WESTERN SYDNEY UNIVERSITY

Science

SUITABLE FOR MASTER OF RESEARCH

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Graft-Antenna for Nerve Stimulation and Regeneration

Dr Antonio Lauto: a.lauto@westernsydney.edu.au

Research area: Medical science

Peripheral nerve repair is a challenging problem because axon regeneration is often inadequate and only 50% of patients regain some function after surgery. Existing electrical stimulators can improve nerve regeneration and functionality but have significant limitations not yet addressed. A major disadvantage is their inability to function concurrently as wireless non-invasive stimulators and conduits for nerve grafting. To date, there are no implantable devices capable of repairing and stimulating neural tissue at the same time. We have recently overcome this major obstacle by developing an innovative technology, which combines in a single device (the graft-antenna) the ability to concurrently stimulate and repair injured nerves with a conduit. Until now, these functions have been carried out by two distinctive implants, namely a wireless stimulator and a biocompatible conduit. While existing stimulators are bulky and fabricated with complex electronics to create and deliver a voltage to tissue, our device is capable of stimulating nerves without circuitry components as it relies on a new stimulation mechanism.

The aim of this proposal is to prove that the graft-antenna can stimulate and regenerate nerves more effectively than conventional suture repair. We plan to test the regenerative capacity of the graft-antenna by exploiting its superior ability of stimulating and thus regenerating axons when compared to conventional suturing.

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Impact of Microwave-induced Currents on Cells

Dr Antonio Lauto: a.lauto@westernsydney.edu.au

Research area: Medical science

Axons can regenerate over gaps caused by trauma and reconnect with the nerve distal stump by recreating functional contacts. Peripheral nerve injuries that produce long gaps require the implantation of a bridge between the proximal and distal nerve stumps to restore the organ innervation and function. Autograft are typically employed in patients but a second surgical procedure, limited availability and permanent denervation at the patient site are the major disadvantages. This study will explore the suitability of electrically conducting materials, which may be incorporated in polymeric grafts, to enhance nerve regeneration in combination with microwaves.

This project aims to assess the impact of microwaves on neuron-like cells, which are seeded on conducting biomaterials. Conducting polymers, such as polypyrrole for example, have the unique properties to combine electrical stimulation of the nerve along with biocompatibility. The biocompatible materials will range from metals (titanium, gold on Mylar, Indium Tin Oxide on glass) to polymers (polypyrrole). Microwaves will induce electric currents in the conductive biomaterial on which cells are seeded. These currents in turn may stimulate growth of cells. This stimulation is non-invasive as it does not require insertion of electrodes.

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Photodynamic Treatment of Nail Fungal Infections

Dr Antonio Lauto: a.lauto@westernsydney.edu.au

Research area: Medical science

Fungal infections of the skin and nails are often caused by Trichophyton rubrum. Treatment is difficult due to high recurrence rates and problems with treatment compliance. For these reasons, alternative therapies are needed. Dr Lauto's group has recently developed a new photodynamic treatment that relies on the activation of rose bengal (RB) using a green laser (wavelength=532 nm) to attack the fungus. This treatment was successful in killing effectively the Trichophyton rubrum in vitro.

The aim of the study is to optimize the photodynamic treatment parameters and technique for clinical applications.

The fungus will be cultured with keratinocytes and then treated with the photodynamic technique in order to optimize the relevant parameters for clinical applications. Saccharomyces cerevisiae (budding yeast), will serve as a closely related model fungal system, and will also be irradiated with the same technique and used as a genetic model to find key pathways involved in the fungal killing.

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Simulating Magnetic Resonance Experiments using Symbolic Algebra

Professor William S Price: w.price@westernsydney.edu.au

Supported by: Dr Tim Stait-Gardner

Research area: Computer simulation, Diffusion, Mathematics, MRI, NMR

Magnetic resonance has applications from industry and agriculture to clinical medicine (i.e., MRI). Magnetic resonance has enormous untapped potential. Sometimes experiments lead the theory but often we can design better or even unheralded experiments if we start from theory. The theory of magnetic resonance centres around 'spin dynamics', in short, how the magnetic properties of atomic nuclei interact between themselves and with respect to external magnetic fields. This leads to the development of new pulse sequences - these are the magnetic resonance analogue of a musical score - they determine the information an experiment can provide.

In many instances we must resort to computer simulations (i.e., numerical or symbolic algebra) to develop the theory and ultimately develop new pulse sequences. In this project students will simulate experiments based on a full understanding of spin-dynamics. This will lead to enhanced magnetic resonance methods (e.g. water suppression, diffusion measurements, MRI).

This project suits applicants interested in Mathematics, MRI, NMR and Physics.

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Increasing the Accuracy and Speed of NMR Diffusion Measurements

Professor William S Price: w.price@westernsydney.edu.au

Research area: Diffusion, NMR, MRI, Optimisation, Pulse sequence

Diffusion NMR is routinely used to study various molecular properties, and interactions occurring in solution. This technique is also valuable in MRI as it can be used to probe microscopic structures in biological tissues.

Typically, an NMR measurement of the diffusion coefficient is performed without any selective excitation (i.e., a hard rf pulse is used to excite the entire accessible sample volume). In this project, diffusion measurements will be investigated using excited slices of diminishing thickness for the Pulsed Gradient Spin Echo (PGSE) and Pulsed Gradient STimulated Echo (PGSTE) sequences.

Theoretically the diffusion attenuation and hence the measured diffusion coefficient should be independent of slice thickness. Of course, a smaller excited volume will lead to a lower signal and hence a lower signal-to-noise ratio (SNR). However, a smaller excited volume will also have less variation in the magnetic field from magnetic field inhomogeneities potentially leading to more accurate measurements of diffusion coefficient (if the SNR is sufficient).

The aim of this project is to attempt to find answers to the following questions. What is the expected outcome of a PGSE experiment with a slice selective excitation pulse? What is the best way to handle the inversion pulse (hard or slice selective)? How think can the excited slices be? Can multiple slices be excited simultaneously or in quick sequence to achieve a faster measurement of the diffusion coefficient?

This project suits applicants interested in NMR, Physical chemistry, Physics and who have a mathematics background of at least Maths 1B.

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Applications of Diffusion in Benchtop NMR

Professor William S Price: w.price@westernsydney.edu.au

Research area: Biological microstructure, Diffusion, MRI, NMR

Diffusion NMR is routinely used to study various molecular properties, and interactions occurring in solution. This technique is also valuable in MRI as it can be used to probe microscopic structures in biological tissues including cancer. It can also be used to analyse mixture of compounds as in 2D DOSY experiments. Benchtop NMR has particular applications to industrial problems. Recently, the capability of benchtop NMR to perform diffusion and imaging experiments has significantly improved to a point that it may now be possible to perform some useful diffusion experiments on such small portable NMR instruments.

In this project, we study the feasibility of performing various diffusion experiments on the benchtop NMR. The available NMR diffusion methods on the benchtop NMR will be first evaluated using various test samples in order to determine its suitability for routine analysis. Its performance will also be compared with that of the conventional NMR system that is available in the Biomedical Magnetic Resonance Facility. The implementation of other useful diffusion methods such as DOSY will also be investigated.

This project suits applicants interested in Biology, Mathematics, Medical physics, Physical chemistry, MRI or NMR.

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Trialling a novel combination treatment on patients with persistent dizziness

Dr Cherylea Browne: c.browne@westernsydney.edu.au

Research area: Medical science

Post-concussion syndrome (PCS) occurs when symptoms of a concussion or mild traumatic brain injury (mTBI) last longer than the expected recovery period. Symptoms may include headaches, dizziness, and problems with concentration and memory. My interest is in persistent dizziness, imbalance and increases in visual sensitivity in patients that are unable to be effectively treated by vestibular physiotherapy or behavioural optometry.

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Developing a telehealth rehabilitation program for patients with persistent dizziness and visual induced dizziness.

Dr Cherylea Browne: c.browne@westernsydney.edu.au

Research area: Medical science

Post-concussion syndrome (PCS) occurs when symptoms of a concussion or mild traumatic brain injury (mTBI) last longer than the expected recovery period. Symptoms may include headaches, dizziness, and problems with concentration and memory. My interest is in persistent dizziness, imbalance and increases in visual sensitivity in patients that are unable to be effectively treated by vestibular physiotherapy or behavioural optometry.

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Trialling a novel combination treatment on Mal de Debarquement Syndrome (MdDS) patients

Dr Cherylea Browne: c.browne@westernsydney.edu.au

Research area: Medical science

Mal de Debarquement Syndrome (MdDS) is a rare neurological condition characterized by a perception of persistent self-motion (i.e. rocking, swaying and bobbing), and occurs after disembarking from prolonged exposure to passive motion. This type of onset has been termed as Motion Triggered (MT). Approximately 10% of MdDS cases are not attributable to a motion event. Nevertheless, these patients develop MdDS symptoms spontaneously, also referred to as Non-Motion Triggered (NMT). In addition to the self-perception of motion, MdDS patients report a range of other symptoms, such as brain fog, depression, anxiety and heightened visual sensitivity. Treatment is quasi-experimental, and quality of life impacts are unrelenting.

This project will trial a novel combination treatment on MdDS patients, involving Theta Burst Stimulation and Vestibular Ocular Reflex readaptation protocols.

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Assessing the effects of gonadal, thyroid and adrenal hormones on MdDS symptomology

Dr Cherylea Browne: c.browne@westernsydney.edu.au

Research area: Medical science

Mal de Debarquement Syndrome (MdDS) is a rare neurological condition characterized by a perception of persistent self-motion (i.e. rocking, swaying and bobbing), and occurs after disembarking from prolonged exposure to passive motion. This type of onset has been termed as Motion Triggered (MT). Approximately 10% of MdDS cases are not attributable to a motion event. Nevertheless, these patients develop MdDS symptoms spontaneously, also referred to as Non-Motion Triggered (NMT). In addition to the self-perception of motion, MdDS patients report a range of other symptoms, such as brain fog, depression, anxiety and heightened visual sensitivity. Treatment is quasi-experimental, and quality of life impacts are unrelenting.

This project will assess the effects of gonadal, thyroid and adrenal hormones on MdDS symptomology, compared with other vestibular disorder patients such as those with Vestibular Migraine and Persistent Postural-Perceptual Dizziness.

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Animal Physiological Ecology

Dr Chris Turbill: c.turbill@westernsydney.edu.au

Research area: Animals, Ecology, Mammals, Physiology, Thermal ecology

A range of possible projects are available, including:

- Thermal ecology of birds and mammals (e.g. understanding the use of energy-saving mechanisms like torpor in wild animals, and responses to extreme heat).
- Linking physiology (e.g. thermoregulation and metabolism) with behaviour (e.g. activity) and life-history ecology (e.g. survival) to understand how animals cope with environmental challenges like food shortages and climatic extremes.
- Conservation physiology: applying behavioural and physiological knowledge and methods to improve the outcomes of conservation management actions (e.g. animal reintroductions (rewilding and translocation).

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Avian Nest Construction

Dr Christa Beckman: c.turbill@westernsydney.edu.au

Research area: Animal behaviour, Ecology

Nest structures are essential for successful reproduction in most bird species. Many bird species go to great lengths to camouflage their nests in order to avoid detection by predators, such as building nests that are shaped to blend into their surroundings. Using an experimental approach, this study will examine the effects of nest characteristics on nest predation rates.

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The Evolution of Female Song in Birds

Dr Christa Beckman: c.turbill@westernsydney.edu.au

Research area: Animal behaviour, Ecology

While birdsong is a model system for animal communication studies, our knowledge is derived primarily from the study of only one sex and is therefore incomplete. Bird song has long been considered a male trait, sexually selected to enhance attractiveness to females. However, in some species, females may also produce songs even with comparable complexity to that of males. This study will examine song and singing behaviour in both male and female grey fantails, with the aim of contrasting song complexity and singing behaviour between the sexes.

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The Evolution of Colour Patches on Bird Tail Feathers

Dr Christa Beckman: c.turbill@westernsydney.edu.au

Research area: Animal behaviour, Ecology

Colourful and elaborate feathers are important traits for sexual selection in birds. Distinct tail white patches are present in many species of birds, yet they remain little studied. Some studies have shown that the white spots on tails of males indicate male quality and influence female mate choice. In particular, most research to date has focused on species that are sexually dimorphic. This project will explore the differences between and variance within males and females in tail plumage colour in non-sexually dimorphic species. The project could include work with museum specimens, trapping and banding birds using mist-nets, taking measurements and photographs of tail feathers, and behavioural observations.

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The Reaction of 1-cubyl Radical with Dioxygen: A Mechanistic Exploration

Dr Dave Harman: d.harman@westernsydney.edu.au

Research area: Science

The reactivity of bridgehead radicals rises as the degree of bond strain increases. Hyperconjugation - a major means of stabilisation - is compromised as the geometry of a carbon-centred free radical departs increasingly from planarity.

In a recent ion trap mass spectrometry study of strained distonic radical anions, it was discovered that 1-admantyl-3-carboxylate underwent reaction with O2 gas to give an adamantylperoxyl radical as anticipated. However, when the more highly strained 1-cubyl-4-carboxylate radical anion was subject to the same conditions, no products could be detected. Subsequent experiments demonstrated that a reaction between the cubyl radical and oxygen was indeed occurring, but that degradation of the intermediate(s) was occurring, yielding undetectable products.

The junior researcher will first synthesise a molecule from which 1-cubyl radical can be generated. This compound will be irradiated with visible light in the presence of oxygen gas and the products of the free radical reaction will be subsequently isolated and characterised with the help of NMR, GC-MS and LC-MS. Conclusions will then be drawn about the mechanism of reaction between 1-cubyl radical and dioxygen.

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Mode of Action of Novel Anti Prostate Cancer Drugs

Dr Dave Harman: d.harman@westernsydney.edu.au

Supported by: Associate Professor Kieran Scott and Dr Shadma Fatima

Research area: Science

Prostate cancer (PCa) is one of the most common cancers in men in Australia with around 20,000 new cases diagnosed each year. Despite improvements in cancer therapies, current medications cannot stop the impact of PCa, which takes the lives of 3,500 men each year. These statistics emphasize the gap in current available therapies and signifies the urgent need for improved and safer therapies that can rapidly be translated to the clinic. With the intent to overcome this gap we have synthesized unique cyclic peptides, that inhibit tumour cell proliferation by inhibiting inflammatory oncogenic signals. One of our novel peptides (c2) has proven to be safe, non-toxic and absorbed into the bloodstream when given orally to men with advanced prostate cancer, demonstrating the clinical potential of our experimental drug.

Our data show that c2 is the first in a completely new class of anti-inflammatory anti-cancer drug that can interact with an enzyme secreted phospholipase A2 (hGIIA) and a protein vimentin. Multiple studies have confirmed the role of vimentin in acquisition of invasive capacity and a motile cellular phenotype making it an attractive metastatic drug target. We hypothesize that c2 interacts with vimentin and will work as a two-way sword and kill oncogenic signals of vimentin and inflammatory signals of hGIIA and will kill and inhibit cancerous cells.

In this project we would like to further explore the mechanism of action of our lead compounds. We will first reconfirm the tumour inhibiting potential of drugs in patient derived PCa cells cultured as 3D tumoroids. The transcriptomic and lipidomic signatures of treated and untreated tumoroids will be identified for assessing their mechanism of action and their impact on cancer progression pathways. We will identify differential lipidomics and proteomics signatures relevant for treating inflammation and PCa and will test them in our well-established efficacy evaluation assays. Utilising sophisticated data-driven analytical tools drug-induced multi-omic profiles will be interrogated for understanding the mechanism of action of these drugs. Further to improve treatment efficacy, an innovative network-based computational approach will be developed to effectively prioritise clinically efficacious c2-based drug combinations for c2-based multi-component therapy against PCa.

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Discrete Interlocked/Intertwined Supramolecular Assemblies

Dr Feng Li: feng.li@westernsydney.edu.au

Research area: Science

In the realm of supramolecular chemistry, finite nano-scale interlocked/intertwined metallo-supramolecular ensembles with interesting and beautiful molecular structures have received very considerable attention over recent years. Such metallo-architectures range from large metal protein to a small number of intricately interwoven structures that bridge the boundaries between Art and Science. These ensembles, which typically form on the nanometer scale, display both considerable beauty and applications. However, the generation of new structures of this type has remained a very significant synthetic challenge. A condition for the rational strategies of such metal organic structures is that the metal ion(s) and organic component(s) display the required steric and electronic complementarity to promote formation of the molecular architecture of interest.

The application of cation and/or anion templated syntheses to the design and construction of new practical molecular devices and machines, including sensors, (opto)electronic devices (including electronic components ranging from transistors to logic gates) and enzyme-like catalysts remains a significant intellectual and practical challenge. To probe the construction of novel molecular devices, which show molecular movement of interlocked/intertwined constituent parts that can be triggered by cation and/or anion binding controls, is anticipated to lead to novel supramolecular assemblies for practical applications in molecular memory and molecular machines. The proposed interlocked supramolecular systems could also contribute to the development of nanoscale molecular machines that, for example, might mimic the role of sophisticated biomolecular entities.

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Metal Directed Assembly of Discrete Supramolecular Systems

Dr Feng Li: feng.li@westernsydney.edu.au

Research area: Science

The metal-ion directed assembly of discrete molecular architectures, and especially those with interesting supramolecular topologies, has received very considerable attention over recent years, because of their specific applications in recognition, catalysis, magnetic materials and synthetic membranes for ion channels. Yet the rational design and synthesis of discrete coordination architectures or polymeric coordinations still remains a great challenge. The ultimate aim of metallo-supramolecular systems is to control the structure of the target product with expected properties and functions. These include novel redoxactive, magnetism, photoactive, conductive (including superconductive), catalytic and non-linear optical properties.

The design of suitable organic ligands and the selection of the correct metal ions for favouring structure-specific self-assembly play important roles in the construction of discrete coordination architectures. Thus much attention in this project will be focused on the synthetic approach and the structural control of coordination architectures, especially for those with multidimensional structures. The organic components to be employed all incorporate i-diketonate, pyridylpyrazole and/or imidazole schiff base sites - motivated in part by the availability of the extremely well documented metal coordination behaviour of these 'classical' coordination entities. Furthermore, characterization and functionality of such systems will be investigated for specific applications in host-guest chemistry and spin-crossover (SCO) studies. This will elucidate fundamental aspects of metallo-supramolecular chemistry (including the role that both metal ions and organic species may play in the assembly process), factors influencing host-guest inclusion behaviour and the nature of electronic/magnetic interactions between spin-crossover and magnetic coupling energies.

The overall aim of the project is to employ directed assembly procedures, stepwise syntheses and template controls for constructing innovative nanometre-scale materials.

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Self-Assembly of Coordination Cages

Dr Feng Li: feng.li@westernsydney.edu.au

Research area: Science

The self-assembly of coordination cages has continued to receive considerable attention over the past decade because of their many potential applications in gas adsorption, drug delivery, catalysis, magnetic materials, host-guest phenomena and synthetic membranes for ion channels. Although a number of coordination cage types have been developed, the design and successful construction of these systems, particularly those with heteronuclear coordination motifs, still represents a significant challenge.

The design of suitable organic ligands and the selection of the correct metal ions for favouring structure-specific self-assembly play important roles in the construction of discrete coordination cages. Thus much attention in this project will be focused on the synthetic approach and the structural control of coordination architectures, especially for those with multidimensional structures. This will elucidate fundamental aspects of metallo-supramolecular chemistry (including the role that both metal ions and organic species may play in the assembly process), factors influencing host-guest inclusion behaviour and the nature of electronic/magnetic interactions between spin-crossover and magnetic coupling energies.

Three synthetic procedures have been successfully exploited for the construction of discrete heteronuclear coordination architectures: 1) exploitation of the inherent coordination properties between ligands and different metal ions for the metal-directed assembly of discrete metallo-supramolecular architectures; 2) formation of discrete metallo-assemblies preorganised for binding a second metal ion, or ions, to yield discrete heterometallic architectures; 3) employing preformed metalloligands functionalised for use as building blocks reacting with additional metal ions and sometimes extra ligands.

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The Conservation Status of Australian Invertebrates

Dr Kate Umbers: k.umbers@westernsydney.edu.au

Research area: Zoology, Insects, Animal behaviour, Conservation, Fire

Australia's Black Summer has mobilised the conservation community to rapidly understand the impact of the continuing threat of fire on Australia's fauna and flora. Support is generally underway to determine new conservation priorities for plants and many vertebrate animal species. However, in the wake of the fires, Australia has been exposed for its poor support of research into invertebrate fauna, with no immediate capacity to even guess how many and which species were at greatest risk from the fires. This project aims to assess the conservation status of invertebrate species affected by the Black Summer fires and beyond to future-proof our invertebrate fauna. It could include field work and lab work, meta-analyses, spatial analyses, and/or conservation genetics.

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Conservation in Australia's Alpine Sky Islands

Dr Kate Umbers: k.umbers@westernsydney.edu.au

Research area: Zoology, Insects, Animal behaviour, Conservation, Fire

Australia's alpine region is among the world's ecosystems most threatened by climate change. It harbors many species found nowhere else each with unique characteristics that are emblematic of the richness of the region. This project aims to understand how species are connected across Australia's alps and identify geographic regions of conservation priority based on genetic data and using museum specimens for a range of species. This project could include field work, lab work, genetic analysis, conservation, and visiting museum collections.

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The Evolution of Anti-predator Defences in Insects and Their Allies

Dr Kate Umbers: k.umbers@westernsydney.edu.au

Research area: Zoology, Insect, Animal behaviour, Conservation, Fire

Mind boggling diversity is the only way to describe the myriad ways in which insects and other invertebrates defend themselves from predators. Lots is known about 'primary defences' like camouflage, those which prey use to evade being detected or identified by predators but secondary defences, those used by prey once they're under attack, are complex and highly variable. Some insects display shocking colours, and others spray noxious chemicals, others still use a multitude of defences in combination to ward off threats. The project aims to determine how secondary defences evolve and how effective they are against predators. It could include field work, lab work, animation and model making and behavioural experiments.

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Developing an Enteric Coating for Capsaicinoid Extracts from Capsicum Stems and Leaves

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Supported by: Dr Sunil Panchal and Dr Richard Thomas

Research area: Human nutrition

The capsaicinoid extract can be produced from capsicum and chilli plants which may help lower obesity and metabolic complications. This extract is pungent and may lower the patient compliance. To increase acceptability for those who dislike the characteristic pungency, an enteric coating can be used to capsulate the powdered extracts. There is an array of coating materials commonly used in the pharmaceutical industry with different physical and chemical properties. This project aims to develop a suitable enteric coating based on the dosage and delivery of capsaicinoids and the commonly used coating materials.

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Understanding the Mechanistic Role of New Human DNA Repair Proteins - Novel Avenues to Treat Cancer

Associate Professor Liza Cubeddu: l.cubeddu@westernsydney.edu.au

Supported by: Dr Roland Gamsjaeger

Research area: DNA repair, Proteins, Cancer

Humans have evolved multiple mechanisms to ensure the integrity of their genetic information, which is carried by DNA. Each cell suffers more than 100 000 insults a day to its DNA; therefore an effective DNA damage response is crucial for the maintenance of genetic integrity and for survival. One of the main outcomes of not upholding our genetic integrity is mutation; some mutations predispose individuals to developing cancers. The development of novel therapeutic agents for cancer treatment has been hindered because the molecular details of most human DNA repair pathways are not fully resolved. We have discovered two new human proteins, from the oligonucleotide binding domain family, that have critical roles in the DNA damage response. We are working toward a molecular understanding of the roles of these proteins using a combination of biochemical, functional and structural techniques to develop innovative therapeutics to selectively kill cancer cells.

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Tracing Light through Fractal Galaxies

Dr Luke Barnes: l.barnes2@westernsydney.edu.au

Research area: Astrophysics, Cosmology, Radiative transfer, Galaxy formation

Astronomy interprets observations of light, and sometimes the light we see has taken a meandering path from its source to our telescopes. In particular, ultraviolet light from young, hot stars will reflect of clouds of hydrogen gas inside the galaxy in which it is formed, and can be absorbed by dust clouds.

This project will use fractal methods to create realistic distributions of gas and dust clouds in the interstellar space in a simulated galaxy. It will then use Monte Carlo methods to trace the path of light (specifically, Lyman alpha radiation) through these simulated galaxies, building up a realistic picture of observations.

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Nuclear Reactions in Expanding Space

Dr Luke Barnes: l.barnes2@westernsydney.edu.au

Research area: Astrophysics, Cosmology, High Energy Physics

In the first few minutes after the Big Bang, our universe was hot enough and dense enough for nuclear reactions to occur. Tracing these reactions gives one of the key pieces of evidence for the Big Bang model. Because the universe expands quickly, the reactions only create light elements: hydrogen, helium and trace amounts of helium.

What would it take for the universe to produce heavy elements in its earliest stages? Can we make a universe of pure iron? This project will study nuclear reaction chains in a slowly expanding universe. We will extend existing nucleosynthesis codes to higher elements, and simulate the formation of iron, nickel and more in expanding space. This project will address deep questions about the origin of useful (low entropy) energy in our universe.

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Will We Survive the Andromeda Collision?

Dr Luke Barnes: l.barnes2@westernsydney.edu.au

Research area: Astrophysics, Cosmology, Radio astronomy, High Energy Physics

The Milky Way's nearest galactic neighbour - of similar size - is Andromeda, located 2.5 million light years away. We know that Andromeda is moving towards us at about 300 km/s, which means that it will arrive at the Milky Way in about 2-3 billion years. What happens when it arrives? Astronomers have simulated the collision and merger of massive galaxies, which is a relatively common process in the universe. We see many galaxies that seem to be in the process of collision. Using computer codes that model the interaction of matter under gravity, hydrodynamics and more, we can produce simulations of collisions that follow the gravitational pull of dark matter, gas and stars, the compression of gas disks, the resultant burst of star formation, and more. What hasn't been investigated, using these simulations, is: what would happen to life forms in the galaxies? If life remained in the solar system, or on a similarly habitable planet, what would they experience during the collision? This project will analyse simulations of the Milky Way-Andromeda collision to answer these questions.

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Milky Way Spiral Arms and Mass Extinctions

Dr Luke Barnes: l.barnes2@westernsydney.edu.au

Supported by: Professor Miroslav Filipovic

Research area: Astrophysics, Cosmology, Radio astronomy, High Energy Physics

You will use the most up-to-date Milky Way model and solar orbit data in order to test the hypothesis that the Sun's galactic spiral arm crossings cause mass extinction events on Earth. To do this, we will create a new model of the Milky Way's spiral arms by combining a large quantity of data from several different surveys. We intend to combine this model with an elsewhere derived solution for the solar orbit to determine the timing of the Sun's historical passages through the Galaxy's spiral arms. We intend to design a new model with a symmetrical appearance, with the major alteration being the addition of a spur at the far side of the Galaxy. Furthermore, we will identify all known historical mass extinction events that might be explained by the motion of the Sun around our Galaxy.

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Public health and safety

Dr Maggie Davidson: ma.davidson@westernsydney.edu.au

Research area: Environmental health, Environmental management

We have a range of opportunities available in the following areas:

- Farm to Pharmacy - promoting occupational health and safety in the emerging Australian medicinal cannabis and industrial hemp industry (AMCREC)
- Health and hygiene of workers to Respirable Crystalline Silica (RCS) during wet processing of engineered stone
- Public health hazards and infection control in nail salons
- Biological hazards associated with thermal comfort water misting systems and pro-inflammatory potential of plant dusts

- Blue Mountains and Lithgow Air Watch Program: use of low dost KOALA air quality sensor to track and report on local air quality in communities.

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Agriculture After Bushfire: Investigating Impacts on Primary Food Production

Michelle Mak: m.mak@westernsydney.edu.au

Supported by: Li Li

Research area: Human nutrition

The Australian agricultural industry is a key contributor in both international and domestic food security. During the 2019-20 Australian 'Black Summer' bushfire disasters, farming communities were severely impacted on multiple levels. Systematic guidelines or recommendations for planning to minimise disturbance to food production appear lacking, in contrast to a suite of financial and technical assistance packages provided in the public and private sectors. A question thus remains to be answered in regard to how many farmers and small businesses will take up the challenge of rebuilding. The themes that have prevented or promoted the full recovery of the food network have rarely been explored. The impacts on the rural communities who are made up of, and support, these farms and associated allied services is unknown. Data from this project can pinpoint the strengths and limitations of the current food system and recovery support services. This information will serve as the basis to propose targeted recommendations to improve current food production practice, as well as the scope of support for medium and long-term recovery. This is to help enhance the long-term resilience of the food system to promote local food sovereignty and contribute to international food security.

The project team will conduct surveys and experimental work to provide preliminary answers to the following research questions:

- How has the 2019-2020 Illawarra to Central Coast bushfires impacted primary producers' production and their desire and effort to remain in the industry?
- Can measurable changes in mineral deposition or pollutant residues of soil, irrigation water sources and resulting crops (e.g. lettuce) have potential impacts on the nutritional value of produce or consumer health?

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Can We Use Metabolomics to Identify Trees that are Resistant, Before Infection Occurs

Dr Michelle Moffitt: m.moffitt@westernsydney.edu.au

Supported by: Dr Jonathan Plett

Research area: Microbiology, Plant pathogens, Mass spectrometry, Metabolomics, Biodiversity

Australia is facing a significant biosecurity threat to Australian ecosystems and industries, caused by the parasitic fungus, Austropuccinia psidii (myrtle rust). Myrtle rust was first detected in Australia in 2010 and as a result, several plant species are under severe decline and may soon be extinct. Myrtle rust can infect many of our iconic plants belonging to the Myrtaceae, including eucalypts, tea trees and paperbarks. While some plants appear to be highly susceptible to the disease, others have innate resistance, although it is not clear why.

Research question: Can we use metabolomics to identify trees that are resistant, before infection occurs?

Students involved in this project will learn metabolomics and big data analysis to establish a set of metabolites that can be used as biomarkers for resistant plants. Students may assist in harvesting plant leaves, testing susceptibility of cuttings and metabolite extractions. This may include sample collections in the field and interactions with the NSW Department of Primary Industries. This project could be adapted to biology students with an interest in plant pathogens and biosecurity, or chemistry students with an interest in analytical chemistry and mass spectrometry.

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Imaging Large and Small Magellanic Cloud with the Penrith Observatory Telescope

Professor Miroslav Filipovic: m.filipovic@westernsydney.edu.au

Supported by: Dr Ain De Horta

Research area: Astronomy, Optical astronomy, Imagining

We propose to use our own Western Sydney University 60-cm optical telescope to survey two neighbouring galaxies - Large & Small Magellanic Cloud - with narrow band filters. After the imaging we will identify all known Supernova Remnants that exist in these galaxies and estimate their shock excitation states and velocities.

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ASKAP-EMU and Multi-frequency Study of Neighbouring Magellanic Clouds

Professor Miroslav Filipovic: m.filipovic@westernsydney.edu.au

Supported by: Dr Luke Barnes

Research area: Astrophysics, Cosmology, Radio astronomy, High energy physics

This is an exciting time for the study of nearby galaxies to our own Milky Way. These nearby external galaxies offer an ideal laboratory, since they are close enough to be resolved, yet located at relatively known distances. Various new generation surveys of both Clouds through the entire waveband reflect a major opportunity to study different objects and processes in the elemental enrichment of the interstellar medium. The study of this interaction in different domains including radio, optical and X-ray, allow a better understanding of intrinsic objects such as Supernova remnants (SNRs), Planetary Nebulae, HII regions, (Super)Bubbles and their environments. Namely, various new high resolution and sensitivity surveys of the Magellanic Clouds such as XMM-Newton & Chandra (X-rays), Herschel and Spitzer (IR), MCELS (optical) and ATCA/MOST (radio) provided solid base for the study of radio objects within and behind the MCs. To date, some 95 SNRs in the MCs are well established with other 20 waiting for confirmation. Similarly, over 50 PNe and hundreds of HII regions are identified. Also, we have detected over 8500 sources behind the Clouds - mainly AGN, radio galaxies and quasars. Finally, some comprehensive studies of these galaxies magnetic fields are also taken with the present generation of radio-continuum surveys.

The aim of the study is to discover, study new and to make the first complete sample of intrinsic sources to MCs (SNRs, PNe, HII regions, (Super)Bubbles).

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Young Stars in the Milky Way

Dr Nick Tothill: n.tothill@westernsydney.edu.au

Research area: Astrophysics, Cosmology, Radio astronomy, High energy physics

While there are many well-known and well-studied regions of star formation in the Milky Way, there are many more that have not been well studied, largely due to limits on telescope time. Many of these are in the southern hemisphere. With the advent of new surveys that cover most or all of the sky, it’s now quite easy to get the data to understand these regions. An example of this Simeis 188, which is near the much better-known Lagoon Nebula (M8). We wish to use the new generation of surveys such as GAIA and Skymapper to take a first look at this cluster of young stars and compare it to other, better-known clusters. In particular, we would like to assess whether it’s related to the bigger Lagoon Nebula - is it part of one giant star formation event? This project will particularly suit students with interests in modern data analysis techniques, mainly in python.

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Ionised Molecular Gas in the Milky Way

Dr Nick Tothill: n.tothill@westernsydney.edu.au

Research area: Astrophysics, Cosmology, Radio astronomy, High energy physics

Interstellar gas clouds include many simple molecules, and some of these are molecular ions (eg HCO+). This ionised molecular gas should trace the effect of ionisation by cosmic rays, the highly energetic particles that play a major role in the evolution of galaxies. We wish to find out how much of this molecular gas is found in multiple locations in the galaxy and compare that to some simple estimates of the amount of cosmic rays nearby. This comparison should give us some clues as to the effect of the cosmic rays on the molecular gas clouds, and therefore the evolution of the Milky Way. The molecular gas data for this project will come from published surveys such as MALT90, taken with the Mopra radio telescope near Coonabarabran. The cosmic ray data will come from the HESS Galactic Plane Survey. All of these data are publicly available. The project will suit a student with interests in data analysis (chiefly using python), astronomy and astrophysics, and the physics and chemistry of interstellar gas - some knowledge of molecular spectroscopy would be a benefit, but not required.

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Understanding Communication Between Microbes in the Biofilm Using a Metabolomics Approach

Dr Oliver Morton: o.morton@westernsydney.edu.au

Supported by: Dr Michelle Moffitt and Dr Colin Stack

Research area: Biofilm, Metabolomics, Drug resistance, Infection control, Photodynamic therapy

This project will focus on performing experiments to understand communication in microbial biofilms and investigate novel fungus-derived molecules as anti-biofilm agents. Biofilms are communities of microbes that form on surfaces and are a particular problem on medical devices leading to catheter-associated infections. Most research has focused on single organism biofilms but in this project the student will study polymicrobial biofilms formed from different species of bacteria or from combinations of bacteria and fungi. Biofilms are inherently more resistant to drugs than individual cells due to the structure of the biofilm slowing the access of drugs to the microbial community.

The main aims of the study are to understand communication between microbes in the biofilm using a metabolomics approach. We will also investigate the potential of compounds produced by fungal hyperparasites to disrupt polymicrobial biofilms at the structural or signalling level. There is also the scope for a project to examine the usefulness of photodynamic treatment on the disruption of biofilms.

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Testing Anti-fungal Resistance as an Important Factor in Fungal Virulence

Dr Oliver Morton: o.morton@westernsydney.edu.au

Research area: Host-pathogen interactions, Microbial pathogenesis, Antimicrobial treatment, Invertebrates

The research in the laboratory of Dr Morton has been focussed on understanding how pathogenic fungi cause disease but we have an increasing interest in bacterial pathogens. Many of the most important fungal pathogens are opportunist infectious agents that exhibit a genetic capacity to adapt to a variety of environments, which directly influences their ability to cause infection in man. This research uses interaction studies between fungal pathogens and invertebrate host (meal worm) models to determine the factors necessary for the establishment of infection and evasion of the immune system.

Research in the group has identified polymorphisms in genes that may contribute to Aspergillus fumigatus virulence. A student project would focus on testing anti-fungal resistance as an important factor in fungal virulence by testing clinical isolates of the fungus in meal worms given antifungal prophylaxis.

Projects in microbial virulence or novel antimicrobials will also be considered. Students will have the opportunity to become proficient in a range of skills from culture and handling of PC2 microbes, microscopy, virulence assays, to molecular biology.

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Identifying the Molecular Mechanisms Responsible for Abnormal Responses to Injury

Associate Professor Peter Shortland: p.shortland@westernsydney.edu.au

Supported by: Dr David Mahns, Professor Janice Aldrich-Wright and Zoran Pletikosa

Research area: Pain, Plasticity, Histology, Behaviour, Neurodegenerative diseases

Current research focusses on mechanisms involved in acute and chronic pain, using various preclinical models of conditions such as nerve injury and repair, chemotherapy-induced peripheral neuropathy, multiple sclerosis, motoneuron disease, and spinal root avulsion injury. Emphasis is on alterations in somatosensory processing in dorsal root ganglion neurons and the spinal cord using animal models, which show symptoms similar to that seen in humans. The emphasis is on investigating mechanisms that contribute to synaptic rearrangements, phenotypic plasticity, glial and vascular responses, neuronal survival mechanisms that contribute to the pathobiology of these conditions. The ultimate aim is to be able to identify the molecular mechanisms/factors that are responsible for the abnormal responses to injury, to reduce/alleviate the associated neuropathic pain and to try to restore normal function after such injuries using growth factor or other pharmacological agents alone or in combination with surgical strategies. These basic science findings may then translate into clinical settings via collaborations with hospital clinical researchers.

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Radio Stars in ASKAP Radio Surveys

Professor Miroslav Filipovic: m.filipovic@westernsydney.edu.au

Supported by: Professor Ray Norris

Research area: Astrophysics, Radio astronomy, High energy physics, Milky Way

The aim is to discover an estimated 100 new radio stars in our ASKAP (Australia SKA Pathfinder) pilot surveys. In 2020, several radio continuum fields of the ASKAP-EMU survey are completed. We propose that in this project, the student will search for the new radio stars by comparing our new radio images with existing star catalogues in optical, IR and X-ray bands. The work required for this project includes positional correlations and estimates of the number of random positional associations between the optical and radio surveys of the whole sky. All three catalogues, GAI, the eROSITA and ASKAP are available for download. In addition, we could include other radio catalogues such as the SUMSS and NVSS. Another possibility is to include any ATCA moderately large area mosaics with a list of sources. The above project can also be used with WISE, 2MASS & SDSS catalogues which could provide proper motions and therefore can be included.

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Dark Matter in the Halo of Magellanic Clouds

Professor Miroslav Filipovic: m.filipovic@westernsydney.edu.au

Supported by: Dr Luke Barnes

Research area: Astrophysics, Cosmology, Radio astronomy, High energy physics

In the currently most investigated particle dark matter (DM) scenario, the DM is in form of WIMPs. Their annihilations and decays are expected to inject electrons and positrons, which in turn act as source of synchrotron radiation. We aim at constraining the WIMP parameter space by searching for diffuse radio emissions in structures of the Local Universe (such as dwarf spheroidal galaxies, clusters and edge-on spiral galaxies), present in the fields of early science observations. Targets are selected according to the current knowledge on their DM distribution and magnetic field. The main results of the project will consist of bounds on the mass and annihilation/decay rate of WIMPs. AIM: In synergy with EMU-ASKAP to test the presence of a diffuse synchrotron radiation induced by particle dark matter in the halo of Magellanic Clouds (MCs) and to constrain the parameter space of weakly interacting massive particles (WIMPs) Dark Matter (DM). We also expect to improve our understanding about cosmic-ray electrons (and their diffusive transport) in dwarf spheroidal and spiral galaxies.

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Are Supermassive Black Holes Lined Up Over Cosmic Distances?

Professor Ray Norris: r.norris@westernsydney.edu.au

Supported by: Professor Miroslav Filipovic

Research area: Machine learning, Artificial intelligence, Astronomy, Black holes, Galaxies

If you look up at the nighttime sky with your eyes, you see stars. If you look up with a radio telescope, the sky is dominated by pairs of blobs of radio emission, caused by jets of electrons streaming out from supermassive black holes, close to the speed of light. We expect these jets to be pointing in a random direction in the sky.

However, some researchers have recently claimed that they tend to be lined up, so black holes a few million light years apart tend to be pointing in the same direction. This is an unexpected and controversial result. If true, it probably means that supermassive black holes were formed from the same gas cloud soon after the Big Bang.

In this project, you will test this claim by analysing data from CSIRO's new Australia Square Kilometer Array Pathfinder telescope in two parts of the sky - one around the Large Magellanic Cloud, and one in an area of sky known as the GAMA fields. The project involves identifying the jets in the radio images, and then testing whether they are aligned. If the project is successful, you will be invited to participate in the writing of a paper for an international journal.

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Predicting Change in Australia's Environmental Microbiomes

Dr Thomas Jeffries: t.jeffries@westernsydney.edu.au

Research area: Metagenomics, Microbial ecology, Microbiomes, Biogeography, Statistics

Recently, continent-scale molecular surveys of Australia's soil and marine environments have provided a 'treasure-trove' of data on the abundance of individual microorganisms in the context of variation in their environments. By modelling the distribution of these organisms and identifying key-environmental variables that drive these patterns, we can predict how future changes in climate and aridity will influence microbial biodiversity. As microbes underpin nutrient-cycling and productivity in these habitats, and are sentinels of ecosystem change, this project will have implications for environmental management.

The project will be computational and involve mining large 16S rDNA datasets using multivariate statistics and applying data to distributional models linking microbial composition to the environment. It would suit a candidate with an interest in microbial ecology and some knowledge of statistics, data-management and computational biology. There will be opportunity for collaboration with other researchers in the Australian Microbiome Project.

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Investigation of Micro-organisms Inhabiting Sediment Ponds at the Captains Flat Mine Site

Dr Thomas Jeffries: t.jeffries@westernsydney.edu.au

Supported by: Dr Val Spikmans

Research area: Metagenomics, Environmental microbiology, Microbiomes, Aquatic contamination, Ecotoxicology, DNA sequencing

This project will use molecular microbiology techniques to investigate the microbial community associated with tailings dams and waterways at the Captains Flat mine-site, ACT. For almost a century, the site has been a source of contaminants to the adjacent Molonglo River, as the result of erosion from the exposed waste dumps and through seepages or springs from which leachate from the mine site enters directly into the River. The tailings dams are highly acidic and metal-laden, yet flourishing with microorganisms. This project will seek to profile this microbiome in the context of toxin levels and with the long-term aim of remediating the site.

The candidate working on this project will have the opportunity to conduct field sampling at the site, extract metagenomic DNA, conduct Next-Generation sequencing of the 16S rDNA gene and the associated bioinfomatic analysis. Samples will also undergo chemical testing and profiling to provide contextual data.

This project would suit a student interested in environmental microbiology, bioremediation and environmental forensics with a strong background in molecular laboratory techniques and/or analytical chemistry skills. The student should have a willingness to learn computational bioinformatics techniques and some statistics.

This project is in collaboration with the NSW Department of Planning, Industry and Environment and thus provides industry relevant experience.

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SUITABLE FOR MASTER OF RESEARCH / PHD

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Multi-frequency Study of Neighbouring Magellanic Clouds

Professor Miroslav Filipovic: m.filipovic@westernsydney.edu.au

Supported by: Dr Luke Barnes and Dr Nick Tothill

Research area: Astronomy

This is an exciting time for the study of nearby galaxies to our own Milky Way. These nearby external galaxies offer an ideal laboratory, since they are close enough to be resolved, yet located at relatively known distances. Various new generation surveys of both Clouds through the entire waveband reflect a major opportunity to study different objects and processes in the elemental enrichment of the interstellar medium. The study of this interaction in different domains including radio, optical and X-ray, allow a better understanding of intrinsic objects such as Supernova remnants (SNRs), Planetary Nebulae, HII regions, (Super)Bubbles and their environments. Namely, various new high resolution and sensitivity surveys of the Magellanic Clouds such as XMM-Newton & Chandra (X-rays), Herschel and Spitzer (IR), MCELS (optical) and ATCA/MOST (radio) provided solid base for the study of radio objects within and behind the MCs. To date, some 95 SNRs in the MCs are well established with other 20 waiting for confirmation. Similarly, over 50 PNe and hundreds of HII regions are identified. Also, we have detected over 8500 sources behind the Clouds -- mainly AGN, radio galaxies and quasars. Finally, some comprehensive studies of these galaxies magnetic fields are also taken with the present generation of radio-continuum surveys. AIM: To discover, study new and to make the first complete sample of intrinsic sources to MCs (SNRs, PNe, HII regions, (Super)Bubbles).

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Milky Way Spiral Arms and Mass Extinctions

Professor Miroslav Filipovic: m.filipovic@westernsydney.edu.au

Supported by: Dr Luke Barnes

Research area: Astronomy

The Student will use the most up-to-date Milky Way model and solar orbit data in order to test the hypothesis that the Sun's galactic spiral arm crossings cause mass extinction events on Earth. To do this, we will create a new model of the Milky Way's spiral arms by combining a large quantity of data from several different surveys. We intend to combine this model with an elsewhere derived solution for the solar orbit to determine the timing of the Sun's historical passages through the Galaxy's spiral arms. We intend to design a new model with a symmetrical appearance, with the major alteration being the addition of a spur at the far side of the Galaxy. Furthermore, we will identify all known historical mass extinction events that might be explained by the motion of the Sun around our Galaxy.

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Saving our Soils: Carbon Sinks and Closed Loops

Dr Jason Reynolds: j.reynolds@westernsydney.edu.au

Research area: Soil science

The urbanisation of western Sydney presents challenges to how communities will source food and interact with the environment on catchment-level scales. With climate modelling indicating a warmer and drier western Sydney region, the application of organic materials to land areas may be of benefit to blue and green landscape management, agriculture, and horticulture.

This research entails field and lab-based investigations of organic materials and soil interactions to ensure future land management is appropriate for maximising nutrient capture in soil and minimising losses due to leaching, runoff and greenhouse gases.

Whilst based within the soil sciences, you will have opportunity to specialise in your area of interest. This project will generate impact through benefits to landscape productivity and resource sustainability within the western Parkland City.

This is your opportunity to contribute to how a rapidly developing western Sydney shapes itself through the inclusion of green and green grids. You will be working with leading organisations to close loops, utilise resources more efficiently, and protect our soils for future generations.

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Saving Australia's Native Plants from an Invasive Fungal Parasite using Metabolomics

Dr Michelle Moffitt: m.moffitt@westernsydney.edu.au

Supported by: Dr Jonathan Plett

Research area: Plant microbe interactions and metabolomics

Australia is facing a significant biosecurity threat to Australian ecosystems and industries, caused by the parasitic fungus, Austropuccinia psidii (myrtle rust). Myrtle rust was first detected in Australia in 2010 and as a result, several plant species are under severe decline and may soon be extinct. Myrtle rust can infect many of our iconic plants belonging to the Myrtaceae, including eucalypts, tea trees and paperbarks. While some plants appear to be highly susceptible to the disease, others have innate resistance, although it is not clear why.

Research question: Can we use metabolomics to identify trees that are resistant, before infection occurs?

Methods: Students involved in this project will learn metabolomics and big data analysis to establish a set of metabolites that can be used as biomarkers for resistant plants. Students may assist in harvesting plant leaves, testing susceptibility of cuttings and metabolite extractions. This may include sample collections in the field and interactions with the NSW Department of Primary Industries. This project could be adapted to biology students with an interest in plant pathogens and biosecurity, or chemistry students with an interest in analytical chemistry and mass spectrometry.

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Inhibiting the Reproductive Cycle of SARS-CoV-2 Virus by Binding of Novel Drugs

Dr Roland Gamsjaeger: r.gamsjaeger@westernsydney.edu.au

Supported by: Associate Professor Liza Cubeddu

Research area: Biochemistry, SARS-CoV-2, Coronavirus, COVID-19

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a novel highly infectious RNA virus that belongs to the coronavirus family. The World Health

Organization has declared the ongoing outbreak to be a global public health emergency. Replication of the viral genome is a fundamental step in the virus life cycle and the protein, Non-structural protein 9 (Nsp9), was found to be essential for virus replication through its ability to bind RNA. Homologs of the Nsp9 protein have been identified in numerous coronaviruses including SARS-CoV-1 (Nsp9SARS), human coronavirus 229E (Nsp9HcoV), avian infectious bronchitis virus (Nsp9IBV), and porcine epidemic diarrhoea virus (Nsp9PEDV). Three-dimensional structures of Nsp9 proteins from these viruses have been determined, revealing similarities to single-stranded DNA binding proteins from humans. Interestingly, despite the major role that Nsp9 plays in viral replication, its binding to RNA is very weak.

In this project, we are working towards determining the molecular details of Nsp9 involvement in viral replication with the long-term aim of developing drugs that specifically inhibit Nsp9 and thus combat SARS-CoV-2. To achieve this, we use a combination of biophysical and structural methods such as Biolayer Interferometry (BLI) and Nuclear Magnetic Resonance (NMR) spectroscopy.

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Simulating the Effect of Radiation Damping on WaterControl NMR Experiments

Dr Gang Zheng: g.zheng@westernsydney.edu.au

Research area: Physical chemistry, Differential equations, Numerical simulation, NMR spectroscopy

Just like a solar filter is needed for your camera to capture the silhouette of the moon during a solar eclipse, a specially designed "water signal filter" is indispensable for the observation of the weak biomolecular NMR signals which would otherwise be significantly masked by the intense water signal. The WaterControl NMR filter is the first of its kind that affords quantitative water signal filtering, but its implementation on high field (> 800 MHz) NMR spectrometers is hampered by the undesirable strong interaction between water signal and RF coil (i.e. radiation damping).

To address this problem, the student will be simulating WaterControl experiments using the modified Bloch equations including radiation damping terms and thus providing insights into the effect of radiation damping on water signal filtering in general. Modifications will be made to the current version of WaterControl technique based on the simulation results so that it can be readily applied to biomolecular structural elucidations that necessitate the application of a high magnetic field (> 800 MHz).

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Metabolomic Study of Dealcoholised Wines

Dr Gang Zheng: g.zheng@westernsydney.edu.au

Supported by: Dr Rosalie Durham

Research area: Analytical chemistry

Drinking habits of Australians are changing. Reducing alcohol consumption has become a trend due to growing awareness of diet, fitness and health conditions brought about or affected by alcohol consumption. Just like their alcoholic counterparts, dealcoholised wines provide the sophisticated flavour with food and choices that complement a celebration or occasion. Growing consumption of dealcoholised wines pushes for a detailed metabolic profiling of these products so that their organoleptic characteristics (i.e. taste, aroma, mouth feel, appearance, bouquet) can be well linked with their chemical profiles, which will, in turn, inform the manufacturing process that may include fermentation, dealcoholisation, reconstitution and/or blending.

In this study, the student will be performing a metabolic analysis of dealcoholised wines using 13C NMR, chemical exchange saturation transfer analysis, and head-space NMR. The obtained NMR data will be further analysed using unsupervised machine learning models (e.g. PCA, K-means clustering, and self-organising maps) to identify the hidden patterns or intrinsic structures in the NMR data. Professional wine tasting service will be utilised to obtain the organoleptic characteristics of all the samples, which will be correlated with their chemical profiles using supervised machine models (e.g. PLS and support vector machines).

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Proton Exchange Based Molecular Imaging by MRI

Dr Gang Zheng: g.zheng@westernsydney.edu.au

Supported by: Dr Tim Stait-Gardner and Professor William S. Price

Research area: Physical chemistry, Chemical kinetics, MRI contrast, Proton exchange

In general chemistry, we have learned that acidic protons are constantly hopping between solute molecules and water molecules. The efficiency of this hopping process is affected by many factors and one of these factors, pH, is directly linked to the disease state of biological tissues (e.g., metastasis of cancer), which means we can achieve medical diagnosis by measuring the micro-environmental acidity in diseased tissues.

In this project, the student will study the basics of chemical kinetics, nuclear magnetic resonance (NMR), and experimental magnetic resonance imaging (MRI). From this background, the student will then develop novel chemical exchange saturation transfer (CEST) techniques for the study of proton exchange in solutions and tissues, focusing on the observation and quantification of the CEST peaks close to the water signal of diagnostically important metabolites such as myo-inositol and glucose in the NMR spectrum. If the newly developed techniques afford the distinction between metabolite and water signals in the water-proximate region in the experiments on phantom samples, they will be applied in animal experiments in the School of Medicine, Johns Hopkins University.

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Metallo-supramolecular Materials (including Nano Materials): Molecular Recognition, Catalysis, Optical and/or Magnetic Properties

Dr Feng Li: feng.li@westernsydney.edu.au

Research area: Metallo-supramolecular chemistry, materials, Chemosensor, Molecular magnet, Nano-Switches and Memory devices

The application of nanotechnology in nanomaterials for supramolecular systems has been a vigorous, fast-growing and fascinating area of current research with inorganic, organic, and biological processes and in environment. It is a highly interdisciplinary field with wide-ranging collaborations between chemists, physicists, biochemists, biologists, environmental scientists, engineers, theoreticians, mathematicians and others. Because the structure and properties of nanomaterials differ significantly from those of atoms and molecules as well as those of bulk materials, the synthesis of functional nanomaterials and new assembled nanostructures has been characterized by explosive growth derived in part from their use as models for metal-proteins in a substantial number of metalloproteins, their use as synthetic ionophores, the study of their associated magnetic exchange phenomena, their use as therapeutic reagents in chelation therapy, their application as antibiotics that owe their antibiotic action to specific metal coordination and, more generally, as hosts for specific guests.

This project is focused on three significant issues in the area of nanomaterials in supramolecular systems: 1) the use of designed metal-ion directed assembly for constructing new nanometer-scale supramolecular entities and the investigation of host-guest inclusion behaviour in metallo-supramolecular systems; 2) the construction of organic metal hosts for gas or/and solvent absorption in metallo-supramolecular systems; 3) the exploration of optical and dielectric properties of spin-crossover (SCO) materials and the development of memory effects and switching in SCO systems.

The objectives of the project are as follows:

- To employ metal-directed assembly procedures to generate a range of metallo-supramolecular derivatives in which perturbations of topologies are induced by variation of guest species;
- To probe relationships between structure and function by variation of the steric nature of ligand type, the associated metal ions and guests.
- To observe and study the host-guest association in metallo-supramolecular materials and develop devices for sensing molecular and ionic species, leading to molecular recognition, gas absorption and catalysis in practical applications.
- To construct metallo-supramolecular materials by the linking of SCO centres and to investigate their optical and dielectric properties, leading to nano-chemical switches and memory devices in practical application.

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Metallo-supramolecular Materials in Biological Applications: DNA Binding, Drug Delivery and MRI Contrast Agent

Dr Feng Li: feng.li@westernsydney.edu.au

Research area: Metallo-supramolecular chemistry, Spin-switch materials, DNA binding, MRI contrast agents, Drug delivery system

The aim of this proposal is to design and synthesise several new classes of discrete spin transition metallo-supramolecular nanomaterials for applications in biology and medicine including DNA binding, magnetic resonance imaging (MRI) and drug delivery. There is wide opportunity to explore, for the first time, DNA binding for cellular targeting using spin-crossover (SCO) assemblies and to develop an innovative approach for probing DNA binding using such metallo-supramolecular materials that undergo motional or mechanical changes triggered by fine tuning the spin state of the switching sites. At the applied level, spin transition metallo-supramolecular assemblies are expected to spur the development of a new class of tumour-selective drugs and spin-activated MRI contrast agents that involve switching between paramagnetic and diamagnetic states. In addition, metallo-supramolecular assemblies exhibiting three-dimensional cage-like architectures with mesoporosity will be designed as drug carriers to deliver a drug to a desired location and then release it by mechanically opening the door of the carrier in a spin-controlled manner.

The specific objectives are as follows:

1) Nanoscale discrete spin-switch metallo-supramolecular assemblies

- To employ directed assembly procedures, hierarchical or stepwise syntheses and template controls for constructing innovative finite nanometre-scale spin-switch assemblies;
- To observe and study spin-switching behaviours by variation of both the steric nature of the ligand type employed and the applied external stimulus (e.g., temperature and light) as well as to explore the structural and electronic features that impart electronic communication in such SCO systems;
- To integrate such materials that show an abrupt spin transition near the body temperature into practical applications involving DNA interaction, MRI and drug delivery.

2) DNA interaction

- To investigate DNA recognition by variation of both the steric nature of the ligand type and the external stimulus (e.g., temperature and light);

- To determine how the selectivity of DNA binding can be fine-tuned using geometric modification of the metallo-intercalators associated with the spin transition process;
- To develop new SCO-based DNA probes as therapeutic agents which can recognize and cleave DNA, in particular metal-based DNA-binding drugs which target abnormal cells (e.g., cancerous cells) in the presence of normal cells, and investigate DNA-mediators of electronic communication.

3) Spin-activated MRI contrast agents

- To develop new spin-activated chemical exchange saturation transfer (CEST) agents that can switch between paramagnetic and diamagnetic states by variation of an external stimulus (e.g., temperature and light) and to integrate traditional Gd3+-based MRI contrast agents into SCO assemblies to produce multifunctional contrast agents;
- To explore the variation of the image intensity achieved by both spin-activated MRI contrast agents and multifunctional contrast agents under the same conditions by just tuning the external stimulus and observing the relationship between Gd3+-based and spin-activated sites of multifunctional contrast agents;
- To exploit iron(II)-based CEST contrast agents using MRI techniques in living specimens and achieve new classes of MRI contrast agents for eventual use in clinical applications.

4) Drug delivery

- To explore the potential of new delivery systems based on spin transition coordination cages which incorporate readily variable functional groups (e.g., unsaturated metal sites to increase loading capacity) and tuneable pores sizes.
- To investigate drug release processes involving motional changes triggered by tuning of the spin state of the switching sites leading to control release mechanisms.
- To develop new classes of optimal drug-delivery materials involving multifunctional components.

In summary, while the focus of this project is on the design of metallo-supramolecular materials and evaluation of their molecular recognition properties and molecular imaging involving spin transition behaviour, as outlined above it is anticipated that the materials produced will have potential applications in DNA binding, drug delivery and MRI contrast agents.

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Determining the Outcomes of Host-pathogen Interactions

Dr Oliver Morton: o.morton@westernsydney.edu.au

Supported by: Dr Michelle Moffitt and Dr Colin Stack

Research area: Microbial pathogenesis

The Microbiology Group has been focussed on understanding how eukaryotic microbial pathogens cause disease but we have an increasing interest in bacterial pathogens. Many of the most important pathogens are opportunist infectious agents that exhibit a genetic capacity to adapt to a variety of environments, which directly influences their ability to cause infection in host organisms such as animals or plants.

This research uses interaction studies between pathogens and host (e.g. fungal pathogens with human epithelial cells) models to determine the factors necessary for the establishment of infection and evasion of the immune system.

Projects in microbial virulence or novel antimicrobials will also be considered. We would like to develop project ideas in collaboration with prospective students.

Students will have the opportunity to become proficient in a range of skills from culture and handling of PC2 microbes, microscopy, virulence assays, to molecular biology.

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Microbial Biofilms, Examining the Complex Relationships Between Microbes

Dr Oliver Morton: o.morton@westernsydney.edu.au

Supported by: Dr Michelle Moffitt and Dr Colin Stack

Research area: Microbiology

This project will focus on performing experiments to understand communication in microbial biofilms and investigate novel fungus-derived molecules as anti-biofilm agents. Biofilms are communities of microbes that form on surfaces and are a particular problem on medical devices leading to catheter-associated infections.

Most research has focused on single organism biofilms but in this project the student will study polymicrobial biofilms formed from different species of bacteria or from combinations of bacteria and fungi. Biofilms are inherently more resistant to drugs than individual cells due to the structure of the biofilm slowing the access of drugs to the microbial community.

The main aims of the study are to understand communication between microbes in the biofilm using a metabolomics approach. We will also investigate the potential of compounds produced by fungal hyperparasites to disrupt polymicrobial biofilms at the structural or signalling level. There is also the scope for a project to examine the usefulness of photodynamic treatment on the disruption of biofilms.

We would like to develop project ideas in collaboration with prospective students.

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Development of a Mass Spectrometry-based Method for the Early Detection of Atherosclerosis

Dr David Harman: d.harman@westernsydney.edu.au

Supported by: Associate Professor Anand Hardikar and Dr Aiden O'Loughlin

Research area: Medical diagnostics

Atherosclerosis, the obstruction of arteries caused by the accumulation of fatty plaque deposits, is the single largest cause of human death worldwide. Despite the serious disease burden presented by this condition, medicine still lacks a simple, cheap, non-invasive test permitting its detection well before symptoms are observed. At present, diagnosis often relies upon angiography, a technique which is expensive, time consuming and imparts a significant radioactivity load to the patient.

Furthermore, existing technologies only enable detection of the disease in its more advanced stages. In contrast, the development of a new and more sensitive test would enable atherosclerosis to be detected in its early stages, thus providing an opportunity for prevention of acute coronary events, including heart attack. A class of biomarkers which potentially exhibit high specificity for predicting future atherosclerosis have been identified. Micro ribonucleic acids (miRNAs) are short, non-coding RNA molecules containing approximately 20 nucleotides, their function thought to be mainly gene regulation.

A liquid chromatography/mass spectrometry method to detect and quantify miRNAs has recently been developed, and this method will be applied to this project. The junior researcher undertaking this PhD project will aim to achieve several things: 1) transform raw LC-MS/MS data into a format which allows database searching of miRNA identities; 2) extract spiked miRNAs from human blood and confirm identities via database searching; 3) analyse blood samples from human subjects without or with atherosclerosis using the methods developed and validate these results using gold standard qPCR-based detection methodologies. 20 samples each for disease and control will be used.; and 4) use machine learning workflows to identify the most reliable miRNA biomarkers for atherosclerosis. During the project the junior researcher will be trained to use state of the art analytical instrumentation, work with bioinformatics software, and develop lab skills in the extraction of miRNAs from blood (plasma-EDTA preferred) samples.

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Noisy Neighbours: Do Native Birds Call Less When Invasive Birds Are Calling?

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Supported by: Associate Professor Anand Hardikar and Dr Aiden O'Loughlin

Research area: Animal behaviour, Invasive species, Animal communication

Biological invasions are one of the greatest threats to biodiversity on the planet. A large amount of research has targeted influences of invasive species on native species, and such studies have shown that invaders can modify habitats, or consume, compete with, hybridise with or spread disease or parasites to native species. Recently, the vocalisations of invasive species have been identified as potentially harmful to native species, as they can elicit changes in functionally important vocal behaviour. We know that novel noises, in particular anthropogenic noise (such as industry or traffic noise) can affect various animal behaviours, and changes to vocal behaviour are some of the most documented. The calls of invasive species are an important source of novel noise, yet their effects on native species are poorly understood. To date, few studies have examined the responses of native species exposed to the vocalisations of invasive species, therefore the response of native species to the introduction of these noises to their habitats is relatively unknown.

This project will examine the effects of invasive song birds on the vocal activity of native Australian birds to investigate whether: 1) native bird calling behaviour is affected by invasive bird calls, and 2) if the calls of the native species overlap in frequency with those of invasive birds. Using Automated Recording Units (ARU), vocalizations of native and invoice species will be recorded during the breeding season. Additionally, the student can conduct a playback experiment, presenting native birds with recordings of invasive species, a synthetic 'pink' noise, and a silent control with the aim to determine if and how the calling behaviours of native birds are affected by the invasive species.

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Optimising NMR Diffusion Measurements

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Supported by: Dr Tim Stait-Gardner and Dr Allan Torres

Research area: Chemical reactions, Diffusion, MRI, NMR

Diffusion NMR is routinely used to study various molecular properties, and interactions occurring in solution. It is also increasingly important in clinical medicine where it is used in MRI to probe microscopic structures in biological tissues (e.g., cancer versus normal tissue).

The utility and power of Diffusion NMR is increased as the experiment becomes more accurate and the ability to measure more quickly allows time-sensitive systems to be studied.

In this project two approaches will be investigated: (i) the development of an adaptive acquisition protocol to greatly shorten the total acquisition time and (ii) a comprehensive investigation of the use of slice selection in NMR diffusion sequences.

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A Cancer Biomarker Discovery and Translation Pipeline from High-field MRI

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Supported by: Dr Tim Stait-Gardner and Dr Trang Pham

Research area: Health, MRI

Around 150,000 new cancer cases occur per year in Australia and radiotherapy is the treatment of choice for roughly half. Tumours are biologically heterogeneous and dynamic in nature with the microenvironment characterised by temporal and spatial variations in vasculature, oxygenation, cellularity and metabolism, and these factors can influence radio-sensitivity, and are a major cause of cancer recurrence.

MRI offers a range of functional techniques, many unexplored in cancer, that can assess tumour heterogeneity (e.g., cellularity, hypoxia, metabolism), and predict treatment response. Ultra- high field strength MRI has microscopic resolutions and can be directly correlated with histopathology for 'ground-truth', allowing for exploration and evaluation of untapped MRI biomarkers of cancer biologic heterogeneity and radiotherapy response. Diffusion MRI (including diffusion tensor imaging) is a specialised functional technique that can characterise tumour cellularity and organisation. Chemical Exchange Saturation Transfer (CEST) MRI can characterise cancer proteins and metabolism. Ultra-high field MRI provides images with microscopic resolution permitting visualisation of tissue details approaching that of histopathology.

The aim of this project is to create a biomarker discovery and translation pipeline from ultra-high field MRI to clinical MRI to target the heterogeneity of tumours and improve cancer control. The ability to think quantitatively is important as part of this project will involve the co-registration of high-field and low-field MRI datasets and histopathology and the development of new techniques to do this accurately for ex-vivo specimens. This project would suit students with backgrounds in mathematics, chemistry, physics and medical science.

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Magnetic Resonance Imaging of Plants

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Supported by: Dr Tim Stait-Gardner

Research area: Horticulture

Magnetic Resonance Imaging (MRI) is a non-invasive versatile imaging modality capable of providing many forms of contrast from simple proton weighted images to images quantifying diffusion and flow. The most familiar application of this technology is used in radiology for medical imaging. However, MRI can also be applied to animals, plants, insects and some materials too.

The focus of this project will be the application of MRI to living plants. In particular, the development of techniques to image plant roots and observe seed germination. There are a number of challenges involved due to the paramagnetic substances present in soil that will have deleterious effects on the MR signal and resulting image quality. A substantial portion of the project will be to investigate soil and soil alternatives for use with MRI, experimental setup for supplying the necessary nutrients and light during imaging, as well as the exploration of techniques for applying MRI that minimise distortions. The project is suitable for students with backgrounds in mathematics, chemistry and biology.

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Investigating Azeotropic Mixtures with NMR Diffusometry and Relaxomtery

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Supported by: Dr Allan Torres and Dr Abhishek Gupta

Research area: Magnetic resonance and azeotropes

Inhomogeneities at the microscopic level in liquids are often related to the observed anomalous physical properties. A good example of this is the unusual distillation properties of azeotropes. An azeotrope is a mixture comprising of two or more liquids in a ratio such that its composition cannot be changed by simple distillation. This results from the vapour of a boiled azeotropic solution having an identical ratio of the substituents to that of the original liquid mixture. But azeotropic behaviour is of importance in other fields too including waste disposal and environmental chemistry. Investigations into azeotropic properties, especially at the azeotropic point, have been limited due to lack of methods and the inability to separate the components using ordinary fractional distillation methods. NMR based measurements of the molecular diffusion and relaxation of the sample components and other NMR spectroscopic techniques are likely to provide deep insight into the molecular-level basis of the azeotropic properties. In this project pulsed gradient spin-echo (PGSE) diffusion and field-cycling relaxometric measurements and NMR spectroscopy will be used to study a range of azeotropic systems to try and elucidate the molecular level interactions that results in azeotropic behaviour.

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Harnessing the Power of Defensive Microbes and Discovering New Antibiotic Drugs for Medicine or Fungicides for Agriculture

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Research area: Microbiology

Can we harness the power of defensive microbes to combat human disease or plant pathogens? In the unseen world of microbiology, bacteria, fungi and viruses are waging war against each other. Many use small chemical compounds as their weapons, while others compete for nutrient resources or cause parasitism. The first antibiotic drug, penicillin, was discovered from a fungus and many more of the antibiotic drugs that we use today were derived from compounds produced by microbes.

Defensive microbes live symbiotically with humans and plants, working with the host to help protect it from pathogens. Our research is to isolate and characterise novel chemical compounds produced by defensive microbes and harness them in the fight against antibiotic resistant human diseases or plant pathogens.

We have a group of fungal strains that are defensive microbes. They were discovered for their ability to parasitise or inhibit the growth of the plant parasite, rust. We are using a combination of fungal genome sequence analysis (bioinformatics), culturing techniques, mass spectrometry and assays to identify new compounds with antibacterial or antifungal activity.

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Proton Exchange Based Molecular Imaging by MRI

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Supported by: Dr Tim Stait-Gardner and Professor William S Price

Research area: Chemistry, Health, MRI

In general chemistry, we have learned that acidic protons are constantly hopping between solute molecules and water molecules. The efficiency of this hopping process is affected by many factors and one of these factors, pH, is directly linked to the disease state of biological tissues (e.g., metastasis of cancer), which means we can achieve medical diagnosis by measuring the micro-environmental acidity in diseased tissues.

In this project, the student will study the basics of chemical kinetics, nuclear magnetic resonance (NMR), and experimental magnetic resonance imaging (MRI). From this background, the student will then develop novel chemical exchange saturation transfer (CEST) techniques for the study of proton exchange in solutions and tissues, focusing on the observation and quantification of the CEST peaks close to the water signal of diagnostically important metabolites such as myo-inositol and glucose in the NMR spectrum. If the newly developed techniques afford the distinction between metabolite and water signals in the water-proximate region in the experiments on phantom samples, they will be applied in animal experiments in the School of Medicine, Johns Hopkins University.

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