REU Site: Research in Chemistry at West Virginia University

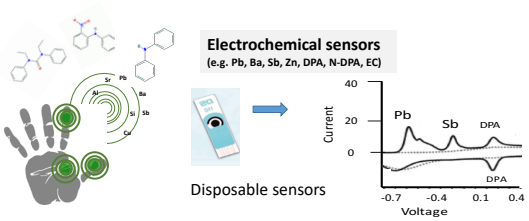
2019 Project Descriptions

Electrochemical Analysis of Organic Compounds in Firearm Discharge Residues

Main faculty supervisor

Dr. Luis E. Arroyo (Department of Forensic and Investigative Science ; https://forensics.wvu.edu/faculty-and-staff/faculty/luis-arroyo

Goals of the project (for the summer)



The primary purpose of this study is to utilize electrochemical techniques that allow the screening and detection of organic nitro compounds present in firearms discharge residues. The primary focus will be the implementation of methods, like cyclic voltammetry or differential pulse voltammetry, for the analysis of a suite of organic gunshot residue (OGSR) materials including: ethyl centralite (EC), nitroglycerin (NG), dinitrotoluene (2,4-DNT), diphenylamine (DPA), 2 nitrodiphenylamine (2-NDPA), and 4-nitrodiphenylamine (4-NDPA).

Different firearms and ammunition will be fired at the WVU-FIS Ballistic Laboratory under control environmental conditions. Gunshot residues samples will be collected from the hands of a shooter (palm and back of right and left hands), and non-shooters as well as negative controls. Sample collection will be performed by using carbon conductive tabs mounted on graphite planchets over aluminum stubs. The samples will be stored on single mount storage boxes and transported to the laboratory for analysis.

Project description

Firearms generate a wide array of residual materials after an ammunition discharge event. The expelled gases, vapors and mainly particulate residues are deposited on the hands and clothes of an individual who has discharged a firearm; handle a firearm that has recently been fired; was in proximity to the firearm; touched an object that has been handled by a person who recently fired a firearm. Several chemical entities are released, and they are collectively called firearm discharge residue (FDR) or gunshot residues (GSR). Organic gunshot residues (OGSR) particles originate from the ammunition propellant, but other sources include the primer mixture, lubricants and organic materials present in the firearm. The primary hypothesis of this study relies on the informative power of organic compounds and the additional evidentiary value attribute to their presence in the questioned material. Additionally, electrochemical methods provide a faster, non-destructive, and more affordable approach towards the detection of relevant nitro-compounds.

Experimental/theoretical skills that participant will acquire

- Analytical chemistry, electrochemistry, developing experimental procedures, sample collection, and analysis of organic gunshot residues.
- Data acquisition and Data interpretation.

Location of the project

Department of Forensic and Investigative Research Labs (Rooms OGH 203) WVU Downtown Campus

Key references for further reading

1. T. Trejos, C. Vander Pyl, K. Menking-Hoggatt, A.L. Alvarado, L.E. Arroyo "Fast Identification of inorganic and organic gunshot residues by LIBS and electrochemical methods," *Forensic Chemistry* **8**, 146-156 (2018).
2. A.M. O'Mahony, J. Wang, , "Electrochemical Detection of gushot residue for forensic analysis: a review," *Electroanalysis.* **25**, 1341-1358 (2013).
3. W.A. Cox, "Gunshot Residue Analysis," *Forensic Science Newsletter.* www.forensicjournals.com (July 2016).

Separation-Based Characterization of Biological Therapeutics

Main faculty supervisor:

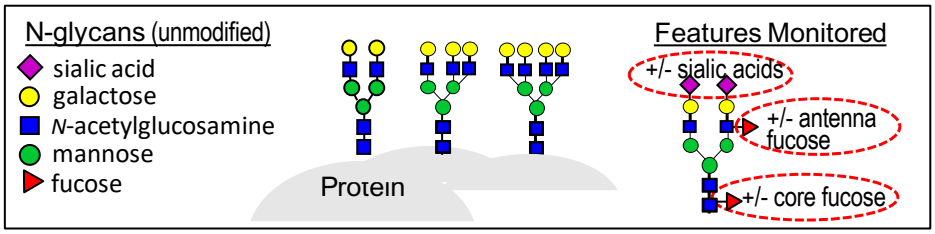
Lisa Holland (C. Eugene Bennett Department of Chemistry); http://www.as.wvu.edu/~lholland/

Goals of the project (for the summer)

Sequence and quantify post-translational glycosylation in an antibody therapeutic.

Project description

Biological therapeutics, which are protein-based drugs, are new and successful treatment strategies for cancer. Biotherapeutics are estimated to comprise $125 billion of the annual global market by 2020. Glycans are post-translationally added to proteins and play critical roles in signaling and communication. Glycosylation on antibody therapeutics represent on 1.5% of the protein mass; yet, control the effectiveness of antibody-based strategies to mark cancer cells to be cleared by the immune system. Glycan analyses are challenging because the saccharide monomers that form them are structurally similar and can be combined in a wide variety of ways. Pharmaceutical manufacturers and regulators struggle to ensure that the protein glycosylation is appropriate for patented drugs and generics. Characterization of biotherapeutics through capillary electrophoresis methods benefit from small sample volume requirements, rapid analysis times, and high resolution separations. The Holland lab has developed a novel separation additive called a nanogel to rapidly identify and quantify protein glycosylation. The student researcher will use this technique to characterize a biological drug. The research will be documented through the REU poster and will be included in a publication. The student will learn analytical figures of merit, fundamentals of separations, and glycan analyses.



Experimental/theoretical methods

- Capillary electrophoresis
- laser induced fluorescence
- glycan conjugation

Location of the project

Chemistry Research Labs (Rooms 351, 353), WVU Downtown Campus

Key references for further reading

G. Lu, L.A. Holland, Profiling the n-glycan composition of igg with lectins and capillary nanogel electrophoresis, *Anal. Chem.*, 91 (**2019**) 1375–1383.

G. Lu, C.L. Crihfield, S. Gattu, L.M. Veltri, L.A. Holland, Capillary electrophoresis separations of glycans, *Chem. Rev.*, 118 (**2018**) 7867-7885.

Collection of Mass Spectra to Support the Development of a new Mass-Spectral Comparison Algorithm

Main faculty supervisor

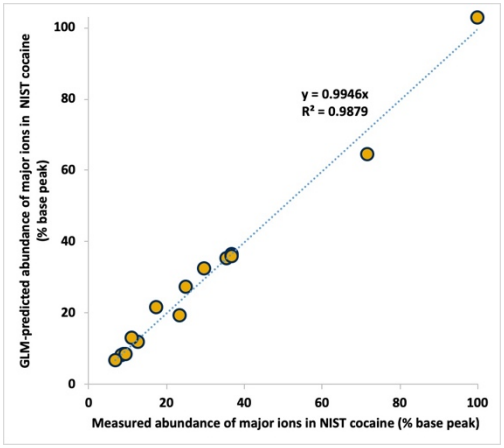
Dr. Glen P. Jackson (Forensic and Investigative Science and C. Eugene Bennett Department of Chemistry); http://glen-jackson.eberly.wvu.edu/

Goals of the project (for the summer)

The student will collect replicate spectra of a variety of drug standards on multiple instruments over several weeks. The student will then export the data and perform some preliminary data pre-processing to provide a suitable database of spectra for the project. This research will address a long-standing problem in forensic science in which analysts struggle to provide a level of confidence with their drug identifications. The data will be used to develop and test a new algorithm that will provide both probabilities of identifications with measures of false positive and false negative rates.

Project description

Current mass-spectral comparison algorithms attempt to provide probability-based scores for the identity of the substance providing the queried spectrum [1-3]. However, existing algorithms tend to provide a list of the closest matching spectra in a database rather than providing a probability of a certain compound. Our algorithm is different in that it accounts for non-random variance between replicate spectra and minimizes the uncertainty in ion abundance measurements. The result is that the new algorithm is far more precise than other algorithms and can enable the differentiation of stereoisomers like cocaine and pseudococaine. This project will enable a better understanding for the interpretation of evidence.



Experimental/theoretical skills that participant will acquire

- Calibration and tuning of a gas chromatography/mass spectrometer
- Sample preparation and analysis
- Data acquisition and interpretation
- Critical and analytical reasoning

Location of the project

Oglebay Hall 221 and 207, WVU Downtown Campus

Key references for further reading

[1] F.W. McLafferty, D.A. Stauffer, S.Y. Loh, C. Wesdemiotis, Unknown Identification Using Reference Mass Spectra. Quality Evaluation of Databases, *J. Am. Soc. Mass Spectrom*. 10 (1999) 1229-1240.

[2] S.E. Stein, D.R. Scott, Optimization and Testing of Mass Spectral Library Search Algorithms for Compound Identification, *J. Am. Soc. Mass Spectrom*. 5 (1994) 859-866.

[3] S. Stein, Mass spectral reference libraries: an ever-expanding resource for chemical identification, *Anal. Chem*. 84(17) (2012) 7274-82.

On the Degradation of Promethazine in "Purple Drank"

Main faculty supervisor

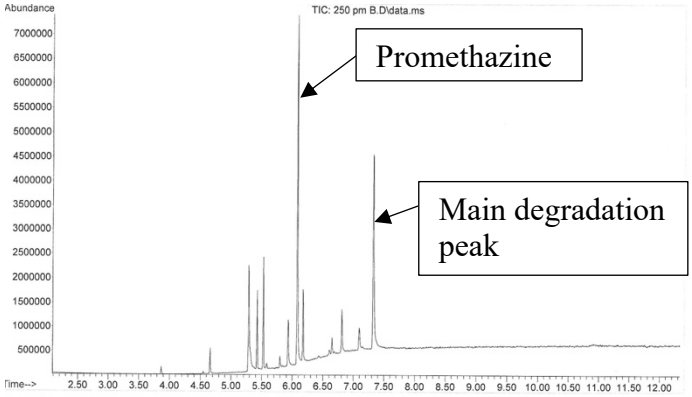
Dr. Glen P. Jackson (Forensic and Investigative Science and C. Eugene Bennett Department of Chemistry); http://glen-jackson.eberly.wvu.edu/

Goals of the project (for the summer)

The student will study the factors that affect the degradation of promethazine in forensic samples of "purple drank" [1]. The student will use a variety of chemical analytical techniques to understand the chemical nature of different degradation products of promethazine under different conditions. This knowledge will help drug analysts characterize prescription-strength cough syrups in casework samples which have undergone degradation.

Project description

Previous work in our laboratory has shown that short-wave UV light is responsible for converting promethazine into a substance that is most likely an oxidation product of promethazine, which causes significant problems in crime labs where "purple drank" samples are commonly analyzed. This project will investigate the reaction kinetics and solution chemistry conditions that influence the occurrence of degradation of promethazine.



Experimental/theoretical skills that participant will acquire

- Calibration and tuning of a gas chromatography/mass spectrometer
- Use of HPLC, UV-Vis and FTIR
- Sample preparation and analysis
- Data acquisition and interpretation
- Critical and analytical reasoning

Location of the project

Oglebay Hall 221 and 207, WVU Downtown Campus

Key reference for further reading

1. L.E. Agnich, J.M. Stogner, B.L. Miller, C.D. Marcum, Purple drank prevalence and characteristics of misusers of codeine cough syrup mixtures. Addict Behav. 38 (2013) 2445-2449.

Acoustic Wave based Fluid Manipulation in 3D Printed Microdevices

Main faculty supervisor

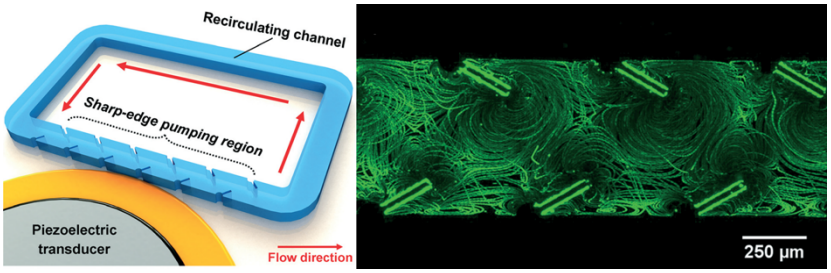
Dr. Peng Li (C. Eugene Bennett Department of Chemistry);
http://community.wvu.edu/~pl0010/

Goals of the project (for the summer)

Develop acoustic wave based fluid manipulation method for point of care diagnosis.

Project description

Microfluidic devices are miniature systems that process fluid samples down to the picoliter level. The potential to use extremely small sample volumes has generated significant interest in diverse fields such as cell biology, genomic analysis, and medical diagnostics. Nevertheless, only a few devices have yet been developed for practical applications and commercialized. The goal of my research program is to develop portable and high-performance point-of-care (POC) medical diagnostic systems based on acoustofluidic technology as applied to key fluid operation units such as fluid pumping and mixing devices. Devices such as these are critical to the success of shifting healthcare from curative medicine to preventive and personalized medicine. We will exploit advanced 3D printing technologies to produce the devices. Particularly, we will design, build and test various geometrical configurations to determine optimal designs for medical applications dealing with human blood. The participating student will join ongoing efforts to develop novel fluid mixing and pumping methods for 3D printed microdevices with unique advantages of active operation, rapid response, minimum peripheral equipment requirements, and high biocompatibility.



Experimental/theoretical skills that the participant will acquire

- Learn basic microfabrication techniques;
- Learn the principle of light microscopy and its application in microfluidics.
- Understand the application of acoustic waves in biomedical research.
- Design 3D printing ready microstructures and investigate its impact on acoustic streaming;
- Acquire and process digital images.

Location of the project

Chemistry Research Labs (Rooms 456, 558, 560), WVU Downtown Campus

Key references for further reading

1. P.-H. Huang, N. Nama, Z. Mao, P. Li, J. Rufo, Y. Chen, Y. Xie, C.-H. Wei, L. Wang, and T. J. Huang., *Lab on a chip*, 14, 4319-4323 (2014).
2. P. Li, Z. Mao, Z. Peng, L. Zhou, Y. Chen, P.-H. Huang, C. I. Truica, J. J. Drabick, W. S. El-Deiry, M. Dao, S. Suresh, and T. J. Huang, *PNAS*, 112, 4970-4975 (2015).

Chemical Imaging of Gunshot Residues by Laser-Induced Breakdown Spectroscopy (LIBS)

Main faculty supervisor

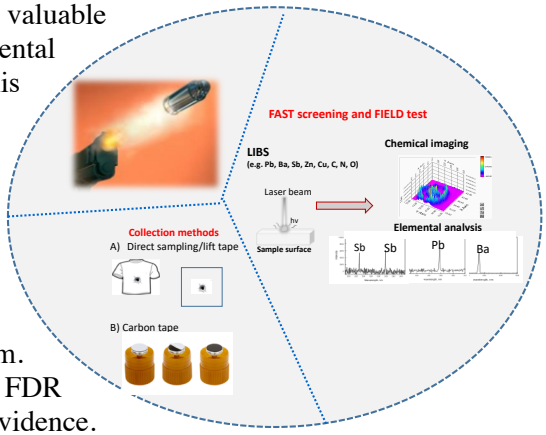
Dr. Tatiana Trejos (Department of Forensic and Investigative Science); https://forensics.wvu.edu/faculty-and-staff/faculty/tatiana-trejos

Goals of the project (for the summer)

We will collect gunshot residues from clothing and glass windows and analyze the inorganic components by LIBS and colorimetric tests. Comparisons will be made to evaluate the efficiency and reliability of the methods for estimation of shooting distances and identification of bullet holes in target substrates.

Project description

The detection of firearm discharge residues (FDR) provides valuable information in cases involving homicides, suicides, accidental shootings, and terrorism. Despite the scientific validity of this discipline, there are persisting challenges regarding the speed of analysis, preservation of the evidence, and interpretation of results. Consequently, there is a critical need to develop methods that can improve the response time and reliability of these determinations.



Our long-term goal is to develop a comprehensive approach to overcome these significant concerns and to enhance current capabilities in the criminal justice system. This project aims to develop and validate fast tests for FDR detection and statistical models for the interpretation of the evidence.

Our central hypothesis is that LIBS will provide screening methods that are quicker, more selective, and more informative than current colorimetric assays. A notable advantage of LIBS is that it can identify a more substantial number of elements used in modern ammunition and generate 3D-chemical images of the spatial distribution of FDR for more objective estimations of shooting distance, identification of bullet holes and scanning of large areas. The advanced technology is expected to be a transformative approach for enhancing the efficiency and efficacy of FDR examinations.

Experimental/theoretical skills that participant will acquire

· Analytical chemistry and forensic chemistry techniques associated with sample collection and analysis of gunshot residues.
· Data acquisition with LIBS instrument and colorimetric tests.
· Data analysis and interpretation for semi-quantitative comparisons and chemical imaging patterns for shooting distance determinations and characterization of gunshot residues.

Location of the project

Department of Forensic and Investigative Science research labs (Rooms 315, G1 and 217B), WVU Downtown Campus

Key references for further reading

1) T. Trejos, C Vander Pyl, K Menking-Hoggatt, AL Alvarado, L Arroyo. Fast Identification of Inorganic and Organic Gunshot Residues by LIBS and Electrochemical Methods, **in press,** *Forensic Chemistry, Elsevier*. Available online March0318 https://doi.org/10.1016/j.forc.2018.02.006
2) Blakey, L. S.; Sharples, G. P.; Chana, K.; Birkett, J. W. Fate and Behavior of Gunshot Residue: A Review. *J. For. Sci.* **2017**, 1-11.
3) López-López M., Alvarez-Llamas C., Pisonero J., García-Ruiz C., and Bordel N. An exploratory study of the potential use of LIBS for visualizing gunshot residue patterns. Forensic Science International. 2017; 273:124-131.

Comparative Metabolomic Profiling with LC-MS

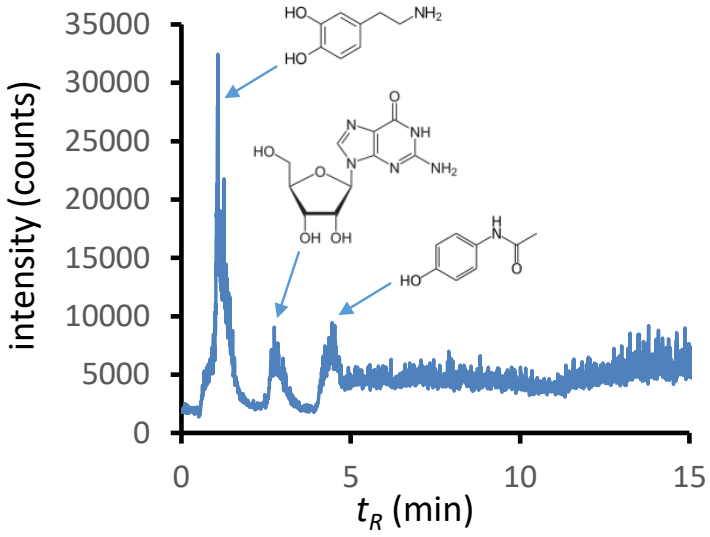
Main faculty supervisor

Dr. Stephen Valentine (C. Eugene Bennett Department of Chemistry);
http://chemistry.wvu.edu/faculty-staff/faculty/stephen-valentine

Goals of the project (for the summer)

We will develop liquid chromatography (LC) – mass spectrometry (MS) methods for characterizing complex metabolite mixtures. Upon optimization of the LC-MS methods, the techniques will be demonstrated for comparative metabolomics analyses.

Project description



Metabolite extracts produce complex mixtures of chemicals. Analyses of such mixtures requires multiple separation techniques to allow individual comparisons. The figure shows a recent LC-MS separation of three metabolite compounds. Although the three analytes are baseline resolved in this first attempt, significant improvements in LC separation and ionization efficiency are required for comparisons of complex metabolite mixtures. In the experiments proposed here, improved methods for compound separation using a C18 column will be developed. Additionally, MS methods development will allow improved ionization of separated metabolite compounds. Upon optimization of the separation and MS methods, the techniques will be used to characterize standard compound mixtures having different analyte concentrations to demonstrate figures of merit for comparative metabolomics analyses. The improved separation and ionization capabilities may potentially aid comparative 'omics studies aimed at determining biomarkers associated with disease onset and progression.

Experimental/theoretical skills that participant will acquire

- Analytical chemistry techniques associated with metabolomics sample preparation
- Data acquisition with LC-MS instrument
- Data manipulation and interpretation for semi-quantitative comparisons

Location of the project

Clark Hall Instrumentation Lab (Room 400), WVU Downtown Campus

Key references for further reading

1. Maleki, H.; Karanji, A. K.; Majuta, S.; Maurer, M. M.; Valentine, S. J. *J. Am. Soc. Mass Spectrom.* **2017**, doi: 10.1007/s13361-017-1798-5.
2. Maleki H.; Maurer, M. M.; Valentine, S. J. *Anal. Chem.* **2017**, *89*, 6399-6407.

Reactions of biofuel derivatives with combustion free radicals

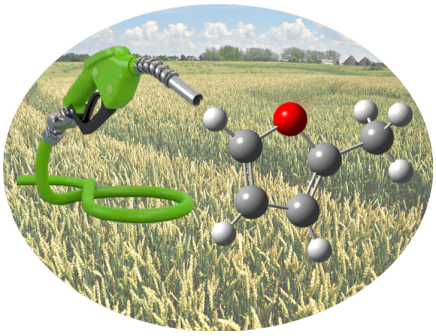
Main faculty supervisor

Dr. Fabien Goulay (C. Eugene Bennett Department of Chemistry);
https://fabiengoulay.faculty.wvu.edu/

Goals of the project (for the summer)

Using laser photolysis and laser spectroscopy to measure the reaction rate coefficient of the CN radical with methyl-furan (C_5H_6O) from room temperature to 700 K. The experimental data will be coupled to computational results in order to infer the most likely reaction mechanism.

Project description



Combustion chemistry is governed by complex free radical reaction schemes at temperatures up to 2000 K, and ultimately leading to the production of energy and unwanted products. The transition toward an efficient use of biomass derived fuels is still limited by our understanding of combustion chemical mechanisms, especially the formation of large molecules containing both nitrogen and oxygen heteroatoms. Furan derivatives are formed during the thermal processing of biomass and are an archetypal molecule for the study of biofuel combustion chemistry. Their reactions with the combustion abundant CN radical may lead to the formation of large molecules containing both an oxygen and nitrogen atom. The reaction of CN with methyl furan will be investigated in a static reaction cell and pulsed fast flow reactor using pulsed laser photolysis and laser induced fluorescence. The data will be used to infer the most likely reaction products. This will improve our understanding of biofuel combustion chemistry and accelerate the transition toward a more efficient use of biomass as a source of energy.

Experimental/theoretical skills that participant will acquire

- Physical chemistry, developing experimental procedures
- Data acquisition and Labview programing
- Laser spectroscopy
- Vacuum techniques
- Initiation to Gaussian 09

Location of the project

Chemistry Research Labs (Rooms 473), WVU Downtown Campus

Key references for further reading

1. Thapa, J.; Spencer, M.; Akhmedov, N. G.; Goulay, F. *J. Phys. Chem. Lett.* **2015**, 6, 4997–5001
2. Carrasco, E.; Smith, K. J.; Meloni, G. J. Phys. Chem. A **2018**, 122, 280-291

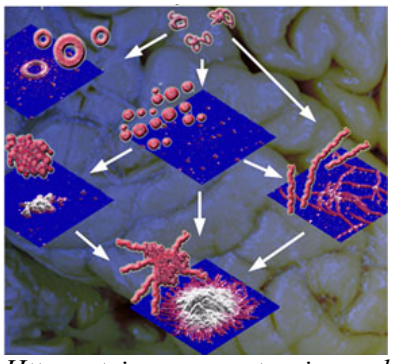
Molecular Mechanisms of Huntingtin Interactions with Lipid Membranes

Main faculty supervisor

Dr. Justin Legleiter (Associate Professor); http://legleiterlab.wvu.edu/

Goals of the project (for the summer)

The goal is to elucidate the role of lipids on huntingtin (htt) misfolding, aggregation, and related toxicity by determining the impact htt aggregates have on the integrity of cellular and subcellular membranes. We are pursuing these specific aims: 1) Identify lipid components that modulate binding of htt to membranes; and 2) Determine how post-translational modification (PTM) alter htt/lipid interactions.



Htt protein aggregates imaged by AFM.

Project description

There is a fundamental gap in understanding how small aggregates formed by mutant forms of htt with expanded polyQ tracts gain toxic biological properties causing Huntington's disease (HD) and, more specifically, how these proteins interact with cellular surfaces comprised of lipids. Continued existence of this gap represents an important problem because these interactions may represent a fundamental step in htt-induced cellular toxicity and understanding of this phenomenon can lead to new targets for therapeutic intervention. Students will use scanning probe and a variety of vesicle-based assays to characterize and measure the endogenous interactions occurring between htt and membranes enriched with cholesterol, sphingomyelin, or GM1. They will also use a combination of spectroscopic, mass spectrometry, and scanning probe techniques to study the role biologically PTMs play in modulating htt/lipid interactions.

Experimental/theoretical skills that participant will acquire

- Biophysical chemistry, scanning probe microscopy, protein/peptide preparation.
- Data analysis and MatLab programing.

Location of the project

Chemistry Research Labs (Rooms 251 and 556), WVU Downtown Campus

Key references for further reading

1. Gao X., Campbell IV W.A., Chaibva M., Jain P., Frey S.L., and Legleiter J. Cholesterol modifies huntingtin binding to, disruption of, and aggregation on lipid membranes. Biochemistry (2016) 55:92-102.
2. Chaibva M., Burke K.A., and Legleiter J. Curvature Enhances Binding and Aggregation of Huntingtin at Lipid Membranes. Biochemistry (2014) 53:2355-2365.
3. Burke, K.A., Yate, and Legleiter, J. Biophysical insights into how surfaces, including lipid membranes, modulate protein aggregation related to neurodegeneration. Frontiers in Neurology (2013) 4:17.

Computational characterization of the binding and folding process of the drug delivery pHLIP peptide

Main faculty supervisor

Assistant Professor Blake Mertz (Bennett Dept. of Chemistry); http://www.mertzlab-biophysics.com

Goal of the project (for the summer) Accurately determine the energetic contribution of the cell membrane to the folding process of pHLIP.

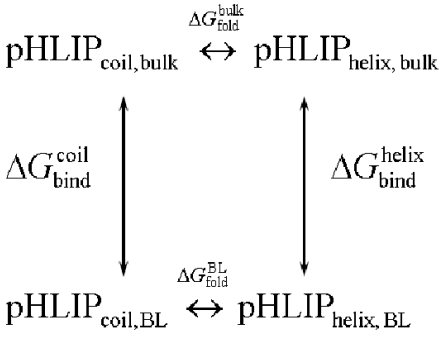
Project description: pH-Low Insertion Peptide (pHLIP) is a peptide that has the ability to insert itself into a cell membrane. In solvent at physiological (pH 7.2-7.4), pHLIP exists as a monomer in a coiled conformation. When pHLIP encounters a cell membrane, it binds to the membrane as a coil. Upon lowering the pH to acidic levels (pH 4-6.5), pHLIP folds into an α-helix and unidirectionally inserts into the membrane. This ability to bind, fold, and insert into a cell membrane in acidic environments presents the opportunity to utilize pHLIP as a carrier of drugs or imaging agents that can target specific areas of the body that possess an acidic microenvironment, such as cancer cells. However, the thermodynamics and structural details of the binding and folding process are poorly understood.

pHLIP sequence: AEQNPIYWARYA**D**^{14}WLFTTPLLLL**D**^{25}LALLV**D**^{31}A**D**^{33}**E**^{34}GCT

Methods: You will carry out four sets of steered molecular dynamics simulations:

1. Binding of coiled pHLIP (net charge -5) from solvent to the lipid bilayer surface
2. Binding of α-helical pHLIP (net charge -5) from solvent to the lipid bilayer surface
3. Binding of coiled pHLIP (net charge -3) from solvent to the lipid bilayer surface
4. Binding of α-helical pHLIP (net charge -3) from solvent to the lipid bilayer surface

We will conduct two sets of simulations because pHLIP folds into a helix only after 1) it's bound and 2) the pH drops from alkaline (pH 8) to acidic (pH 4) levels, and we can't model instantaneous pH changes using MD simulations. After carrying out the MD simulations, you will calculate the potential of mean force (PMF) for each binding event (see Park and Schulten 2004). Once you have obtained the PMF, you can then calculate the free energy of binding (ΔG_{bind}) that is gained when pHLIP binds to the bilayer surface. Knowledge of this information will allow you to calculate the corresponding free energies of the upper and lower reactions in the thermodynamic cycle shown to the right:



Experimental/theoretical skills that participant will acquire

- Biophysical chemistry: learning how to conduct computational molecular dynamics (MD) simulations.
- Data analysis and basic command line and programming skills.

Key references for further reading

1. Deacon, J.C., Engelman, D.M., Barrera, F.N. "Targeting acidity in diseased tissues: Mechanism and applications of the membrane-inserting peptide, pHLIP." *Arch. Biochem. Biophys.* (2015) 565: 40-48.
2. Park, S., Schulten, K., "Calculating potentials of mean force from steered molecular dynamics simulations." *J. Chem. Phys.* (2004) 120:5946-5961.
3. Primer on how molecular dynamics works: https://www.youtube.com/watch?v=lLFEqKl3sm4

Chemical synthesis of pharmacologically active molecules

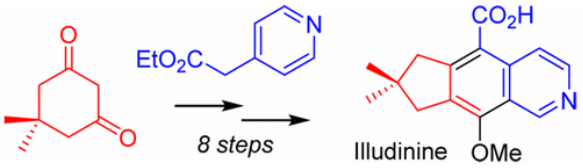
Main faculty supervisor

Dr. Gregory Dudley (C. Eugene Bennett Department of Chemistry);
http://www.chemistry.wvu.edu/faculty-and-staff/directory/chair-and-leadership/gregory-dudley

Goals of the project (for the summer)

Apply recent methodology from the Dudley lab to prepare high-value alkyne building blocks, and use them for the synthesis of important molecular targets.

Project description



Our fundamental research goal is to devise, develop, and apply new ideas in organic chemistry to the efficient synthesis of interesting molecules, particularly natural products with medicinal applications. Natural products research impacts the development of many important drugs; relevant examples include aspirin, penicillin, cortisone, and paclitaxel. Complex natural products arise from millions of years of evolutionary screening, and often target specific interactions in intricate biological systems. In these and many other cases, organic synthesis plays a key role in helping us capitalize on desired biological activities. We can continue to benefit from this natural selection process by developing practical syntheses of natural products and analogs.

Experimental/theoretical skills that participant will acquire

- Synthesis of organic and inorganic molecules.
- Manipulation of air-sensitive materials.
- Purification and separation of chemical mixtures.
- Characterization of compounds by modern analytical methods.
- Experimental design and scientific method

Location of the project

Chemistry Research Labs (Rooms 358 and 360), WVU Downtown Campus

Key references for further reading

1. Morrison, A. E.; Hoang, T. T.; Birepinte, M.; Dudley, G. B. Synthesis of illudinine from dimedone. *Org. Lett.* **2017**, *19*, 858–861.
2. Kramer, N. J.; Hoang, T. T.; Dudley, G. B. Reaction discovery using neopentylene-tethered coupling partners: cycloisomerization/oxidation of electron-deficient dienynes. *Org. Lett.* **2017**, *19*, 4636–4639.
3. Hoang, T. T.; Dudley, G. B. Synthesis of high-value 1,6-enynes by tandem fragmentation / olefination. *Org. Lett.* **2013**, *15*, 4026–4029.

Development of New C-C Bond Forming Reactions Catalyzed by First Row Transition Metals

Main faculty supervisor

Dr. Jessica Hoover (C. Eugene Bennett Department of Chemistry);
http://chemistry.wvu.edu/faculty-staff/faculty/jessica-hoover and http://community.wvu.edu/~jmhoover/

Goals of the project (for the summer)

We will develop and study new C-C and C-X bond-forming reactions catalyzed by first-row transition metal systems. We will use our recently established Cu and Ni catalyst systems as a spring-board for the identification of new and interesting reactivity patterns.

Project description

Our research focuses on the development and understanding of new catalytic methods for organic synthesis. Catalytic reactions are becoming more commonly used in the synthesis of complex structures - pharmaceutical molecules (medicines), polymers (plastics, clothing) and fuels - among others. Unfortunately, in the application of catalysis to small molecules, it is not always clear how the reaction happens. If we can better understand the reactions and the catalysts, then we can develop improved methods that will be less expensive and generate less waste. In particular, our group has been interested in developing and understanding catalytic oxidative decarboxylative coupling reactions. These are reactions in which simple benzoic acids can be utilized as coupling partners to generate substituted arenes after the loss of CO_2. In this project, students will work towards the development of new catalytic reactions that use carboxylic acids to build new C-C or C-X bonds. This class of reactions is important for the efficient synthesis of biologically and pharmaceutically relevant molecules.

Experimental/theoretical skills that participant will acquire

- Synthetic organic chemistry skills (including basic reaction set-up and workup procedures, TLC analysis, column chromatography, etc.)
- Air-free synthetic methods such as Schlenk and glovebox techniques
- Spectroscopy (including ^{1}H and ^{13}C NMR, IR, and mass spectrometry)

Location of the project

Chemistry Research Labs (Rooms 550 and 583), WVU Downtown Campus

Key references for further reading

1. L. Chen, L. Ju, K. A. Bustin, J. M. Hoover *Chem. Commun.* **2015**, *51*, 15059-15062.
2. A. P. Honeycutt, J. M. Hoover *ACS Catal.* **2017**, *7*, 4596-4601.
3. R. A. Crovak, J. M. Hoover *J. Am. Chem. Soc.* **2018**, *140*, 2434-2437.

Luminescent Metal Complexes for Solar Energy Conversion

Main faculty supervisor

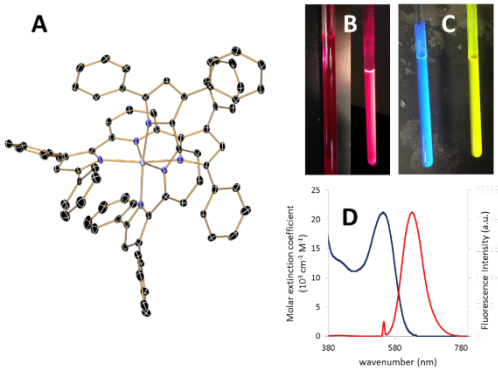
Dr. Carsten Milsmann (C. Eugene Bennett Department of Chemistry);
http://chemistry.wvu.edu/faculty-staff/faculty/carsten-milsmann

Goals of the project (for the summer)

Synthesize and characterize a new class of photo-active transition metal complexes for photovoltaic and photosynthetic applications.

Project description

Providing renewable and clean energy for the production of electricity and the synthesis of commodity and fine chemicals remains a major challenge of our time. The Milsmann group aims to replace precious, heavy metal photocatalysts based on ruthenium or iridium with compounds based on the readily available, non-toxic metals titanium and zirconium to enable large scale production of devices for solar energy conversion at low-cost. The REU student will be part of our team investigating the photochemical properties of early transition metal complexes and their application as photocatalysts in electron transfer reactions. The synthetic component of this research encompasses preparation of the ligand framework using established organic chemistry procedures followed by synthesis of the transition metal complexes under inert-atmosphere using a glovebox or Schlenk line techniques. The resulting complexes will be studied using a number of physical methods such as electrochemistry and various types of spectroscopy (NMR, UV-vis, EPR) to establish their photophysical and redox properties.



Experimental/theoretical skills that the participant will acquire

- Synthesis and characterization of organic and inorganic molecules.
- Manipulation of air-sensitive materials.
- Application of UV-vis absorption and fluorescence spectroscopy.
- Introduction to electrochemical methods.

Location of the project

Chemistry Research Labs (Rooms 458 and 460), WVU Downtown Campus

Key references for further reading

1. Zhang, Y.; Petersen, J. L.; Milsmann, C. *J. Am. Chem. Soc.* **2016**, *138*, 13115.
2. Loukova, G. V.; Smirnov, V. A. *Chem. Phys. Lett.* **2000**, *329*, 437.

Mild carboxylation methods using homogeneous base-metal catalysis

Main faculty supervisor

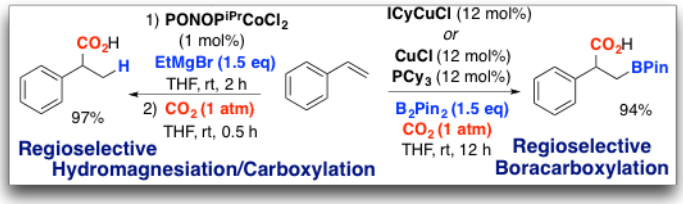
Dr. Brian Popp (C. Eugene Bennett Department of Chemistry);
http://community.wvu.edu/~bvpopp/index.html

Goals of the project (for the summer)

Develop new and improved synthetic methods for base-metal-catalyzed reductive carboxylation reactions.

Project description

Homogeneous transition-metal-catalyzed processes have supplied significant inspiration for the synthesis of many natural products and serve as methods to produce chemical feedstocks for nearly all consumer goods produced today. Unsaturated hydrocarbons, a byproduct of the catalytic cracking of petroleum, provide a route for the instillation of functional groups that are more useful precursors to the synthetic community. Historically, precious metal catalysts were heavily utilized; however, owing to environmental and economic drawbacks, the catalysis community has spent considerable effort to move away from these metals and towards the use of earth abundant metals (eg., Mn, Fe, Co, Ni, Cu). The Popp Group is specifically interested in the use of biocompatible cobalt and copper to replace rhodium- and platinum-based reduction chemistries. Recently, several reductive functionalization methods have been reported that allow for carboxylation under very mild conditions.[1] Our research group is actively developing new catalyst systems that achieve similar reactions. In order to fully unlock the potential of our new systems, we need to obtain a better understanding of the mechanism of catalyst action during the reaction. The participating student will join ongoing efforts to develop and expand carboxylation methodologies as well as to develop ways to achieve temporal resolution of these reactions through the use of diverse analytical monitoring techniques such as in situ infrared analysis.



Experimental/theoretical skills that the participant will acquire

- Learn basic techniques in synthetic chemistry
- Manipulate air-sensitive compounds and reactions;
- Apply the fundamentals of organometallic chemistry and catalysis;
- Design time-resolved assays using chromatographic and spectroscopic techniques;
- Assess and critically interpret data.

Location of the project

Chemistry Research Labs (Rooms 455, 460 , 462, 464), WVU Downtown Campus

Key references for further reading

1. Butcher, T. W.; McClain, E. J.; Hamilton, T. G.; Perrone, T. M.; Kroner, K. M.; Donohoe, G. C.; Akhmedov, N. G.; Petersen, J. L.; Popp, B. V. *Org. Lett.* **2016**, *18*, 6428.
2. Liu, Q.; Wu, L.; Jackstell, R.; Beller, M. *Nat. Commun.* **2014**, *6*, 1.