AIBN Master Projects | Dr Amanda W. Kijas

https://aibn.uq.edu.au/profile/3353/amanda-kijas

Get creative, make your own synthetic collagen III

Lead Investigator: Dr Amanda W. Kijas (a.kijas@uq.edu.au)

Collagen is the most abundant protein in our bodies, contributing to the rich diversity of extracellular matrix proteins. The extracellular matrix assists in providing an interconnected network contributing to both the biochemical and biophysical cues to bring about biological responses in cells/tissues. In the initial stages of wound healing collagen III plays a key role in guiding the initial stages of repair. Here we will employ a defined synthetic collagen III to study how this form of collagen assists to guide these early cellular responses of key skin cell types employing 3D live imaging models.

This project will involve growth of various skin cell types, working with 3D culture systems, live confocal imaging, wound healing assays, gene expression, immunostaining and simple chemistry to functionalise biomaterials.

Collagen the founding matrix of our bodies but cellular production is not as simple as we might think.

Lead Investigator: Dr Amanda W. Kijas (a.kijas@uq.edu.au)

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This project will involve growth of various skin cell types, working with 3D culture systems, live confocal imaging, wound healing assays, gene expression, immunostaining and simple chemistry to functionalise biomaterials.

Guiding wound healing through biophysical control

Lead Investigator: Dr Amanda W. Kijas (a.kijas@uq.edu.au)

Wound healing is a dynamic process requiring a coordinated response to repair the damage. The extracellular matrix assists in providing an interconnected network contributing to both the biochemical and biophysical cues to bring about biological responses in cells/tissues. We have defined natural biomaterials to establish 3D cell model systems to study these activities using live confocal microscopy to investigate the role of matrix signalling.

This project will involve growth of various skin cell types, working with 3D culture systems, live confocal imaging, wound healing assays, gene expression and immunostaining.

AIBN Master Projects | Dr Amanda W. Kijas

https://aibn.uq.edu.au/profile/3353/amanda-kijas

Osteocytes the master regulator of bone formation

Lead Investigator: Dr Amanda W. Kijas (a.kijas@uq.edu.au)

The cells of the bone are uniquely isolated from other tissues in our body contained within the hard, impermeable hydroxyapatite matrix. Where osteocytes, the master regulators of bone turnover are the longest living of the bone cells and are individually buried in small hydroxyapatite chambers. Employing a unique live 3D model system this project will investigate how the extracellular matrix properties of osteocytes can alter their signalling to the other bone cells, controlling the constant and ongoing turnover of bone to maintain its integrity and health.

This project will involve osteocyte cell growth and differentiation, working with 3D culture systems, live confocal imaging, gene expression, immunostaining and simple chemistry to functionalise biomaterials.

Bone cell extracellular vesicles, natures ultimate nanoparticles driving cell signalling

Lead Investigator: Dr Amanda W. Kijas (a.kijas@uq.edu.au)

Extracellular vesicles are nature's way of packaging up precious cargo and delivering it to the intended target site to bring about specific biological responses. Bone cells are known to produce a myriad of signalling molecules to communicate with other bone cells and to communicate with distant tissues through systemic delivery. We have identified a novel population of extracellular vesicles that are produced in response to extracellular matrix changes, containing a key signalling molecule. But there is much more to this story and this project will focus on unravelling this further.

This project will involve osteocyte cell growth, working with 3D culture systems, extracellular vesicle characterisation, extracellular vesicle purification, liquid chromatography with tandem mass spectrometry, live confocal imaging, gene expression, western blotting and immunostaining.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Amanda W. Kijas

a.kijas@uq.edu.au

07 33464178

AIBN Master Projects | Dr Nasim Amiralian

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/3084/nasim-amiralian

Development of sustainable food packaging from agricultural waste

Dr Nasim Amiralian and Prof Alan E. Rowan

Single-use plastics are the most significant contributor to plastic pollution. In 2016, Australians sent 2.2 million tonnes of plastic to landfill. There is an urgent need for sustainable packaging materials to tackle plastic pollution.

This project aims to develop 100% bio-based and biodegradable single-use packaging materials using sugarcane waste. After extracting sugar from sugarcane, the remaining material known as bagasse is turned into pulp which can be pressed into any desired form. Cane-based materials are biodegradable, compostable, thermally stable, and they are grease and moisture resistant, making them suitable for packaging hot or cold food. However, stronger and lighter materials are needed to make sugarcane packaging an economical alternative to plastic packaging. This project uses cellulose nanofibres derived from sugarcane bagasse to reinforce sugarcane pulp to increase its strength and produce durable, lightweight packaging.

Plant-derived nanofibres have many advantages, such as being natural, abundant, biodegradable, and are exceptionally light and strong. These nanofibres are excellent candidates for use as sustainable materials to reduce the use of petroleum-based plastics in industries such as packaging, automotive, aerospace, and healthcare. For sugarcane packaging, the addition of a small amount of nanofibres to the pulp is expected to significantly improve its mechanical properties as well as increasing the shelf-life of food due to the high oxygen and moisture barrier properties. This material rapidly degrades in both industrial and home compost along with foods, as well as being recyclable, significantly reducing the amount of waste going to landfill. In addition to reducing plastic pollution, this project advances Australia manufacturing by applying nanotechnology and capitalising on organic waste.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Nasim Amiralian

Email : n.amiralian@uq.edu.au

Telephone Number : 07 334 64179

AIBN Master Projects | Dr Nasim Amiralian

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/3084/nasim-amiralian

Antiviral materials for the personal protective equipment

Dr Nasim Amiralian and Prof Alan E Rowan

COVID-19 is a novel viral disease, and there is no pre-existing immunity in our community. There is an urgent need to develop simple materials that reduce the risk of infection when handling contaminated products. Every individual should protect themselves from SARS-CoV-2 infection by using personal protective equipment in areas at risk of virus exposure. There are currently no specially developed masks or clothing to protect against viruses. Existing N95 and surgical masks do not completely protect from aerosols in the air and are often in short supply. This project will develop sustainable materials using novel approaches to manufacture antiviral cellulose nanofibres derived from sugar waste industry.

Development of the proposed antiviral materials in collaboration with industry partners will assist the fight against a broader range of viruses and can be applied to a diverse range of surfaces. As a result, the project outcomes will assist with the management of viral pandemics and preparedness for similar events, and in adding value to waste from the sugar industry.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Nasim Amiralian

Email : n.amiralian@uq.edu.au

Telephone Number : 07 334 64179

AIBN Master Projects | Dr Mahdie Molazade

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/6652/mahdie-mollazade

The dynamics of mechanosensing

Dr Mahdie Mollazade and Prof Alan E. Rowan

Cells are constantly exposed to a diverse range of mechanical signals that change over time. Mechanical signals are sensed and converted by cells into biochemical signals; a process known as cell mechanosensing. Cellular mechanosensing is mediated with the involvement of various intracellular structures with high spatiotemporal dynamics, such as caveolae and focal adhesions. Caveolae and focal adhesions are membrane structures that undergo dynamic reorganizations upon responding to the mechanical signals from the environment. With our multi-disciplinary team of chemists, biophysicists and biologists, we have built a bio-mimicking system for application of a range of mechanical signals to cells, where the cellular response can be simultaneously monitored at high spatio-temporal resolution using our FLIM-integrated STED confocal microscopy. This multidisciplinary project will combine our expertise in super resolution microscopy and materials sciences to unravel the dynamics of mechanosensing.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Mahdie Mollazade

Email: m.mollazade@uq.edu.au

Telephone Number : 07 334 64179

AIBN Master Projects | Dr Mahdie Molazade

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/6652/mahdie-mollazade

Traction force microscopy for inside-out signalling

Dr Mahdie Mollazade and Prof Alan E Rowan

Inside-out signalling refers to the traction force that is exerted by cells to the neighbouring cells and the substrate. Cellular traction force is crucial for cell development, morphogenesis, and migration. Quantification of cellular traction force is thus needed for proper understanding of cellular behaviour and processes. Traction force microscopy (TFM) is a commonly used and powerful method for measuring the cellular traction force. One common approach in TFM is by using deformable substrates with elastic properties such as hydrogels for seeding cells. The substrate is also embedded with fluorescent beads, which undergo displacement as a results of substrate deformation upon the exertion of cellular force on the substrate. Substrate deformation and the cellular force can then be measured by tracking the displacement of the fluorescent beads. The aim of this project is to optimise TFM for 3D measurement of the dynamic map of cellular traction force. This involves the use of super-resolution stimulated emission depletion (STED) microscopy combined with fluorescence lifetime imaging microscopy (FLIM) for tracking the fluorescent beads, and computational algorithms for image post-processing.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Mahdie Mollazade

Email: m.mollazade@uq.edu.au

Telephone Number : 07 334 64179

AIBN Master Projects | Dr Michael Taylor

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/5985/michael-taylor

Brillouin microscopy to measure microscale stiffness around cells

Dr Michael Taylor and Prof Alan E Rowan

Brillouin scattering occurs when light is scattered from acoustic vibrations, and provides information about the mechanical properties of the medium. Brillouin microscopes use this scattering to measure sample stiffness in 3D at microscopic scale, without requiring physical access. This permits measurement of sample stiffness in otherwise inaccessible places such as the interior of cells. However, it remains a challenge to draw a direct connection between the Brillouin scattering data and the rheological properties in highly inhomogeneous materials. We have recently developed and built a new type of Brillouin microscope, and are working to establish its capacity for biomechanical experiments.

Cells sense and respond to the stiffness of the surrounding extracellular matrix (ECM) via a process called mechanotransduction. An increasing number of studies show that the mechanical properties of the ECM have a crucial role in determining cellular fate and various different cellular processes in tissues. One confounding effect when studying the influence of ECM stiffness on cell function is that the cell itself modifies the surrounding extracellular matrix, making it very difficult to know what mechanical cues the cell is actually subject to. Our Brillouin microscope offers the capacity to directly measure the stiffness of the ECM, and hence quantify how cells influence the mechanical properties directly surrounding them. This multidisciplinary project will investigate how to process information from Brillouin scattering in biological and biomimetic matrices, and use this insight to study how cells shape their own local environments.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Michael Taylor

Email: m.taylor@sbs.uq.edu.au

Telephone Number : 07 334 64179

AIBN Master Projects | Dr Michael Taylor

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/5985/michael-taylor

Studying how an applied force influences extracellular matrix and cellular mechanotransduction

Dr Michael Taylor and Prof Alan E Rowan

The mechanical properties of extracellular matrix (ECM) are sensed by cells via a process called mechanotransduction. An increasing number of studies show that the stiffness of the ECM has a crucial role in determining cellular fate and various different cellular processes in tissues. ECM is also well known to exhibit strain stiffening, such that an applied force can stiffen the material. While cells have been shown to respond to the stress stiffening properties of the medium, it remains unclear how this relates to mechanotransduction of stiffness. For instance it is not known if the stiffening due to applied force has a similar effect on cells as an increase in the material stiffness.

This multidisciplinary project will explore how application of force influences the viscoelastic properties of ECM, and how this influences cell activity. We are uniquely equipped to study this using a STED confocal–rheometer instrument which allows real-time fluorescent imaging of 3D volumes and the simultaneous application of force to the ECM material while measuring its viscoelastic properties.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Michael Taylor

Email: m.taylor@sbs.uq.edu.au

Telephone Number : 07 334 64179

AIBN Master Projects | Dr Naatasha Isahak

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/2847/naatasha-isahak

https://aibn.uq.edu.au/profile/6652/mahdie-mollazade

Study of cells in microgravity conditions

Dr Naatasha Isahak, Dr Mahdie Mollazade and Prof Alan E Rowan

Every living organism is affected by gravity. With returning astronauts suffer bone loss of up to 1.5% a month, along with lowered levels of calcium, dysregulated immune systems, and muscle atrophy- it is clear that gravity has a profound effect on cell functions and behaviour. As cells monitor the surrounding mechanical cues from the extracellular matrix, they transmit them through focal adhesion connections to initiate signal pathways that cause reorganization of the cytoskeletal structure. Through the aid of a synthetic hydrogel with regulated sites for focal adhesion, this project will investigate the effects of microgravity on the cytoskeletal structure of the cells and determine how gravity affects cell behaviours.

This is a multidisciplinary project that would expand your skills in confocal microscopy techniques, cell culture and material synthesis and characterization.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Naatasha Isahak

Email: naatasha.isahak@uq.edu.au

Telephone Number : 07 334 64178

AIBN Master Projects | Dr Naatasha Isahak

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/2256/ernst-wolvetang

https://aibn.uq.edu.au/profile/2847/naatasha-isahak

Studying of organoids in polyisocyanide gels

Dr Naatasha Isahak, Prof Ernst Wolvetang and Prof Alan E Rowan

Biological systems are influenced by intra- and extracellular mechanics, which are governed by structural proteins such as microtubules, actin, intermediate filaments and collagen. As a general design motif, these proteins self-assemble into helical structures and superstructures with differing size scales that provide a wide range of mechanical properties. Among the mechanical responses of cytoskeletal gels, stress stiffening is one that has been shown to direct cellular responses yet has been previously absent in synthetic polymeric and low-molar-mass gels.

Here we work with polyisocyanides (PIC), which is a synthetic biomimetic gel that closely resembles natural ECM both in the helical structure and the stress stiffening mechanical properties. Prepared from isocyanopeptides, the PIC used in this study are functionalised with thermo-responsive oligo(ethylene glycol) side chains to form a radical free hydrogel system with tunable thermal transition through bundle formations. In addition to its thermoresponsive behaviour, they are also functionalised with biological cues to improve matrix to cell interactions. This project will study organoids cultured in PIC gels, with the aim to improve the biomimetic properties of the PIC gels. This project will involve exciting experiments in organoid culture, stem cells differentiation and materials synthesis and characterisation.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Naatasha Isahak

Email: naatasha.isahak@uq.edu.au

Telephone Number : 07 334 64178

AIBN Master Projects | Dr Jan Lauko

https://aibn.uq.edu.au/rowan

https://aibn.uq.edu.au/profile/3533/alan-rowan

https://aibn.uq.edu.au/profile/4267/kristofer-thurecht

https://aibn.uq.edu.au/profile/3319/jan-lauko

Synthesis and characterisation of novel polymers for biodistribution studies

Dr Jan Lauko, Prof Kristofer Thurecht and Prof Alan E. Rowan

In this project focused on organic and polymer synthesis, we are looking for a candidate with a synthetic background, to prepare and characterise a library of in-house developed polymeric compunds and in a collaborative approach study their relevant biomimetic and biodistribution properties.

Unlike most other polymers, the polyisocyanopeptides (PIC) developed and extensively studied in our group, do not form sphere-like particles, but form relatively stiff, several hundred nm long rod-like particles (Rowan, Nature, 2013). This is because of their helical backbone structure which is stabilised by peptide hydrogen bonds. PIC's essentially do not have a hydrodynamic radius making it both difficult to determine their molecular weight by standard analytical methods used in polymer science, but also making them interesting in terms of their distribution in body.

The aim of this project will be to synthesize functionalized PIC polymers, study their mobility in a model system, with the ultimate aim to follow their biodistribution in a mouse model. These pioneering studies, should unravel the relationship between nano-scale geometries of materials and their biodistribution for future applications in targered drug deliveries.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

Contact Information

Dr Jan Lauko

Email : j.lauko@uq.edu.au

Telephone Number : 07 334 64179