to current condensed matter research. This will reduce the current gap between lab course content and what's really going on in multidisciplinary advanced research.

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