COLORADO COLLEGE

Department of Chemistry & Biochemistry

FACULTY RESEARCH

The **Department of Chemistry and Biochemistry at Colorado College** has been at the core of the college since its founding in 1874. Originally aligned with mining and metallurgy, it has since swelled to house a full range of chemistry specialties with faculty in analytical, biochemical, environmental, inorganic, organic, computational, materials, and physical chemistry. Research programs within the department range from studying the fate and transport of chemical contamination in groundwater systems, to the development of novel nano-optical sensors, the evaluation of thermodynamic parameters influencing metal binding in proteins, and to the design and development of new antibiotics based on natural product scaffolds. In support of these aims, the department is home to an array of modern instrumentation for undergraduate use and has dedicated laboratory space for collaborative faculty-student research. This booklet is aimed at students interested in conducting research in Chemistry or Biochemistry with intentions of highlighting recent work in the department, the process by which students engage with research (both on campus and off campus), and available projects associated with each faculty member.

Mission: *To enhance our understanding of the chemical sciences and their connections to the modern world through teaching, research, and service.*

Vision: *Students and Faculty join to advance lifelong learning, to stimulate intellectual and ethical growth, and to foster a climate of mutual respect among scientists and non-scientists. We advocate for greater mutual understanding of how the chemical sciences impact the world community, and we strive to make our endeavors a positive force in the resolution of global problems.*

Interested in a Summer Research Position?

Here are the steps for contacting a potential summer research advisor (see also the timeline for contacting below):

1. Draft an email with the following information. *Note that depending on availability, you may consider contacting 2-3 faculty members with research of interest.*
    a. Provide a brief biography including courses relevant to the research project. Be sure to check the 'required courses' listed under the advisor's research summary in this booklet.
    a. Include a description detailing your particular interests in certain project(s). You can list several projects in the order of interest if desired.
    a. Suggest several meeting times to chat more in person. To ensure a meeting, list as many available times as possible in the next couple of weeks. If you don't receive a response within one week, send a follow up email.

Example of an email sent prior to Block 5:

Dear Professor Seaborg,

My name is Allison Smith. I am a second year student with an interest in Chemistry. I have yet to declare my major, as I'm still weighing my options. So far, I have completed CH107, CH108 and CH250. I am enrolled in CH241 and CH251 in blocks 5 and 8 of this year. I plan to take CH275 and CH382 next year. After graduation, I am hoping to either pursue a graduate degree in Nuclear Chemistry or apply to medical school. I'm hoping a summer research experience will help me understand which route I would enjoy most.

After reviewing the different research projects described in the summer research booklet, I was very intrigued by your project of producing plutonium-239 through the bombardment of uranium. I am particularly interested in investigating new avenues for producing fissile materials that could be used for green energy production. I am also interested in your project investigating new methods of isolating neptunium and americium.

When you are available, could we talk more about the prospects of me participating in a research project with you this coming summer? I am free to meet on Tuesdays after 1pm, Wednesdays after 3:30pm, and any day after 4pm in the next two weeks. Please let me know if any of those times work for you.

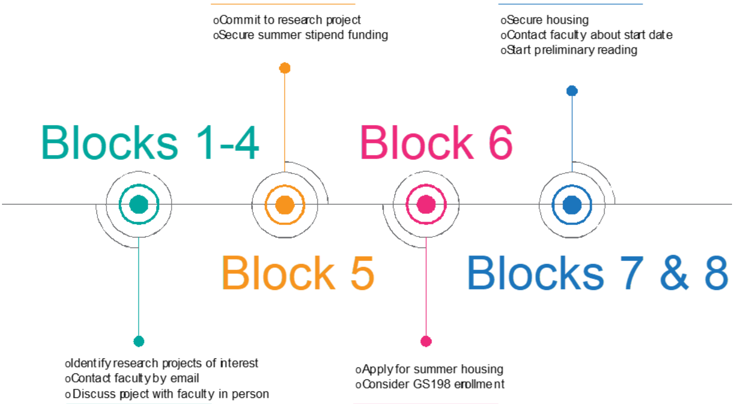
I look forward to talking more about research soon.

Sincerely,
Allison Smith

2. Meet the faculty member in person.
    a. Ask about project availability. If the project you are most interested in isn't available, are there other projects that would be a good fit?
    b. Ensure you have completed any required courses for the project.
    c. Ask about funding options for the project including timelines for proposal submissions.
    a. Ask about this faculty's expectations of summer researchers, including time commitments, what a typical day looks like, start and end dates, etc. Be sure to discuss expectations/ outcomes of the specific project.
    b. Ask about any specific expectations for research presentation.
    c. Determine a plan and timeline moving forward regarding the research position.

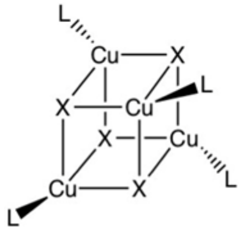
Timeline for Contacting Potential Summer Research Advisors:

1. To ensure the best chances of securing a position, contact faculty prior to Block 4.
2. By Block 5, commit to a research project/advisor. Talk with advisor about securing summer stipend funding.
3. In Block 6, start thinking about summer housing. Discuss the option of enrolling in GS198.
4. In Blocks 7 & 8, ensure you've secured summer housing. Discuss the start date with your advisor. Ask about any background reading required to get the project started.



2018 Summer Research Highlights
Bowman Lab:

Fluorescent Copper Clusters -
Shiyen Sinclair, Jessica Song



Fluorescent materials have many interesting applications, including in light emitting devices, inks and textiles, temperature sensors, road safety signs, and environmental applications such as heat-responsive window glass and car paints. The goal of this project was to synthesize new fluorescent copper clusters, $Cu_4X_4L_4$ (X = halide, L = neutral ligand). This summer was spent exploring new clusters containing iodine and bromide halide ligands, and pyridine and nitrile neutral ligands, and characterizing the complexes using UV-Vis, infrared, ^{1}H NMR, and fluorimetry.

Air-free synthesis methods were developed for the bromide compounds, which were determined to be very air-sensitive. This project also explored the thermchromism of the fluorescence, which is the change in the color of fluorescence with changing temperature of the copper cluster. The results will be presented at a future American Chemical Society meeting.

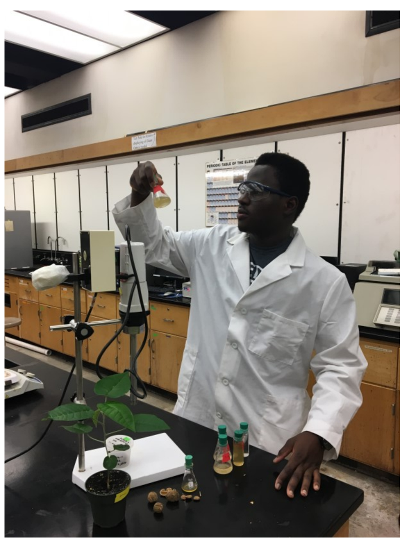
Activated Carbon Materials for Water Purification -
Alma Jukic, Caroline Wu

Water contamination from industrial and agricultural waste is a serious problem in many parts of the world. These contaminants can cause acute health effects in addition to chronic toxicity due to bioaccumulation. Therefore, development of non-toxic, economical, and easy to use water treatment materials is essential. Activated carbon materials have been explored as adsorbents for contaminants commonly found in drinking water, such as pesticides and heavy metal ions. This research project explored the use of natural and waste materials (sugar with sand, orange peels, bamboo, and coconut shells) as carbon sources for water purification materials. These materials were tested for their ability to remove contaminants from water using inductively-coupled plasma (ICP) and UV-Vis spectroscopy. A range of water contaminants were investigated, including chromium (VI), lead (II), and rhodamine dye. The filtration ability of the materials was explored under different pH and time conditions.

Brasuel Lab:

Nutritional Evaluation of Croton Nut Protein - Israel Ashiagbor

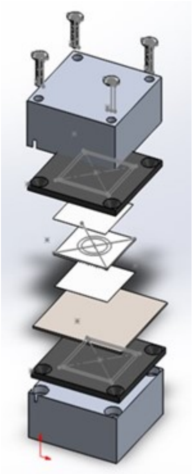
Croton nuts are indigenous to central East Africa and are currently underutilized commercially. However, the oil and protein of Croton nuts have numerous potential applications. The oil has potential uses in biofuel, cosmetics, and paints. In order to make use of the oil in applications such as cosmetics and paints, a better understanding of its natural variation in composition is needed. Students in the fall 2017 Analytical Chemistry course (CH241) analyzed the variation in the oil composition of Croton nuts from Croton plants located in different geographic locations. Therefore, to further improve and build on the work accomplished in CH241, this project aimed to analyze the protein content of Croton nuts in order to discern croton nut viability as a protein source for human and livestock applications. The analysis on our findings will be shared with the Eco Fuel Kenya (EFK) group. (http://www.efkgroup.co.ke/about-efk) The EFK group is actively working to improve the livelihood of smallholder farmers in East Africa by finding commercial applications for the Croton nut. The Croton nut grows easily, is fast growing, and does not require a high resource input to maintain.



Israel Ashiagbor '20

Fahrenkrug Lab:

Controlling Reaction & Crystallization Pathways with
Electric Fields -
Jose Monge Castro and Prakhar Gautam



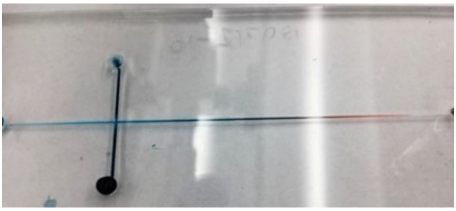
The aim of this summer research was to utilize electric fields to influence the position and alignment of molecules as they stack themselves in the solid state. We started the project by designing and constructing a special reaction cell that allows controlled application of an electric field to a small solution volume. Our initial goal was to assess the functionality of the cell by evaluating the electric field influence on the Lewis-acid catalyzed epoxide rearrangement model reaction. After the cell is effectively able to apply electric fields to solutions, it will be used to influence the crystallization of the drug Paracetamol. Our hypothesis is that under certain applied field conditions, the crystallization kinetics of Paracetamol can be leveraged to access a different crystal form.

Fountain Valley Water Project -
Keenan Wright

The family of chemical contaminants known as perfluoroalkyl substances (PFAS) are tied to a variety of human health problems. They persist and accumulate indefinitely in organisms and ecosystems. Several communities have been exposed to PFAS through drinking water contamination from a variety of sources. So far, the largest single exposure in the US exists in the local communities of Fountain, Security, and Widefield, CO. The goal of this project is to (1) assess the extent of the chemical plume in the underlying Widefield aquifer, (2) monitor the plume over the next several years, and (3) articulate the risk to the affected stakeholders. This summer has been spent constructing the scientific study. This includes connecting with private well owners in each district, refining the analytical method and sampling protocols, constructing a website, and initiating preliminary surface water analyses to identify the vector of chemical transport.

Developing Simple Microfluidic Capillary Electrophoresis Separation Platforms - Keenan Wright

Imagine you are at a hospital donating blood for medical analyses. Certain assays require initial separation of complex matrices which is time-intensive and often costly. The field of microfluidics provides a new platform for rapid separation and analysis of complex samples in a cost effective manner. This summer research project has focused on developing a simple fabrication process and analytical method to electrophoretically separate small molecules inside a plastic microfluidic chip that can be prepared in an undergraduate laboratory. This first required developing and refining a laser cutting protocol to etch micro channels in plastic. Then, a solvothermal sealing process was refined. From there, separation variables were systematically assessed within an optimization protocol.



Lab-on-a-Chip Method for Measuring Pb in Drinking Water - Nick Humphrey

In Flint, Michigan, tens of thousands of people are living without the personal ability to verify a safe, reliable source of drinking water. In fact, more than half of the US water supplies remain untested or rely on outdated data for lead. Armed with science, however, bringing aid to these scientifically underserved communities is very achievable. This summer project focused on developing a high throughput analysis platform for heavy metals (such as lead) in water sources using a bipolar electrochemical approach. The project started by developing a laser ablation approach for the rapid production of the microchip platform. From there, a cathodic electrochemiluminescence dye was leveraged to serve as an analytical reporter for the amount of lead in a simulated drinking water sample. The project faced many technical issues that required systematic troubleshooting. There is still much to learn about the system before its ready for commercial use.

Grover Lab:

Thermodynamics of Bulged-G RNA Structure - Ethan Moore

A specific RNA motif, known as the bulged-G motif, makes an S-shape in the RNA backbone that is present in ribosomes of all living organisms. Two RNA strands must pair together in order to form the S-shaped RNA, and the reasons behind why this motif form the S-shape are currently being researched and examined. Our lab is looking at specific sequences of the RNA motif that have been modified and assessing whether the S-shape continues to form based off of the energetics and stability of the various constructs. The strands of RNA are combined (with isothermal titration calorimetry) or pulled apart (via thermal denaturation melts) while measuring the stability of the strands. The differences in stabilities between the various constructs that we are studying helps to give insight on if the S-shaped structure is forming.

Thermodynamics of the Kink-Turn Motif - Cole McCaskill

Our lab studies thermodynamics of different naturally occurring bulge- and internal-loops in RNA. We study those RNA where magnesium ions are expected to play a significant role in structure and function. My project is based on the RNA kink-turn motif, which causes bends in RNA structures. The kink-turn conformation requires the binding of metal-ions. We are examining the thermodynamics of the kink-turn RNA in the presence of magnesium ions. Using thermal denaturation, we measure the temperature at which the double strands separate into two strands to determine the energy it takes to pull the RNA apart; this tells us about the stability of RNA in a particular condition. We also use isothermal titration calorimetry, where binding of RNA to magnesium ions is measured by the microcalories of heat released. We aim to understand the role of RNA sequence and metal ions in forming the kink-turn structures in RNA.

Kisunzu Lab:

Investigations of Aryne Reactivity with Dicarbonyl Compounds -
Katie Thompson, Simone Hall, Henos Negash

The focus of this project is the investigation of how strained aromatic alkynes derived from benzene (called "benzynes", **2**, Figure 1) react with different compounds. Previous research has shown that the aromatic ring can insert into the carbon-carbon bond of b-ketoesters (for example, **3**) to form new structures (**4**). Additional dicarbonyl compounds like malonic acid half thioesters (MAHTs, **5**), monothiomalonates (MTMs, **6**), and monothiomalonamides (MTMAs, **7**) have not yet been used to react with benzynes, and their reactivity is therfore unknown. Thioesters and amides are functional groups that are abundant in nature, and the development of new methods can be useful in the synthesis of biologically or medically relevant small molecules. Students will have the opportunity to present this research at various conferences, including local SCoRe and CSURF symposia and national American Chemical Society (ACS) and National Association for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE) meetings.

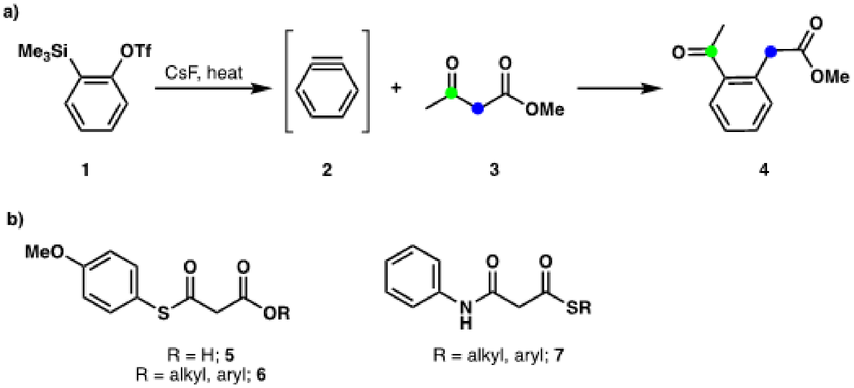


Figure 1. a) Formation of benzyne (**2**) and reactivity with β-ketoesters. b) Additional reaction partners of interest.

Frequently Asked Questions about Summer Research

1. How do Summer and Block research differ?

Block research is a graded research experience conducted over a single block with a faculty member in the department. Faculty in the department have one dedicated research block per academic year. Block research can be conducted at several levels including 201, 301, and 401. For more information about individual courses, see the Course Catalogue. Summer research is a non-credit and funded research experience over a 10-week summer period.

2. How long is a summer research position?

Positions are typically for 10 weeks over the summer. Start and end dates can vary depending on project and advisor.

3. What is the summer research schedule?

Most projects/advisors will require a 40 hour/week research commitment. Specific allocation of that time over the week is project-dependent and may include laboratory experiments, reading of primary literature, paper writing, and other tasks.

4. Do I need previous research experience to be eligible for a summer research position?

Previous research experience is typically not necessary, although certain projects may require students to have completed particular courses. See each faculty member's research page in this booklet for required and suggested courses for research. This should be discussed directly in your first correspondence with the research advisor of interest.

5. Do I get funded for the summer research position?

Summer research students receive a $4000 stipend (pre-tax) for the 10-week duration.

6. Can I volunteer (i.e. perform research without a stipend)?

Due to legalities of insurance coverage of you, of our instruments, and of other school property, and issues of equity we cannot allow you to volunteer for summer research.

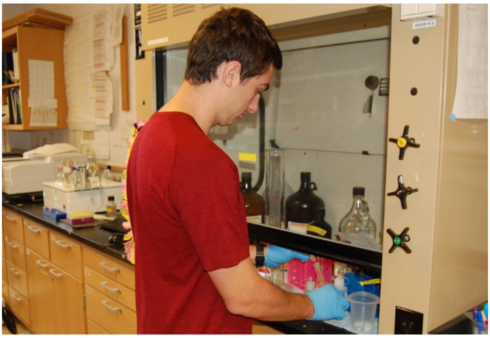
7. Does the stipend include a meal plan subsidy?
The $4000 stipend does not include a separate meal plan subsidy. Students who elect to live on campus will be required to purchase a meal plan from their stipend for their housing period.

8. How do I get funded for summer research?
Summer research stipends are supported by either internal or external grants hosted by a particular faculty member. As a potential summer researcher, it is *your responsibility* to inquire with faculty about summer funding options. This often requires appealing to internal funding through small grants applications, such as the Faculty-Student Collaborative Grant. Most internal grant applications are due in Block 5. For that reason, it is critical that you discuss potential interest in summer research positions with faculty prior to Block 4 of the academic year you would like to conduct research. Failure to secure funding may result in an inability to support your summer research experience.

9. Is there any additional financial help for international students participating in summer research?
The Center for Global Education & Field Study may offer additional housing and meal support for international students.

10. Can international students participate in summer research positions?
Students can participate in summer research regardless of national citizenship. As such, tax rates for the summer stipend may vary.

11. If I'm interested in a summer research position, how and when do I get involved?
See the 'How to Get Involved' and 'Timeline' sections of this booklet.



Ethan Moore '19

12. Where will I live during my the summer research?
Students can elect to live either on or off campus during their summer research. A need-based housing scholarship is available for eligible students to reside on campus in a double occupancy room while completing their summer research.

Frequently Asked Questions about Summer Research, Continued

Simone Hall '19

13. What year am I eligible for summer research?

Eligibility is not dependent on your academic year. Instead, it is specific to the project and advisor.

14. What are the expectations for communicating my research experience to broader audiences?

As a summer research student, you are expected to participate in the Student Collaborative Research (SCoRe) Summer Research Symposium in either poster or oral format. The event highlights student-faculty collaborative research over Family & Friends Weekend at the college. Many summer researchers also have the opportunity to participate in discipline-specific regional or national meetings. This option should be discussed with your particular advisor.

15. Do I get credit for summer research?

Since summer research is a funded research experience, students will not receive academic credit. For those interested in recognition of their research on their academic transcript, they can enroll in GS198.

16. What is GS198? And do I have to take it?

GS198 is a *voluntary* course that summer research students can elect into allowing the summer research experience to be added to their academic transcript. The course is offered only as pass/fail. Students are required to keep a set of initial expectations, keep a research journal, and submit information through a GS198 Canvas portal. More information about GS198 can be obtained from Lisa Schwartz (lisa.schwartz@coloradocollege.edu) or Andrea Culp (andrea.culp@coloradocollege.edu).

17. As a Chemistry or Biochemistry major, why should I conduct summer research?

Either on- or off-campus research experiences are essential for those interested in pursuing graduate studies in the chemical or medical sciences. It demonstrates your capacity to conduct research over an extended period which is important in the graduate school application process. At the same time, it allows you to identify which components of the research you enjoy most (or least).

18. What if I'm not a Chemistry or Biochemistry major – can I still participate?

Eligibility does not depend on your declared major. Contact advisors of interest for more information.

19. What if I don't know what type of research I want to do?

Make sure you read through the available research projects for each faculty member in this booklet. If anything stands out as particularly interesting, contact that faculty member for more information.

20. What's expected of me as a student researcher?

You will be expected to think creatively, solve problems independently, and talk and write knowledgably about what you are researching. You are also expected to demonstrate the dependability, work ethic, attention to ethics, and awareness of safety required of a professional scientist.

21. What does a typical day look like as a summer researcher?

Specific allocation of that time over the week is project-dependent and may include laboratory experiments, reading of primary literature, paper writing, and other tasks. Typical days start at 9am and finish at 5pm.

Shiyen Sinclair '18 and Jessica Song '19

Murphy Brasuel

Associate Professor of Chemistry & Biochemistry

Areas: Analytical Chemistry, Bioanalytical Chemistry, Fluorescent Sensors
Courses Required for Research: CH241 or CH250 with COI
Courses Helpful for Research: CH342, CH382, CH475

Measuring Bacterial Interference with Eukaryotic Ion-Channel Function

Viral infection of eukaryotic cells is achieved by a variety of mechanisms. One suspected route is the endocytosis of the virus from the extracellular environment into the cell. Endocytosis is the natural mechanism for a cell to internalize nutrients from its environment, see figure 1. Under normal conditions as the endosome matures the contents of the endosome are acidified through H^+ ATPases, and Na-H exchangers. After acidification the "digested" nutrients are released from the endosome into the cell. Viral cells must overcome endosome acidification to effectively use this route for infection. Research suggests that some virus strains are pH resistant and others can shut down the Na-H exchangers responsible for endosome acidification. When the mature endosome releases its contents into the cell the virus has effectively crossed the eukaryotic cell membrane intact and can begin the infection of the cell.

Previous research with students has led to the development, characterization, and optimization of PEBBLE nano-sensors for the measurement of intracellular pH. These sensors have been successfully applied to the measurement of pH in the endosomes of *Dictyostelium discoideum*. It was demonstrated that the endosomal pH of *Dictyostelium discoideum* can be successfully quantified using pH-sensitive PEBBLEs. This was the first quantification of the endosomal pH changes that occur after chemotactic stimulation. We observed a decrease in pH which is consistent with previous work that identified acidic vesicles, not the cytosol, as the main sources of protons for the cAMP-induced proton efflux.

Professor Brasuel's research interests span from cell signaling to forensic analysis of art. Some ongoing projects are outlined below, but I am open to exploring new avenues for the application of analytical chemical methods.

Advances on this project can be divided into sensor development and characterization, sensor delivery and intracellular measurement of ion flux, and protein identification and purification.

This provides the opportunity for mentoring students interested in analytical chemistry, biology, physiology, and biochemistry.

Other ongoing projects include the development of rapid and portable assays for capsaicin (the pungent component of chili), nutritional analysis of croton nuts, and forensic analysis of fakes and forgeries.

Selected Publications:

Wise, W., and Brasuel, M., "The current state of engineered nanomaterials in consumer goods and waste streams: the need to develop nanoproperty-quantifiable sensors for monitoring engineered nanomaterials," *Nanotechnology, Science and Applications, 2011,* **4**, *73-86*.

Brasuel, M., McCarter, A. D., and Bower, N., "Forensic Art Analysis Using Novel Reflectance Spectroscopy and Pyrolysis Gas Chromatography – Mass Spectrometry Instrumentation," *The Chemical Educator,* 2009, **14**, 150-154.

Moding, E., Hellyer, J., Rank, K., Lostroh, P., and Brasuel, M., "Characterization of PEBBLEs as a Tool for Real-Time Measurement of Dictyostelium discoideum Endosomal pH," *Journal of Sensors,* 2009, vol. 2009, Article ID 235158.

Contact:

Barnes Science Center #202
mbrasuel@coloradocollege.edu

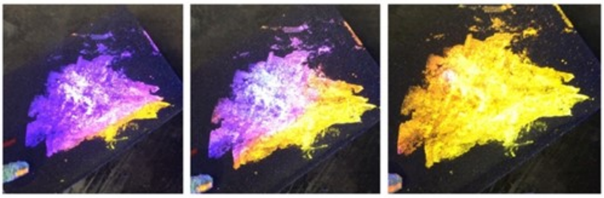
Amanda Bowman

Assistant Professor of Chemistry & Biochemistry

Areas: Inorganic, Organometallic, Bioinorganic, Spectroscopy
Courses Required for Research: CH107/8, CH275
Courses Helpful for Research: CH241, CH250, CH475

Fluorescent Copper Clusters

Fluorescent materials have many interesting applications, including in light emitting devices, inks and textiles, temperature sensors, road safety signs, and environmental applications such as heat-responsive window glass and car paints. The goal of this project is to synthesize new fluorescent copper clusters, $Cu_4X_4L_4$, and characterize their properties and electronic structure (X = halide, L = neutral ligand). Many different types of spectroscopy, such as UV-Vis, infrared, ^1H NMR, and fluorimetry, will be used to characterize these clusters. Computational chemistry may also be used to understand how the electronic structure of these complexes correlates to the observed fluorescence emission.



This project is ideal for students who are interested in synthetic chemistry and spectroscopy, and potentially computational chemistry as well.

Spin-Crossover Cobalt Complexes

The goal of this project is to synthesize cobalt-based coordination complexes that exhibit temperature-dependent spin crossover behavior, evaluate their electronic structures, and investigate their potential applications. Spin crossover (SCO) is a significant change in the spin-state of a transitional metal complex, generally from low-spin to high-spin. SCO complexes are of interest due to applications as molecular magnets and in the development of thermochromic materials (such as optical indicators of temperature in paint and ink, and in thin films as a means of regulating color and/or opacity of windows in response to heat and sunlight to promote energy efficiency). Many different types of spectroscopy, such as UV-Vis, infrared, ^1H NMR, and magnetometry, will be used to characterize these complexes.

This project is ideal for students who are interested in synthetic chemistry and spectroscopy, and potentially computational chemistry as well.

Professor Bowman's research explores the synthesis of new inorganic compounds and materials, and explores their properties through spectroscopy and computations.

Activated Carbon Materials for Water Purification

Water contamination from industrial and agricultural waste is a serious problem in many parts of the world. These contaminants can cause acute health effects in addition to chronic toxicity due to bioaccumulation. Therefore, development of non-toxic, economical, and easy to use water treatment materials is essential. Activated carbon materials have been explored as adsorbents for contaminants commonly found in drinking water, such as pesticides and heavy metal ions. This research project explores the use of waste materials like used coffee grounds, eggshells, and orange peels as carbon sources for water purification materials. These materials are tested for their ability to remove contaminants from water using inductively-coupled plasma (ICP) and UV-Vis spectroscopy.

This project is ideal for students who are interested in inorganic materials chemistry and environmental applications.

Selected Publications:

Bowman, A. C.; Tondreau, A. M.; Lobkovsky, E.; Margulieux, G. W.; Chirik, P. J. "Structure and electronic structure diversity of pyridine (diimine)iron tetrazene complexes." *Inorg. Chem.* **2018**, ASAP.

Ben-Daat, H.; Rock, C. L.; Flores, M.; Groy, T. L; Bowman, A. C.; Trovitch, R. J. "Hydroboration of alkynes and nitriles using an a-diimine cobalt hydride catalyst." *Chem. Commun.* **2017**, *53*, 7333-7336.

Contact:

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abowman@coloradocollege.edu

Margaret (Peggy) Daugherty

Associate Professor of Chemistry & Biochemistry

Areas: Protein biochemistry and molecular biophysics
Courses Required for Research: CH107/8, CH 250,, CH 251, CH 382
Courses Helpful for Research: CH241, CH383, CH400

Purification and Characterization of a phosphorylation triad in *A. Bayli* ADP1

Acinetobacter baylyi ADP1 is of interest to scientists due to its ability to utilize a diverse set of nutrients as a source of carbon and nitrogen, and to its high level of competence with regards to natural transformation (1,2). Recent findings showed that A. baylyi ADP1 survives starvation induced conditions during long term stationary phase through upregulation of thirty genes, approximately 25% of which are denoted conserved hypothetical genes (3). Conserved hypothetical genes are those that have been identified through genetic analysis, but have not had a protein product identified. Subsequently, as shown in Figure 1, collaborators and I have identified that a number of associated genes are encoded in an operon, suggesting that they work together to confer resistance to starvation conditions (4). The goal of my lab is to clone selected genes and characterize their biological function. We are initially focusing on genes that have been identified by bioinformatics to encode for enzymes with testable function. We have initially used bioinformatics, and identified and characterized a gene that potentially encode for a cysteine protease (gene ACIAD1960), which we have named StiP, for stationary phase induced protease.

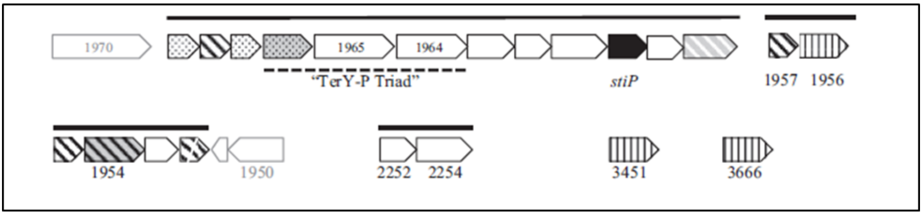

Figure 1: Genes that are identified to be associated with StiP, a cysteine protease that is upregulated during long term stationary phase (4).

My lab is currently interested in a triad of genes called the Ter Y-P that occurs in the same operon as StiP. Bioinformatic analysis suggests that they encode a kinase (gene ACIAD1964), and a phosphatase (gene ACIAD1965) and a protein of unknown function (gene ACIAD1966).

Students interested in protein function and characterization are encouraged to apply.

Professor Daugherty's current research is to investigate the role of protein interactions in bacterial survival.

Specifically, my research plans in the future are to:

1). Characterize the gene product for ACIAD1960, the cysteine protease, StiP. We will characterize the solution conditions that contribute to maximal activity, including pH, ionic strength, metal ion dependence and contribution of reducing agents.

2). Clone and characterize the gene product for ACIAD1964. We will test the hypothesis that the protein that is encoded by this gene is a kinase, as has been indicated by bioinformatics approaches.

3). Clone and characterize the gene product for ACIAD1965. We will test the hypothesis that the protein that is encoded by this gene is a phosphatase, as has been indicated by bioinformatics approaches.

4). Clone and characterize the gene product for ACIAD1966. We will test the hypothesis that the protein that is encoded by this gene forms a multimeric complex with the gene products of ACIAD1964 and ACIAD1965.

References:
1). Barbe, V., et al., (2004). Unique features revealed by the genome sequence of Acinetobacter sp. ADP1, a versatile and naturally transformation competent bacteriumNucleic Acids Research, 32(19), 5766-5779.
2). de Berardinis, et. Al., (2009). Acinetobacer bayli ADP1 as a model for metabolic system biology. Current Opinion in Microbiology, 12, 568-576.
3). Lostroh, C. P., Voyles, B. A. (2010). Acinetobacter baylyi Stavation-Induced Genes Identified through Incubation in Long-Term Stationary Phase. Applied and Environmental Microbiology, 76(14), 4905-4908.
4). Reichert, et al., (2013) Acinetobacter baylyi Long Term Stationary Phase Protein StiP Is a Protease Rerquired for Normal Cell Morphology and Resistance to Tellurite. (2013) Journal of Microbiology, 59(11): 726-736.

Selected Publications:

Reichert, et al., (2013) Acinetobacter baylyi Long Term Stationary Phase Protein StiP Is a Protease Rerquired for Normal Cell Morphology and Resistance to Tellurite. (2013) Journal of Microbiology, 59 (11): 726-736.

Contact:

Barnes Science Center #326
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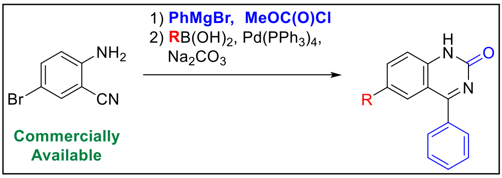
Amy Dounay

Associate Professor of Chemistry & Biochemistry

Areas: Organic Chemistry, Medicinal Chemistry, Drug Discovery for Neuroscience and Neglected Diseases, Chemical Education
Courses Required for Research: CH250, CH251
Courses Helpful for Research: CH351, CH410

Design and Synthesis of New Drugs for African Sleeping Sickness

African sleeping sickness threatens millions of people in sub-Saharan Africa. Current treatments for this disease are inadequate due to their poor safety profiles, marginal efficacy, and complex dosing protocols. A safe, orally administered drug that is effective against early- and advanced-stage infections could pave the way for eradication of the disease. Through this program, students learn drug discovery strategies and techniques analogous to those used in the pharmaceutical industry. Our lab works with multiple collaborator labs at for biological testing of our new molecules.



Students will gain experience in design, synthesis, computational modeling (with collaborator labs), and characterization of new drug leads.

Developing Green Synthesis Methods Using Flow Reactors

Flow hydrogenation has emerged in recent years as a safer alternative to batch hydrogenation reactions. Our lab has worked to develop new synthesis methods using the ThalesNano H-Cube Mini for flow hydrogenation. Our initial studies on simple model systems provide significant advances in the safety, efficiency, and green chemistry aspects of this reduction compared our previous batch hydrogenation methods. We are currently evaluating extending our flow method to more complex molecules required for our African sleeping sickness research program.

Students interested in organic synthesis, process engineering, and green chemistry methods are encouraged to apply.

Professor Dounay's research seeks to design and prepare new drugs for treatment of neglected diseases and to use green chemistry principles in drug synthesis.

Distributed Drug Discovery (D3): Global Collaborations

Through international collaboration, the D3 program links undergraduate chemistry education to research in neglected disease drug discovery. This program introduces students to drug discovery, solid-phase synthesis, and combinatorial synthesis. Students working on this program will help develop and validate new protocols for use in organic chemistry instructional labs worldwide. These protocols must prove to be simple and reliable to ensure that students in various academic environments worldwide can contribute to preparing new drug leads for this program. Students may also assist in screening new molecules for biological activity using simple bioassays.

Students interested in medicinal chemistry, drug design and synthesis, chemical education, and global health are encouraged to apply. Students may have opportunities for domestic and international travel to work with collaborators.

Selected Publications:

Scott, W.L.; Samaritoni, J.G.; O'Donnell, M. J.; A.B. Dounay, Fuller, A.A.; Dave, P.S.*; Sanchez, J.M.*; Tiano, D.G.*; Rivera, D.G. "Ernest Eliel Workshop – US and Cuba Collaboration in Chemistry Education and Neglected Disease Drug Discovery" in *Stereochemistry and Global Connectivity: The Legacy of Ernest Eliel,* ACS Publications, 2017.

Pham, T.;* Walden, M.;* Butler, C.; Diaz-Gonzalez, R.; Pérez-Moreno, G.; Ceballos-Pérez, G.; Gomez-Pérez, V.; García-Hernández, R.; Zecca, H.;* Krakoff, E.;* Kopec, B.;* Ichire, O.; Mackenzie, C.;* Pitot, M.;* Ruiz, L.M.; Gamarro, F.; González-Pacanowska, D.; Navarro, M.; Dounay, A. B. "Novel 1,2-dihydroquinazolin-2ones: Design, synthesis, and biological evaluation against *Trypanosoma brucei*," *Bioorg. Med. Chem. Lett.* **2017**, *27*, 3629-3635.

Ichire, O.; Jans, P.*; Parfenov, G.*; Dounay, A. B. "A Safe and Selective Method for Reduction of 2-Nitrophenylacetic Acid Systems to *N*-Aryl Hydroxamic Acids Using Continuous Flow Hydrogenation," *Tetrahedron Lett.* **2017**, *58*, 582-585.

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Eli Fahrenkrug

Assistant Professor of Chemistry & Biochemistry

Areas: Analytical Chemistry, Materials Science, Lab-on-a-Chip, Electrochemistry, Nanoscience
Courses Required for Research: CH107/8, CH250
Courses Helpful for Research: CH241, PC241/2, CH342, CH275, CH475

Electric Field Controlled Polymorph Crystallization

Tuning the way molecules arrange themselves in a crystal (i.e. polymorphism) affords control over the physical and chemical properties of the material. In the pharmaceutical industry, the specific crystal polymorph underpins all key attributes of drug solubility, bioavailability, and stability. This project employs dipole-coupled external electric fields to kinetically select certain polymorphic crystallization pathways over others.

Students interested in materials chemistry, organic synthesis, physics, mechanical engineering, and computational chemistry are encouraged to apply.

The Fountain Valley Water Project

Fountain Valley Water Project

Drinking water contamination with perfluoroalkyl substances (PFASs) poses lasting health risks to consumers. Recent reports indicate elevated PFAS levels in drinking water across the southern Colorado Springs Metro Area. This cross-disciplinary project aims to evaluate the geospatial and temporal extent of the water contamination plume in the affected communities. Student researchers are also tasked with empowering those communities through various modes of scientific communication (web development, public speaking, etc.) The project incorporates faculty, staff, and students from several departments and programs at CC.

Students involved in this project will be exposed to environmental chemistry, hydrology, ArcGIS, scientific communication, and community engagement. Any interested student (independent of major or department affiliation) is encouraged to ask about how to get involved.

Professor Fahrenkrug's research reimagines the role of electric fields at the interface of materials science and analytical chemistry.

'Wireless' Electrochemistry for Heavy Metal Ion Analysis in Water

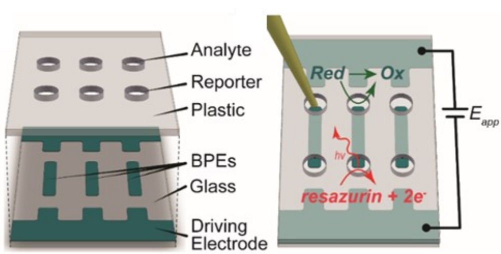
A dynamic understanding of metals in water requires an equally dynamic, sensitive, and ideally, deployable analytical process. Bipolar electrode (BPE) arrays can be leveraged to 'wirelessly' measure hundreds of water samples simultaneously under influence of an external electric field. To achieve this, light emission from a carefully chosen chemiluminescent dye at one pole of each BPE electrode can be used to quantify the amounts of Pb or Cu at the opposite pole. So far, we have developed both the device and methodology for Pb analysis in water using BPE arrays. Future goals aim to extend this sensor technology to paper-based disposable sensors that can be read by a smartphone camera.

This project is great for students who enjoy modern fabrication techniques (3D printing, laser cutting, metal machining), sensor design, and electroanalytical chemistry.

Selected Publications:

Fahrenkrug E., DeMuth, J., Ma, L., Maldonado, S., Electrochemical Liquid Phase Epitaxy (ec-LPE): A New Methodology for the Synthesis of Crystalline Group IV Semiconductor Epifilms. *J. Am. Chem. Soc.,* 139, 6960-6968 (**2017**).

Fahrenkrug, E., Alsem, D. H., Salmon, N., Maldonado, S., Electrochemical Measurements in In Situ TEM Experiments. *J. Electrochem. Soc.*, 164, H358-H364 (**2016**).



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Neena Grover

Professor of Chemistry & Biochemistry

Areas: Nucleic Acid Biochemistry, Small RNA Thermodynamics, RNA-Magnesium Binding
Courses Required for Research: CH107, CH108
Courses Helpful for Research: CH382, RNA

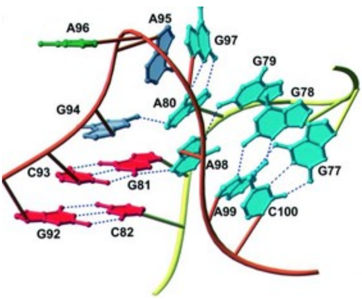
We examine small internal- and bulge-loops in RNA. Often these small motifs are the functional sites of a large RNA and serve as binding sites for proteins and ions. We are particularly interested in those RNA that are implicated in site-specific magnesium binding as we want to quantify the interactions between RNA and magnesium ions. Magnesium ions are essential for folding the RNA into its active structures and for many of its catalytic activities.

Research in the laboratory starts by selecting a small RNA to study. Students design small RNA constructs based on their understanding of the available structure-function data on a given RNA. New students join existing projects before designing their own RNA. We design modifications of the small RNA that provide insights into the sequence and ion-binding sites. The constructs we design are then examined using thermal denaturation and isothermal calorimetry. We use native PAGE gels and fluorescence experiments to study RNA conformations. We also examine the solution conditions that influence the stability of RNA.

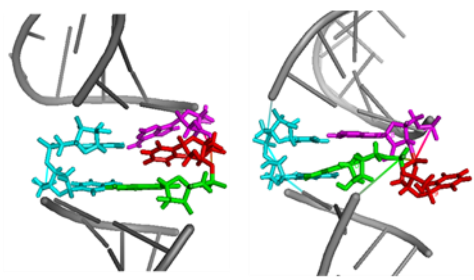
In addition to studying the stability of RNA, we design DNA-equivalent of interesting RNA. DNA forms a B-form helical structure whereas RNA forms an A-form structure. The differences in sugar pucker, phosphate distances and hydrogen bonding etc. result in differences in major and minor grooves in nucleic acids. We are interested in comparing the stability and differences in magnesium binding in various internal- and bulge loops.

The research in our laboratory examines thermodynamic properties of small RNA with an emphasis on quantifying magnesium-nucleic acid interactions.

Examples of motifs that are currently being studied in the laboratory:



Kink-Turn RNA



pH 8.0: U80 (red) is stacked within helix

pH 5.7: U80 (red) is flipped out of helix

The U6 RNA

Selected Publications:

Strom S[UG], Shiskova E[UG], Ham YE[UG], Grover N, Thermodynamic Examination of One- to Five-Nucleotide Purine Bulge Loop RNA and DNA Constructs, RNA. 2015, 21, 1313-22.

Carter O'Connell I[UG], Booth D, Eason B[UG], and Grover N, Thermodynamic Examination of Trinucleotide Bulged RNA in the context of HIV-1 TAR RNA, 2008, RNA Vol 14, 3550 -2556

Auffinger P, Grover N, and Westhof E, Metal Ion Binding to RNA, in Metal Ions in Life Sciences: Structural and Catalytic Roles of Metal Ions in RNA, Volume 9, Sigel A, Sigel H, Sigel RKO, Editors, The Royal Society of Chemistry, Cambridge, UK, 2011

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Jessica Kisunzu

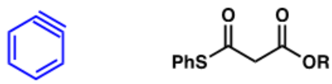
Assistant Professor of Chemistry & Biochemistry

Areas: Organic Chemistry, Methodology Development, Strained Intermediate Reactivity, Natural Product Synthesis
Courses Required for Research: CH250, CH251
Courses Helpful for Research: CH351

Investigations of Aryne Reactivity with Dicarbonyl Compounds

Alkynes in ring systems (often 5 to 8-membered rings) are very reactive due to the increased strain of the compressed triple bond. We are interested in understanding how strained alkynes derived from benzene, called benzynes (**1**), react with a variety of dicarbonyl compounds. Starting compounds are malonic acid half thioesters (MAHTs, **2**) and monothiomalonates (MTMs, **3**), as well as other compounds that have either the sulfur or oxygen atom (or both) replaced by a nitrogen. Thioesters, amides, and substituted rings are functional groups that are abundant in nature, and the development of new methods can be useful in the synthesis of biologically or medically relevant small molecules. These dicarbonyl compounds have not yet been used to react with benzynes, therefore their reactivity is unknown.

a) b)



benzyne, **1**

2, R = H; *MAHT*
3, R = alkyl, aryl; *MTM*

Students interested in organic synthesis, developing new reactions, and structure determination and analysis are encouraged to apply.

Photochemical Benzyne Chemistry

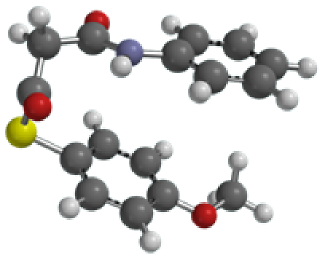
One of the ways to generate benzynes is to use UV light. We are interested in investigating the way that these photochemical reactions work and what types of starting compounds are necessary. We can then incorporate groups into the dicarbonyl reaction partners that will also react in the presence of UV light, and monitor what reactivity follows. Students will synthesize both sets of reaction partners and test reactivity.

Students working on this project will explore organic synthesis, radical reactions, photochemistry, and structure determination and analysis.

Dr. Kisunzu's research explores the formation and application of highly strained, reactive organic intermediates.

Computational Analysis of Arynes

Since strained aromatic alkynes are so reactive, a lot of work has gone into studying them computationally. Density Functional Theory (DFT) methods have been used analyze angle sizes, relative energies, and electron density around the ring. Students will be using computer programs



(for example, Gaussian and Spartan) to not only become more familiar with the opportunities that computational modeling has to offer, but also to learn more about the makeup of our strained intermediates and how they interact with other compounds around them.

This project is great for students who are interested in the connection between computational methods for molecular modelling and organic synthesis. Prior knowledge of the computational programs is not required.

Selected Publications:

Rigling, C.; Kisunzu, J. K.; Duschmalé, J.; Häussinger, D.; Wiesner, M.; Ebert, M.-O.; Wennemers, H. Conformational Properties of a Peptidic Catalyst: Insights from NMR Spectroscopic Studies. *J. Am. Chem. Soc.* **2018,** DOI: 10.1021/jacs.8b05459

Kou, K. G. M.; Pflueger, J. J.; Kiho, T.; Morrill, L. C.; Fisher, E. L.; Clagg, K.; Lebold, T. P.; Kisunzu, J. K.†; Sarpong, R.† A Benzyne-Insertion Approach to Hetisine-Type Diterpenoid Alkaloids: Synthesis of Cossonidine. (†Corresponding authors) *J. Am. Chem. Soc.* **2018,** *140*, 8105-8109.

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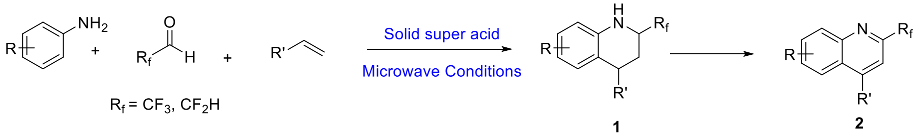
Habiba Vaghoo

Associate Professor of Chemistry & Biochemistry

Areas: Organic Chemistry, Organofluorine Chemistry
Courses Required for Research: CH250, CH251
Courses Helpful for Research: CH351

Microwave-Assisted Solid Acid Catalyzed Multi-component Synthesis of Fluorinated Heterocylces

Multicomponent reactions (MCR) are synthetically very useful as they allow the construction of an extensive collection of complex molecules rapidly. In general, these reactions involve three or more reactants that react sequentially in one pot to afford the desired product with high atom economy and selectivity. MCRs play an important role in the synthesis of biologically important compounds and their fluorinated derivatives are attracting more attention due to the increased interest in fluorine from the medicinal chemistry community. Thus, the need for new methodologies for the incorporation of fluorine in small molecules is an area of active research. In addition, Microwave-assisted organic synthesis (MAOS) is becoming more appealing for the synthesis of small organic molecules for its efficiency in terms of reagents, time, and energy. This project enables the use of MCR, microwave technology and commercially available solid acids to synthesize biologically important molecules via an environmentally friendly and synthetically efficient route. The first MCR that we are interested in developing involves the in-situ formation of a CF_3/CF_2H aryl-aldimine and its subsequent reaction with styrene via the Povarov reaction to afford fluorinated tetrahydroquinolines and eventually the corresponding quinolones derivatives (Scheme 1).



Scheme 1. One pot synthesis of 2-CF_3/CF_2H-Tetrahydroquinoline/ quinolone derivatives.

Dr. Vaghoo is an organic chemist whose research interests are in the area of organofluorine chemistry. She works on developing new reactions to introduce fluorine and fluorinated groups to small organic molecules of biological interest using microwave technology.

Tetrahydroquinolines and quinolones in general are important scaffolds that are present in both natural products and pharmaceuticals as they have interesting biological properties. Fluorinated quinolines have also been studied and shown to exhibit important biological properties such as antimalarial activity. Mefloquine, sold as Larium, is a major antimalarial drug that is used for both prevention and treatment of malaria. On the other hand, fluorinated tetrahydroquinolines have not been widely explored for their biological properties; the reason for which may be attributed to the fact that methodology to synthesize these compounds are limited. Nevertheless, given the importance of fluorinated heterocycles and the academic quest to develop new synthetic methodology, these class of compounds make interesting and worthwhile targets.

([i]) Van der Heijden, G.; Ruijter, E.; Orru, R. "Efficiency, Diversity, and Complexity with Multicomponent Reactions." *Synlett*. **2013**, *24(6)*, 666.

([ii]) Wu, J.; Cao, S. "Multicomponent Reactions based on Fluoro-Containing Building Block." *Curr. Org. Chem.* **2009**, *12*, 1791.

([iii]) (a) Sridharan, V., Suryavanshi, P. A. and Menéndez, J. C.," Advances in the chemistry of tetrahydroquinolines". *Chem. Rev.* **2011**, 111, 7157.

([iv]) (a) Lutz, R. E.; Ohnmacht, C. J.; Patel, A. R. "Antimalarials. 7. Bis(trifluoromethyl)-.alpha.-(2-piperidyl)-4-quinolinemethanols". *J. Med. Chem.* **1971**, 14, 926; (b) Grellepois, F.; Grellier, P.; Bonnet-Delpon, D.; Begue, J.-P." Design, synthesis and antimalarial activity of trifluoromethylartemisinin-mefloquine dual molecules." *ChemBioChem*. **2005**, *6*, 648.

Selected Publications:

Prakash, G. K.; Narayanan, A.; Nirmalchandar, A.; Vaghoo, H.; Paknia, F.; Mathew, T.; Olah, G. A. "Direct synthesis of 2-/3-(trifluoromethyl) thiochroman-4-ones: Superacid-induced tandem alkylation-cyclic acylation of benzenethiols using 2-/3-(trifluoromethyl)acrylic acid" *J. of Fluo. Chem.* **2017**,*196*, 63.

Vaghoo, H**.**; Prakash, G. K.; Narayanan, A.; *Choudhary, R*.; Paknia, F.; Mathew, T.; Olah, G. A. "Superelectrophilic Activation of Crotonic/Methacrylic Acids: Direct Access to Thiochrom-4-ones from Benzenethiols by Microwave-Assisted One-Pot Alkylation/ Cyclic Acylation." *Org. Lett.* **2015**, *17*, 6170.

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Sally Meyer

Professor of Chemistry & Biochemistry

Areas: Physical Chemistry, Computational Chemistry

Courses Required for Research: Project 1- None; Project 2– PC441, CH367

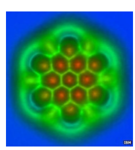
Courses Helpful for Research: Any Physics, Chemistry, Math and Computer Science

Dr. Meyers' research investigates quantum chemistry, computational modeling, and applications to energy efficiency and fundamental physical chemistry.

Modeling Home Energy Improvements

This project involves learning how to do an energy audit of an existing house. The information gathered will be used to model the cost and benefit of different improvements to the house. After learning how to do the audits students will write computer code to model the physics of energy waste within the house. The goal of this research is to improve the process of auditing houses and help make it available to everyone.

Non-Born Oppenheimer Quantum Chemistry



It is impossible to solve the Schrodinger equation exactly for any molecule without using the Born-Oppenheimer approximation. This approximation was introduced in 1927 and since then has been considered valid for most chemical systems. Recently it has been discovered that for some systems of interest this approximation is not valid. The goal of this research is to find ways to solve Schrodinger's equation for these systems without the approximation, which is challenging and requires large computers and efficient codes.

Students interested in quantum chemistry, math and computer science are encouraged to apply.

Selected Publications:

Wierzba, A.L.; Morgenstern, M.A.; Meyer, S.A.; Ruggles, T.H.; Himmelreich, J.; Energy Efficiency, 4 (4) Page: 587-597, 2011 "A Study to Optimize the Potential Impact of Residential Building Energy Audits"

Morgenstern, Mark; Meyer, Sally; Whitten, Barbara and Reuer, Matt. Jour. of College Science Teaching, 37(5), 2008: "The Energy Retrofit of a Building: A Journey Through Bloom's Learning Domains".

References:

https://www.ulb.ac.be/cpm/people/bsutclif/bornopn_corr.pdf

https://pubs.acs.org/doi/10.1021/cr200096s

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Lina Basal

Riley Scholar

Areas: Analytic Chemistry, Inorganic Chemistry, Coordination Compounds

Courses Required for Research: CH107/8

Dr. Basal's research applies analytical, organic, and inorganic chemistry techniques to investigate biological questions.

Metal ion detection using ^{19}F-MRI

Detecting metal ions noninvasively *in vivo* can give valuable information about biological processes involved in disease. One way to detect metal ions noninvasively is using fluorine-19 magnetic resonance imaging (^{19}F-MRI). ^{19}F-MRI has no detectable background signal *in vivo*; as a result, detection of any ^{19}F signal arises from the introduced imaging agent. The imaging agent is composed of a fluorinated ligand and metal. A library of fluorinated ligands that are expected to coordinate biologically-relevant metals will be synthesized and screened against metals. The resulting mixtures will be characterized with UV-vis, fluorescence, and nuclear magnetic resonance spectroscopy to evaluate metal coordination. The high throughput screen enables evaluation of ion specificity to the ligands and how the metal ion changes the magnetic properties of the ^{19}F nuclei on the ligand.

Students who are interested in magnetic resonance imaging, one- or two-step organic synthesis, coordination compounds, and spectroscopy are encouraged to apply.

Selected Publications:

Basal, L. A.; Bailey, M. D.; Romero, J.; Ali, M. M.; Kurenbekova, L.; Yustein, J.; Pautler, R. G.; Allen, M. J. Fluorinated Eu(II)-Based Multimodal Contrast Agent for Temperature- and Redox-Responsive Magnetic Resonance Imaging. *Chem. Sci.* **2017**, *8*, 8345–8350.

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Research Opportunities Outside of Colorado College

National Science Foundation (NSF) Research Experience for Undergraduates (REU): The Research Experiences for Undergraduates (REU) program supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation. REU projects involve students in meaningful ways in ongoing research programs or in research projects designed especially for the purpose. NSF funds a large number of research opportunities for undergraduate students through its REU Sites program. An REU Site consists of a group of ten or so undergraduates who work in the research programs of the host institution. Each student is associated with a specific research project, where he/she works closely with the faculty and other researchers. Students are granted stipends and, in many cases, assistance with housing and travel. Undergraduate students supported with NSF funds must be citizens or permanent residents of the United States or its possessions. An REU Site may be at either a US or foreign location.

See: https://www.nsf.gov/crssprgm/reu/

Summer Undergraduate Research Fellowship Program (SURF, SURP): SURF is a national program hosted by many institutions across the country. SURF is modeled on the grant-seeking process. Students collaborate with a potential mentor to define and develop a project. Applicants write research proposals as part of the application process. Faculty review the proposals and recommend awards.

See: https://www.aamc.org/members/great/61052/great_summerlinks.html

DAAD-RISE Program: A German scientific internship for undergraduate students studying at a North American University/College with a major in biology, chemistry, computer science, physics, earth sciences or engineering. Internships are hosted at a variety of German academic institutions covering a wide range of project topics. Students are matched with a host university or institute according to their area of interest. DAAD provides students a monthly stipend for three months to help cover living expenses. German language is not required and the working language will be in English.

See: https://www.daad.de/rise/en/rise-germany/

SCI Scholars Internship Program: The Society of Chemical Industry (SCI), American Institute of Chemical Engineers (AIChE), and the American Chemical Society created the SCI Scholars Summer Internship Program to introduce chemistry and chemical engineering students to careers in the chemical industry. Exceptional sophomores and juniors majoring in chemistry and chemical engineering can apply for a prestigious SCI Scholars summer internship. Students are selected based on the strength of their application, statement of interest in an industrial internship, and letters of recommendation.

See: https://www.acs.org/content/acs/en/education/students/college/experienceopp/scischolars.html

Amgen Scholars Program: The Amgen Scholars program provides students the opportunity to conduct research in biology, chemistry, and bio-technical related fields under the guidance of seasoned research mentors. The goal of the program is to provide research opportunities to students interested in pursuing a Ph.D. or M.D./Ph.D. program in STEM fields. The program is also committed to providing research opportunities to students traditionally underrepresented in STEM fields and to those who attend schools where undergraduate research is limited. Amgen Scholars receive a $6,275 stipend for the ten-week period.

See: http://www.amgenscholars.com/us-program

University of Colorado SMART Program: The SMART program is intended for undergraduate students who are interested in preparing for graduate degrees in science, math and engineering. SMART offers students the opportunity to conduct research under the guidance of a faculty mentor, and participate in workshops designed to strengthen scientific writing and oral presentation skills. SMART interns earn upper-division undergraduate credit in independent study, and receive a stipend, room and board, and travel expenses.

See: https://www.colorado.edu/smart/undergraduates/smart-program-information

Research Opportunities Outside of Colorado College, Continued

Big 10 Universities Summer Research Opportunities Program (SROP): A summer research program that provides undergraduate students from populations underrepresented in graduate study with an opportunity to explore careers in research. The program provides students with an experience that will help strengthen their knowledge, skills, and understanding of graduate school. Since 1986, Summer Research Opportunities Program (SROP) has brought talented undergraduate students from across the US and its territories, such as Puerto Rico, as an introduction to graduate study, research, and the admission process. The many activities offered through the SROP gives participants an opportunity to establish important relationships with faculty in their respective fields of study and conduct graduate-level research under the supervision of a renowned faculty member. Participants will also become acquainted with the culture of graduate school and learn what is needed & expected of them as graduate students in their discipline.

See: http://www.btaa.org/resources-for/students/srop/introduction

Kansas University Undergraduates Studying Pharmaceutical Chemistry: The Department of Pharmaceutical Chemistry offers a 10-week summer undergraduate research program. Students perform independent research under the supervision of faculty members, applying chemical principles to problems involving drugs and related molecules. In pharmaceutical chemistry, the emphasis is on promoting the therapeutic effects of the drug or minimizing toxicity, or controlling delivery of the drug to specific sites of action. This involves increased attention to physical-organic, physical and analytical chemistry. Participants receive basic instruction in laboratory and research techniques, including laboratory safety, effective use of major university science library, and instruction in first-hand use of specialized laboratory instrumentation of importance to a given research problem. The program is designed to provide an opportunity for students to evaluate the possibility of entering a graduate program in the pharmaceutical sciences. Accordingly, students are provided the opportunity of engaging in a full-time research experience in close collaboration with faculty members and graduate students. As a direct result of the summer undergraduate research experience, many of our former participants have entered graduate schools and successfully completed doctoral degrees.

See: https://pharmchem.ku.edu/undergraduate-research-programs

Summer Internship in Biomedical Health (SIP) at the National Institutes of Health (NIH): Summer programs at the National Institutes of Health (NIH) provide an opportunity to spend a summer working at the NIH side-by-side with some of the leading scientists in the world, in an environment devoted exclusively to biomedical research (At the NIH "biomedical sciences" includes everything from behavioral and social sciences, through biology and chemistry, to physics, mathematical modeling, computational biology, and biostatistics). The NIH consists of the 240-bed Mark O. Hatfield Clinical Research Center and more than 1150 laboratories/research groups located on the main campus in Bethesda, MD, and the surrounding area as well as in Baltimore and Frederick, MD; Research Triangle Park, NC; Hamilton, MT; Framingham, MA; Phoenix, AZ; and Detroit, MI. Internships cover a minimum of eight weeks, with students generally arriving at the NIH in May or June. The NIH Institutes and the Office of Intramural Training & Education sponsor a wide range of summer activities including lectures featuring distinguished NIH investigators, career/professional development workshops, and Summer Poster Day.

See: https://www.training.nih.gov/programs/sip

MIT Summer Research Program (MSRP): The MIT Summer Research Program (MSRP) seeks to promote the value of graduate education; to improve the research enterprise through increased diversity; and to prepare and recruit the best and brightest for graduate education at MIT. MSRP began in 1986 as an institutional effort to address the issue of underrepresentation of African Americans, Mexican Americans, Native Americans, and Puerto Ricans in engineering and science in the United States. Today, this program's goal is to increase the number of underrepresented minorities and underserved (e.g. low socio-economic background, first generation) students in the research enterprise. MSRP seeks to identify talented sophomores, juniors, and non-graduating seniors who might benefit from spending a summer on MIT's campus, conducting research under the guidance of MIT faculty members, post-doctoral fellows, and advanced graduate students. Students who participate in this program will be better prepared and motivated to pursue advanced degrees, thereby helping to sustain a rich talent pool in critical areas of research and innovation.

See: http://odge.mit.edu/undergraduate/msrp/

Research Opportunities Outside of Colorado College, Continued

Woods Hole Fellowship in Oceanography for Minority Undergraduates: Summer Student Fellowships are awarded to undergraduate students who are completing their junior year at colleges or universities and are studying in any of the fields of science or engineering including but not limited to the fields of biology, chemistry, engineering, geology, geophysics, mathematics, meteorology, physics, oceanography, and marine policy. Students must have at least a tentative interest in the ocean sciences, oceanographic engineering, mathematics, or marine policy. Persons from underrepresented groups are encouraged to apply. WHOI actively recruits underrepresented minorities in ocean science as defined by the National Science Foundation (African-, Hispanic- and Native-Americans, and Pacific Islanders) in all of our education programs, as well as programs of the Woods Hole Diversity Initiative, such as the Woods Hole Partnership Education Program.

See: http://www.whoi.edu/page.do?pid=8065

Research Intensive Summer Experience (RISE) at Rutgers: a nationally acclaimed summer research program for outstanding undergraduates from diverse backgrounds. Scholars participate in 10 weeks of cutting-edge research in the biological, physical, and social/behavioral sciences, math, engineering, and exciting interdisciplinary areas under the guidance of carefully matched faculty mentors. A comprehensive professional development component, including GRE preparation, complements the research.

See: https://www.rise.rutgers.edu/

Binghamton Louis Stokes Alliance for Minority Participation (LSAMP) Summer Research Internship: The LSAMP Summer Research Internship Program is an 8 week paid summer internship here at Binghamton University, during which you will work as a Research Assistant on a faculty-designed research project, at least 30 hours a week. LSAMP is funded to increase the number of underrepresented minorities (African-American, Latino, Native American, Alaskan Native, Hawaiian Native, and Native Pacific Islander) who pursue careers in science, technology, engineering and mathematics.

See: https://www.binghamton.edu/lsamp/summer-research.html

Naval Research Enterprise Internship Program (NREIP): Provides an opportunity for college students to participate in research at a Department of Navy (DoN) laboratory during the summer. The goals of NREIP are to encourage participating college students to pursue science and engineering careers, to further education via mentoring by laboratory personnel and their participation in research, and to make them aware of DoN research and technology efforts, which can lead to employment within the DoN. NREIP provided competitive research internships to approximately 560 college students last summer. Participating students spend ten weeks during the summer conducting research at approximately 38 DoN laboratories.

See: https://nreip.asee.org/

Department of Energy (DOE) Science Undergraduate Laboratory Internships (SULI): The Science Undergraduate Laboratory Internship (SULI) program encourages undergraduate students to pursue science, technology, engineering, and mathematics (STEM) careers by providing research experiences at the Department of Energy (DOE) laboratories. Selected students participate as interns appointed at one of 17 participating DOE laboratories/facilities. They perform research, under the guidance of laboratory staff scientists or engineers, on projects supporting the DOE mission. The SULI program is sponsored and managed by the DOE Office of Science's, Office of Workforce Development for Teachers and Scientists (WDTS) in collaboration with the DOE laboratories/facilities. Applications for the SULI program are solicited annually for three separate internship terms. Internship appointments are 10 weeks in duration for the Summer Term (May through August) or 16 weeks in duration for the Fall (August through December) and Spring (January through May) Terms. Each DOE laboratory/facility offers different research opportunities; not all DOE laboratories/facilities offer internships during the Fall and Spring Terms.

See: https://science.energy.gov/wdts/suli/

National Renewable Energy Lab (NREL): Undergraduate students have the opportunity to join the NREL team as an intern while gaining valuable mentoring experience, participating in the lab's research and development programs, and establishing ongoing collaborations through NREL's Research Participant Program. Full-time undergraduate students currently enrolled in a U.S. college or university who have successfully completed at least the sophomore year of school by June of the current year and plan to continue full-time enrollment during the following fall term are eligible for NREL's Research Participant Program internships. Students must have a minimum cumulative GPA of 3.0 in the last completed semester to be eligible. The internship term is flexible, with up to 40 hours per week in the summer.

https://www.nrel.gov/careers/nrel-internships.html

Research Opportunities Outside of Colorado College, Continued

Nakatani RIES Fellowship For U.S. Students: The Nakatani RIES Fellowship for U.S. Students is a 13-week, summer research internship in science & engineering that is open to freshman and sophomore engineering students from universities nationwide. This summer program seeks to cultivate interest in science & engineering research among young U.S. undergraduate students, especially those from underrepresented groups, and encourages such students to pursue future graduate study. To be eligible students must be U.S. citizens or permanent residents. Up to 12 students will be selected to participate annually.

See: http://nakatani-ries.rice.edu/u-s-fellows/about-u-s-program/

Oak Ridge National Laboratory (ORNL): Oak Ridge National Laboratory has two internship programs that support summer research, the Nuclear Engineering Science Laboratory Synthesis (NESLS) and the Higher Education Research Experiences (HERE). NESLS provides nuclear engineering research opportunities and associated activities for undergraduate students through cooperative research with mentors at the national lab. The program is open to full- or part-time student enrolled at an accredited U.S. college or university in a nuclear engineering, science, or eligible related degree with a cumulative GPA of 3.0. US citizenship is not required. The internship duration is flexible, with a suggested minimum of 10 weeks in summer with a required poster session. HERE provides research opportunities and associated activities for undergraduate students. The program is designed to complement academic programs by utilizing the unique resources of ORNL to enhance science, technology, engineering, and mathematics (STEM) education, encourage careers in science and technology, and improve scientific literacy, while at the same time contributing to the Laboratory mission. Participating students must Be currently enrolled as an undergraduate student at a U.S. accredited institution and have a cumulative GPA of 2.5. The internship duration is flexible. Students must be a U.S. Citizen or Legal Permanent Resident at the time of application to be eligible.

https://orise.orau.gov/ornl/nesls/default.html

https://orise.orau.gov/ornl/hereatornl/undergraduates.html