School of Chemistry

Honours Projects

2018
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INTRODUCTION - Honours 2018

This booklet is intended to provide an overview of the research activities within the School of Chemistry and to give you an indication of the Honours projects that will be offered in 2018. You are encouraged to study these and to speak with the research supervisors. This research project makes up 75% of the final mark for the Honours year, with the other 25% from the coursework component which runs in first semester.

Current third year students are eligible to do Chemistry Honours (Clayton) in 2018 provided that they fulfil the entry requirements and that a supervisor is available.

Students will be allocated to supervisors and projects on the basis of their third year results and their preferred projects. Great care is taken to ensure that all students are treated equitably and where possible that they are be allocated to the area and supervisor of their choice.

All Honours candidates must discuss prospective projects with at least four supervisors before choosing their preferred project. They should then select at least three potential supervisors and projects in order of preference. The application forms – one for Honours entry which is from the Faculty of Science, the other is the project nomination form which is from the School of Chemistry – are both available on the School of Chemistry web page.

Please note that the project descriptions are quite short, and more comprehensive details can be obtained when speaking to supervisors.

We look forward to seeing you in the Honours course next year. Please contact me if you have any questions about the Honours year!

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Our research group carry out research at the boundaries of analytical chemistry, physical chemistry, environmental chemistry, materials chemistry and biochemistry. Our research activities cover both fundamental and applied research projects, and is multi-disciplinary in nature, combining chemistry with aspects of biology, biochemistry, medical science, nanotechnology, and environmental science.

**Our current research foci are in Nanobiosensors, Microbial Fuel Cells and Enzyme-Based Fuel Cells.** Target applications in these research are for environmental monitoring, clinical and medical diagnostics, as well as energy recovery systems.

Our research on nanobiosensors focus on the use of novel electrochemical strategies for integration of nanomaterials, such as graphene, carbon nanotubes, nanoparticles, and nanowires with biological recognition molecules, such as enzymes, DNA, proteins and other biomolecules, for fabrication of ultrasensitive nanobiosensors for detection of substances, such as cholesterol, formate, glucose, nitrate, penicillin, phenols, phosphate, sulphite, and urea (see First figure). On the other hand, our research on microbial and enzyme-based fuel cells involve development of strategies for achieving highly efficient energy recovery from wastewaters, as illustrated below in the second Figure. A key focus of this research is on the development of novel highly efficient anodes and cathodes for fuel cells.

The two available honours projects are:

1. **Speciation of Phosphate in Soil with a Phosphate Nanobiosensor**  
This project aims to develop a more simplified and rapid approach for speciation of phosphate in soil by using a phosphate nanobiosensor. It will involve verification of a phosphate nanobiosensor already developed in our research group. Main focus of the project will be on the adoption of this device for detection of the different phosphate species in soil which are currently determined by the very long and tedious traditional methods. The aim is to both simplify the approach and to substantially reduce the required analysis time with the use of the phosphate nanobiosensor.

2. **Development of a Urea Nanobiosensor for Rapid Monitoring of Kidney Health**  
This project will involve construction of an ultrasensitive and reliable urea biosensor based on the immobilisation of the enzyme, urease, with graphene. The presence of urease catalyses the hydrolysis of urea to ammonia and carbonic acid. These two products are then further hydrolysed to generate ammonium and bicarbonate ions: The urea concentration can thus be quantified indirectly from the levels of either NH\textsubscript{3}, NH\textsubscript{4}\textsuperscript{+}, CO\textsubscript{2}, HCO\textsubscript{3}\textsuperscript{-} or the associated pH change. The resulting device will be used to analyse urea in blood samples from patients with kidney diseases.
Professor Phil Andrews
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This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research can be seen at:
http://monash.edu/science/about/schools/chemistry/staff/Andrews.html

1. **Combating multi-resistant bacteria with metal complexes (Bi vs Fe vs Ga)**
   (with Prof. Ross Coppel, Microbiology)

   In tackling the continued growth in multi-resistant bacteria and the increasing rate of antibiotic resistance, this project focuses on the development of bismuth(III) compounds which show high activities against common and resistant strains of bacteria (eg MRSA, VRE). Read more: Chem. Eur. J., 2014, DOI: 10.1002/chem.201404109.

2. **Development of new bismuth and gallium based anti-Leishmanial drugs**
   (with Dr Lukasz Kedzierski, Peter Doherty Institute, University of Melbourne)

   Leishmaniasis is a parasitic infection prevalent in the developing world. Current frontline drugs are based on Sb(V) compounds which show severe side-effects and for which resistance has begun to appear. This project focuses on developing and testing new bismuth and gallium compounds as more active and less toxic alternatives. Read more: Dalton Trans., 2014, 43, 12904 – 12916.

3. **Developing new antimicrobial materials and coatings**
   (with Dr. Warren Batchelor, Chemical Engineering; Prof. Michael Mehring, TU-Chemnitz)

   This project investigates the formation of novel bismuth(III) complexes which have high antimicrobial activity and their incorporation into natural and synthetic polymers and materials. The antimicrobial activities of the new materials and their potential as 'clean surfaces' will be assessed. Read more: Eur. J. Inorg. Chem., 2014, 4218 - 4227.

4. **Targeting Novel Chiral Heterobimetallic and Metallocyclic Main Group Complexes**
   (with Dr. Victoria Blair)

   This project investigates the synthesis and full characterization of novel chiral hetero-di-anionic and hetero-bimetallic complexes of alkali metal, and d or p-block elements (Zn, Cu, Al, Ga, In, Sn, Sb). The second part will utilise dilithiated chiral allylamides as precursors to a new and unique family of chiral hetero-di-anionic metallocycles. Requires inert atmosphere handling techniques. Read more: Organometallics, 2012, 31, 8135–8144.

5. **Development, efficacy and mode of action of new bismuth-NSAID anti-cancer drugs**
   (with Dr. Carolyn Dillon, University of Wollongong)

   The aims of this project are the synthesis of bismuth complexes with increased potency towards ovarian and bowel cancer cells, and identifying promising candidates for animal testing using chemical stability monitoring and cell culture screening. Read more: J. Inorg. Biochem., 2014, 135, 28–39.

6. **Targeting Helicobacter pylori: overcoming clarithromycin resistance with bismuth drugs**
   (with A/Prof Richard Ferrero, Hudson Institute of Medical Research)

   H. pylori is the bacterium responsible for gastritis, duodenal and peptic ulcers and stomach cancers. This project focuses on the synthesis of novel bismuth compounds which are highly active against the bacterium, and investigating their mode of action. Read more: Dalton Trans., 2015, 44, 16903–16913
Coordination Polymers and Supramolecules

We are designing and making coordination polymers (sometimes also known as metal-organic frameworks, or MOFs) and supramolecular species for a variety of interesting applications, including adsorption of gases such as hydrogen (for hydrogen fuelled cars) and carbon dioxide (greenhouse gas capture), long or short range magnetic ordering, molecular switching (for information storage or molecular sensing), and as new materials for molecular separations. We are pursuing a number of approaches to this, including:

- New classes of bridging ligands in which the bridging length can be controlled by the presence or nature of e.g. group I or II metals (Chem. Commun., 2009, 5579).
- Large (3 nm in diameter) spherical supramolecules (or ‘nanoballs’) (Angew. Chem. Int. Ed. 2009, 48, 2549 & 8919; ChemPlusChem 2012, 77, 616) which show a large variety of properties. For example, they can switch between two magnetic spin states. The change may be induced by change in temperature or, as a series of experiments in Bordeaux, France showed, irradiation of light. The molecular packing also creates cavities within the solid state, and thus the crystals will readily absorb solvent vapours, hydrogen, and CO2. Finally, the nanoballs also show catalytic activity.
- Incorporation of amine groups into porous MOFs in order to increase the selectivity of CO2 sorption over other gases, such as N2. This is part of a large multi-institutional program focussed on developing MOFs for “real world” CO2 capture.
- Porous MOFs for the chromatographic separation of molecules based on size, chirality or other chemical features. Surprisingly little work has been done in this field, and we are currently exploring this potential in depth (Chem. Commun. 2014, 50, 3735).

Chemistry of Small Cyano Anions

We have been investigating the chemistry of small cyano anions (Chem. Commun. 2011, 47, 10189). They have shown some remarkable chemistry, including the synthesis of a large range of transition metal and/or lanthanoid clusters which may have applications as single molecule magnets, interesting new coordination polymers and discrete complexes showing unusual packing motifs and ligand binding modes, new hydrogen bonding solid state networks, nucleophilic addition of alcohols and amines across the nitrile groups to give new anion families, and the production of ionic liquids containing either the free anions or even metal complexes of the anions. The versatility and range of applications of these simple anions is unprecedented.
In the Bell Fluorescence Lab, we apply advanced fluorescence techniques to answer questions in materials science and cell biology. In most of our research we operate at the ultimate level of resolution – single molecules – which allows us to detect hidden events and distributions. Application of single molecule detection allows us to perform super-resolution imaging and break the diffraction limit of light to reveal previously obscured details, even inside cells.

www.super-resolution.org.au   Instagram: Bell_Fluorescence

Visualising cellular remodelling caused by viral proteins:
Viruses have developed all kinds of mechanisms for hijacking cellular systems for their own needs, as well as for avoiding the immune response. This project will use super-resolution imaging to examine changes to the cellular architecture in order to decipher the functions of proteins made by viruses like Rabies and Hendra. (The image shows microtubules forming large bundles in the presence of rabies P protein)

Deciphering the photophysics of antibody-conjugated fluorophores for bio-imaging:
Alexa and ATTO dyes bound to antibodies are used extensively in biological imaging applications because of their high specificity and bright, stable fluorescence. Recently, the seconds-long ‘blinking’ of these dyes has been harnessed for super resolution imaging. While the photophysics behind blinking has been well characterized for individual molecules, this project will investigate the photophysical interactions available, such as energy funnelling and annihilation, to the clusters of ~4-6 fluorophores on each antibody.

Investigating DNA damage response in sub-nuclear compartments:
When the cell senses a DNA double strand break, a signaling cascade involving thousands of proteins is triggered. Recently, a new pathway within this cascade was discovered to involve recruitment of protein NBS1 to the nucleolus where it affects ribosomal RNA transcription. This project will use super-resolution imaging to directly visualize the proteins involved in nucleolar sub-compartments to determine the underlying mechanism and its interplay with other DNA damage response pathways. (The image shows Treacle protein ‘puncta’ inside the nucleolus)

Imaging DNA double strand breaks and their repair in cells:
DNA damage is caused by exogenous toxins as well as everyday replication and transcription. Defects in repair result in serious genetic diseases and can lead to cancer. However, imaging of damage and repair inside cells is incredibly difficult because only a few breaks occur at a time. This project will use multicolor super resolution imaging to focus on these few breaks and track the temporal interactions involved in their (mis)repair.

Quantifying orientation in FRET at the single molecule level:
The orientation of the donor and acceptor molecules in energy transfer (FRET), can efficiency up to a factor of 4, but has never been shown directly in single molecules. This project will visualize emission dipoles of single molecules undergoing FRET by using ‘defocused imaging’ of single molecules and simultaneously measuring FRET efficiency. The defocused images reveal a molecule’s dipole directly and thus its orientation. (The image shows defocused patterns for 2 single molecules about 3 microns apart)
Research in the Food Chemistry group at Monash spans broad applications of physical, analytical and physiological properties of food components, with applications in human health and food technology. The following Honours project topics are available in 2018, or let’s discuss your personal research interests in food chemistry.

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<thead>
<tr>
<th>Project Topic</th>
<th>Description</th>
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<tr>
<td><strong>Nutritional properties of germinated plant seed proteins</strong></td>
<td>This project will evaluate protein nutritional quality from some novel sources of plants, with significance for supply of dietary protein and human food security.</td>
</tr>
<tr>
<td><strong>Characterizing intestinal absorption properties of phytochemicals using physicochemical properties</strong></td>
<td>This project will characterise the absorption properties of a phytochemicals present in a selected class of PC-rich foods, eg, fruit, herbs, spices, wholegrains, using the human Phytochemical Absorption Prediction model, and use the results to optimise their health effects.</td>
</tr>
<tr>
<td><strong>Therapeutic phytochemical products from lignin</strong></td>
<td>This project will seek to develop useful therapeutic phytochemical products derived from lignin, involving chemical depolymerisation and characterising absorption properties of products by the human Phytochemical Absorption Prediction model.</td>
</tr>
<tr>
<td><strong>Amino acid specificity of protein oxidation by chemical oxidants</strong></td>
<td>This project will relate the chemical anti-oxidant activity of dietary proteins to specific amino acids, and to understand if electron, hydrogen atom or other quenching mechanism is involved in protein reactivity with anti-oxidants. This will help to understand how proteins may be chemically transformed during food processing.</td>
</tr>
<tr>
<td><strong>Therapeutic phytochemical products from lignin</strong></td>
<td>This project will seek to develop useful therapeutic phytochemical products derived from lignin, involving chemical depolymerisation and characterising absorption properties of products by the human Phytochemical Absorption Prediction model.</td>
</tr>
<tr>
<td><strong>Characterising brain absorption properties of essential oils using physicochemical properties</strong></td>
<td>This project will determine if the bio-distribution of extracts of volatile EOs (ie, essential oils, EOs) between the brain and body circulation, can be related to physicochemical properties of EOs. The project would suit a student who is also interested in biology and using mice as a model for biodistribution studies.</td>
</tr>
<tr>
<td><strong>Relationships of protein aggregate particle size and close packing with gelation properties of dairy products</strong></td>
<td>This project will investigate the control of protein aggregate size and consequences for close packing of particles and regulation of syneresis and gelation properties in dairy products. The research is relevant to using physical chemistry to optimise the quality of fermented and gelled dairy products.</td>
</tr>
<tr>
<td><strong>The Role of Glycosylation in the Milk Protein κ-Casein</strong></td>
<td>This project involves a collaboration with CSIRO-Werribee. κ-casein is one of four (αs1, αs2, β, κ) casein proteins that collectively represent ~80 % of total protein in cow’s milk. All casein proteins are phosphorylated, but only κ-casein is also glycosylated, with unknown functional purpose. This project aims to compare functional properties of glycosylation in A and B variants of κ-casein using chemical and biochemical research methods.</td>
</tr>
<tr>
<td><strong>Effects of thermal processing on bioavailability of proteins</strong></td>
<td>This project involves a collaboration with the Charles Perkins Centre (CPC) in Sydney, who have pioneered concepts of nutritional ecology in explaining the outcomes for health associated with different macronutrient ratio intakes. An important additional consideration is the bioavailability of dietary protein which is highly susceptible to process-mediated loss of quality and will be studied using the mouse diets of previous studies undertaken at CPC.</td>
</tr>
<tr>
<td><strong>Functional properties of Moringa leaves</strong></td>
<td>This project involves a collaboration with CSIRO-Werribee. The aim is to extract and characterize proteins from the leaves of the fast-growing, drought-resistant Moringa plant. Extraction methods will compare solvent, physical and enzymatic treatments and protein-enriched products will be characterized in order to assess nutritional and functional properties, for potential dietary applications.</td>
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</table>
Dr Victoria Blair  
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This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).
My group undertakes applied chemistry research on topics that are, in some way, related to biomass and fossil fuel utilization. For example, new approaches to the preparation of industrial chemicals, specialty liquid fuels (eg, jet fuel), road bitumen, coke for steel making, and specialist high surface area active carbons are being developed so as to minimize energy losses and CO₂ emissions. We also investigate the capture of CO₂ emissions by adsorption and, once captured, its transformation back into useful products by heterogeneous catalysis. In doing so, innovative new materials such as mesoporous silicas, metal organic frameworks (MOFs) and ionic liquids (ILs) are employed as adsorbents, catalysts and/or solvents. These novel materials are often sourced from other research groups within the School. Molecular modeling tools are also frequently applied in these studies, so that experiment and theory inform each other. More information on my research can be found at:

http://monash.edu/science/about/schools/chemistry/staff/CHAFFEE.html

Turning Carbon Dioxide into Fuel

Waste CO₂, when combined with ‘renewable H₂’ (eg, from photovoltaic water splitting) over appropriate catalysts, leads to reduced C₁ products (formaldehyde, methanol). Methanol can be used directly as fuel in petrol engines or be dehydrated to dimethylether, a diesel fuel substitute. Nanoparticulate catalysts of varying metal cluster size, supported on high surface area mesoporous substrates, will be sought that improve reaction rates and product selectivity.

Chemicals from Biomass (with Dr Emma Qi)

This project will make use of CO₂, both as a supercritical fluid in its own right and as one component of a novel series of recyclable ionic liquids (known as DIMCARBs) to selectively extract discrete chemical classes (phenols, carboxylic acids, aliphatic or aromatic hydrocarbons, depending on the conditions used) from various forms of biomass and/or coal. With biomass, this approach offers a renewable alternative to deriving these fundamental chemical feedstocks that are now mostly supplied from the petroleum industry.

Capturing Carbon Dioxide from Air (with Dr Greg Knowles)

Prior work in the group has identified amine-based adsorbents that have the ability to reversibly capture and release CO₂ at concentrations (~15 wt%) and temperatures typical of the flue gas from power stations. Another approach to controlling CO₂ in the atmosphere could be to adsorb it directly from air at atmospheric concentration (~400 ppm). This project will prepare and evaluate new adsorbent formulations for this purpose involving high surface area mesoporous silica (such as SBA-15) as a support material.

Environmental Applications of Active Carbon Monoliths

The group has recently developed a new form of monolithic carbon that provides for efficient gas and liquid contact with low pressure drop. These materials have exceptional surface areas and, therefore, multiple potential applications as adsorbents, catalysts, electrodes, etc. Their inherent electrically conductive means that they can, in principal, be very efficiently regenerated by ohmic heating. Projects are available that investigate their performance for the removal of pollutants from gas phase (e.g., NOₓ) or from liquid phase (e.g., heavy metal) streams, their regenerability, as well as optimization of fabrication methods.
If you have any further queries or would like to explore the possibility of future collaborative research placements at the University of Warwick (UK) through the Monash-Warwick Alliance, please do not hesitate to contact me (details above). More information on my research can be found at: https://www.monash.edu/science/schools/chemistry/our-people/staff/professor-philip-wai-hong-chan

Sustainable Organic Chemistry and the Application of Catalytic Strategies for Natural Products Synthesis and Drug Discovery

Works in our laboratory are focused on the development of operationally straightforward and sustainable catalytic strategies of broad utility to synthetic organic chemistry. We are interested in the application of these novel stereoselective catalytic methodologies to the construction of bioactive natural products and as practical synthetic tools for the assembly of complex molecules of current biological and materials interest.

For example, we recently established a method to prepare tricyclic bridged heptenones and hexenones efficiently from gold(I)-catalyzed double cycloisomerization of 1,11-dien-3,9-diyne benzoates (Scheme 1a, Rao, W.; Susanti, D.; Ayers, B. J.; Chan, P. W. H. J. Am. Chem. Soc. 2015, 137, 6350). The suggested reaction pathway provided only a handful of examples of divergence in product selectivity achieved by fine-tuning the steric nature of the ligand of the Au(I) catalyst. In the field of C–H bond activation, we recently developed a method to prepare -acyl-amino acid and 2,2-diacyl aziridine derivatives efficiently from Cu(OTf)2 + 1,10-phenanthroline-catalyzed amination and aziridination of 2-alkyl substituted 1,3-dicarbonyl compounds with PhI=NTs (Scheme 1b, Ton, T. M. U.; Tejo, C.; Tiong, D. L. Y.; Chan, P. W. H. J. Am. Chem. Soc. 2012, 134, 7344). By taking advantage of the orthogonal modes of reactivity of the substrate, control in the divergence of product selectivity was realized. In collaboration with researchers at the University of Macau and Hong Kong Baptist University, we also recently reported a synthetic method to prepare 3a,6-methanoisoindole esters efficiently by gold(I)-catalyzed tandem 1,2-acyloxy migration/Nazarov cyclization followed by Diels-Alder reaction of 1,4,9-dienyne esters (Susanti, D.; Liu, L.-J.; Rao, W.; Lin, S.; Ma, D. L.; Leung, C. H.; Chan, P. W. H. Chem. Eur. J. 2015, 21, 9111). In this study, one example was found to inhibit binding of tumor necrosis factor-(TNF- ) to the tumor necrosis factor receptor 1 (TNFR1) site.

**Scheme 1.** Sustainable synthetic strategies for preparing (a) -acyl-amino acid and 2,2-diacyl aziridine derivatives, (b) 2,4a-dihydro-1H-fluorenes, and (c) 3a,6-methanoisoindole esters
Since the industrial revolution we have doubled the rate at which bioavailable nitrogen enters the biosphere. My research looks at what happens to this nitrogen.

The role of cable bacteria in the nitrogen cycle

In 2012, a new form of life, cable bacteria, was discovered that can oxidise hydrogen sulfide (eq 1) and transport electrons to the sediment surface where oxygen is reduced to water (eq 2).

\[
\begin{align*}
\text{H}_2\text{S} + 4\text{H}_2\text{O} & \rightarrow \text{SO}_4^{2-} + 10\text{H}^+ + 8e^- \quad (\text{eq 1}) \\
4\text{H}^+ + 4e^- + \text{O}_2 & \rightarrow 2\text{H}_2\text{O} \quad (\text{eq 2})
\end{align*}
\]

We have found these organisms in the Yarra River estuary and believe they also play a role in the nitrogen cycle. This project will study whether cable bacteria play a role in the nitrogen cycle.

Figure 1 shows sediment colonized by cable bacteria. Oxidation of hydrogen sulfide (grey zone) leads to the dissolution of iron monosulfides (black zone) liberating Fe^{2+} where it diffuses to the sediment surface and is oxidized forming an orange iron oxydroxide layer at the sediment surface.

Novel metabolic pathways of lipid and hydrogen production in sands

Sand sediments dominate our coastline and contain high abundances of micro algae (diatoms). How these organisms survive regular burial and anoxia within these sediment is not understood. We have recently discovered that sands have high rates of hydrogen production when exposed to anoxic conditions indicating fermentation by algae may be an important metabolic pathway. Depending on your interest, this project can take one of two directions. 1 Deeper analysis of the metabolic pathways. We believe lipid production is a major end product of anoxic metabolism and this project will investigate what lipids are produced under anoxic conditions. 2 Hydrogen emission rates from the sediment. There have been no measurements of in-situ hydrogen release rates from the sediment and this project will take samples from sites around Port Phillip Bay to determine hydrogen release rates from the sediment.

Stable isotopes as tracers of nitrogen sources and cycling in seagrass beds

Nitrogen is thought to be the key nutrient controlling seagrass productivity in Port Phillip Bay. Understanding where nitrogen comes from is therefore critical to managing the health of the Bay. The ratios of $^{15}$N/$^{14}$N is increasingly being used to trace nitrogen sources and cycling. We have observed a large range of $^{15}$N/$^{14}$N ratios within seagrasses collected from Port Phillip Bay, currently this large variation is not well understood. This project will investigate the $^{15}$N/$^{14}$N ratios of NH$_4^+$ using a newly developed method to better trace nitrogen sources in Port Phillip Bay.
Rare earth elements (Group 3-Sc, Y, La and the lanthanoids Ce - Lu)

Rare earths are currently seen as the strategic materials of the 21st century, with considerable international concern over the Chinese domination of the supply of separated elements. Our group provides fundamental knowledge to underpin industrial developments in the area. **Australia has abundant rare earth resources which have been mainly neglected** despite their widespread uses, e.g. ceramic supports for exhaust emission catalysts, alloy magnets in all car engines, and catalysts for artificial rubber production. Potential applications include green corrosion inhibitors (below). Their metal-organic chemistry is a major new frontier and is generating great excitement, for example in the discovery of new oxidation states. We are particularly interested in high reactivity rare earth organometallics (Ln-C), organoamides (Ln-NR₂) and aryloxides (Ln-OAr), and have developed unique synthetic methods to obtain them. Features of these compounds include low coordination numbers and extraordinary reactivity including C-F bond activation, the most resistant carbon-element bond. To prepare and structurally characterize the compounds represents a major challenge. **The program involves extensive international collaboration. Some specific projects follow:**

1. **Heterobimetallic complexes and pseudo solid state synthesis** (with Prof. Peter Junk (JCU) and Dr David Turner)
2. **Carbon-fluorine activation with reactive rare earth complexes** (with Dr Victoria Blair and Prof Peter Junk)
3. **New Approaches to Metal-Based Syntheses** (with Prof. Peter Junk (JCU) and Dr David Turner or Dr Victoria Blair)
4. **Green Corrosion Inhibitors** (with Prof. Peter Junk (JCU), Dr David Turner and Prof. Maria Forsyth (Deakin University))
5. **New Materials Derived from Small Cyano Anions** (with Prof. Stuart Batten)
6. **Platinum Anti-Cancer Drugs** (with Prof. Alan Bond, A/Prof Bayden Wood)

**Novel recent structures**

<table>
<thead>
<tr>
<th>Project 1</th>
<th>Project 2</th>
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<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
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Inert Atmosphere handling; X-ray crystallography including Synchrotron use; X-ray powder diffraction; IR, UV-Vis, NMR spectroscopy, Mass spectrometry; Pseudo solid state synthesis, solvothermal synthesis

**Some recent papers**

Description of Project Areas
When matter is divided into tiny, tiny particles, that is, into crystals of nanometer sizes (1 nm = 1 \times 10^{-9} \text{ m}), its physical properties change. We are interested in the changes to the optical properties, or colour. For example, very tiny spheres containing only 1000’s of gold atoms are red. The colour of very tiny spheres of CdSe only a few nanometers in diameter can be tuned across the visible region by changing their size. This effect is due to quantum confinement and the spheres are called quantum dots (QDs). The colours of nanoparticles can be controlled by:

- Changing the size or shape of the crystal
- Changing the environment of the crystal
- Bringing two or more nanocrystals into close proximity

The nanocrystals have potential applications in nanoscale energy transfer (with metal nanocrystals acting as nanoscale optical fibres), sensing, colour responsive coatings for glass, solar photovoltaics and in medicine in the areas of drug delivery and cancer therapies.

Our research group is part of the **ARC Centre of Excellence in Exciton Science**. The Centre is a collaboration to research better ways to manipulate the way light energy is absorbed, transported and transformed in advanced molecular materials. The research in the centre aims to find innovative solutions for renewable energy in:

- Solar energy conversion
- Energy-efficient lighting and displays
- Security labelling and optical sensor platforms

Our research involves synthesis and investigation of the optical properties of nanocrystal systems. We investigate the mechanism of growth of nanocrystals, making use of electron microscopy (TEM and SEM). We use dark-field microscopy, fluorescence microscopy and scanning near-field optical microscopy to determine the optical properties of **single nanoparticles** and **single nanoparticle superstructures**.

Potential honours project titles include:

**Light Harvesting and Directed Transfer on the Nanoscale**: Investigation of the control of light (energy) transport through nanoscale structures, including switching transport on or off, energy and electron transfer between nanocrystals, across interfaces and within self-assembled films.

**Changing the Colour of Nanoparticles - Nanoparticle Coupling**: Assemblies of nanocrystals have optimal characteristics for many applications. This project aims to make, understand and use these.

**Metal Nanoparticles and Nanowires as Nanoscale Optical Fibres**: Metal nanowires are able to transport energy below the diffraction limit of light. This project will investigate how the three-dimensional shape of the nanowire changes the efficiency of the energy transport.

**Elucidating the Growth Mechanism of Nanorods and Nanobars (Nanoscale Gold Bullion!?!)**: Understanding nanocrystal growth, the ultimate form of crystal assembly, will allow fine control of the nanocrystal optical properties – many questions remain unanswered!
These projects can be modified to suit the interests of the student – from physical, analytical and/or environmental chemistry and biogeochemistry through to aquatic and/or restoration ecology. A project is available for students who wish to combine synthetic and environmental chemistry.

Assessing the impacts of pharmaceuticals on aquatic ecosystem processes

Awareness of the effects of common pharmaceuticals on organisms (insects, fish) living in streams and lakes has slowly emerged over the last decade. Despite their prevalence in urban waterways, there has been almost no published research on how these pharmaceuticals can affect rates of fundamental ecosystem processes. Work in our group has shown that some of these chemicals can have dramatic effects. This project will use novel pharmaceutical diffusing substrates and bioassay techniques to investigate effects of common drugs like antibiotics, mood modifiers, painkillers and antihistamines on a range of fundamental ecosystem processes including photosynthesis, respiration, biomass accrual and denitrification in urban waterways.

Constructed wetlands – environmental benefactors or villains?

This project will examine the extent to which wetlands around Melbourne generate greenhouse gases (GHGs) including CH₄, N₂O and CO₂. The prevailing wisdom is that wetlands must be beneficial for the environment as they are designed to remove nutrients and other pollutants from stormwater in urban creeks. However, previous work in the Water Studies Centre has shown that under a range of relatively common conditions, wetlands can also generate significant quantities of GHGs. This project will measure rates of GHG production in several wetlands around Melbourne and develop understanding of the key wetland characteristics and conditions that control production. Links with nitrogen cycling will be explored. Experimental work will involve field measurements and laboratory mesocosm (sediment core) investigations.

Developing luminescent probes to determine levels of environmentally relevant ions and reactive oxygen species with Dr Kellie Tuck

Please see Kellie’s project descriptions for more information. This project is ideally suited to a student with interests in both synthetic and environmental chemistry.
Catalytic reactions with Pd(I) (With Dr Adrian Chaplin, University of Warwick)
The use of palladium catalysis in organic synthesis is a lynchpin that underlies modern organic chemistry. Palladium catalysts usually exploit the Pd(0)-Pd(II) redox cycle, with the occasional foray into less common oxidation states, such as Pd(IV). For the first time, we have been able to use a newly discovered palladium catalyst with a stable +1 oxidation state to perform selective oxidative cross coupling chemistry. Projects in this area could include mechanistic investigations into this new reaction, or exploring new types of reactivity in this area.

Synthesis of α-flouro-α-amino acids
The synthesis of unnatural amino acids gives us the opportunity to control the structure and reactivity of peptides and proteins beyond what nature has provided. While fluorinated amino acids have shown intriguing properties, fluorination at the critical α-position remains elusive. Initial studies have shown that these compounds are isolable, although a robust synthetic route has yet to be developed. This project will allow this chemistry to be further developed and applied to peptides.

Activation of carbon-sulfur bonds (With A. Prof. David Lupton)
In a 2016 honours project, we have shown that the activation of C-S bonds with copper allows us to modify the sulfur based end-groups of RAFT polymers, giving us a powerful strategy to prepare functional materials. We will apply this newly patented chemistry to a number of ideas in polymer chemistry, as well as developing sulfur-based couplings relevant to biomolecules such as proteins.

Modern Main Group Chemistry

In the past 10 years remarkable progress has been made in the chemistry of very low oxidation state and low coordination number s- and p-block compounds. It is now possible to prepare and investigate the fascinating reactivity of compounds that were thought incapable of existence until a few years ago. The fundamental and applied aspects of this area are rapidly expanding in the Jones group (see group website for further details). Representative examples of the many potential Honours projects that are available within this exciting area are as follows:

(i) Low oxidation state Main Group systems: replacements for transition metal catalysts.
In recent years "trans-bent" compounds containing multiple bonds between two p-block metal(I) centres have been stabilised by ligation with extremely bulky alkyl or aryl substituents (R). These include the remarkable heavier group 14 analogues of alkynes, viz. RE=ER (E = Si, Ge, Sn or Pb). In this project you will prepare examples of related bulky amido substituted "metalynes" (see picture), and related compounds, and explore their use for the reversible reductive activation of H₂, CO₂, NH₃, ethylene etc. If this can be achieved, the exciting possibility exists to use such compounds replacements for expensive and toxic transition metal catalysts in numerous industrial processes; and for the conversion of the Greenhouse gas, CO₂, to chemical products such as methanol.


(ii) Stabilisation and application of complexes of Group 2 metals in the +1 oxidation state.
It has previously been only possible to prepare compounds containing the Group 2 metals (Be, Mg or Ca) with the metal +2 oxidation state. Recently, we have reversed this situation with the landmark preparation of the first thermally stable compounds to contain Mg-Mg bonds (e.g. see picture). The formal oxidation state of the magnesium centres in these compounds is, therefore, +1. As a result, these species are highly reducing, a situation which has lent them to use, in our laboratory, as specialist reagents in organic and organometallic synthetic methodologies. You will further explore this potential, in addition to examining the possibility of preparing the first dimeric calcium(I) compounds. Furthermore, you will examine the use of such systems as soluble models to study the reversible addition of dihydrogen to magnesium metal (yielding MgH₂). This poorly understood process is of great importance for future hydrogen storage technologies which will be essential for viable zero emission vehicles powered by fuel cells. The activation of other gaseous small molecules (e.g. CO₂, N₂, NH₃ etc.) will be investigated at high pressure (ca. 200 atm.) with the aid of high pressure sapphire NMR tube technology developed in the Ohlin group at Monash.

We discover new catalytic reactions focusing on understanding the how and why of these processes. In addition we use synthesis to make materials designed for function.


Over the last 20 years organocatalysis has emerged as a powerful approach to reaction discovery. We have been active in the area since 2007, focusing on re-imagining the chemistry of reactive intermediates to deliver reactions that produce molecular complexity with high selectivity (enantio-, diastereo- and chemo-). We maintain an interest in the acyl azolium (A) and sulfonyl azolium (B) although studies this year will focus on more recent discoveries from the lab focused on the chemistry of the β-azolium ylide (C), dienyl acyl azolium (D) and aza-Breslow intermediates (E). New reactions, new catalysts and mechanistic information regarding these species is our goal for 2018. A number of honours projects broadly based on this topic are available. Key references: 1) see references in figure 1; 2) For reviews see: Ryan, S. J.; Candish, L.; Lupton, D.W. Chem. Soc. Rev. 2013, 42, 4906 and Zhang, C.; Hooper, J. F.; Lupton, D. W. ACS Catal. 2017, 7, 2583.

2. Structural Modification of linozelid antibiotics.

Structural information with biological materials using X-ray analysis remains challenging. Using next generation cryo-EM approaches the structure of the ribosome with antibiotics bound have recently been obtained. Using this data we are performing structure based drug design with the ribosome. Having obtained recent proof of principle for this approach, we will complete a rigorous analysis of linozelid (and related structures) guided by cryo-EM in 2018. (Collaboration: Dr Belousoff, Microbiology) Key references: 3) Belousoff M. J. et. al. MBio 2017, 8, pii: e00395–17; 4) Lupton, D. W.; Belousoff, M. J. Future Microbiology 2017, DOI:10.2217/fmb-2017-0126.

3. Catalysis with Chiral High Nucleophilicity Phospines (with Dr Joel Hooper); Polymer modifications (with Dr Joel Hooper and CSIRO); Visible light Catalysis for Hydrophobic material synthesis (with Dr Oliver Hutt, CSIRO); Studying the Properties of Carbenes (with Prof. Herbert Mayr, LMU, Munich); Redesigning Enzymatic Processes (with Dr. Colin Jackson, ANU).

A number of collaborations exist that can be developed into honours projects for 2018. A few key collaborators are listed above, as are the areas of collaboration.
This document will give you an idea of the type of research we are undertaking Much more at: www.chem.monash.edu.au/ionicliquids

Solar Fuels (with Dr Xinyi Zhang)
Hydrogen is one of the ideal fuels for the future but needs to be generated in some sustainable way. Solar cells capable of directly splitting water into hydrogen and oxygen are one approach to this. The materials which support the photolysis of water are the key to a viable process. It is relatively easy to find materials which will work, but the challenge is to develop materials that will do so at high efficiency. We have recently claimed the world record for solar to fuel efficiency. At Monash we are developing semiconductor materials capable of harvesting photons at wavelengths around 450nm and below. The project will expand this range of materials and test them in prototype cells to quantify their catalytic performance and lifetime. One of the key aspects of this is the interaction of the electrode material with the electrolyte and the project will investigate a number of electrolyte types. The project will suit someone with interests in materials or energy chemistry.


Synthesis of Novel Ionic Liquids (with Dr Mega Kar and Dr Thomas Ruether (CSIRO))
Organic salts based on the FSO2-N-SO2F anion have recently been shown in our group to have some very unusual solvency properties, especially for metal cations of interest in batteries. In this project we will explore the chemistry of FSO2- based anions more broadly - a very large family of new compounds is possible from this simple starting point. This project will suit someone interested in ionic liquid synthetic chemistry, with some physical and spectroscopic property measurement work to aid in understanding the behaviour of these new salts.

Protic Ionic Liquids for CO2 Capture (with Dr Katya Pas)
We are developing novel ionic liquid systems having high capacity for CO2 capture, and able to do so at relatively low energy cost. The origins of the lower energetics of the uptake and release lie in modulation of the basicity of the amine base involved. We are synthesizing and testing these ionic liquids, as well as carrying out high level quantum calculations of their interaction with CO2.
This document provides an idea of the type of research we undertake in my group. If you have further queries on these or related projects, please do not hesitate to contact me (details above).

**More information:** [http://www.monash.edu/science/schools/chemistry/our-people/staff/marriott](http://www.monash.edu/science/schools/chemistry/our-people/staff/marriott)

**General area of project interests**

The Marriott Group specialises primarily in Analytical Chemistry, and specifically Separation Science / Chromatographic methodology, supporting a broad repertoire of applications studies. We develop new methods in GC, including comprehensive two-dimensional GC (GC×GC), and multidimensional GC (MDGC), using a range of specific detection technologies, including mass spectrometry (MS). We study ultrahigh resolution separations, unusual processes in GC, and extend chromatography analysis to complex samples. Recently, two GC-triple quadrupole MS systems were delivered; we have access to a GC-Q-TOFMS, and cold EI. These transform our studies, and with our MDGC research we now lead the world.

**Description of Example Project Area(s)**

1. **Chemical transformation and interconversion studies in essential oils (EO):** Unusual chromatography behavior can arise when compounds change their structure during GC separation [A]. Examining this phenomenon usually requires maths modeling of peak shapes. Our 2D GC analysis can provide separation of the interconverting species, so allows detailed information of the dynamic process. This has relevance to understanding transformations in complex samples as in the Myrrh example shown here. We will extend our prior studies to studies of interconverting molecules shown here.

2. **Applications of nitrogen-phosphorus detection in GC.** Nitrogen compounds can be selectively detected by use of the NPD. These compounds are rich in coffee aroma (pyrazines etc.), and are aroma “character compounds” in Sauvignon Blanc wines. Our GC×GC and MDGC methodologies [B] provide much greater separation performance, and with NPD will give improved detection; we expect to identify a much wider range of N-compounds than it presently reported in coffee and wine.

**Person-portable GC-MS for forensic remote site analysis:** We will test the Tridion-9 [C] in situations that require fast profiling of volatiles, without sample transport back to the lab. Diverse applications include: BTEX analysis at remediation sites (developing validated methods cf standard protocols); field assessment of natural products such as fruit for profiling and/or optimum harvest conditions; process monitoring for fermentation in beer manufacturing. You will be able to choose the most appropriate and interesting of these applications.

**Studies in soft, hard and cold ionisation in GC-MS analysis:** The use of the correct ionisation process in GC is critical for precise and accurate identification of compounds through library searching. New types of presentation methods such as GCxMS with soft ionisation (e.g. CI [D]) give intriguing possibilities. We will apply a range of ionisation methods – hard EI, soft CI, & cold EI with MS/MS, to investigate new applications and novel presentation formats for GC-MS analysis with an aim to better identify and quantify analytes.
 Assoc. Professor Lisa Martin
Room No. 157/23S, Tel: 9905 4514, email: Lisa.Martin@monash.edu

This page will give you an idea of some of the research projects in my group, but I will be overseas until the end of 2017, so, if you are interested or want more details, email me and we can arrange a skype.

Bioinspired Chemistry: Many of the global challenges facing us are in biomedical science; however these problems need an understanding and knowledge of basic molecular and electronic properties. The Martin group draws on these tools for projects in medicine and materials. Some projects are below….

1. The evolution of steroid hormones: Dinosaurs, Ratites, Monotremes & Marsupials
Steroid hormones are essential for the regulation of water and salt (mineralocorticoids), metabolism (gluco-corticoids) and reproduction (androgens and oestrogens). The evolution of steroid hormones offers some fascinating stories, yet to be told. We have several projects involving unique Australian species.

1. Lungfish are the ancestors of all tetrapods, an ancient class of fish that was able to ‘walk’ and breathe air using lungs but still could live in the water extracting air using gills. Survival on land required development of the hormone aldosterone that controls salt and water homeostasis that is made in the adrenal gland in mammals. This project will undertake analysis of steroid hormones from the Australian lungfish.

2. The enzyme aromatase synthesises oestrogen and is responsible for female characteristics. Aromatase is the last enzyme to have evolve in the steroid synthesis pathway. In mammals, all but one species has one gene hence one aromatase enzyme, but did the ancestors of mammals also have only one enzyme? By studying aromatase from ancient lizards (descendents of dinosaurs), flightless birds (emu), monotremes (platypus) and marsupials (wallaby) we can examine how the geographical isolation of Australia influenced the evolution of aromatase.

Honours projects will include aspects of the steroid analysis, modelling of enzyme structure These species are selected to transition from reptiles (including birds), to egg laying mammals (monotremes) to pouched (marsupials) and extrapolated to higher mammals such as humans.

2. Is Alzheimers Disease linked to an aberrant antimicrobial peptide?
A number of neurological diseases are linked to protein/peptide aggregation eg Alzheimer’s Disease (AD). In fact, ~70% of all late-onset dementia cases are due to AD and with an aging population in Australia, intense research is therefore required to find better therapeutic approaches. Although there are several treatments available for AD, these can only manage the disease and offer no reversal, hence there is no cure. This project aims to provide the fundamental molecular knowledge needed to regulate and control peptide aggregation.

3. Redox semiconductors with novel applications (with Prof. Alan Bond)
Novel semiconductors can be prepared from combinations of redox cations and anions with accessible redox states, e.g. tetrathiafulvalene (TTF) and 7,7,8,8-tetracyanoquinodimethane (TCNQ). We have developed an electrosynthetic approach to make these materials using metal and non-metal cations, eg we have prepared the first amino acid TCNQ biomaterial, a sophisticated 3-D H-bonding structure and a semiconductor. This project offers the chance to explore other bio-molecules with TCNQ. This project offers enormous scope to develop skills in electroanalysis, microscopy and X-ray crystallography.
This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above). More information on my research can be seen at:
http://monash.edu/science/about/schools/chemistry/staff/murray.html

Project 1. Synthesis and Magnetostructural Investigations of Mononuclear and Polynuclear Spin Crossover Compounds of Iron and Cobalt
(Co-Supervisor: Dr. Stuart Batten)

Spin crossover centres are a well-known form of an inorganic electronic switch, for which a variation of temperature, pressure or light irradiation leads to a change in d-electron configuration (high-spin to low-spin) often accompanied by a change in structure, colour and magnetism. The project involves synthesis, structure (including the synchrotron) and magnetic measurements. Future applications of such materials are in “switchtronic” materials. A typical recent paper by Dr Wasinee Phonsri who is a post-doc in our group; involves Fe(III) complexes with two different ligands, W. Phonsri et al. Chem. Eur. J. 2016, 22, 1322 (see Figure below).

Project 2. Synthesis, crystal structures and physical properties of ‘spin-coupled’ Mn, Fe and M-Ln ‘metallo-supramolecular’ cluster compounds
(Co-Supervisor: Dr. Stuart Batten)

This project involves the synthesis, structures and properties of new, large clusters of Mn, and of f-block-only or mixed d-block/lanthanide combinations, that display “quantum effects” (single molecule magnets, SMMs); with possible future uses in “spintronics”/molecular computers). Work by Dr Stuart Langley’s (recent Post doc fellow) and K.R. Vignesh (IITB Mumbai-Monash PhD) has revealed excellent SMM features in mixed {Mn2Ln2} clusters. [Figure Mn – pink; Gd – green; La – orange]
This document will give you an idea of the type of research we are undertaking within the Chemistry Education Research Group. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research can be seen at:
http://www.monash.edu/science/schools/chemistry/our-people/staff/professor-tina-overton

In the Chemistry Education Research Group we are interested in investigating how undergraduates learn chemistry, how we can help them achieve the best outcomes possible and how we can inculcate skills that will help make them eminently employable. We are engaged in a range of projects, some examples of which are given below, but projects can be tailored to meet the interests of individual students. You might like to consider a project with us if you are interested in expanding your skills and your horizons or interested in education at any level, but particularly in universities. The research skills that you will develop will be useful inside or outside of science employment.

**A creative guide to creative problem solving**
There is much research evidence that problem solvers can be described as either ‘experts’ or ‘novices’. We are interested particularly in how undergraduate chemists solve complex or open-ended problems and we have identified some features of expert and novice problem solving. Can we help ‘novice’ problems solvers to become ‘expert’ by designing interventions and ‘training’? Do individuals solve problems differently form groups and what can we learn from them?

**Mapping interaction and team working in the lab**
As we move towards less prescriptive and more open and inquiry-driven laboratory experiences for undergraduate students, can we better understand how the experience is changing for them. This project will look at how undergraduates interact together in the laboratory in the context of different styles of laboratory work; recopies, guided inquiry and open-ended. This project will help us to better understand the skills and capabilities that students are able to develop through different styles of lab activity.

**Using laboratory experiences to prepare undergraduates for industry**
Traditional undergraduate laboratory experiences lead students through recipe-like activities which have little opportunity for investigative or creative outcomes. University laboratory experiences seldom mimic the contexts found in industry where scientists work on complex problems which need speedy solutions whilst considering drivers such as economics, safety, manpower, logistics and environment. Can we reimagine undergraduate laboratories in chemistry to deliver a meaningful curriculum in which students tackle authentic and interesting industry-based investigations, thus motivating them to learn and prepare them for the word of work?

**Modelling effective pre-laboratory experiences**
Pre-labs are widely used in science education and they come in many forms. Can we investigate which types of activities best prepare students to undertake laboratory activities?
This document will give you an idea of the type of research we are undertaking within my group, Monash Research Computational Chemistry Group. In our research we apply computational chemistry methods to a range of chemical problems. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research & other potential projects can be seen at: https://vera125.its.monash.edu.au/cms/about/

Description of Project Area(s)

**Studying long-range order in ionic liquids in electric field (with Prof. Tom Welton, Imperial College London)**

It has been assumed that ionic liquids consisting entirely of ions possess a long-range order of electrostatic interactions over a few Angstroms. Recent experiments conducted by Prof. Welton indicated that the long-range order stretches much further when ionic liquids are placed in the electric field. This project aims at analyzing the effect electric field on the structural arrangement in ionic liquids using multi-scale calculations.

**Enhancement of chemical reactions in ionic solvents (with Prof. Michelle Coote, ANU)**

Recently Coote et al. showed how the oriented electric field could help manipulate the kinetics and thermodynamics of a simple Diels-Alder reaction that does not contain any redox species. Their experiment identified that the kinetics of the reaction increased five-fold when the electric field was aligned with the forming bonds. This research aims at assessing whether ionic solvents can essentially act as a replacement for the electric field in commonly performed Diels-Alder reactions.

**Development of empirical dispersion correction for condensed systems**

Recently our group developed a method called Spin Component Scaled MP2 (SRS-MP2) that allows us to predict the strength of intermolecular interactions with high accuracy (2 kJ mol⁻¹). This research aims at developing a cheaper dispersion correction for treating dispersion forces in condensed systems including pharmaceutical drugs and ionic/molecular solvents.

**Improving solubility of N₂ and NH₃ in ionic liquids (with Prof. Doug MacFarlane, Monash)**

Conversion of N₂ into ammonia through the Haber-Borsch process requires a significant input of energy to compress the N₂ and H₂ gasses and activate the catalyst to increase the yield of NH₃. It was shown that fluorination of hydrocarbons leads to significantly improved solubility of molecular gasses. This research aims at understanding the mechanism of solvation of N₂ and NH₃ in fluorinated traditional and ionic solvents and development of best suited solvents.

**Solvation of organic molecules and peptides (with Dr Alister Page, University of Newcastle and Dr Tam Greaves, RMIT)**

One of the promising applications of the developed SRS-MP2 method is the prediction of solvation effects. This research aims at establishing the importance of dispersion forces for solvating organic molecules from natural products to peptides in molecular and ionic solvents. This will lead to the development of more reliable implicit models for studying solvation effects.
If you have any questions, or would just like to chat, please contact me. More information can be found at: https://mon.clients.squiz.net/science/schools/chemistry/our-people/staff/dr-brett-paterson

Research in my group investigates the application of synthetic inorganic/organic chemistry to biology. We focus on coordination chemistry to generate metal-based drugs and radiopharmaceuticals for imaging and therapy. The research is multidisciplinary. We use a wide range of analytical techniques including multinuclear NMR, mass spectrometry, spectroscopy, and X-ray crystallography. Our collaborators in Monash Biomedical Imaging (MBI) in Clayton and the AMREP in Prahran assist with radiochemistry and biological evaluation.

Technetium, Copper and Gallium Radiopharmaceuticals

Molecular imaging utilises probes to acquire images for the diagnosis of disease and the monitoring of treatment of diseases such as cancer and cardiovascular disease. Radioactive probes, called radiotracers, can be detected using non-invasive modalities such as positron emission tomography (PET) and single photon emission computed tomography (SPECT). The advantage of radioactivity in molecular imaging is that the extreme sensitivity of radiation detection means that only miniscule concentrations are required. We have Honours projects that aim to design and synthesise ligands that can form stable complexes with metallic radioisotopes such as technetium-99m ($^{99m}$Tc), copper-64 ($^{64}$Cu) and gallium-68 ($^{68}$Ga). An example of one of our novel ligand systems coordinating $^{99m}$Tc/Re is shown in Fig 1. We use non-radioactive isotopes such as rhenium to assist with characterization.

Figure 1. (left) Radiolabelling a ligand with $^{99m}$Tc(V) and (right) the X-ray structure of the Re(V) analogue.

Targeted Therapy

Non-penetrating ionising radiation such as beta and alpha particles can be used to treat diseased tissue by destroying cancerous DNA. Honours projects will aim to create stable complexes with radioisotopes that emit high energy ionising radiation for their use in cancer therapy such as the beta and alpha emitting radioisotopes $^{67}$Cu and $^{177}$Lu, $^{212}$Pb/$^{212}$Bi and $^{225}$Ac/$^{213}$Bi.

Figure 2. (left) Alpha particle decay can be used to damage DNA and stop tumour growth and (right) the X-ray structure of a Pb(II) complex.

Bioconjugation Chemistry

Successful imaging and therapy requires that the radiation is confined locally to the target area with minimal exposure and retention in normal tissues. Bioconjugation is a chemical strategy to form a stable covalent link between two molecules, at least one of which is a biomolecule. The chemical modification must be achieved in such a way that the biological activity is retained. Honours projects will utilise biomolecule targeting vectors such as peptides and antibodies that can direct the radiation to the area of interest. These projects may involve solid-phase peptide synthesis.

1. Lignocellulose Biomass Projects (with Prof Doug Macfarlane & Prof Roy Jackson)
1. Various project options are available involving the examination of selected biomass waste streams, particularly from food production (e.g., coffee grounds, processing wastes) to evaluate their potential for producing valuable chemical feedstock compounds, organic fertilisers and soil additives. Extraction with various solvents types (including ionic liquids) and chemical reactivity of different isolated fractions will be investigated. Products of interest include gallic acid, 5-hydroxymethyl furfural and levulinic acid.

![Gallic Acid](image1)

![Levulinic Acid](image2)

2. Lignin Depolymerisation (see entry under Dr Kei Saito)
Lignin, a stable and insoluble polymer, composes 30% of wood tissue and is a significant component in many plants. This project will investigate the depolymerization of lignin derived from biomass, leading to potential useful building blocks for biodegradable polymers.

2. Soil Organic Matter, Soil Carbon Sequestration, Organic-based Fertilisers and Soil Fertility (with Prof Roy Jackson and Dr Vanessa Wong-School of EAE)
Understanding the role and dynamics of soil organic matter (SOM) in soils is critically important in maintaining soil fertility, water retention and nutrient cycling. SOM plays an important function in the long-term sequestration of carbon. This area of investigation allows a number of projects to be undertaken, including: fertilizer potential of nutrient enriched biomass waste streams; an evaluation of soil amendments (from discarded biomass or waste) on soil physicochemical and biological properties; effect of humic rich materials on plant growth and soil fertility.

3. Industrial Honours Projects

3.1 With Biofuel Innovations – Dandenong. Enzymic conversion of waste oils to biodiesel. Grease trap waste and waste cooking oils can act as a feedstock for biodiesel production and concurrently using the waste as a feedstock. This project will explore the optimisation of reactions conditions for the production biodiesel using enzymes to treat grease trap waste and used cooking oils combined with ethanol and methanol.

3.2 With New South Wales Department of Primary Industries. Wollongbar Research Institute. The Fate of common Herbicides in Australian Soils. (with Prof Bart Follink) The long-term fate of herbicides in soils has been an issue of concern worldwide. While modern herbicides have been designed for relatively rapid degradation, it has become evident that their breakdown is not necessarily as rapid as predicted and data developed overseas does not necessarily apply to Australian conditions. Unexpected levels of herbicide residues have been found in soils receiving regular applications, ground water, run-off from paddocks and in plant residues. Working with NSW – Department of Primary Industry, this project will involve a study of herbicide behaviour (adsorption, degradation, by-products formed) in several Australian soil types. A selection from commonly used and new emerging herbicides will be targeted (e.g., glyphosate, clopyralid, imazamox). The project will involve spending some time at the NSW-DPI research institute at Wollongbar.
This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

**Catalysis**

Our group has a long standing interest in catalysis, particularly when it is applied to asymmetric synthesis, natural products and peptidomimetics. We are currently interested in the synthesis of new ligands and catalysts, developing efficient tandem catalytic processes for organic transformations and industrial feedstocks, solid supported catalysts and the application of catalysis to bioactive targets and natural products. The development of new catalysts to perform catalysis in water are of particular interest. Recent targets are shown below (a) with associated synthetic strategy (b).

![Chemical structures](image)

**Cyclic peptides**

Nature uses cyclisation to protect peptide backbones from proteolytic cleavage. Unstable cystine bridges can be replaced with non-proteinaceous dicarba linkages. Using tandem catalytic sequences and specially designed non-proteinaceous amino acids, we have developed a way to control the formation of multiple dicarba-bridges. We have several projects examining the preparation of carbocyclic derivatives of naturally occurring cystine containing molecules, including biologically active peptide neurotoxins, cyclotides and somatostatin derivatives. Structural characterisation of new peptidomimetics is performed in collaboration with research teams across Australia.

**Insulin superfamily**

One important class of disulfide containing peptides is the insulin super family, which includes, insulin, relaxin and a number of insulin-like growth factors (IGFs). These peptides are involved in important biological functions such as glucose metabolism and partuition where several disulfide bonds are formed but whose specific function in the resultant biological function remains unknown. Recently we have made significant progress in understanding insulin’s mode of action at its receptor but there is still a lot to uncover! This is important for the design of non-peptidic analogues for the treatment of diabetes.

**Analgesic conotoxins**

We are also examining the preparation of carbocyclic derivatives of marine derived conotoxin molecules. These natural products exhibit potent analgesic activity yet their mode of action is currently unknown. Projects in the area aim to identify potent and selective analogues for the treatment of chronic pain.
Dr Kei Saito  
Room No. 227/Green Chemical Future, Tel: 9905 4600, email: Kei.Saito@monash.edu

Green Polymer Chemistry

Our projects will focus on developing new synthesis and production methods for novel sustainable/environment benign polymeric materials based on the principles of green chemistry by understanding naturally occurring mechanisms that can be extrapolated to synthetic systems using polymer chemistry. If you have any further queries, please do not hesitate to contact me (details above). More information on my research can be seen at:

https://www.monash.edu/science/schools/chemistry/our-people/staff/saito

1. Developing Reusable (Reversible) Polymers using Self-assembly

Reversible polymers are polymers in which bonds can be easily broken. Most conventional polymers are structurally irreversible because their monomer units are connected by strong covalent bonds. Reversible polymers have a reversible bond within their structure that can be formed from the monomer units and cleaved back to the monomer units by heat or light. Such novel polymers are of interest because of their potential applications as recyclable environmentally benign materials, photo-resists, and biomedical materials. This project will investigate novel polymerization methods for reversible polymer syntheses.

2. Controlled Topochemical Polymerisation

This project will investigate topochemical (crystalline solid state) polymerization inside limited spaces to develop a new method to control the molecular weight of polymers to target monodisperse (uniform) polymers.

3. Self-healing Polymers (Co-Supervisor: Prof. George Simon, Material Engineering)

Our group is working on creating smart polymeric materials for coatings, films, adhesives that have the ability to repair damage. We will investigate thermal and photo self-healing epoxy and acrylic resin using several cross-linkers with reversible units. This project will involve aspect of organic synthesis, polymer synthesis and polymer characterization techniques.

4. Lignin and Hemicellulose Degradation and its Biomass Application (Co-Supervisors: Assoc. Prof. Tony Patti)

Lignin, which composes 30% of wood tissue, is produced by oxidative polymerization of phenol derivatives catalyzed by laccase, an enzyme in nature. Lignin is known as a stable and insoluble polymer and the disposal and recycle of lignin has been a big resolved issue for industries. This project will focus on lignin degradation and fine chemical production from lignin.

5. Therapeutic phytochemical products from lignin (Co-supervisor: Prof. Louise Bennett)

This project will seek to develop useful therapeutic phytochemical products derived from lignin, involving chemical depolymerisation and characterising absorption properties of products by the human phytochemical absorption prediction model.
Dr Rico Tabor  
Room No. G24b, Tel: 9905 4558, email: rico.tabor@monash.edu

This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research and recent publications can be seen at: www.ricotabor.com

The chemistry of functional colloids, smart surfaces and nanomaterials

We are researching a range of topics in fundamental and applied colloid chemistry, including:
- New surfactants, stabilisers and emulsifiers for use in foods, energy and industry.
- Responsive materials that change their properties due to an internal or external stimulus such as pH, light or magnetic/electric fields.
- Nanomaterials for functional colloids – controlled surface chemistry, sensing substrates, capsules, liquid crystals, etc.

Some examples of possible projects are provided below. Projects can involve synthesis, analysis, visits to large-scale facilities including the Australian Synchrotron and OPAL reactor, Lucas Heights, NSW. To find out more specific information, please get in contact.

**Smarter fluids for energy recovery** – Emulsions that can be controlled by external and internal stimuli such as electric fields, heat, pressure and pH are big business in energy and resources industries – oil, gas, mining, etc. You will develop new materials that have properties tailored to specific stimuli such as dissolved CO₂ or pH changes, using surfactants and polymers that can respond to their environment. These will help make more efficient processes for recovering energy resources in an environmentally conscious way.

**Controlling liquids with light** – Controlling liquid interfaces is central in designing tailored emulsions, foams and coating systems for fluid handling in printing, diagnostics and nanotechnology. Using a range of recently synthesised light-sensitive surfactants (and potentially new molecules that you design and synthesise), you will create new droplet and bubble systems to encapsulate cells and nanomaterials that can be manipulated using light.

**New emulsifiers for food applications** – Emulsifiers are key to stabilising food materials, contributing to shelf-life, texture, mouthfeel and processing. We seek to design new stabilisers that promote use of Australian crops, such as Canola, while moving away from environmentally deleterious feedstocks such as Palm oil. Your project will involve developing and making new molecules, as well as testing them in typical food emulsions with our industrial partners.

**Encapsulation for advanced delivery** – Capsules on the micron scale offer a unique way to protect, deliver and release chemicals, from chemotherapeutics to pesticides, flavours and scents. In this project, you will design a new encapsulation system that incorporates the 2D nanomaterial graphene oxide, and explore how to use it to release a range of active materials.

**Design your own project!** If you have an interest in colloids, nanomaterials or physical forces, then talk to us about what you’d like to study. From the rheology and texture of chocolate to the best way to lubricate drills for mineral exploration, we research all things soft, squishy and self-assembling.
This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

**Ultrasound: synthesis and biomedical applications**

**Ultrasound and acoustic cavitation**

Ultrasound refers to sound waves at a frequency higher than the threshold of human hearing. As sound waves propagate through a medium, they can undergo acoustic cavitation. This phenomenon creates extremely high pressures and temperatures, resulting in a range of chemical and physical effects. The concept of ultrasound is used in many different fields such as in the synthesis of nanoparticles, environmental and food applications, mixing (emulsions) and biomedical imaging and therapy (Figure 1).

Below are some examples of potential honours projects. They also involve collaborations with other faculties within the university (Engineering, Medicine and Physics) and possibly at the University of Melbourne. For more information, please contact Boon for a chat.

1) **Synthesis of acoustically active nanoparticles for ultrasound imaging and therapy.**

   We are interested in making novel colloids that are acoustically active for ultrasound imaging and therapy. Ultrasound triggered drug delivery have a range of beneficial implications such as targeted and enhanced drug delivery, combinatorial therapy, multimodal imaging (e.g. photoacoustics imaging) and can target a wide range of diseases (e.g. infectious diseases, cancer, heart and vascular diseases).

2) **Ultrasound processing of alcoholic beverages**

   Ultrasound has also been used as a green technology in the food processing industry. We are interested in the application of ultrasound to a variety of alcoholic beverages to investigate the fermentation process which produces alcohol, flavour and taste. We want to investigate if there is a possibility of improving flavours of alcoholic beverages, or introducing new ones.

3) **Synthesis of Janus particles**

   We are also interested in making a range of Janus nanoparticles, named after the Roman God. Due to the anisotropic nature of such particles, they have a wide range of applications, ranging from catalysis, to electronic displays and environmental sustainability and drug delivery. You will chemically synthesize a range of Janus particles with interesting physical properties and apply them to a variety of applications, specifically in the biomedical fields, in biosensing and drug delivery.
More information can be obtained by contacting me (details above) or through my web page http://monash.edu/science/about/schools/chemistry/staff/thang/. Our research group is interested in advancing some aspects of the Reversible Addition-Fragmentation Chain Transfer (RAFT) polymerization, a process discovered in 1998 by Moad, Rizzardo and Thang. The RAFT process has the potential to become the method par excellence with its versatility, effectiveness and industrial friendliness for the production of a wide range of specialty polymers of well-defined architectures. To-date, >10,000 papers on RAFT have been published in literatures.

Reversible Addition-Fragmentation Chain Transfer

(RAFT) Process


The following projects are offered to Honours student(s) to undertake and learn the RAFT process, synthetic organic chemistry and polymer chemistry.

Functional bio-inspired RAFT-derived polymeric micelles or colloids in cellular delivery (with Dr Toby Bell)

In this project, you will study and make RAFT-derived functional bio-inspired nanomaterials (in the form of polymeric micelles or colloids) as novel carriers to (i) immobilise and effectively deliver payloads (drugs, proteins, siRNA or mRNA or DNA) to the cytoplasm or nuclei of particular targeted mammalian cells while enabling the retention of biological activity of these biomolecules and, (ii) gain a detailed understanding of the transport of these therapeutics carriers throughout the entire endocytosis process using advanced imaging techniques.

Design, synthesis and characterization of novel RAFT polymers – Drug conjugates

Many potent anticancer drugs such as Camptothecin SN38, Paclitaxel and Doxorubicin are hydrophobic with very poor solubility in aqueous formulation. In this project, you will work on making novel RAFT agent covalently linked to Doxorubicin via the available hydroxyl groups and/or the amino functionality. Subsequently, synthesis of water-soluble, non-toxic and non-immunogenic polymer-Doxorubicin conjugates will be carried out to establish this new polymeric therapeutics as one of the first classes of anticancer nanomedicines.

Design, synthesis and characterisation of new polymer architectures: Ladder-like polymers and/or Helical-like polymers?

With the advent of living radical polymerization techniques such as NMP, ATRP and RAFT in the past two decades, it is now possible to access many polymer architectures (e.g., AB diblock, ABA triblock, ABC triblock, multi-arm star-shaped, palm-tree ABn, H-sharped B2AB2, dumbbell, ring diblock, etc.) and the range of structures possible only by the creativity and imagination. Here, an exceptional research opportunity for you (an ambitious student) to work on the design, synthesis and characterisation of new polymer architecture: ladder-like and/or helical-like polymers by the RAFT polymerisation of novel monomers.
In the **Chemistry Education Research Group** we are interested in investigating how undergraduates learn chemistry, how we can help them achieve the best outcomes possible and how we can inculcate skills that will help make them eminently employable. We are engaged in a range of projects, some examples of which are given below, but projects can be tailored to meet the interests of individual students. You might like to consider a project with us if you are interested in expanding your skills and your horizons and interested in education at any level, but particularly in universities.

**Project Areas include:**

**Student Perspectives of Atoms and Molecules**

This project will explore undergraduate chemistry students’ ability to visualise atoms and molecules at the submicro scale, and their capacity to represent this imagined reality. Educators often take for granted that the pictures in the minds of students’ is consistent with theirs, however research shows this is routinely not the case. This project will specifically explore students’ perceptions, and their ability to describe their hands-on experiments by representing the same chemistry at the submicro scale on paper.

**Employable Monash graduates**

What skills and qualities do new science graduates need to success in the workplace? Who is best placed to identify those skills, employers of the new graduates themselves. What can Monash learn about graduate employability from talking to employers and recent graduates and how can we embed business awareness and personal skills into an already crowded curriculum?

**Using laboratory experiences to prepare undergraduates for industry**

Traditional undergraduate laboratory experiences lead students through recipe-like activities which have little opportunity for investigative or creative outcomes. University laboratory experiences seldom mimic the contexts found in industry where scientists work on complex problems which need speedy solutions whilst considering drivers such as economics, safety, manpower, logistics and environment. Can we reimagine undergraduate laboratories in chemistry to deliver a meaningful curriculum in which students tackle authentic and interesting industry- based investigations, thus motivating them to learn and prepare them for the word of work?

**The effectiveness of inquiry-oriented learning in undergraduate science – perceptions versus reality**

Inquiry-oriented learning (IOL) involves students in the design, framing of hypotheses, and the analysis, interpretation and presentation of experimental data. Alongside problem solving and critical thinking, inquiry provides a strong nexus between teaching and research. Despite a wealth of research, the student perspective has been largely overlooked. This project will involve evaluation of IOL-type activities, and gathering student perspectives for these activities compared to traditional recipe-type practicals.
Dr Kellie Tuck  
*Room No. 250S, Building 23, Tel: 9905 4510, email: kellie.tuck@monash.edu*

This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research can be seen at:  
[http://monash.edu/science/about/schools/chemistry/staff/tuck/](http://monash.edu/science/about/schools/chemistry/staff/tuck/)  
and [http://www.kellietuckgroup.com/](http://www.kellietuckgroup.com/)

**Environmental and Biological Sensors** (collaboration with Assoc. Prof. Mike Grace (Chemistry))

We are interested in the design, synthesis and analysis of luminescent sensors for the detection and quantification of analytes in environmental and biological samples. A particularly attractive and exciting feature of our sensors is the ability to carry out measurements where a short delay is introduced between excitation and detection of the emitted luminescence. Figure 1 shows the ‘turn-on’ luminescence when the analyte of interest binds. We are currently interested in the detection of ammonia, Zn\(^{2+}\), HS\(^{-}\) and GMP. Projects in this area will involve *synthesis* and subsequent *analysis* of sensors.

![Figure 1: Luminescent output in the A) absence of analyte. B) presence of analyte.](image)

**Medicinal Chemistry** (collaboration with Assoc. Prof. Peter Duggan (CSIRO))

Our work in this area investigates the development and synthesis of small molecules that have the potential to be new analgesics. We are developing molecules inspired by a peptide found in the toxin of a cone snail (Figure 2); Two examples of the scaffolds we have investigated are shown in Figure 2. The most potent molecule that we have synthesised to date is compound 3. Recently we have undertaken a structure-activity relationship (SAR) study on these scaffolds and have discovered exciting activity. The honours project will involve the *synthesis* of compounds that will be tested for their ability to inhibit the N-type calcium channel.

![Figure 2: The 3D-structure of w-Conotoxin GVIA with the relevant residues highlighted. Structure of two core scaffolds. Most potent compound 3 MONIRO-1 synthesised to date and the fraction of blocked channels when 100 μM compound is added.](image)
This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research can be seen at: http://monash.edu/science/about/schools/chemistry/staff/turner.html (follow link to personal site)

Description of Project Areas

All research projects in my group are concerned with aspects of crystal engineering and supramolecular chemistry. Our research primarily aims to design porous coordination polymers - materials that resemble nano-scale scaffolding - which will be able to selectively store, sense or separate small molecules. All projects involve (i) the synthesis of organic ligands that will be able to bridge between metal atoms to construct the framework and which will possess additional sites for supramolecular interactions, (ii) synthesis of coordination polymers and/or coordination cages, (iii) structural characterization by X-ray crystallography (typically involving the Australian Synchrotron) and (iv) analysis of the physical properties of the materials for separation/storage/sensing where appropriate. Current project areas include (but are not limited to):

- **Chiral coordination polymers for separation.** Using quite simple bis- or tris-amino acid ligands, we have been able to construct several coordination polymers that are able to provide resolution of racemic mixtures in small-scale liquid chromatographic experiments.

- **Crystal Engineering with Aromatic Carboxylates.** Trying to understand the interplay between different intermolecular interactions within a crystalline material requires a systematic approach to materials design/synthesis. We explore the structural impact on coordination polymers of subtle chemical changes to the system.

- **Coordination cages.** In addition to coordination polymers, we are also interested in forming discrete cages that are able to trap small molecules inside. These chiral cages will be studied for their catalytic behavior and ability to trap guests in their internal space.

Links to recent papers and more information about recent projects and results can be found on my website (http://users.monash.edu/~dturner).

Right: A small cage-type complex (Boer et al., Chem. Commun., 2015).
Catalysis is the main research theme in our group. We are developing green and sustainable catalysts that are capable of performing a variety of organic transformations.

**Project 1. Catalytic deuteration of polyunsaturated fatty acids**
This project is performed in collaboration with a pharmaceutical company Retrotope (https://www.retrotope.com/) that is developing treatments for various neurodegenerative illnesses including Alzheimer's, Parkinson's, atherosclerosis and various retinal diseases. The overall treatment is based on deuterated polyunsaturated fatty acids (PUFAs) that contain deuterium (2H or D) instead of hydrogen atoms only at specific positions (bis-allylic positions) along the fatty acid chain. Recently we have developed (J. Org. Chem. DOI: 10.1021/acs.joc.7b02169) a quite elegant approach to perform the target H/D exchange (deuteration) under exceptional kinetic control. Nevertheless, the simplest PPUFA (i.e. linoleic acids) could not be site-specifically deuterated. Therefore, we aim to prepare a bis-metallic complex that could be used for this purpose. Furthermore, we are interested in heterogenization of existing catalysts which will aid separating the catalyst from the PUFAs.

**Project 2. Lewis acid catalysis using well-defined aluminium-based complexes**
Recent literature has suggested that the field of Lewis acid catalysis is plagued with the presence and consequent activity of hidden Brønsted acids. Beside proper synthesis, identification and use of Lewis acids, the use of various control experiments is crucial for exploring the catalytic activity of these electron deficient species. We believe that majority of the published research is lacking proper steps in minimizing if not eliminating the influence of Brønsted acids. Our Lewis acids are well-defined and well-characterized complexes based on aluminium as it is the most abundant metal in the Earth's crust. We have prepared several aluminium-based complexes that showed remarkable catalytic activity regarding a variety of Diels-Alder cycloadditions (Dalton Trans. 2017, 46, 753. Chem. Eur. J. 2015, 21, 11344). In fact, we have recently discovered that one of our catalytic systems is capable of polymerizing cyclic dienophiles which could be considered as functionalized polyolefins. The preparation of functionalized polyolefins, in general, is very difficult as ill-defined and low-molecular weight materials are normally prepared, while our procedure offers to drastically change that. Therefore, the aims of this project include further exploration of our catalytic systems with respect to several other organic transformations such as borylations, Michael additions, transfer hydrogenations etc. Also, we would like to further explore the synthesis of functional polyolefins in order to determine all their properties.
Biospectroscopy, an emerging field within the spectroscopic examination of living tissue or body fluids, combines information from physical sciences with advanced computational analysis in order to shed new light on biological processes. This field is at the cutting edge of chemistry and biology research, continually developing knowledge about the structure and activity of biological molecules. Crucially biospectroscopy has the potential to revolutionize clinical diagnostic processes, fulfilling the constant demand for new technologies that can identify diseases to a high level of objectivity, sensitivity and specificity.

Operating in this context, the Centre for Biospectroscopy, located in the School of Chemistry, has flourished over the course of the past decade. With its broad range of state-of-the-art equipment, strong roster of multidiscipline staff and robust collaborations with other researchers, the world class Centre is driving the development of biophysics and biotechnology.

The Centre of Biospectroscopy, is dedicated to solving biomedical problems using vibrational spectroscopic techniques including FTIR and Raman imaging spectroscopy, Attenuated Total Reflection spectroscopy, portable hand held Raman and FTIR spectrometers and near-field techniques including Tip Enhanced Raman Spectroscopy and nano-FTIR. We have a number of different research themes that broadly fall under the banner of vibrational diagnostics and monitoring. Specific research areas include malaria diagnosis and treatment, point-of-care sepsis detection, dengue fever, cancer diagnosis, sepsis diagnosis, HIV, HBV, HCV, IVF, stem cell research, heart disease, liver disease, phytoplankton studies, aquatic wet land studies and fundamental studies of how light interacts with matter. If you are interested in any of these research themes please feel to contact me to discuss the specifics of the various projects. More information on my research can be seen at: http://www.monash.edu/science/cfb/home
This document will give you an idea of the type of research we are undertaking within my group. If you have any further queries, please do not hesitate to contact me (details above).

More information on my research can be seen at: [www.chem.monash.edu.au/staff/zhang](http://www.chem.monash.edu.au/staff/zhang)

**Title of Project: Electrocatalytic activation of small molecules for energy applications**

The main focus of this project is to develop nanostructured catalysts for electrochemical activation of small molecules in the important processes, such as water splitting, carbon dioxide reduction and alcohol oxidation, for energy conversion and storage. If you are interested in this project and would like to know more details about it, please feel free to talk to Dr. Zhang directly.
Nanoporous hierarchical membranes for solar-driven conversion of CO\textsubscript{2} to fuels (with Professor Douglas Macfarlane)

Depletion of our fossil fuel reserves and increasing CO\textsubscript{2} emissions from fossil fuel combustion are two of the most serious concerns facing humanity today. The logical solution is to use renewable energy (eg. solar, wind etc). We are developing advanced catalysts based on nanomaterials for solar-driven conversion of CO\textsubscript{2} to fuels, therefore converting a pollution problem (CO\textsubscript{2} emissions) into a fuel source.

New materials hold the key to fundamental advances in energy conversion and storage. Porous materials with hierarchically ordered porosity, namely, macropores in combination with mesopores, are of particular interest because macropores allow access to large guest molecules and an efficient mass transport through the porous structures is enabled while mesopores enhance the active surface area. The aim of the proposed project is to design and fabricate novel classes of nanoporous hierarchical membranes with fully controlled geometry and structure. Photoelectrochemical cells based on nanoporous hierarchical membranes will be developed and used for solar-driven conversion of carbon dioxide into liquid fuels and valuable chemicals under ambient conditions.
Industrial Project

Biofuel Innovations Several Industry Research Project Options

<table>
<thead>
<tr>
<th>BFI Supervisor: Dr Rebecca Yee</th>
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<tr>
<td>Monash Supervisors: Assoc/Prof Tony Patti and Prof Andrea Robinson</td>
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<tr>
<td>Project Title: Investigation of ultrasonic performance on enzyme transesterification of biodiesel</td>
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<tr>
<td>Other staff Dr Henry Sabarez (BFI)</td>
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<td>Questions about this project should be directed to: Associate Prof Tony Patti</td>
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<tr>
<td>Other information: This project is a collaboration with Biofuel Innovations, a small start-up that focuses on developing commercial technology for processing waste oil into biodiesel. (<a href="http://www.biofuelinnovations.com.au">www.biofuelinnovations.com.au</a>). The pilot plant is based in Dandenong South. Project applicants must be able to travel to Dandenong South.</td>
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Biodiesel is a sustainable and biodegradable combustion fuel that can be used in any diesel engine. Waste cooking oil can be converted into biodiesel using a chemical process known as transesterification.

\[
\text{Triglyceride} + \text{Alcohol} \rightarrow \text{Glycerol} + \text{Mono-alkyl Methyl Esters} \\
(\text{Used Cooking Oil}) \quad \text{(Methanol)} \quad \text{(Biodiesel)}
\]

The process is catalyzed by an enzyme, which limits operation to 35-40°C. This process requires up to 24 hours to achieve complete conversion. This process can theoretically be sped up significantly using ultrasonic mixing. Faster reaction conversion will help to increase the plant’s production capacity.

Project option 1

Ultrasound waves create bubbles and as their size increases with time, the bubbles burst and cause a large amount of dispersion. The bursting of the bubbles is known as cavitation. Energy released by ultrasound during the cavitation phenomena can be used to enhance mass transfer, hence increasing the rate of products formation. Ultrasound mixing is considered a “green” technology due to its high efficiency, low instrumental requirement and significant reduction of processing time in comparison to other techniques.

As a biological additive, the enzyme can be deactivated by heat or overly aggressive mixing. This project aims to establish suitable ultrasonic operating conditions that can increase the reaction rate of biodiesel production from used cooking oil or trap grease.

**Aim:**
To determine suitable operating conditions to produce high conversion of biodiesel under ultrasonic mixing.

**Scope:**
- Literature Review (ultrasonic mixing, biodiesel production using ultrasound, ultrasonic affect on enzymes)
- Test biodiesel production in a lab-scale ultrasonic water bath
  - Determine reaction rate for certain volume
- Optimise conditions for ultrasonic mixing and alcohol ratios

Project option 2

The BFI Pilot Plant uses a triglyceride feedstock oil of used cooking oil sourced from fish and chip shops and other restaurants. BFI has a unique enzymatic process that is able to use lower quality oil as a feedstock. Grease traps are used by food manufacturers and shops to capture waste grease and oils before entering the wastewater disposal system. This brown sludge waste is typically collected.
and slowly digested and broken down by microorganisms in through anaerobic digestion. There is currently no market for this trap grease and a significant amount is produced in Victoria alone.

Current biodiesel manufacturers also use methanol as the alcohol reagent. Methanol is sourced from crude oil and is non-sustainable. Ethanol can replace this alcohol and is able to be sourced from renewable crop waste. BFI aims to develop a completely sustainable biodiesel production process that uses very low grade feedstock waste oil.

**Project Aim:**
To determine the composition of trap grease and establish suitable operating conditions for biodiesel production using completely renewable reagents of trap grease and ethanol.

**Scope:**
- Literature Review (brown grease, trap grease, ethyl esters)
- Run experiments at lab scale
- Establish lab scale reaction parameters

**Project option 3**

The BFI process generates a high quality crude glycerin byproduct at an approximate rate of 10% yield. Pure glycerol has a limited market, but can be used as a valuable base molecule that has many potential uses. The following figure illustrates the various chemical products that be generated through various catalytic pathways.

**Project Aim:**
To determine suitable catalysts for conversion of glycerol into value-added chemicals. The pathway for high value market products will be developed to a pilot scale plant to process ~50L batches of crude glycerol.

**Scope:**
- Literature Review (brown grease, trap grease, anaerobic digestion)
- Test catalysts at lab scale
Industrial Project

Fire resistance in polyisocyanurate foams for use in insulated panels.

This is an industrial project and will be carried in whole or part at Pacific Urethanes, Carrum Downs, Victoria. See [http://www.pacificurethanes.com/](http://www.pacificurethanes.com/)

Academic supervisor will be identified before the project allocations.

There will be a significant increase in the demand for insulated panels for domestic and commercial insulation applications with a requirement for a high standard of fire retardancy. Polyurethane and Polyisocyanurate foams provide highly efficient insulation per unit of thickness but being organic materials they will burn when exposed to sources of ignition. The resistance to burning of Polyurethane foams can be increased by the addition of fire retardant additives but the improvements are limited. The fire resistance of Polyisocyanurate foams is achieved by the generation of high molecular weight trimerised Isocyanate within the structure of the foam and this high molecular weight structure increases the melting point of the foam polymer causing the surface to char

This project will investigate

- The mechanism of trimerisation and char formation in polyisocyanurate foams;
- The factors affecting the rate and the amount of trimerisation that occur during the production of a polyisocyanurate foam;
- The optimum level of trimerisation to achieve the optimum fire resistance;
- The influence of other components of the foam formulation on the flammability of the foam.