Washington State University

Department of Chemistry

Dear Students:

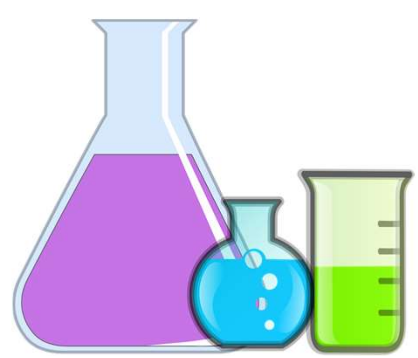
Welcome to Washington State University! All of us – faculty, students, post-docs, and staff – are glad you are here. You will be hard pressed to find another department that combines our world-class facilities, excellence in teaching, and cutting-edge research, with our low student-to-faculty ratios, friendly atmosphere, and supportive environment - all situated in a beautiful outdoor setting that is close to river rafting, pastoral bike paths, hiking, and skiing. Look around, ask questions, talk to us, and I think you will be impressed. You will see a department that is enthusiastic, vigorous, and interdisciplinary. You will find research efforts with emphases in our three focus areas of Chemistry of Energy and the Environment, Chemistry of Biological Systems, and Chemistry of Materials. These focus areas tie in closely with governmental resources at nearby Pacific Northwest National Laboratory and Idaho National Laboratory, which can often provide additional research opportunities during your graduate studies.

Whatever it is you want to do in your career, a WSU Ph.D. can take you there. Our alumni are at colleges, universities, and national laboratories across the country, places such as the University of Utah, Central Washington University, and Emory University, as well as Pacific Northwest National Laboratory, Argonne National Laboratory, Oak Ridge National Laboratory and the Air Force Weapons Laboratory. They are also in every kind of industrial setting, from the smallest start-up companies to the largest multi-national corporations like Seagate Technology Inc. Our graduates have also gone on to other types of careers in public policy, business and law. Regardless, it is our goal to provide you with a solid graduate education in chemistry so that you can excel.

Enjoy your visit to the Department. I hope to see you here again this fall!

Cliff Berkman

Professor of Chemistry and Chair



Faculty

Laura Bartley

Associate Professor
Institute of Biological Chemistry
Organic/Biochemistry
Ph.D. Stanford University, 2002
laura.bartley@wsu.edu

Understanding and controlling plant metabolic processes and organ cellular architecture toward sustainable production of food, fuels, chemicals, and materials. Target metabolites are abundant plant components including phenolics, such as lignin and tannins; polysaccharides, including xylan; and aliphatics, like suberin. We generate hypotheses through systems biology (e.g., transcriptomics, proteomics, phosphoproteomics) and forward genetics analyses and then test the functions of enzymes and their regulators using in vitro, cellular, and whole-plant assays, key approaches in biochemistry and biotechnology.

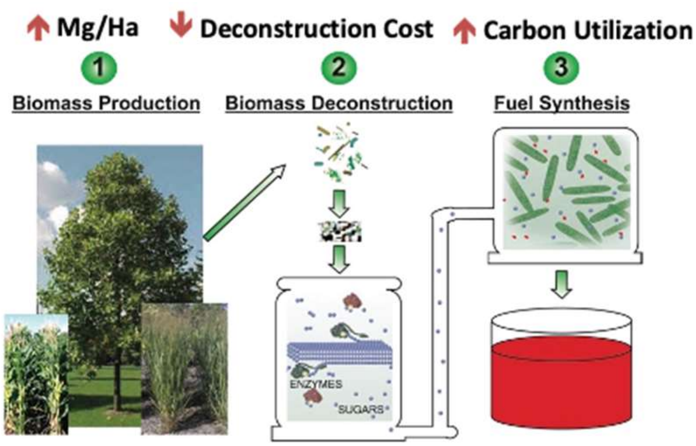


Figure 1. Scheme for making biofuels (and chemicals) from plant biomass.

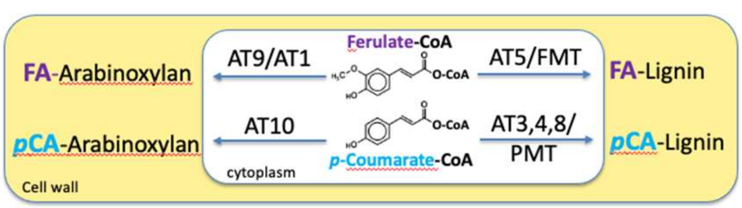


Figure 2. Cell wall modification enzymes from biofuel grasses

Jeffrey G. Bell

Assistant Professor
Analytical, Physical, Materials Chemistry
Ph.D. University of Windsor, 2017
Postdoctoral Fellow, Harvard University, 2020
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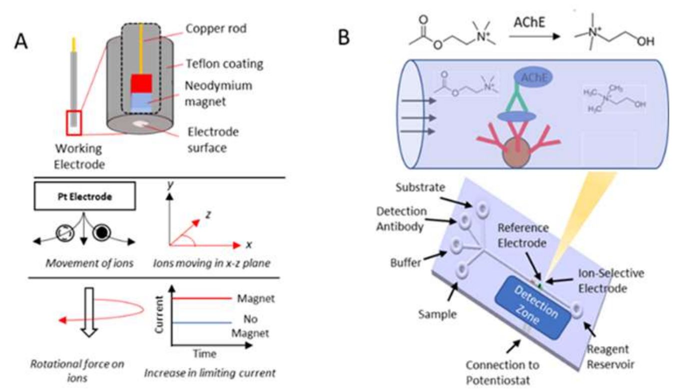
Research in the Bell Lab addresses the problem of creating effective, accessible and affordable diagnostic tools capable of detecting and differentiating between diverse analytes and biomarkers. A major component of this research is the merging and exploitation of magnetism with electrochemistry with the focus on analytical chemistry. Research in this lab will (i) gain fundamental knowledge of the electroanalytical processes which are influenced by magnetic fields, (ii) fabricate sensors to detect and monitor health-related biomarkers and (iii) develop new classes of point-of-care devices. Research areas will be connected through the investigation of electrode-surface processes, magnetism and microfluidics.



(A) Schematic representation of a magnetic platinum electrode where a neodymium magnet is placed behind the electrode surface. Ions diffusing from the electrode surface in the x-z plane will experience the Lorentz force. A rotational force on the ions results in a higher limiting current (i.e., signal amplification). **(B)** Schematic representation of a universal point-of-care based ELISA consisting of ion-selective electrodes and a high turnover rate enzyme in a vertical flow device.

Cliff Berkman

Professor
Organic Chemistry, Biological Systems
Ph.D. Loyola University of Chicago, 1993
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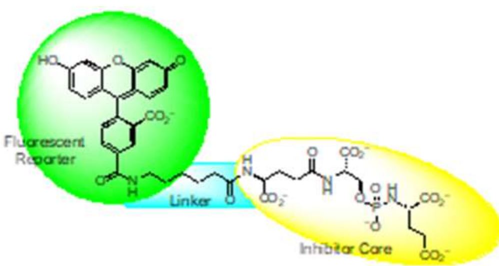
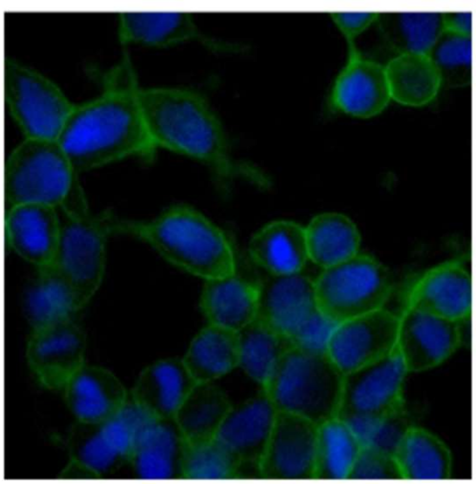
We are focused on developing diagnostic agents for cancer and heart disease. These agents are designed to target cell-surface enzymes unique to these diseases. Our designs include an enzyme targeting core linked to a diagnostic or therapeutic payload. Applications include in vitro and in vivo cell imaging, cell-capture platforms, and targeted chemotherapy. Students in my group can learn techniques in organic synthesis, cell and molecular biology, biochemistry, and computational modeling.





Fluorescence microscopy image of prostate cancer cells labeled with fluorescent inhibitor above.

Jim Boncella

Professor, Director of the Institute for Nuclear Science and Technology
Inorganic/Organometallic Chemistry
PhD University of California, Berkeley, 1984
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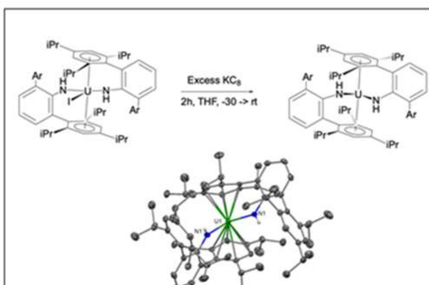
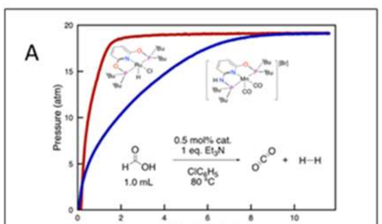
I will be initiating two projects in different areas starting in the Fall of 2019. One will be focused on the synthesis of uranium complexes in unusual oxidation states. We have had a long-standing interest in generating stable U(V) complexes, but the chemistry of these compounds has not yet been fully explored. Our recent synthesis of only the third example of a U(II) complex has provided the opportunity to develop the reaction chemistry of this new oxidation state. The electronic structures of these U(II) compounds are fascinating because of the three examples reported so far, one has a 5f36d1 ground state and the other two a 5f4 ground state. Because our U(II) complex is a neutral compound, the possibility for further reduction to U(I) exists. Understanding the chemistry and electronic structures of these unusual oxidation state will be a priority of this work. The second project area will involve investigating the reactivity of a new class of transition metal pincer ligand hydroxide, hydride and alkyl complexes as catalysts for the hydration of nitriles and the hydrolysis of various ester and amide species. This program has its roots in our recent interest in developing catalysts for the decomposition of formic acid as a means to generate gas pressure from a condensed phase.



Synthesis of a bis(amido)U(II) complex



Formic acid decomposition catalyzed by Ru and Mn pincer complexes. The Mn complex displays surprising reactivity, which is comparable to Ru.

James Brozik

Associate Professor
Physical Chemistry and Material Science
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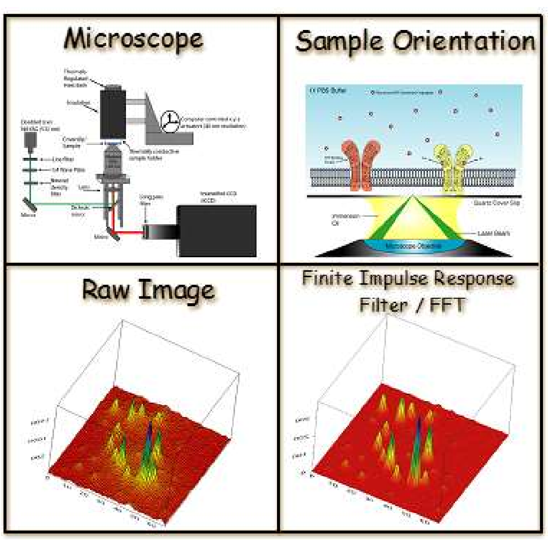
Biological systems contain a tremendous array of molecular machines performing all types of molecular functions, while materials chemistry provides a means of creating new “biologically inspired” machines and platforms suitable for device technology. Our research program combines both biophysical and materials chemistry to understand, in detail, how the machine-like properties of membrane proteins are related to the structure of the individual subunits, the conformations of different protein assembly, the allosteric motions of the different subunits relative to one another, and to determine the free energy changes that drive transitions between different structural states and conformations of the assembly (i.e. their machine-like properties). The laboratory uses a combination of single molecule imaging / spectroscopy, ensemble spectroscopy, electrochemistry, theory, chemical synthesis, and biochemistry. All students are broadly trained in all aspects of the research program.



Brian Clowers

Associate Professor
Analytical, Environmental, and
Radiochemistry (AER)
Ph.D. Washington State University, 2005
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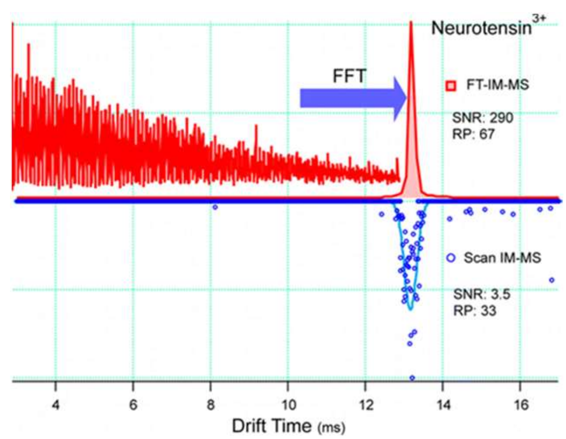
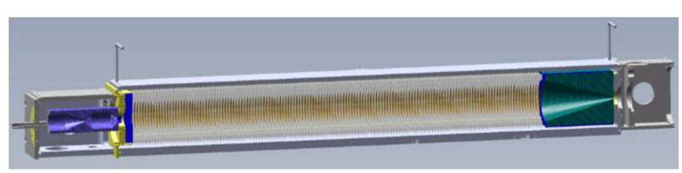
The Clowers Research Group combines ion mobility spectrometry (IMS), mass spectrometry (MS) and optical spectroscopy to probe complex chemical systems in the gas phase. These hybrid methods address a range of chemical problems spanning from the fundamental to the applied. A few of these research topics include carbohydrate structure determination, intelligent stereochemical ligand development, spectroscopy of gas-phase clusters, and selective ion chemistry for threat detection. In addition to focusing on gas-phase ion behavior, students in my group will hone skills related to sample ionization, instrument construction, experimental design and chemometric data analysis. These skills help deliver solutions to a range of chemical problems across domains including national security, environmental analysis, and bioanalytical chemistry.





Xiaofeng Guo

Assistant Professor
Physical Chemistry and Analytical, Environmental, and Radiochemistry (AER)
Ph.D. University of California, Davis, 2014
x.guo@wsu.edu

We focus on solid state chemistry, structures, and thermodynamics under (extreme) P-T conditions, probed by synchrotron, neutron-based techniques, and advanced calorimetric instruments. Current research topics include:

i) Thermochemistry of nano-materials, ceramics, minerals, metals/alloys, molten salts, and low dimensional materials;

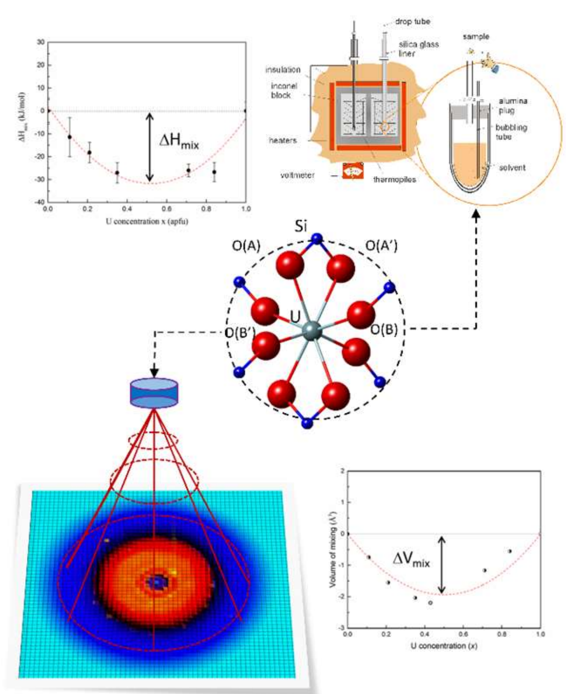
ii) Structure and thermochemistry of lanthanide, actinide-containing materials and minerals;

iii) Nano-materials, composites related to nuclear applications and environmental concerns;

iv) *In situ* measurements of phase alterations and physical properties at high pressure;

v) *In situ* probing the synthesis and speciation under hydrothermal conditions;

vi) Calorimetric instrumentation developments. Students in the group will be trained in inorganic synthesis; X-ray, electron, and neutron-based characterizations (X-ray and neutron scattering, XAS, XPS, SEM, PDF); high pressure (diamond anvil cell) and thermal analysis techniques (DSC, TG, high-T calorimetry).



K.W. Hipps

Regents Professor
Physical Chemistry and Materials Science
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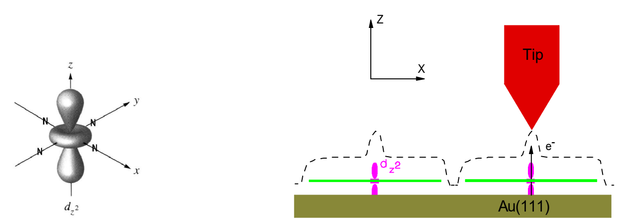
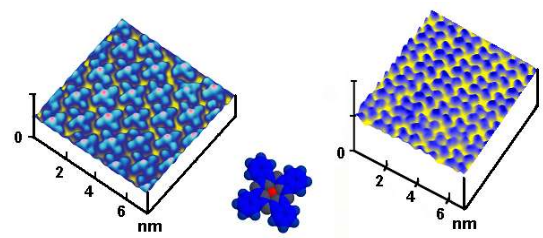
My group's current research interests focus on the nanoscale -- both characterization and supramolecular synthesis. We are internationally recognized experts in electron tunneling microscopy and spectroscopy. Students working in my group use virtually every technique appropriate for studying thin films and surfaces. Our research is divided between UHV studies and those conducted at the solution solid interface. Students will learn Scanning Probe Microscopy, X-ray photoelectron spectroscopy, LEED, Auger, and conventional spectroscopic techniques. Variable temperature and pressure experiments are also frequently performed. Computational surface science is also of interest to my group.

Professor James Brozik and I are also collaborating on a Keck Foundation funded project combining nanoscale synthesis with solution phase exponential growth to create moles of molecular machines.



The occupancy of ***metal*** d orbitals defines the conductivity at the center of the molecule.



CoPc on Au(111) NiPc on Au(111)

ChulHee Kang

Professor and Director
Chemistry of Biological Systems, Biochemistry
PhD University of California – Berkeley, 1987
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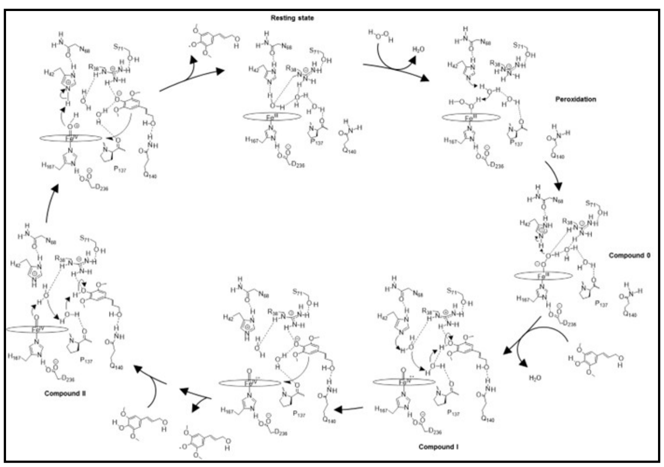
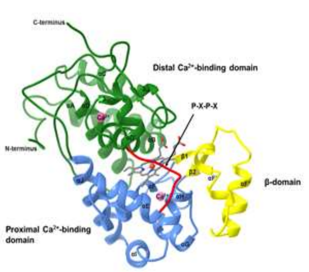
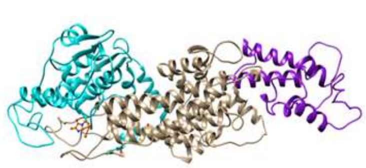
Cardiovascular/Cancer Projects: We investigate the fundamental mechanisms of E-C coupling in heart muscle, oxidative and UV damaged DNA, and essential insight into how they can be improved and help design more effective anticancer drugs.

BioFuel: Manipulating lignin content and subunit composition as a way to enhance biomass conversion is our target. We approach with the detailed structural, biochemical and biophysical knowledge of the key proteins/enzymes in the participating biosynthetic pathway, which will facilitate efficient and targeted manipulation of lignin subunit composition and lignin content, while maintaining plant viability.





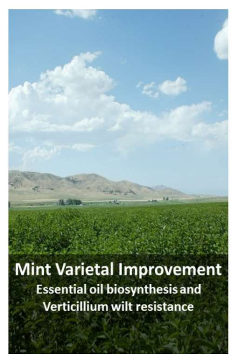


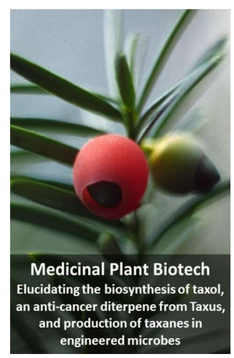
(Moural et al. 2017) *(Jun et al. 2018)*

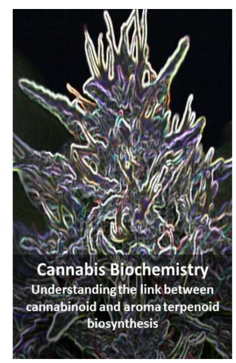
Mark Lange

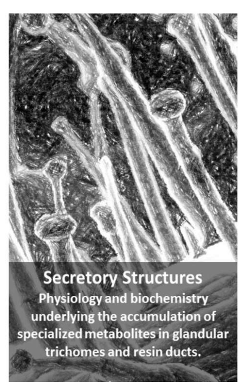
Interim Director and Professor, Institute of Biological Chemistry
Director, M.J. Murdock Metabolomics Lab
Ph.D. University of Munich, Germany, 1995
Lange-m@wsu.edu

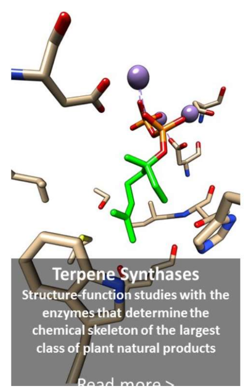
The Lange laboratory investigates the biosynthesis of plant natural products using **integrative approaches,** involving analytical chemistry, biochemistry, molecular biology, and genetics. We are developing **mathematical models** to quantitatively describe the regulation of metabolic pathways. We are particularly interested in understanding metabolism in **specialized plant cell types**, which synthesize and accumulate precursors used to produce essential oils, oleoresins, and pharmaceutically relevant natural products. We are performing **fundamental research** to improve our knowledge base, but also are engaged in applied projects to **develop commercial solutions** in the broad area of plant breeding and engineering.

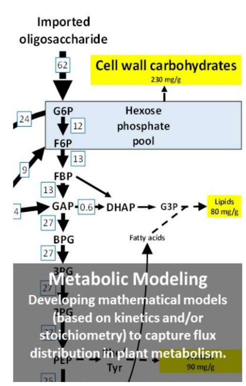








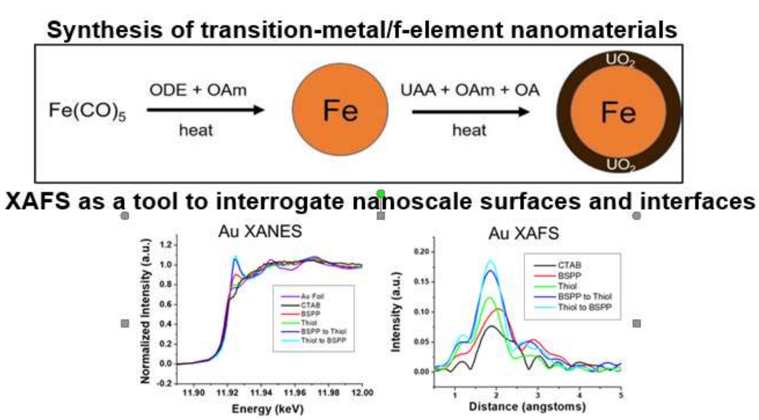




Liane Moreau

Assistant Professor
Radiochemistry
Ph.D. Northwestern University, 2017
liane.moreau@wsu.edu

Research in the Moreau group will focus on understanding the nanoscale properties of f-element materials, particularly at their surfaces and interfaces, and the implications that their size and surface-dependent effects might have for the development of materials for energy applications and environmental considerations. Towards this end, group research areas will fall into three different categories: 1) Synthesis of core/shell and combinatorial transition-metal/f-element nanoparticles to observe how transition metal support structure can be tuned to affect structure and reactivity of f-element shell materials. 2) Interrogating the surface chemistry of actinide-based materials and the characteristics of their interfaces with proximal materials systems. And 3) Designing functional surface chemistry to control nanoparticle lifetime and degradation products. Students will gain experience in nanoparticle synthesis, f-element chemistry, X-ray spectroscopy, scattering and diffraction techniques, chemical characterization methods, electron microscopy, SQUID magnetometry, and the design and fabrication of functional sample containment. Dr. Moreau's group will work at the interface between fundamental nanoscale actinide chemistry and its implications towards the development of materials for catalysis, advanced nuclear fuels, and medical therapy, in addition to a richer understanding of the migration of actinides in the environment and how actinide surfaces interact with proximal materials.



Ursula Mazur

Professor
Physical, Inorganic Chemistry, and Materials Science
PhD University of Michigan, Ann Arbor, 1979
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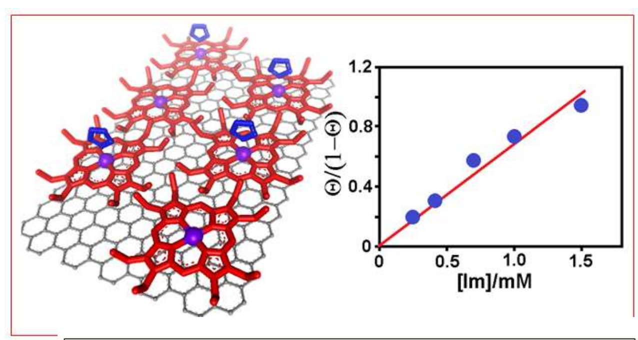
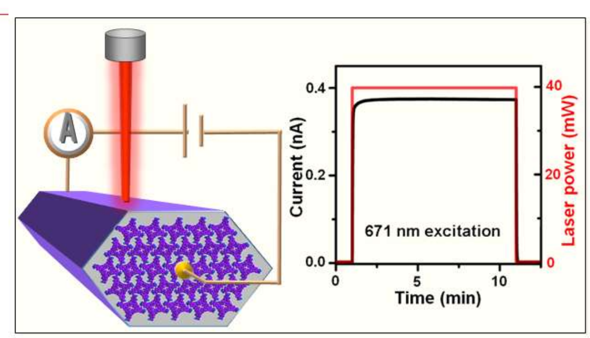
We use a combination of experimental and computational methods to study: (1) metalloporphyrin catalytic reaction kinetics and thermodynamics at a single molecule level and (2) molecular-scale chemical electronic, and material properties of nanostructured aggregates fabricated from synthetic light harvesting complexes. The goal of project (1) is to use microscopy and spectroscopy to provide a detailed molecular and submolecular scale picture of reaction chemistry at the liquid-solid interface. The goal of project (2) is to elucidate the phenomena and principles leading to molecular ordering and behavior at nanometer length-scales, and correlate these principles with the photophysical properties (including optical absorption, energy transfer, and energy trapping) of the electroactive aggregates We apply the newest tools and techniques of nanometer-scale science, including scanning probe microscopy (SPM) and scanning tunneling spectroscopy (STS), transmission electron microscopy (TEM), optical spectroscopy and, modeling calculations to study the structure, dynamics and energetics of single molecules and molecular assemblies at nanometer length scales.





Peter T.A. Reilly

Associate Professor
Analytical, Environmental, and Radiochemistry (AER)
Ph.D. University of Illinois, Chicago, 1992
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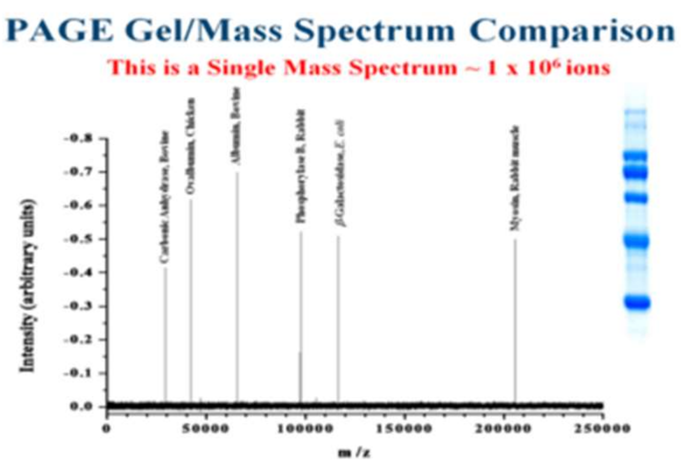
The Reilly research group is focused on developing novel mass spectrometry instrumentation and techniques. One of our primary focuses is developing high resolution mass spectrometry in the ultra-high mass range with a near term goal of measuring intact protein distributions (protein concentration vs. mass) and the interaction of low charge state proteins and complexes with small molecules (Think drug interactions). Ultra-high mass spectrometry is also applicable to the characterization of nanomaterials and catalysts. As part of this effort, we are developing digital waveform technology (DWT) because there is no mass limitation. DWT is game changing and represents the future of mass spectrometry because it vastly expands the capabilities of mass spectrometers while reducing their costs.



MS of SH6 PAGE gel protein mass markers. A single mass spectrum of more than 1 million singly charge protein ions. The Page gel on the right comes from the manufacturer's website.

Anjali Sharma

Assistant Professor
Organic chemistry
Ph.D. McGill University, Quebec, Canada, 2014
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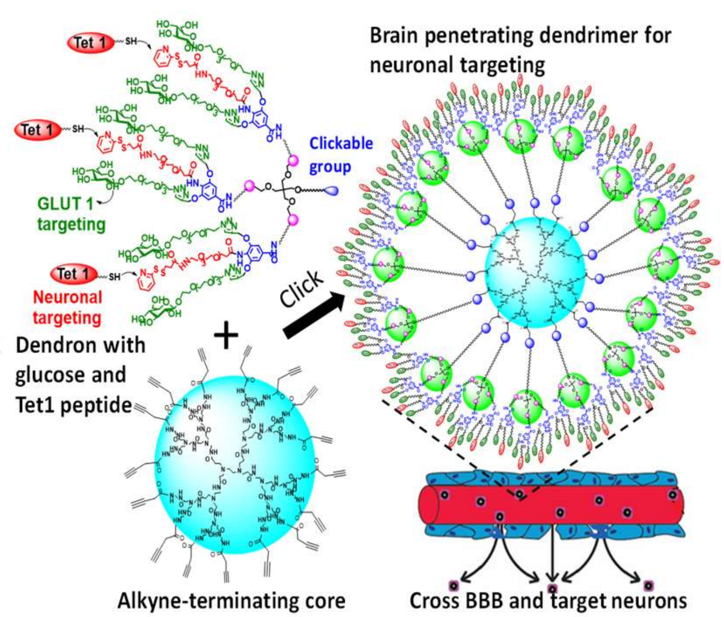
The Sharma Lab is a **Translational Nanomedicines Research Laboratory** that focuses on the development of rationally-designed, novel, smart, and clinically translatable cell-targeted nanotechnologies. The lab utilizes dendrimers and polymers for target-specific drug/gene delivery and imaging applications to help diagnose and treat unmet medical problems. Despite continuous advancements in the field of nanomaterials for medical use, their clinical utility has been limited. This slow commercialization/clinical success of nano-therapies can be traced back to the shortcomings in several key chemistry and engineering criteria associated with their complex design and complicated synthesis process resulting in batch-to-batch inconsistencies in their physiochemical and pharmacological properties. The primary objective of the research in the Sharma Lab is to incorporate the important synthetic elements for clinical translation during the material design itself, to fabricate clinically-translatable nanomaterials that are biocompatible, reproducible, scalable, stable, and inexpensive.

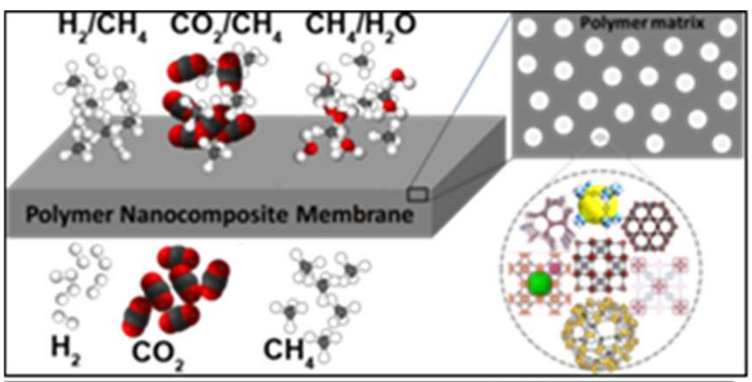
Design of a brain penetrating and cell-targeted nanotechnology platform

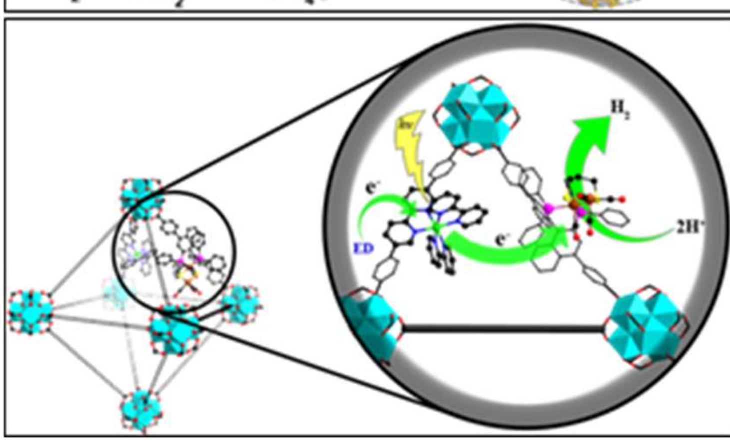


Qiang Zhang

Assistant Professor
Inorganic Chemistry
PhD University of South Carolina, 2013
q.zhang@wsu.edu

Zhang group focuses on the integration of porous materials with molecular compounds and nano-materials or polymers. We work primarily on Metal-Organic Frameworks. The goal of our research is to study the fundamentals and develop methodologies to synthesize novel and multi-functional hybrid materials. The use of these materials in biomimetic catalysis, photocatalysis, dye sensitized solar cells, hydrogen production, sensing, bioimaging, and gas separation will be extensively studied. Students who interest in inorganic chemistry, porous materials, or catalysis/photocatalysis are encouraged to join. Students in Zhang group will be well trained in inorganic and organic synthesis, techniques for handling air-sensitive compounds, column and thin layer chromatography, powder X-ray diffraction analysis, single-crystal X-ray crystallography, thermogravimetric analysis, spectroscopy (UV-vis, FTIR, Fluorescence, NMR), and modern research related software (Origin, Office, Chemdraw, Diamond, Mercury, Olex2 etc.).





Facilities

Our facilities and support staff will do their best to help you succeed. The following state-of-the-art instrumentation is available to faculty and students in support of their research needs:

- Nuclear and Chemical Sciences Core Facility
- The Electron Microscopy Center.
- X-ray and Ultraviolet Photoelectron Spectroscopy (ESCA & UPS)
- Surface and Nanoscale Analysis Laboratory
- Center for Institutional Research Computing

Nuclear and Chemical Science Core Facility

Operated by the Office of Research, the Nuclear and Chemical Science (NUCS) Core Facility is housed in the Dodgen Research Facility and the basement of Fulmer Hall. The NUCS Core Facility is a multi-user facility that serves clients in three colleges on the Pullman campus, as well as researchers in the Tri-Cities and Spokane, at the University of Idaho, in addition to external clients. The NUCS Core Facility in the Dodgen Research Facility houses a 1 MW TRIGA nuclear reactor, a cobalt-60 source for gamma irradiations, an epithermal neutron beamline for boron neutron capture therapy, three ORTEC (two 35% and one 50% efficient) and one 95% efficient Canberra gamma spectrometers, Canberra alpha spectrometers, a Setaram calorimeter, and an easyXAFS 300+ for X-ray absorption/fluorescence spectroscopy.

The NUCS Core Facility in the basement of Fulmer Hall houses three NMR spectrometers and a single crystal x-ray diffractometer. The current NMR spectrometers include a Varian VNMRS 600 MHz spectrometer (capable of solution and solid-state experiments), a Varian Inova 500 MHz spectrometer (capable of solution-state and HR-MAS (biological) experiments), and a Bruker Avance Neo 500 MHz spectrometer (capable of solution-state, diffusion, and HR-MAS experiments). The single crystal x-ray diffractometer is a Bruker D8 Venture system capable of obtaining diffraction data with either a copper or molybdenum x-ray source. Quite recently the NUCS Core Facility received news that their proposal to the Murdock Charitable Trust to purchase a XENOCS Xeuss 3.0 SAXS/WAXS x-ray spectrometer was successful. This SAXS/WAXS instrument will be housed in the Dodgen Research Facility and is anticipated to arrive in March of 2022. The NUCS Core Facility is capable of measuring radioactive samples in almost all of its instrumentation.

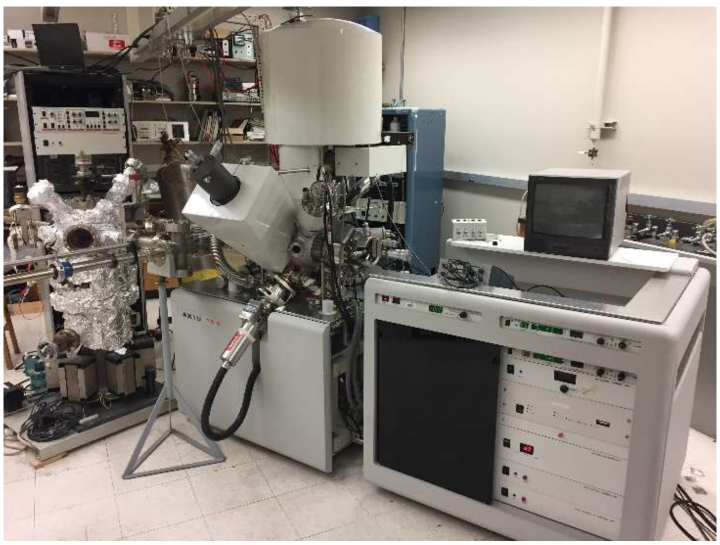
Electron Microscopy Center

The Franceschi Microscopy and Imaging Center (FMIC) is a research and educational facility for the imaging and ultrastructural study of biological and non-biological materials.

The FMIC maintains a TEM, a SEM, two confocal microscopes and various light microscopes. The electron microscopes also have EDX analyzers for elemental analysis. All necessary ancillary equipment, computers for image processing and analysis are maintained for student and faculty use.

X-ray and Ultraviolet Photoelectron Spectroscopy

The chemistry department houses a Kratos multi-technique electron spectrometer recently upgraded to an Ultra. The instrument uses two X-ray sources with analysis spot sizes of 2 mm, 110, 55 and 15 μm capable to generate spectra, elemental mappings, programmed depth profilings at temperature between -100 to + 600°C. In addition, a helium ultraviolet lamp with energies of 21.2 and 40.8 eV is available for probing the electronic property of materials.

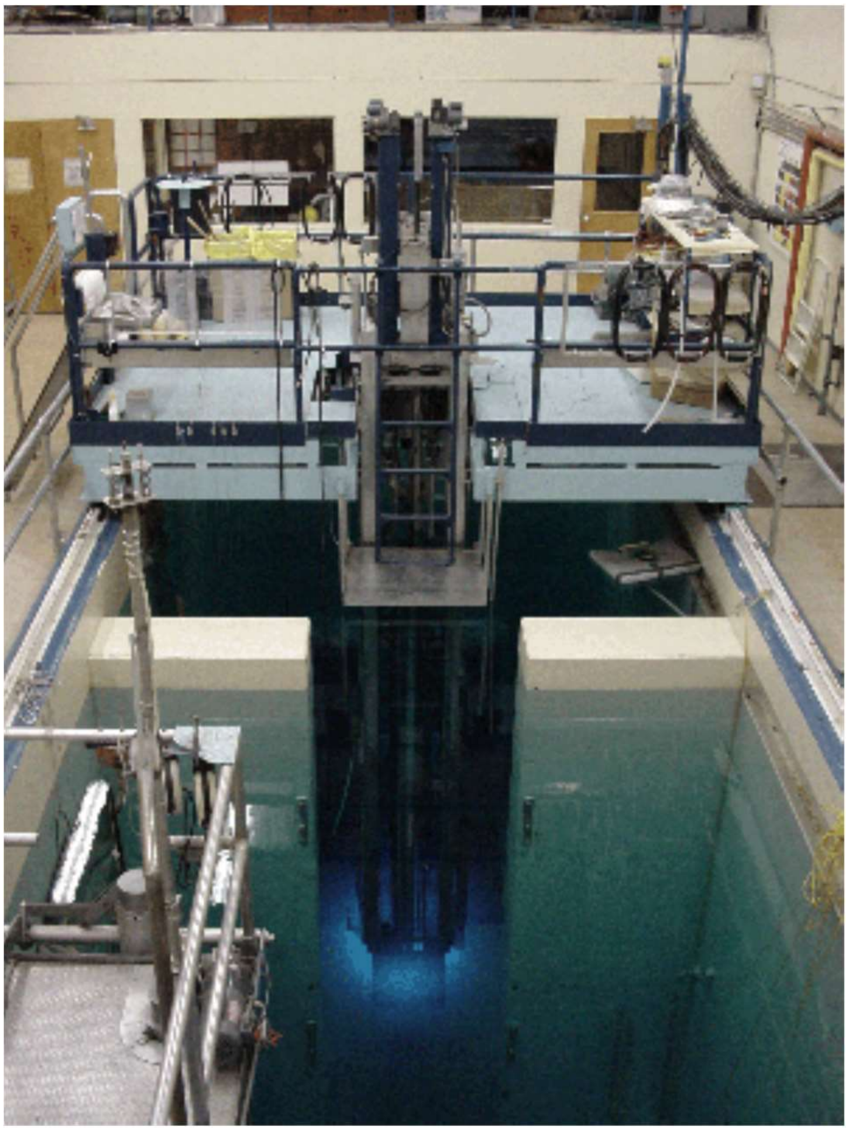


Surface and Nanoscale Analysis and Microscopy

WSU has an exceptional center for the study of Surfaces and Nanostructures. Facilities include XRay and UV photoelectron spectroscopy, IR and Raman surface analysis and microscopy instrumentation, Atomic force microscopes (3), ambient and electochemical Scanning tunneling microscopy instruments (4), and Ultra-high vacuum Scanning probe microscopes (2), with one having variable temperature capability from 25 to 1000 K. In addition, we have one of the finest facilities in the world for scanning tunneling microscopy and for inelastic electron tunneling spectroscopy. We also have instrumentation for preparation of surfaces, thin films, and Langmuir-Blodgett layer systems.

Center for Institutional Research Computing

CIRC is home to WSU's high-performance computing cluster, Kamiak. Kamiak is operated under a condominium-style model, whereby researchers purchase individual compute nodes that are integrated into the system via a highspeed local network. The College of Arts and Sciences currently holds 12 nodes (20 cores each) that are available for use to students and faculty of the college. Overall, the Kamiak cluster currently contains 119 nodes consisting of a total of 2,664 CPU cores and 44 GPUs.

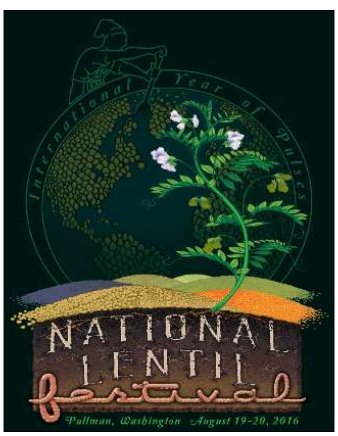


Reactor pool at the Dodgen Research Facility

Surroundings

WSU's unique geographical location in eastern Washington near the Idaho border provides for abundant cultural and recreational opportunities. The rolling hills of the Palouse prairie are home to WSU in Pullman and the University of Idaho just eight miles to the east in Moscow. The two towns are connected with a beautiful bicycle-pedestrian path (The Chipman Trail) that follows Paradise Creek. WSU is a member of the Pac-12 athletic conference.

The presence of two land-grant Universities in the region contributes to a thriving arts scene not ordinarily found in towns without traffic jams. The Lionel Hampton International Jazz Festival at the University of Idaho in February is a four-day feast for music lovers, while the Washington-Idaho Symphony and local community bands can be enjoyed year-round. The National Lentil Festival is held in Pullman every August to celebrate the main agricultural crop of the Palouse, while the annual Moscow Renaissance Fair in May welcomes spring with food, music, arts and crafts.



Outdoor recreational activities are made possible by the proximity of WSU to great expanses of scenic beauty. The Snake, Salmon, and Clearwater Rivers, Moscow Mountain, Kamiak Butte, Steptoe Butte, the Wallowa Mountains of Oregon, Hells Canyon, the Blue Mountains of southeast Washington, and numerous nearby National Forests and Wilderness Areas are within a day's drive of Pullman. Backpacking, hunting, whitewater river rafting, rock-climbing, skiing, and mountain biking are just some of the fun activities enjoyed by residents and visitors alike. The proximity of Pullman to Washington Wine Country and the city of Spokane provides for further entertainment options.