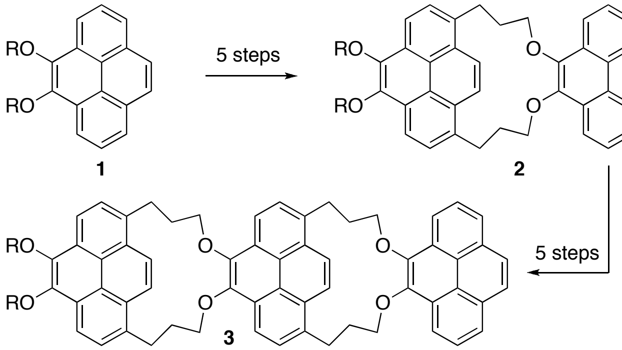
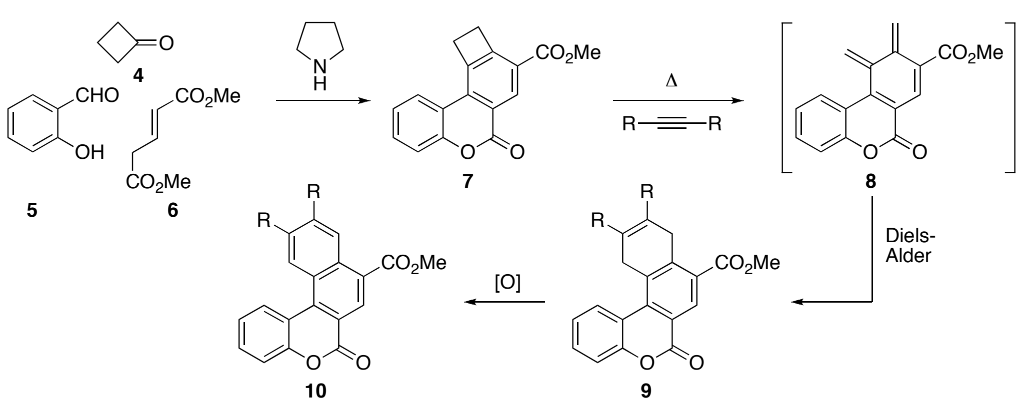
ISREP-Chem Projects 2012-2013

DR. GRAHAM BODWELL

Project 1. An Iterative Approach to Novel (1,8)Pyrenophanes. This project exploits chemistry that has recently been developed in the Bodwell group (*Org. Lett.* **2011**, *13*, 2240–2243). 4,5-Dialkoxypyrenes **1** will be converted into (1,8)pyrenophanes **2** by way of a 5-step sequence of reactions. In principle, such cyclophanes should serve as starting materials for the same 5-step series of reactions, which would lead to a higher pyrenophane **3**. The conformational and photophysical properties of the pyrenophanes should prove to be interesting. Students working on this project will work with a graduate student and learn about target-oriented synthesis.



Project 2. The synthesis of benzo[*b*]naphtho[*1,2-d*]-6*H*-pyran-6-ones using a multicomponent reaction. The inverse electron demand Diels-Alder (IEDDA) reaction is a subject of longstanding interest in the Bodwell group and this has recently resulted in the discovery of a multicomponent reaction (MCR) leading to dibenzo[*b,d*]-6*H*-pyran-6-ones (DBP) (*Org. Lett.* **2012**, *14*, 310–313). In one case (shown below), the product **7** contains a benzocyclobutene unit, which offers the opportunity to generate a novel electron deficient *o*-xylylene **8** upon heating. When done in the presence of a suitable dienophile, this should result in the formation of a new six-membered ring. Dehydrogenation would then afford functionalized benzo[*b*]naphtho[*1,2-d*]-6*H*-pyran-6-ones **10**. Students working on this project will work with a graduate student and learn about methodology-based synthesis.



DR. CHRISTINA BOTTARO

Project 1. Evaluation of Molecularly Imprinted Polymers (MIPs) in Thin-Film Format as a Matrix for Quantitative and Qualitative Analysis of Caffeine. Caffeine is an interesting analyte because it is one of the most widely consumed pharmaceuticals and is universally recognized as an indicator of wastewater contamination in surface waters. In this project, thin-film MIPs will be developed based on systems that have been previously reported for caffeine. The various systems will be tested for binding, selectivity and suitability to thin-film format. MIPs are polymeric systems that selectively bind only molecules used in the original templating process or compounds with a very similar shape and functionality. We have recently demonstrated that MIPs can be used to extract chemicals of interest from water and that detection of these analytes can be accomplished by direct interrogation of the analyte bound in the polymer using ionization methods like matrix assisted laser desorption ionization (MALDI) and desorption electrospray ionization (DESI) with detection by mass spectrometry (MS). With MALDI, the MIP acts as a matrix binding the analyte of interest. When an aromatic monomer is used in the synthesis of the MIP (e.g. vinylpyridine) then the polymer formed has a built-in UV absorbing moiety that can absorb at the wavelength of the UV laser used in MALDI-MS. Thus, irradiation of the MIP-analyte system by the laser can result in ionization of the analyte. Initial studies have shown some challenges associated with achieving the appropriate threshold energy for MALDI-MS; however the use of solvent activation could be used to facilitate the process. Ultimately these films will be incorporated into devices for monitoring of environmental pollutants and rapid on-site analysis. For such applications, merely detecting the analyte of interest is only a first step and the validity of the approach for quantitative analysis must be verified. In this project, MIPs will be synthesized by various means and their performance in terms of extraction efficiency, selectivity of the polymer, linearity and detection limits, will be determined. Analysis will also be carried out using conventional extraction with high performance liquid chromatography with UV and MS detection.

Project 2. Study of the Effects of Matrix, Molecular Weight and Form of Carbon on Solid State NMR Response using Cross-Polarization and Single Pulse Approaches. Solid state NMR is used widely to characterize complex heterogeneous materials typical of natural organic matter (NOM). Cross-polarization (CP) is often used to improve the speed and sensitivity of analysis over the single-pulse (SP) solid state ^{13}C-NMR. Experiments on NOM have shown that CP can significantly bias the signal toward alkyl and aromatic carbon, and against carbonyl and carboxylate carbon. In this project, we will use model compounds to try to understand and quantify the effect of molecular weight, carbon type and other matrix effects on the bias introduced by CP. We will also study the effects of pulse lengths on the CP enhancement and applicability of new CP pulse-sequences recently reported for soil organic matter. We will also apply these techniques to standard NOM samples and compare the results to published data on the NOM composition established by non-NMR methods to see which NMR experiments yield results that agree best with other analytical approaches. By providing a better means to predict the effect of CP on results, and using experiments to give data that better represents the NOM composition, chemists and biogeochemists will be able to make more accurate conclusions about carbon composition and processing of NOM in the environment.

DR. TRAVIS FRIDGEN

Project 1. Structures of Bare and Solvated Metal Cation/Serotonin Complexes in the Gas Phase. Serotonin is a neurotransmitter often associated with feelings of well-being and regulates many behavioural and physiological functions. It has been shown to interact with a number of metal ions (*J. Pineal Res*. **2001**, *31*, 102), which acts to change their chemical behaviour and conductance through biological membranes (*Spec. Med*. **1999**, *21*, 528). We would like to investigate the structures of bare and solvated metal dication complexes, (i.e. Ca^{2+}, Zn^{2+}, Cu^{2+} and Pb^{2+}) with serotonin. The techniques we will use are infrared multiple photon dissociation spectroscopy (gas-phase vibrational spectroscopy), collision induced dissociation, as well as computational methods.

DR. ERIKA MERSCHROD

Project 1. Multiscale materials modeling. In practice, materials properties depend on more than small-scale features such as chemical composition and molecular or crystal structure. Mesoscale features such as polycrystallinity or longer-range interactions can determine material performance in the real world. Through this project, the student will learn tools for multiscale modeling and will apply those tools to a material system of mutual interest. (Possible options include optimizing optical properties, exploring aggregation of small biomolecules, etc.). We will provide access to cutting-edge high-performance computing facilities through various national consortia.

Project 2. Artificial tissue scaffolds. Cartilage, in contrast with bone, does not repair itself well. Artificial tissue scaffolds to promote healing in cartilage would therefore be quite useful! The student will develop composite materials from the primary components of cartilage (type-II collagen, uronic acids, etc.) and evaluate their structure and mechanical properties as key indicators for biocompatibility. The student will learn protein-handling techniques and, depending on progress, there may be opportunities for cell culture studies.

DR. SUNIL PANSARE

Project 1. Asymmetric Synthesis of Aryl Quinolizidine and Indolizidine Alkaloids and their Analogs. Aryl quinolizidines and indolizidines, and the related phenanthro-analogs, form an important group of alkaloids with an interesting biological profile that includes significant anticancer activity. Recent studies in our group have established an enantioselective route to functionalized quinolizidines and indolizidines from chiral-nitroketones which are obtained from an organocatalytic, asymmetric ketone-nitroalkene conjugate addition reaction. This methodology will be applied to the synthesis of selected quinolizidine and indolizidine alkaloids. Structural analogs of these alkaloids will also be prepared. The emphasis of these studies will be the development of solution-phase synthesis methods that are applicable to the preparation of small libraries of aryl quinolizidines and indolizidines for biological testing.

DR. KRISTIN PODUSKA

Project 1. Good Vibrations! Microscopic and nanoscopic level investigations of geological and archaeological materials can reveal important clues about specimen composition, formation, and changes that may have occurred to it over time. This project will combine the use of Fourier tranform infrared (FTIR) spectroscopy and other material characterization techniques to characterize geogenic and archaeological materials that are based on carbonates and phosphates, with the goal of assessing the impact of different material formation and diagenesis processes. This will include comparisons with biogenic and lab-synthesized carbonates (calcite, aragonite, dolomite) and phosphate materials (apatites and iron phosphates) to help establish protocols to distinguish spectroscopic features that are uniquely characteristic of the archaeological specimens. Supporting structural characterization measurements will include techniques such as X-ray diffraction, Raman spectroscopy and/or UV-visible spectroscopy.

This project will be undertaken as part of a larger research effort in my lab, which involves graduate students and other undergraduate researchers, that is designed to aid our understanding of the basic chemistry of how solid materials crystallize, and more specifically, in identifying patterns in the atomic-level disorder that serve as signatures for different kinds of crystallization processes. This is a very challenging problem to tackle because there is no single definitive method for exploring ordering phenomena at different length scales in solid materials. These risks, however, are well worth the payoff. If we can link disorder signatures with specific crystallization processes, we have the possibility of learning how natural geogenic and human-made materials have evolved over time. We would also have the opportunity to design crystallization procedures to produce synthetic materials with specific disorder signatures that have unique physical properties.

DR. CHRIS ROWLEY

Project 1. QM/MM Simulations of Ion Solvation. The solvation of divalent cations such as Mg(II), Ca(II), Zn(II), and Cu(II) in liquid water is of crucial importance to biochemistry and environmental science. Nevertheless, the microscopic structure of water molecules around these ions is still unresolved. Recently, our group has developed a new Quantum Mechanics / Molecular Mechanical method (QM/MM) that allows the solvation of these ions to be studied computationally with a level of accuracy that was previously impossible (Rowley, C.N., Roux, B. *J. Chem. Theory Comput.* **2012** DOI: 10.1021/ct300091w). We are using these methods to understand why ions bind preferentially in different chemical environments depending on parameters such as their ionic radius and polarizabilities. Students working on this project will learn state-of-the-art quantum chemical methods using advanced supercomputing facilities.

Project 2. Molecular Dynamics Simulations of Ionic Liquids. Ionic liquids have emerged as an environmentally friendly alternative to industrial organic solvents. These liquids, formed from molten salts, have unique solvation properties due to their high dielectric constants and low viscosities. The solvation thermodynamics, transport, and reactivity of chemical products within an ionic liquid environment is very complex and it is hoped that computer simulations can reveal the features that are important in the design of improved ionic liquid solvents. Students working of this project will use high performance supercomputing to simulate the dynamics of environmental contaminants within an ionic liquid extraction system.