We come here to be philosophers, and I hope you will always remember that whenever a result happens, especially if it be new, you should say, “What is the cause? Why does it occur?” and you will, in the course of time, find out the reason.

Michael Faraday
Chemistry at Tufts

There has never been a more exciting time to do scientific research. The sequencing of the human genome is providing an unprecedented understanding of life’s inner-workings and has proved essential in the development of new treatments for disease. The emerging field of nanotechnology is poised to transform society through the design of novel materials and devices that will revolutionize energy generation, medical diagnostics, and computing. Improved sensing technologies are being integrated into smart devices that will redefine our relationship with our surroundings and permit the exploration of uncharted extreme environments. Chemistry is a unique science in that it is a language that can be used by others to unlock deeper secrets. Medicine, geology, engineering, biology, and other fields rely on chemistry in their quest for ground-breaking research and answers to the most difficult questions about life and its surroundings.
Why Choose Tufts Chemistry?

There are many factors that go into the selection of the right graduate school. Some questions to ponder on your quest for the program that suits your needs: What size should the program be? What type of research do you want to do? What type of culture would you best fit into? Where do you want to live?

As you learn about chemistry at Tufts, consider the following advantages:

**Small Program, Vast Opportunities**
With an average population of 65-70 students, Tufts’ graduate program in chemistry is large enough to foster stimulating interactions among colleagues but small enough to have a favorable student/faculty ratio. This small department size fosters close working relationships between the students and research advisor, where the advisor is not simply the head of a lab, but a true mentor and colleague who is encouraging and values student contributions.

Additionally, the department has been awarded the Graduate Assistance in Areas of National Need (GAANN) award from the U.S. Department of Education, a financial need grant which provides selected fellows with additional funding to bolster their research. The Department of Chemistry has received this funding annually since 2006. The faculty are committed to providing opportunities for graduate students.

**Excellent Faculty**
Tufts chemistry faculty members are a highly talented and respected group who focus on important problems and adhere to the highest scientific standards. The faculty are also dedicated to serving the larger community. Their efforts include, but are not limited to: coordinating public programs that raise the profile of science and chemistry, collaborating with local schools to provide teachers with additional training and offering demonstrations of chemistry to the students, consulting for the government and industry, and organizing scientific conferences. Finally, chemistry is one of the most entrepreneurial departments on campus, where numerous inventions have been licensed and have formed the technological basis for startup companies.
The graduate program in chemistry at Tufts offers rigorous training in the core areas of organic, inorganic, analytical, and physical chemistry. We also apply chemistry to important problems in a range of fields including materials, surface science, sensor design, nanotechnology, energy generation and storage, and drug development.

**The Ph.D. Program**

Tufts Ph.D. candidates acquire a solid foundation in chemistry and master a field of interest through a combination of scholarship and research. Training begins with advanced course work in the four areas: analytical, inorganic (or molecular biology and biochemistry for the joint program, see page 37), organic, and physical. Two additional graduate courses must also be taken. Command of chemistry and related disciplines are demonstrated through exams in the courses, as well as through the oral presentation of two study topics that are chosen by the student. Through service as a teaching assistant, students will develop their ability to communicate their knowledge of chemistry.

The Ph.D. candidate is expected to excel at research. The first semester is spent getting acquainted with the ongoing research in Tufts chemistry by attending group meetings, speaking one on one with prospective advisors and graduate students, and attending presentations by faculty that introduce their research. An advisor
is typically chosen by the end of the first semester. The candidate will then immerse him/herself in research, learning new laboratory techniques, honing critical thinking skills, mastering a specific field, and cultivating creativity through extensive reading of the primary literature. These hallmarks of a Ph.D. scientist are evaluated continuously by the advisor, as well as formally, through the summer research report at the end of the first summer, the third-year research progress report, the defense of an original research proposition, and finally through the oral presentation of a dissertation reporting significant work of publication quality.

The M.S. Program
The Department offers the M.S. program for students seeking an education in chemistry at an advanced level. Our M.S. program provides rigorous training, and each student must pass eight graduate level courses, of which a minimum of six must be formal classroom instruction. With the approval of the student’s advisor, up to one half of the course work may be taken in related fields outside of the chemistry department. There is no departmental requirement for the completion of the Master's thesis, but is instead left to the discretion of the advisor and student, to judge the importance of a thesis for the candidate’s career plans.
Financial Aid

For full-time doctoral candidates in good standing, the department guarantees five years of financial support in the form of teaching or research assistantships, and full tuition scholarships.

A Teaching Assistant (TA) is a member of the team responsible for running a course. The TA’s duties include direct laboratory supervision, tutorials, and grading. These responsibilities take approximately seventeen to twenty hours per week. As teaching is considered to be an important part of the graduate education, doctoral candidates are required to serve in a teaching capacity for at least one semester.

A Research Assistant (RA) is paid a stipend and performs original research, usually under the direction of her or his research advisor.

Full tuition, health insurance, and a stipend guaranteed for five years for all doctoral candidates in good standing

Graduate students also have opportunities to receive support through the Tufts Provost’s Fellowship, government-sponsored graduate fellowships, or through internships in industrial and government laboratories. Currently the department nominates GAANN fellows, a program designed for at-need students.

The Trustees of Tufts College reserve the right to change the tuition or to establish additional fees or charges for special features or services whenever such action is deemed advisable. The earliest possible notification of changes in tuition and other fees will be given.
The Department of Chemistry consistently receives strong university and external support for the continued development and expansion of its research infrastructure. This funding has permitted the renovation of facilities and the acquisition and maintenance of the most current chemical research tools. In addition to state of the art instruments in faculty research labs, the department manages a large suite of UV-vis, IR spectrophotometers, and fluorimeters, as well as an AA, a GC, and HPLCs. Below is a description of the facilities and instruments that are found in the Pearson Laboratory. From the machine shop to the mass spectrometry lab, the department provides excellent cutting-edge facilities for graduate research that are available 24 hours a day, as well as maintenance and training by professional staff.

**Machine/Electronic Shop:** A machine/electronics shop is readily available to support researchers in instrument repair as well as the design and construction of customized equipment and parts. The facility is fully staffed to provide expertise and one-on-one instruction in machining to facilitate the realization of novel instrumentation.

**Store Room:** The department maintains a well-stocked storeroom with office stationery, glass- and plasticware, first aid, as well as solvents, reagents, and gases, to facilitate the continuous availability of supplies that are used on a routine basis in the department.

**Mass Spectrometry Laboratory:** The department is equipped with three mass spectrometers. A Bruker Microflex MALDI-TOF is ideally suited to peptides and proteins. A Thermo LTQ linear ion trap has electrospray, nanospray, and APCI sources. It is used for small molecule, peptide, and proteomics applications by either direct infusion or LCMS. A Shimadzu single quadrupole GCMS with EI and CI sources is ideal for separating and identifying small molecules.

**Magnetic Resonance Facility:** Two NMR spectrometers with multidimensional and multinuclear capabilities are available for routine small molecule analysis. A Bruker 500 MHz instrument was installed in 2009. At the same time, the existing Bruker 300 MHz was significantly upgraded. Both spectrometers are equipped with a variety of probes, variable temperature controllers and pulsed field gradients. A Bruker EPR spectrometer is available to study organic and inorganic compounds with net electron spin.

**Imaging:** The department houses several Digital Instruments atomic force microscopes for nanoscale imaging and surface studies. A Jeol scanning electron microscope with EDS capability is also available for this same purpose. Department members also have access to an FTIR microscope in the Department of Chemical and Biological Engineering.

**X-Ray Crystallography:** The department recently installed a new single-crystal X-ray diffractometer (Bruker D8 Quest). This modern instrument allows for the relatively simple determination of the molecular structure of crystallizable organic and inorganic compounds. Owing to the large and sensitive CMOS Photon 100 detector and drastically decreased loss of X-ray intensity in the new Triumph monochromator, really small crystals can be analyzed. Low temperature (down to 77 K) experiments are enabled by the Oxford 700 Cryostream cooler. The diffractometer is equipped with APEX2 Software Suite – an industry standard for a comprehensive crystallographic package. Additionally, the Autostructure module provides automated X-ray structure determination.
University Facilities and Resources

The department also has access to resources outside of Pearson Laboratory, including the Micro- and Nanofabrication Facility, Tufts Core Facility, the Mechanical Engineering Machine Shop, and the Nanocatalysis Laboratory. Our collaborations with other science departments allow for interdisciplinary research, and the ability to bolster our research through community resources.

**Biology and Biophysics:** Several research groups are heavily engaged in research at the interface of chemistry and biology and have consequently set up facilities for bacterial and mammalian cell culture, as well as protein expression and purification. Instrumentation for biochemical and biophysical research—such as a Beckman XL-I analytical ultracentrifuge, Perkin Elmer scintillation counter, and Jasco and Aviv circular dichroism spectrophotometers—are also maintained. In addition, chemistry department members also have ready access to nucleic acid and proteomics core facilities at Tufts’ Sackler School of Medicine.

**Information Technology:** Tufts University offers its faculty and students site licenses and discount programs to a number of software tools including Microsoft Office, Adobe Creative Cloud, ChemDraw Pro, EndNote, and MATLAB. Tufts University Academic Computing Services provides and supports a variety of computing services to faculty and students. Tufts Research Cluster, comprised of 172 IBM Linux systems interconnected via a 10-gigabit network, provides high performance computing resources with a total number of 2,092 compute cores and a capacity on the order of 26 TeraFlops.

**Libraries:** Tufts University libraries support the educational and research programs of the university through services to students, faculty, and staff. The Tisch Library’s resources consist of over 750,000 books, 300,000 government publications, 3,000 current periodicals, and a growing collection of over 500 electronic databases and almost 2,000 on-line journals accessible to the Tufts community via the Internet. Additional books and publications are available through the Interlibrary Loan program, of which Tisch Library is a member. Features and facilities include easily accessible open stack areas, seating for over twelve hundred, AV and computer-equipped classrooms connected to the university network, a café, a reading room, group study rooms, and computerized literature searching services.

Tufts’ affiliation with the Boston Library Consortium provides Tufts students and faculty with access to the resources of 11 additional academic and research libraries in the Boston area. Department members also have free access to a host of on-line journals from the major publishers and resources such as the CAS SciFinder Scholar, ISI ChemServer, Science Direct, Ovid, and the ISI Web of Science.
Life as a Graduate Student

Chemistry Graduate Student Council

The Chemistry Graduate Student Council, or CGSC, is a student government organization within Tufts Chemistry. Each graduate student pays the school an annual student activities fee, the sum being controlled by a central Graduate Student Council (GSC). These funds are allocated to the department organizations to plan events and activities throughout the year. Events are open to all graduate students from all departments but are hosted by individual graduate student councils.

We have a very active CGSC. Typically the council organizes a bi-monthly departmental social, Café Chem, held on a Friday afternoon with various themes. Some examples include Superbowl Parties, Cinco De Mayo Celebrations, and Thanksgiving Feasts. Most events are food-themed, where the students get a free meal and a chance to socialize and unwind at the end of the week. Traditionally the CGSC also helps coordinate an annual expedition where new students are welcomed into the department during their first few weeks, giving them the opportunity to forge bonds with other members of the department. This has consisted of new and current students getting together for camping, canoeing, and white water rafting trips.

Additionally the CGSC serves as a liaison not only between the students and the Chemistry faculty, but also with Tufts administration via interactions with the central GSC. Members can serve on Tufts sub-committees where student issues are addressed and discussed, and in the Chemistry Department we can organize meetings with faculty whenever the need presents itself. All student councils have annual elections where current students nominate and vote on members. Chemistry students can serve on the department CGSC but may also run for positions on the central council as well.

Educational Opportunities

Being a graduate student in Tufts Chemistry can be a very rewarding experience. Your education not only progresses through experience in the lab, it is transformed by department-sponsored seminars and teaching. The department sponsors seminars each semester, bringing scholars from around the country to present their latest research. Students are given the opportunity to have one-on-one conversations with the scholar, giving them an opportunity to lunch and network with scientists in a variety of fields. These seminars are complemented by the department’s Journal Club, which provides an informal venue for presentation of papers and discussion.

The department’s commitment to undergraduate research gives undergraduate students the opportunity to work alongside graduate students and Postdoctoral Scholars. Mentoring undergraduate students, whether through teaching or research, provides opportunities to develop proficiency in communication and allows graduate students to develop leadership skills within the context of the laboratory. These exercises are all key to the graduate student experience: learning how to present and articulate concepts, and the process of developing an original idea.
The Chemistry Isotopes, the department softball team
Living in the Greater Boston Area

A Scientific Hub
In addition to the many opportunities for scientific interaction on campus, Tufts is part of one of the largest scientific communities in the United States. The Greater Boston Area has a long history of technological innovation and scientific discovery. The telephone, the microwave, inhalational anesthesia, the sewing machine, the development of consumer electricity, Napster, Facebook, Zipcar, and many other inventions and ideas were developed in the Greater Boston Area. Additionally, Boston was the seat for the first public high school, university, newspaper, and subway in the United States.

This commitment to science and education is still evident today. There are over 50 colleges and universities within 15 miles of Boston. The presence of many other academic institutions and hospitals in the Greater Boston Area facilitates fruitful and stimulating collaborations. This exciting environment provides ample opportunities for scientific interactions off-campus and for enriching your education by attending a plethora of local seminars and conferences that routinely come through town. Our faculty members constantly collaborate and interact with scientists at MIT, Harvard, UMass Boston, and many other local universities. The diversity of schools within Tufts allows for interesting collaborations between different fields. Students and faculty from the School of Engineering, Cummings School of Veterinary Medicine, School of Dental Medicine, School of Medicine, and the Sackler School of Graduate Biomedical Sciences work with the Chemistry Department, allowing the department to extend beyond traditional chemistry-focused curriculum and research goals.

The vibrant academic environment is enhanced by a dense constellation of scientific enterprises. Boston boasts one of the highest concentrations of biotechnology companies in the country. They range from well-established corporations like Genzyme to exciting young startups such as Alnylam Pharmaceuticals. Pharmaceutical companies such as Novartis and Merck have also staked a major presence in the region, largely to take advantage of the scientific talent to which Tufts graduates contribute. Attendant to these research-intensive companies are intellectual property law firms and venture capital firms that both hire and work for scientists. There are very few places in the world with such a long history of synergy between academic research, human health, law, and commerce.

The Local Area
Pearson Laboratory is five miles from Boston and within walking distance to the subway and other public transit, making Boston easily accessible. Still many students enjoy the quieter neighborhoods close to Tufts. Though close to Boston, the Tufts community is nestled into two smaller cities, giving the open campus a more intimate feel.

As Tufts is located in the suburbs of Boston, the area boasts affordable housing, while still giving students access to great shopping and cultural centers, like Medford Square and Davis Square. The vibrant, diverse community is apparent in the area's establishments, including clothing retailers and restaurants, as well as the artistic and cultural events held throughout the year.

If you like hiking but can't get away, the Fells Way Reservation in Medford is a very attractive location to experience a little of the outdoors. If you like cycling, the Minuteman Commuter Bikeway is a multi-use rail trail that currently runs from Bedford to Alewife Station in Cambridge. It connects to other trails, offering access to communities beyond. The future is promising for this bikeway, as there is interest in expanding the path to the Charles River. If you are interested in the ocean, the nearest beach is a 20-minute drive, and opportunities for boating on the Charles River are within 15 minutes.
Davis square, the closest connection to the subway, houses some popular restaurants, a historic movie theatre, and various street performers within the center of its square. Here you can also find excellent coffee shops where students often meet to do work or just relax. The “Joey,” a Tufts sponsored bus, that transports students from Davis Square to various points around campus, stopping right in front of Pearson Laboratory. During the year Somerville hosts open art studio days, porch music performances, and summer movie nights in the park, amongst other activities. Living in the Medford and Somerville areas provides a host of wonderful opportunities outside of the lab environment when you need to unwind and spend time with friends.
Discovering Boston

Universities located in small towns and those in major cities provide students with very different environments for learning. Tufts offers its students an unusual combination: the main campus spans the communities of Medford and Somerville and provides the tranquility, friendliness, and student life of many small-town universities, yet the excitement of Boston is only five miles away. The Boston skyline is clearly visible from the Tufts campus, and the city is readily accessible by public transportation. Boston is one of America's most stimulating and cultural cities. The American Revolution began in this area and Boston is rich in history. Local historical sites include the Freedom Trail, Paul Revere's house, Faneuil Hall, Old North Church, Bunker Hill, the Boston Tea Party Ship and Museum, and the U.S.S. Constitution (Old Ironsides). The presence of many distinguished universities and colleges has fostered an openness to new ideas and a tradition of respect for different lifestyles. Boston offers the Tufts student both formal resources and a variety of informal entertainment. Among academic resources is New England Medical Center, where Tufts students may take courses and pursue research projects. Tufts is also formally affiliated with New England Conservatory of Music and the Museum of Fine Arts. The university holds an institutional membership at the museum, which allows students to visit without charge. But Boston means much more than its formal institutions. It means discovering a charming Beacon Street block or an inconspicuous gourmet restaurant in a bewildering maze of streets and alleys; it means Chinese New Year on Tyler Street, Columbus Day on Prince Street, bell ringers on Beacon Hill; it’s riding the Swan Boats in the Public Garden or taking a baroque-concert cruise around the harbor; it’s St. Patrick’s Day and the Boston Marathon; the Celtics, the Bruins, the Patriots, and the Red Sox; the Boston Pops Orchestra delighting picnickers on the Esplanade, or the Boston Symphony providing a musical feast at Symphony Hall; it’s live theater every day of the week, museums and art galleries, and an endless choice of epicurean dining, ethnic delicacies, coffeehouses, and homemade ice cream bars; it’s walking the Freedom Trail, wandering through Quincy Market, and strolling along the restored waterfront. It’s all Boston—rich in culture and entertainment, a laboratory for learning and a never ending source of discovery for the curious.
The researchers of Tufts Chemistry are well known for conducting world-class, award-winning research in cross-disciplinary fields. Our faculty and graduate students publish routinely in the most prestigious scientific journals. The press has highlighted Tufts faculty members’ research in molecular motors, quantum dot sensing, molecular recognition, and Mars’ aqueous geochemistry. Our faculty are leaders in their fields: they chair conferences, serve as editors and reviewers for prominent journals, and have won prestigious awards, including the Howard Hughes Medical Institute Professor’s Award, the DuPont, Beckman and DARPA Young investigator awards, NSF CAREER and Special Creativity Awards, membership in the National Academy of Engineering, and the ACS National Award for Creative Invention.

Despite all these successes however, what Tufts faculty are best known for are their relationships with their students. The small size of the department lends itself readily to a friendly and collegial atmosphere where graduate students work closely with their advisers.

World-class research, state of the art instrumentation and caring accessible faculty make Tufts Chemistry a great place to pursue doctoral studies. Please read on to learn about the great scientific challenges you can tackle and the mentors with whom you can collaborate.
CARBOHYDRATE CHEMISTRY, ORGANIC SYNTHESIS, BIOORGANIC CHEMISTRY, AND GLYCOIMMUNOLOGY

Complex carbohydrates play critical roles in a number of processes including protein folding, cellular adhesion, signaling, and modulating natural product biological activity. Despite their importance, very little is understood about the molecular basis of their activity. This is due to the fact that it is exceedingly difficult to produce carbohydrates in pure form for use as standards and therapeutics. Research in the Bennett lab is directed at developing new and efficient methods for carbohydrate synthesis, and the application of these methods to developing new therapeutics. Representative projects include:

1. **Reagent Controlled Methods for Stereoselective Carbohydrate Synthesis:**
One of the biggest hurdles to carbohydrate synthesis lies in controlling the stereochemical outcome of glycosylation reactions. Traditional approaches to controlling selectivity frequently rely on extensive optimization of both the coupling partners and reaction conditions. This makes carbohydrate synthesis time-consuming and difficult. To address this we are developing new stereoselective methods for carbohydrate synthesis based on reagent control. In our approach it is possible to obtain either enantiomer (diastereomer) of a glycosidic linkage from the same coupling partners, simply by changing the glycosylation promoter. We have demonstrated that this approach is effective in the construction of 2-deoxy-sugars and 1,2-cis-α-linked glycosides, two of the most difficult glycosidic linkages to synthesize. Ongoing projects include examining the scope and mechanism of our approach, and its application to carbohydrate and glycoconjugate synthesis.

2. **Next Generation Antimicrobial Carbohydrate-Based Vaccines:** Increasing drug resistance in bacteria coupled with a lack of new antibiotics is setting the stage for a major public health crisis. Thus, new strategies are necessary to combat drug resistant pathogens. While biologic-based antimicrobial vaccines do exist, they often fail to be protective in vulnerable populations, such as the elderly, immunocompromised, and very young. In addition, these heterogeneous vaccines are often ill-defined, making characterization and rigorous quality control extremely difficult. In collaboration with investigators at the Tufts University School of Medicine, we are examining the synthesis and evaluation of multivalent carbohydrate-small molecule conjugates for their ability to activate antibody producing cells and induce immunity against pathogens. This approach has advantages over traditional approaches in that our constructs are rigorously defined, and will not require co-administration of adjuvants, which often display undesirable toxicity profiles. More importantly, we anticipate that these constructs will be active in populations which do not gain benefit from currently used vaccine therapies.

**SELECTED PUBLICATIONS:**

Terry Haas

Fulbright Scholar

INORGANIC AND MATERIALS CHEMISTRY

Current work is largely in the area of solid-state electronic and ionic conducting materials, and attempts to achieve useful optical and electronic properties through an understanding of the fundamental contributing effects. An example is the attempt to obtain nearly-free-electron (metallic) behavior in metal oxide bronzes and other intercalation compounds, in both bulk and thin-film materials. Synthesis of new materials and the characterization of their electronic, structural, and transport properties is the major goal of the work.

To this end, we use optical spectroscopic (UV-VIS, NIR, IR) and magnetic measurements to probe electronic ground state structures, single crystal and powder X-ray diffraction to investigate crystallography and conductivity, Hall-effect measurements to probe electronic transport, and electrochemical means to investigate thermodynamic properties and kinetics of ionic motion. Extensive interaction with physicists and engineers of the Tufts Electro-Optics Technology Center is characteristic of this research.
The Kenny research group is focused on the uses of multidimensional fluorescence to solve analytical problems in the environment as well as the fundamental photophysics of fluorescence spectroscopy. Past projects have ranged from detecting pollution in groundwater to supersonic jet spectroscopy to calculation of the effects of greenhouse gases on global climate. Present projects include photophysics of oxygen quenching of fluorescence, development of portable instruments for multidimensional fluorescence measurement, and the developing chemometric methods to analyze three-way data (excitation spectra, emission spectra, and fluorescence lifetime) to characterize dissolved organic matter in natural waters and other complex mixtures. One of the most successful new chemometric approaches to multidimensional fluorescence has been PARAFAC, parallel factor analysis. The analysis of mixtures of fluorophores using PARAFAC is based on the model of additive contributions to the total fluorescence by noninteracting fluorophores. We are investigating the limitations of this model in the analysis of humic materials and petroleum products, in which interactions among components are known or expected. We are also exploring the applicability of PARAFAC to new problems, such as determination of distribution or complexation constants and the determination of fluorescence lifetimes of mixture components using steady state measurements.

SELECTED PUBLICATIONS:

ENVIRONMENTAL ANALYTICAL CHEMISTRY AND PLANETARY SCIENCE

Our research is focused on unraveling fundamental questions in planetary biogeochemical science using modern analytical systems to explore environments where no one has gone before. We are interested in extreme planetary environments because they contain chemical and biological records that provide evidence to better understand, geochemistry and its interaction with biology, clues to global climate change, and their potential to have supported and preserved evidence of past life. Understanding geochemistry is also critical in helping define and constrain forces necessary for the origin of life, and the climatic history recorded in these subsurface layers. Our research encompasses extreme environments on Earth in places such as the Antarctic Dry Valleys, Death Valley, and deep sea thermal vents, and developing analytical techniques which will allow reliable analyses in such places. Our most recent results come from two extreme environments, the surface of Mars and the Antarctic Dry Valleys.

Our research on Mars provided the first in-situ wet chemical analyses of the planet’s soil and changed the way we view its chemistry. Our results revealed a new aqueous geochemistry, an alkaline soil containing calcite, magnesite, a variety of soluble minerals, and perchlorate. Our findings provide evidence that under warmer conditions, water activity and the soil chemistry could have provided a potentially habitable environment. Today however, the surface is highly oxidizing and severely arid.

Our recent expedition to the Antarctic Dry Valleys has yielded new discoveries that may hold clues for Earth’s life and climate. Our group has identified perchlorate in several locations over an area of 50,000 sq-km. The discovery of perchlorate in Antarctica and on Mars has significant implications for its origin and interactions with the aqueous and microbial environments. Our results indicate perchlorate is produced globally and continuously in the Earth’s atmosphere, but deposits survive only in hyperarid areas, such as the Antarctic Dry Valleys or Atacama.

Our group is also involved in other projects, including the study of the chemistry near the deep ocean thermal vents; the development of an in-situ chemical analysis lab (MCAL) for future Mars rovers; measurement of total organic carbon on Mars using a new electroanalytical technique (MOCA); and research to study potential techniques for the unambiguous detection of extraterrestrial microbial life (MIDA).

SELECTED PUBLICATIONS:

*“Detection of perchlorate and the soluble chemistry of Martian soil at the Phoenix Lander site,” Science 2009, 325, 64-67.*
*“Life on Mars may be hidden like Earth’s extremophiles,” Nature 2007, 449, 281.*
BIOORGANIC CHEMISTRY AND CHEMICAL BIOLOGY

The last half-century has seen a revolution in how we understand and treat disease. The modern plan of attack is to understand disease at the molecular level, then judiciously target key proteins in the disease process using small-molecule drugs. However, most existing drugs target only a few types of cellular proteins such as kinases and signaling receptors. The ability to directly target other protein classes would lead to new strategies for treating autoimmune disorders, diabetes, neurodegenerative diseases, and many cancers.

The Kritzer lab uses peptides and peptidomimetics (peptide-like synthetic molecules) to inhibit disease-associated proteins that would be difficult or impossible to target using traditional approaches. These molecules are an exciting and rapidly expanding area of drug development because they can target protein surfaces in ways small molecules rarely do. In one project, we are exploring novel approaches for screening these compounds: we use genetics to generate millions of macrocyclic peptides in living yeast cells and to screen them for those that target specific proteins or disease processes of interest. In this manner, yeast are recruited as a virtual army of medicinal chemists capable of synthesizing and screening millions of compounds in a single week.

Discovering new bioactive peptides is only the first step, however. In several other projects, the Kritzer lab is exploring how these powerful molecules can be modified to promote greater utility as tools for chemistry and biology. We are exploring how intramolecular cross-links can be used to tune the reactivity of peptide-metal complexes to enable their use as chiral catalysts for important organic transformations. We are also exploring how larger peptides can be locked into their bioactive conformation via successive application of covalent bonds as “staples.” These bonds must be carefully designed, but when applied effectively they can make certain classes of peptides more potent, more selective, and more cell-penetrant. This strategy is being applied to inhibitors of diverse signaling proteins involved in human cancers. Through in-lab expertise and collaborations with biomedical scientists at Tufts University School of Medicine and other institutions in the area, the Kritzer lab simultaneously explores these molecules’ structures, functions, and biological effects.

SELECTED PUBLICATIONS:

CHEMICAL BIOLOGY, ORGANIC CHEMISTRY, AND BIOPHYSICS

Our group is involved in areas of research that lie at the interface of chemistry, biology and medicine. The main goal of our research program is to use chemical and biological methods to create novel and functional molecules that allow us to understand the mechanism of, and/or control biological processes. We use the traditional techniques of organic chemistry, such as synthesis and spectroscopy; of biological chemistry, such as recombinant DNA technology, protein purification and enzyme kinetics; of biophysics, including investigation of protein structure in membranes and of cell biology where we use microscopy and other imaging techniques to study structure and function.

Current projects in the laboratory focus on:

- De novo protein design and evolution;
- Combating bacterial resistance to antibiotics;
- Understanding the origin of the intron-exon gene structure of modern day enzymes;
- Catalysis by small molecules and peptides;
- Design of membrane protein architectures for specialized functions including membrane embedded molecules that serve as ligands for development of therapeutics.

SELECTED PUBLICATIONS:

THEORETICAL AND BIOPHYSICAL CHEMISTRY

We use computational tools, including molecular dynamics simulations, Monte Carlo simulations and electronic structure calculations to provide atomistic-level information on protein structure and dynamics.

Glycosylation is one of the most abundant protein post-translational modifications. Elucidating the intrinsic effects of glycosylation is essential for advancing our knowledge of glycobiology. Unfortunately, experimental studies of glycoprotein folding and stability are challenging – particularly due to the difficulty of obtaining homogenous glycoprotein samples, especially with biologically relevant, complex glycan structures. Therefore, we are establishing a state-of-the-art simulation scheme for the analysis of glycoprotein folding and stability using Markov state model analysis. Altered glycosylation is intimately linked to the pathophysiology of diseases ranging from cancer to rheumatoid arthritis. Thus, our finding will help elucidate the molecular origin of glycosylation-associated diseases. Furthermore, understanding the effects of glycosylation on protein will facilitate progress in engineering glycopeptide therapeutics and biomedical science.

Another research focus in our group is to understand how proteins manipulate their aqueous environments. The complexity of water’s structure and dynamics has fascinated scientists in all disciplines. In biology, hydration water is central to protein structure, dynamics and function. Just as water substantially influences proteins, proteins also perturb the structure and dynamics of surrounding water – for example, by retarding water dynamics in protein hydration shells. In order to survive in sub-zero environments, many organisms have evolved “antifreeze proteins” (AFPs), which have the capability to depress water’s freezing point significantly. Previously hypothesized to function by binding to specific ice crystal surfaces, this ice growth prevention mechanism of AFPs has recently been challenged. Results from modern terahertz spectroscopy show that AFPs can perturb surrounding water up to ~35 Å beyond the protein surface. This finding suggests that AFPs can lower the water freezing point through an ice nucleation prevention mechanism by dramatically altering water structure and dynamics. We are using parallel supercomputer and graphics processing unit computing to simulate ice formation in the presence of AFPs to resolve the debate regarding how AFPs prevent water from freezing and to advance our knowledge of protein-water interactions. Ultimately, understanding the molecular mechanism of antifreeze protein activity would advance our knowledge of condensed phase physics and cryobiology and could prove transformative for the design of antifreeze agents for medical and industrial applications.

SELECTED PUBLICATIONS:

“Investigating how peptide length and a pathogenic mutation modify the structural ensemble of amyloid beta monomer,” Biophys. J. 2012, 102, 315-324;
BIOANALYTICAL AND MATERIALS CHEMISTRY

We apply a multidisciplinary approach—combining aspects of chemistry, materials science, biophysics, and engineering—to solve problems in cell biology and global health. We are developing a set of chemical and physical tools to (i) study and manipulate cells and (ii) use cells in diagnostic and therapeutic applications. In addition, the development of our lab's core approaches will have broad significance in the study of the mechanisms that drive self-assembly.

**Immiscible Systems.** When mixed, many solutions of polymers, surfactants, and salts form immiscible phases. Systems that comprise multiple immiscible components form self-assembling step gradients whose physical properties (e.g., density and refractive index) change sharply across the interfaces between phases. These properties do not change over time because the systems are at equilibrium. We can control these properties by the careful selection of components, inclusion of co-solutes, or through polymer chemistry.

We are interested in (i) characterizing the properties of the interfaces between immiscible liquid phases, (ii) understanding the interactions between molecules that result in phase separation, (iii) developing a set of design rules to prepare immiscible systems, and (iv) applying immiscible systems in the study of complex mixtures. We are particularly interested in those immiscible systems that share water as a common solvent.

These aqueous multiphase systems (MuPS) can be used to separate and analyze the components of biological systems (e.g., cells in blood).

**Paper Diagnostics.** Successful implementation of point-of-care diagnostics has the potential to affect the global management of diseases dramatically (e.g., glucometers to monitor blood sugar levels in patients with diabetes). In the developing world, however, restrictions due to cost and a delocalized healthcare system have impeded the effective adoption of new technologies. Paper is an attractive platform with which to develop assays designed specifically for the developing world because the infrastructure required to develop them is minimal and the materials needed to manufacture them are inexpensive. Simple design rules provide access to complex fluidic networks and operations that can be incorporated into paper-based diagnostic assays. We are interested in introducing a broader class of porous media into paper diagnostic assays.

We will develop inexpensive materials—composites of polymers, cellulose fibers, and non-cellulosic fibers—that can enable biochemical assays that are not currently possible using only paper. A major goal of this program is to develop solutions that can be translated outside of the laboratory and into real world applications.

**SELECTED PUBLICATIONS:**

ANALYTICAL CHEMISTRY AND MASS SPECTROMETRY

We work at the interface of analytical chemistry, national security, and sensory analysis. We develop analytical instrumentation so that environmental pollutants can be detected in the field at depth without bringing sample to the surface as well as mold-related organics trapped in walls in sick buildings. Our research centers on correctly identifying target compounds in extremely complex matrices in seconds, not tens of minutes or hours. We rely on mass spectrometers to provide the data, but we analyze the data using spectral deconvolution algorithms we develop that untangle one compound’s mass spectrum from another when components in the mixture co-elute under fast GC or LC separation conditions.

Most people never think about what they eat or drink; only that they enjoy or dislike what they taste or smell. Nor do people question the products used to freshen or sanitize the air they breathe. Some people subscribe to aromatherapies, drink herbal teas, or look for ingredients in food such as antioxidants to prevent disease. Oils, extracted from plants, are the essential components used to flavor foods and beverages or scent perfumes, cosmetics, and household products. Essential oils provide the distinctive flavors and aromas people perceive as likes or dislikes in products we consume. Some people believe botanicals (the actual plant material) and their essential oils possess health benefits. We employ automated, sequential, 2-dimensional GC/MS to separate and identify each component in the sample. Once done, we can differentiate sample components from adulterants and we collaborate with other research groups to learn which compounds elicit sensory response (smell and taste).

For forensic investigations, whether environmental or arson, we use GC-GC/MS to provide compound-specific information related to crude oil and its byproducts as well as coal tar so that we can determine how these materials weather in the environment or behave in a fire when used as an accelerant. We work with instrument manufacturers to build probes that “sniff” pollutants in real-time as the sensor is advanced into the subsurface. Once detected, the sensor stops so that soil-bound pollutants can be volatilized, collected, and transported to the surface for analysis. We work with environmental engineers to produce maps and conceptual site models to predict the extent of contamination and rate of pollutant movement. Recent work with state crime labs suggest new diagnostics we produce may provide better indicators of arson then currently employed.

Although these projects are broad in scope, the group’s goals are focused on how best to quantitatively identify compounds in extremely complex systems.

SELECTED PUBLICATIONS:

BIOORGANIC CHEMISTRY AND CHEMICAL BIOLOGY

An important frontier in chemical biology lies in the ability to develop new chemical methods that transpire at mild temperatures amidst many other reactive species and in parallel with the countless transformations that occur inside of a living cell. Research in the Scheck laboratory focuses on the invention and execution of encodable, bioorthogonal chemical strategies that report on changes in protein function in living cells.

New chemical tools to study complex posttranslational networks.
Posttranslational modifications (PTMs) are important events that lead to defined changes in protein function. Because these modifications occur after translation, they can be difficult to understand based on the genetic template, and are often part of complex posttranslational networks. Our lab is focused on the innovation of chemical methods that can be used to understand the biology of two such PTMs: nitration/nitrosylation and ubiquitination. In the first case, we exploit the unique reactivity of nitric oxide (NO)-derived PTMs to develop new chemistry that can be used to detect proteins modified by NO in live cells. In the second case, we use existing chemical biology methods to develop a one-of-a-kind strategy that can track ubiquitin as it moves through its sequential, multi-enzyme cascade to become linked to a target protein in live cells. In both cases, the developed chemistry will be used to address longstanding questions about the role of these vital, yet elusive, PTMs in biology.

Non-enzymatic PTMs for chemical and synthetic biology.
Most chemistry that occurs within the cell is controlled by enzymes, yet there are several non-enzymatic PTMs that are observed to occur with selectivity in nature. Our lab is interested in understanding the molecular basis for non-enzymatic reactivity in biological systems. In particular, we aim to identify how the local environment on a protein surface influences non-enzymatic reactivity and selectivity. We address this question in two ways: 1) We explore a natural non-enzymatic PTM, called glycation, in order to identify the features of local environment—particularly primary sequence—that lead to enhanced reactivity. 2) We employ engineered organocatalytic peptides to develop new bioorthogonal reactions. This chemistry reports on changes in local environment, especially those involving transitions in tertiary structure. This work will expand the range of non-enzymatic chemistry that can be harnessed to provide valuable chemical and synthetic biology tools.

SELECTED PUBLICATIONS:
PHYSICAL, ANALYTICAL, SURFACE AND MATERIALS CHEMISTRY

We are engaged both in fundamental studies of soft or buried interfaces and in developing novel analytical instrumentation to probe and image such interfaces. Probing soft interfaces such as that of an aqueous solution challenges the experimentalist due to the dynamic, high vapor pressure nature of the surface that prohibits use of many classic vacuum techniques. One very effective tool is the nonlinear spectroscopy, sum frequency generation, which is capable of delivering molecular-level data on surface species. Pioneering work by the Shultz lab has resulted in a new picture of the surfaces of aqueous solutions, particularly salt solutions that are relevant to biological interfaces. Our current efforts are focused on ice, producing the first detailed glimpse of that surface – part of which is illustrated in the image at the right of this page. Each face of ice has its own personality and reactivity, which profoundly affects the fate of materials released into the environment. The same hydrogen-bonding forces that shape ice help shape biological materials, so these studies have far-reaching implications.

Water, specifically cleaning water, is the focus of a second project in the laboratory. It is estimated that half the hospital beds in the world are occupied by people suffering from waterborne diseases. This project focuses on developing effective photocatalysts that can use readily available sunlight to turn contaminants into harmless CO₂ and water. Our recent work has generated a catalyst that is three times as efficient as the nearest competitor; furthermore it achieves this high efficiency by using environmentally benign molecular oxygen as the oxidant. To be economically viable, we need to increase efficiency by about 2.5 times more. This is the current target.

Both projects require development of novel analytical instrumentation to produce the sensitivity and imaging required to develop pictures like those shown on this page. We make heavy use of polarization and the attendant interferences for instrument development and for image analysis. This imaging development project has just launched, so now is a good time to get in on the ground floor.

SELECTED PUBLICATIONS:

Research interests include use of nuclear magnetic resonance spectroscopy in studies of the stereochemistry and conformations of organic molecules, computer applications in teaching and research, and organic synthesis. Projects have included the study of nonchair conformations of cyclohexane derivatives, the influence of electrostatic interactions among polar groups upon conformational equilibria, and conformational studies of molecules of biological interest. Much of this work required the synthesis of organic compounds with deuterium and carbon-13 at specific locations for use in the determination of NMR coupling constants and relaxation times, and is interpreted in terms of conformational equilibria. Experimental conformational energies were also compared with those calculated by use of the methods of computational chemistry. Other projects have involved the use of computers in teaching organic chemistry. The most ambitious of these projects was designed to develop an interactive computer program for teaching of organic synthesis.

SELECTED PUBLICATIONS:

Charlie Sykes

AWS Peter Mark Memorial Award; Camille Dreyfus Teacher Scholar; NSF CAREER Award; IUPAC Young Observer; Arnold and Mabel Beckman Foundation Young Investigator; Cottrell Scholar of Research Corporation

PHYSICAL CHEMISTRY, SURFACE SCIENCE, AND NANOSCIENCE

A Single Molecule Approach to Catalysts, Chirality and Molecular Motors

Scanning probe microscopy (SPM) was invented by physicists and traditionally used to study fundamental surface phenomena. However, SPM can also elucidate the atomic-scale details of important chemical systems. By relating a system’s nanoscale details to macroscopic properties like motion and reactivity, much can be learned about structure-function relationships. For example, we discovered that dispersing single palladium atoms in inexpensive, catalytically-inert copper surface created an ultraselective hydrogenation catalyst. This single atom alloy approach may prove to be a general strategy for designing novel, cost-effective heterogeneous catalysts in which an expensive, catalytically-active element is atomically dispersed in a cheaper, more inert matrix. In the area of molecular motors, we experimentally demonstrated the world’s first single molecule electric motor, which is powered by electrons from a SPM tip. Surprisingly, the direction and rate of the motor’s rotation is related to the chirality of both the motor molecule and the tip, illustrating that the exact geometry and chirality of electrical contacts to molecules can have a large influence on their dynamics. These systems provide important examples of how understanding chemistry at the nanoscale can impact the design of next generation catalysts and molecular devices.

SELECTED PUBLICATIONS:

Research in the Thomas Lab combines physical organic chemistry with polymer synthesis and photochemistry to develop materials that have new light-responsive capabilities and properties. Our research has focused in three areas:

1. Singlet-oxygen responsive luminescent materials. The amplified photochemical production of $^{1}O_2$ is critical in photodynamic therapy for cancer as well as in a number of harmful biological processes. We have developed two families of conjugated polymers that respond to the presence of $^{1}O_2$ by either diminution of fluorescence or a change in fluorescence color. We have extended these systems to work in water, in response to tagged proteins, and with reversibility.

2. Control of conjugated materials. Conjugated organic materials combine the optoelectronic characteristics of inorganic semiconductors, such as mobility of charge carriers and excited states, with the structural variety and solution processability enabled by organic chemistry. Our achievements have centered on combining photocleavable moieties with conjugated materials, and have yielded rationally designed light-activated response in critical characteristics such as solubility and luminescence efficiency.

3. Photochemical control of electrostatics. Intermolecular forces that dictate how collections of molecules behave on microscopic and macroscopic scales are electrostatic. We have developed two new classes of photoresponsive materials in this area: one reversibly changes the sign of charge separation caused by contact electrification (static charging) upon irradiation with light; the second switches attractive interactions (between positively and negatively charged polymers) to repulsive interactions (between negatively charged polymers) to create precisely-fabricated polymer films that can be dissolved only upon irradiation with UV or visible light.

**SELECTED PUBLICATIONS:**

PHYSICAL AND SURFACE CHEMISTRY

We study how and why molecules react on surfaces. Reactions at the gas-surface interface are highly dynamical events. Large-scale atomic and vibrational motions transform reactants into products on the sub-ps timescale and Å length scale. Our experiments probe the ultrafast nuclear motion and energy flow dynamics that underlie important industrial processes including heterogeneous catalysis and chemical vapor deposition. Our goal is to then use this molecular-level picture of energy flow along the reaction path in order to better model existing processes and direct the rational design of new catalytic materials and deposition techniques.

Our experiments use vibrational- and rotational-state selective laser excitation of molecules in a supersonic molecular beam to provide precise control over the energetics (and even orientation) of the gas-phase reagent as it approaches the surface. We then quantify reaction probability and product identity as a function of the reagent’s energetic configuration. Contrary to prior expectations, these experiments show that the vibrational state of the incident molecule can have a profound effect on probability of reaction. For example, in promoting methane’s dissociation on a Ni(111) surface, vibrational energy can be more effective than translational energy and a C-H stretching vibration is more effective than a bending vibration containing 30% more energy. These insights suggested that energy redistribution within the reaction complex is not complete prior to reaction and that the competing kinetics of energy redistribution and reaction might be manipulated to control the outcome of a reaction. We subsequently confirmed this hypothesis by exerting bond-selective control over a heterogeneously catalyzed reaction.

Recently, we have used our ability to control precisely the energy of the gas-phase reagent to highlight the role of surface atom vibrations in promoting reactivity. Our work, along with that of theoretical collaborators, is highlighting the dramatic role that surface atom vibrations can play in promoting reactivity. This effect may be an important source of the enhanced reactivity exhibited by nanostructured catalysts.

SELECTED PUBLICATIONS:

Many early milestones in the life sciences revolution were achieved by chemists who took an interest in molecular biology. This natural partnership between chemistry and biology is only growing stronger. In order to train future scientists who are versed in both chemistry and biology, the Department of Chemistry, in partnership with our faculty colleagues in the School of Engineering, offers a joint Ph.D. program in chemistry and biotechnology. We also provide opportunities to work with other engineering faculty with overlapping interests.

The curriculum differs from the chemistry program in order to take into account the additional emphasis on molecular biology. The Ph.D. candidate in the chemistry-biotechnology program must take core courses in organic chemistry, biochemistry, molecular biology, and one other graduate-level chemistry course. Two other graduate-level courses relating to the molecular biological or chemical sciences must also be taken. Chemistry-biotechnology Ph.D. students must also complete at least one semester of a teaching assistantship, two study topics, defense of an original research proposal, and finally through the oral presentation of a dissertation reporting significant work of publication quality.

Participating faculty from the Department of Chemistry include Krishna Kumar and David Walt, although other faculty may join if an opportunity arises in their research programs (see previous section for their research summaries). Participating colleagues from the School of Engineering include David Kaplan from the Department of Biomedical Engineering, and Kyongbum Lee and Hyunmin Yi from the Department of Chemical and Biological Engineering. Additional faculty such as Maria Flytzani-Stephanopoulos may be open to cross-disciplinary research projects. Profiles of these faculty are provided in the following pages, and matriculating graduate students are invited to explore research opportunities with them as well.
BIOPOLYMER ENGINEERING, BIOMATERIALS, AND TISSUE ENGINEERING

The interface between biology and biopolymer science and engineering is the focus of our research program. Our efforts are aimed at understanding biological synthesis and processing of polymers from a polymer/ materials science perspective. This understanding is relevant to molecular recognition, self-assembly and the formation of materials with well-defined architectures, and biomaterials and tissue engineering.

We utilize a variety of experimental strategies to gain insight into: (1) genetic engineering—exploration of the molecular genetics of biosynthesis pathways for biopolymers, (2) whole cell physiology—manipulation of the cell environment to regulate the chemical and physical features of the biopolymer synthesized, and (3) enzymatic—polymer synthesis or modification using enzymes in vitro in novel environments. In all cases, our aim is to manipulate the structure of biopolymers as a route to understand and control assembly, molecular recognition, and biological interactions. In addition, since the synthesis, modifications, and processing of these polymers are carried out within a biological context, issues related to green chemistry and environmentally compatible processes are fostered.

Within the context of biomaterials and tissue engineering, the impact of selective environmental factors (e.g., growth factors, mechanical stress) on stem cell differentiation, the relationship between biomaterial structure (supramolecular assembly) and stem cell responses, and the role for complex bioreactor designs to study these interactions are current areas of inquiry. We are particularly interested in how environmental cues (biomaterial structure/architecture, mechanical forces) influence stem cell processes and tissue engineering outcomes using both in vitro and in vivo studies. Areas of current focus include: protein-based biomaterials (silk, collagens), fibrous protein structure, assembly, and processing (self fabricating, silk, collagen), polysaccharide-based biomaterials (emulsan, cellulose) and tissue engineering (ligament, bone, nerve, stem cells).

SELECTED PUBLICATIONS:

METABOLIC ENGINEERING

Our research is ultimately aimed at understanding cellular metabolic design and its impact on cellular biochemical activities. The basic premise of this work is that cellular metabolism is accomplished through the concerted actions of a network of biochemical reactions which interact with various other cellular functions through shared substrates, products, cofactors, and other regulatory molecules. In this light, the metabolic network is a focal point of cellular biochemical activity, and rational design approaches to altering or optimizing cell properties will benefit from “systems”-oriented analyses of cellular metabolism. Our goal is to apply these notions to study the interactions between general cellular energy metabolism and cell-specific phenotype development.

Current target systems are the liver and adipose tissue, which are central to whole body energy homeostasis. Disturbances to liver and adipose metabolic functions contribute to a number of disorders, including obesity and diabetes.

Analysis and manipulation of adipocyte energy metabolism
This research studies the metabolic basis for excessive adipose cellular mass expansion with a goal of identifying enzyme targets for obesity drug development. One approach is to develop pattern recognition tools for finding significant discriminatory metabolite and protein markers that distinguish “obese” from “small” adipocytes. The second approach is to engineer smaller adipocytes by “rewiring” metabolic pathways in adipocytes; for example, through forced expression of foreign or endogenous proteins.

Metabolic response of the liver to oxidative stress
In this work, we use experimental and mathematical models to investigate the metabolic response of the liver to oxidative stresses resulting from either inflammation or drug biotransformation.

Sensors for metabolic profiling
This work seeks to develop a portable biosensor array platform for real-time detection, interpretation, and classification of small molecules with broad significance for medical diagnostic applications. This hybrid sensor platform integrates cell-based detection, microscale acidification measurement, biological pattern recognition, and integrated circuit design.

SELECTED PUBLICATIONS:
Hyunmin Yi

NANOBIOTECHNOLOGY

Controlled synthesis of functional nanomaterials is an unmet challenge. We tackle this fundamentally important problem from the biofabrication perspective by exploiting the selective and programmable nature of biological materials and interactions. Specifically, we utilize various biopolymers and genetically modified Tobacco Mosaic Virus (TMV) as nanotemplates toward facile fabrication of functional nanoarchitectures, biosensing platforms and nanocatalysts.

Staged Nanomanufacturing
Our research objective here is to build complex 2D and 3D geometries using TMV building blocks with well-defined dimensions and nucleic acid hybridization-based assembly approach. Through genetic engineering tools, we first build small TMV blocks with precise lengths by assembling individual coat protein subunits around synthetic RNA strands. These building blocks then constitute basic rod-glue units to construct complex nanoarchitectures in a step-by-step addition process.

Viral Templated Nanocatalysis
We also exploit TMV as nanotemplates for functional inorganic materials synthesis. Specifically, genetically modified TMV serves as preferential templates for controlled synthesis of catalytically active palladium (Pd) nanoparticles. We have recently shown that spontaneous formation of Pd nanoparticles on TMV templates leads to size ranges around 1nm with high catalytic activity. We are particularly interested in understanding the nanoparticle growth kinetics and the effects of the particle size on the catalytic selectivity.

Biofabrication of Hybrid Microparticles
Hydrogel-based microparticles offer powerful platforms for rapid and high throughput biosensing as well as advanced materials fabrication. We pursue an integrated fabrication-conjugation approach toward controlled fabrication of hierarchically assembled, multifunctional hybrid materials. In particular, we utilize a robust replica molding technique to fabricate hydrogel microparticles containing a potent polysaccharide chitosan that provides ample conjugation sites for probe biomolecules and TMV templates toward rapid biosensing.

SELECTED PUBLICATIONS:

Visualizing the Area

It can sometimes be difficult to visualize the different cities and landmarks in the Greater Boston Area, a problem derived from the nature of how and when the area was settled, combined with the fact that much of the land comprising Boston today did not exist when the area was first settled. This history led to windy roads, communities that grew up in different ages, and peculiar locations for some buildings, such as the location of the airport on an island. The map to the right has particular landmarks pointed out to help you to understand where Tufts is, relative to the community around it. The gray circle represents five miles from Tufts University. For events going on all over the Greater Boston Area, check [http://calendar.boston.com/boston_ma/events](http://calendar.boston.com/boston_ma/events).

- **Tufts University**, Medford Campus.
- **Davis Square**, Tufts’ nearest connection to the Red Line, and its shopping district.
- **Havard University and Harvard Square**, accessible by the Red Line and bus connections.
- **MIT**, accessible by the Red Line.
- **Boston University**, major student area.
- **Middlesex Fells Reservation**, a great place near campus for those who like the outdoors. Check out [www.fells.org](http://www.fells.org).
- **Revere Beach**, America’s first public beach, accessible by public transit.
- **Boston Common**, the public park of Boston; hosts events during the summer.
- **Fenway Park**, home of the Red Sox, New England’s Major League Baseball team.
- **North Station**, home to the Celtics and the Bruins, also the location of many concerts and performances, as well as a transit station. For more information on public transit, check out [www.mbta.com](http://www.mbta.com).
- **South Station**, a major transit hub, including Amtrak and regional buses.
- **Logan Airport**, Boston’s international airport; accessible by public transit.
Tufts University

Graduate Program in Chemistry
Tufts University
62 Talbot Avenue
Medford, MA 02155

Tel: 617-627-2649
Fax: 617-627-3443
E-mail: chemgradinfo@tufts.edu

HTTP://CHEM.TUFTS.EDU