



Maynooth University

Ollscoil Mhá Nuad

Maynooth University Graduate Teaching Studentship (GTS) in 2019-2020

The Department of Chemistry is pleased to announce that a number of Graduate Teaching Studentships will be available for students intending to commence PhD studies in September 2019.

Full time PhD degree students commencing study in September 2019, and who have a relevant first class or 2.1 honours in their primary degree, or have a relevant Master's degree, are eligible to apply for studentship support in the Department. Students who are in receipt of a university scholarship or who have fees paid from external sources are not generally eligible.

The studentship will entail:

1. Full annual tuition fees support (approximately €6200 per annum);
2. A fixed stipend of €9007 per annum;
3. Duties as a Graduate Teaching Student with a requirement to undertake teaching support duties for up to 25% of the notional study year. This will entail 455 hours of teaching support duties in the course of a year, with not more than 20 hours in any one week (not more than 12 contact hours weekly). These duties will be carried out under the direction of the Head of Department, or a member of staff nominated by the Head.

The studentship will be awarded for 5 years, which is the expected duration of the studies, subject to satisfactory annual review of progress in research, and performance in teaching support.

The studentship will be awarded by the Department on the basis of (i) research potential in an area aligned with the Department's research priorities and (ii) potential and aptitude to provide high quality teaching support.

The teaching support role

A Graduate Teaching Student is a registered postgraduate student of the University who, within the duration of his/her studies is also employed by the University to play an important role in the delivery of the academic programmes of the University by providing teaching support (e.g. as a teaching student, tutor or demonstrator) under the direction and guidance of a supervising member of staff.

Main duties and responsibilities

The Graduate Teaching Student will be required to undertake such duties as may be specified by the Head of Department or their nominee within the stipulated maximum of 455 hours per annum. These duties may include, but are not limited to, the following:

- To assist the delivery of a range of teaching and assessment activities, including tutorials and laboratory demonstrations, in support of the required teaching commitments of undergraduate students;
- To contribute, under supervision, to the development of appropriate teaching materials to ensure that content and methods of delivery meet learning objectives;
- To contribute, where appropriate and under supervision, to the assessment process, using a variety of methods and techniques and to provide effective, timely and appropriate feedback to students to support their learning;
- To be available for consultation by undergraduate students;
- To lead classes with groups of students and/or participate in the supervision of practical work, advising on skills, experimental methods and techniques to assist the transfer of knowledge.
- To undertake limited teaching-related administrative duties as requested by the Head of Department;
- To attend meetings associated with the course they support as requested/ appropriate.

Knowledge, skills and experience

It is essential that studentship holders have the following:

- First class or 2.1 honours primary degree in the subject area, or a relevant masters accepted by the Department.
- Excellent oral and written communication and language skills
- Excellent interpersonal skills and presentation skills
- Time management skills
- Ability to work independently and as part of a team
- Ability to work under supervision
- Self-motivation
- Ability to accept collegiate responsibilities and act accordingly.

Selection and Appointment

- Applications should be received by June 21st 2019. Short-listed candidates will be contacted by the department and invited for interview.

Terms and Conditions

The studentship may be held by full-time registered students only, with a part-time (maximum of 20 hours per week, with no more than 12 hours contact time per week) teaching student commitment, which is offered on a fixed-term basis during the course of study. The teaching support commitment is consistent with and governed by the University's HR policy on Graduate Teaching Students.

Stipend

A fixed stipend of €9007 per annum will be offered. This will be paid in twelve equal instalments from October to September. The studentship will be awarded for the expected duration of the studies, subject to satisfactory annual review of progress in research, and performance in teaching support. PhD students may benefit for not more than 5 years.

The stipend will include 8% holiday pay. The stipend will be subject to such personal taxation and social insurance contributions as will be determined by the Revenue Commissioners; these will be the responsibility of the student¹.

There will be no pension entitlements arising from the studentship.

¹ If the student is receiving no other income and they are eligible for the standard PAYE and single person's tax credits then they would not be liable to pay tax, as their earnings would be under the threshold.

Application Procedure

Applications should include:

1. A completed application form, indicating your order of preference for research projects, from the list below.
2. A complete CV with all academic grades.
3. A personal statement, indicating your suitability for a Graduate Teaching Studentship.

Applications should be sent to: jennifer.mcmanus@mu.ie

The deadline for receipt of applications is June 21st 2019. No late applications will be accepted.

Termination

A Graduate Teaching Studentship's employment with the University is contingent on them being a registered graduate student, and their employment as a Graduate Teaching Student will terminate automatically when they cease to be a registered graduate student. The grounds for termination are that a Graduate Teaching Studentship is primarily a training role offered to postgraduate students to gain experience of teaching: it is a legitimate objective of the university to provide education and training for successive cohorts of postgraduate students, that providing an opportunity to students to develop skills in teaching by serving as a teaching student, tutor or demonstrator is an important part of postgraduate training, so where work as a teaching student, tutor or demonstrator is available, the University makes such work available to postgraduate students as a priority.

In addition, the GTA appointment may be terminated for misconduct, or poor performance, or for other reasons under the general HR policies of the university.

Projects Available

Project 1: Anticancer Copper complexes as DNA binding and cleavage agents: a combination approach between experimental and theoretical investigations

Supervisors: Dr. Diego Montagner and Dr. Tobias Kraemer

Copper is a transition metal whose importance in the field of anticancer drugs is increasing dramatically in the last decades [1]. Copper, being an endogenous metal, is much less toxic than the worldwide approved platinum based drugs and is also much more tolerated by mammals.

The anticancer mechanism of action of Copper based complexes is different with respect to those of platinum based drugs (i.e. cisplatin) [2,3]. Copper is a redox active metal centre with mainly two oxidation states, +1 and +2. Indeed, copper is one metal that plays a major role in the electron transfer chain in respiratory processes that happen in the mitochondria. Due to its redox activity, Copper is involved in the Fenton reaction and can produce ROS (Reactive Oxygen Species) that are able to cleave the phospho-di-ester bond of the DNA.

The modification of the coordination sphere of copper with large planar and aromatic ligands, allow the intercalation of these compounds between the nucleobases of the DNA (Figure 1). These electrostatic interactions, alter the DNA structure avoiding the DNA replication that ultimately bring to the apoptotic cell death[4]. This project will regard the syntheses and characterisation of mono and multinuclear Cu(II) complexes with a library of different planar and aromatic ligands with potential as anticancer agents (Figure 2). DNA binding and cleavage will be experimentally studied together with a theoretical approach.



Figure 1. DNA intercalation of metal complexes

A SAR (Structure Activity Relationship) analyses will be conducted in conjunction with a detailed theoretical study. Redox potential of the species will be experimentally determined *via* cyclic voltammetry and the results will be compared with those of high-level quantum chemical calculations [5]. This project will combine the fields of synthetic chemistry, theoretical simulation and biological evaluation.

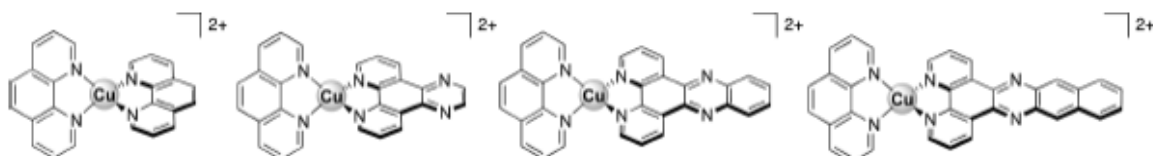


Figure 2. Examples of phantroline modified Cu(II) complexes

- [1] Gandin et al. (2014) *Chem. Rev.* 114, 815.
- [2] Montagner et al. (2018) *Inorg. Chim. Acta* 479, 261
- [3] Montagner et al. (2018) *Nucleic Acid Res.* 46, 9918
- [4] Kellett et al. (2014) *Inorg. Chem.* 5392
- [5] Yan et al. (2016) *Phys. Chem. Chem. Phys.* 18, 5529

Project 2: Forensic Fingertips for Crime Scene Examination (FOR-SCENE)

Supervisor: Dr. Eithne Dempsey

Key chemical techniques/skill set: *electrochemical analysis, printed sensor design and fabrication, voltammetric redox interpretation of target molecules to include 1,3 diethyl-1,3 diphenyl urea, diphenylamine, 2,4 dinitrotoluene and dibutylphthalate, prototype development and testing.*

The ability to screen and test for explosives and firearm residue is an on-going challenge in relation to forensic science, security and defence. A rise in global security threats requires field-deployable detection devices for identification of explosive residues. Printable electrochemical transducers have the potential to provide forensically useful real-time analytical information regarding explosive or firearm discharge. Overall, the type of explosive used could give an investigator a clue as to whether the explosion was related to “normal” criminal activity or to terrorist activity. The identification of traces of explosives/residues on individuals, clothing, cars can establish whether a contact with explosives has occurred with such results are often used as court evidence. The overall aim of this research project is to advance wearable, disposable devices capable of on-site recovery and analysis of explosive residues using rapid electronic sensor technology. Sample recovery from a crime scene will be achieved using a adapted latex finger “cots” – the tips of which will be printed with a novel carbon based ink formulation for organic residue detection. The new recovery and measurement system proposed here enables both collection and analysis with subsequent data transmission, realising swift residue identification as a portable screening tool.

The central research question is whether the underlying principles of an innovative electrochemical sensing wearable device for multiplexed detection of explosive residues can be established. Individual research objectives are listed below:

- a) Advance a detection strategy for the target molecules based on formulation of a novel conducting ink which facilitates the multi-modal sensing capability and sample interface;
- b) Examination of deformation, resistance alterations and elastomeric properties post processing and film deposition to ensure appropriate adhesion and operational stability;
- c) Combine the outputs of (a) - (b) into a printed sensor device on latex test substrates for analytical performance testing in standard solution at the required level;
- d) Translate the sensing platform to functionalised printed conductive sensor surface on wearable latex finger cots with associated solid phase sample transfer via a carbon disk collection “finger”. The conducting hydrogel layer and physical contact establishes electrical connection with sensing layer for testing in real samples.

Project 3: Small molecule activation and catalysis by main group compounds – *in silico* design of catalyst platforms

Supervisor: Dr. Tobias Kraemer

The transformation of chemical bonds to produce new chemicals and materials of intrinsic value to society is one of the cornerstones of chemical research. Catalysis plays a pivotal role in industrial processes as well as small-scale synthesis, opening mechanistically distinct routes to molecules that would not be accessible otherwise. It is estimated that up to ~85% of all commercially produced chemicals require catalysts at some stage during their manufacture. Taken together, about 25% of the GDP in developed countries is generated by sectors that involve industrial catalysis, both directly and indirectly through processes and products.^[1] Traditionally transition-metals (including the lanthanides) and their complexes dominate this area of application, finding utilization in both homogeneous and heterogeneous catalysis. However, more recently main-group chemistry has entered this research arena, owing to the increasing realization that the electronic properties in particular of heavier main-group compounds show significant similarities to transition-metal complexes.^[2] Facilitated by a well-balanced spatial and energetic arrangement of occupied and vacant frontier orbitals, many newly synthesized main-group compounds undergo reactions with small molecules such as H₂, NH₃, N₂, CO and olefins under mild conditions.^[3] These developments are very promising, enabling new pathways into harnessing the reactivity of main group elements in catalytic transformations with a view to long-term sustainability and low toxicity. Despite these advances, mimicking the high reactivity and selectivity of transition-metal catalysts will remain a challenge. Recent work in the Cowley group (University of Edinburgh) has demonstrated that P/B compounds, such as phosphaborete **1**, are able to capture carbon monoxide under ambient conditions (Fig. 1 **A**). Involvement of donor/acceptor interactions in the formation step, emulating transition metal reactivity, is implicated by DFT analysis of its electronic structure.^[4]

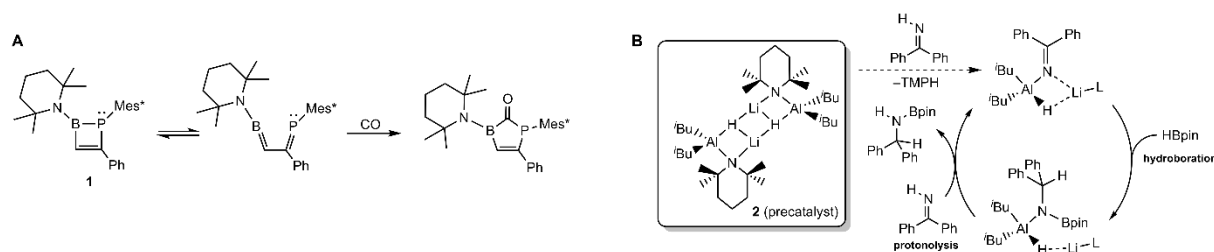


Figure 1. (A) Reactivity of 1,2-phosphaborete **1** towards CO. (B) Proposed mechanism for hydroboration of benzophenone imine catalyzed by **2**.

A plethora of exciting results have also emerged from the Mulvey group (University of Strathclyde), whose interests lie in exploiting synergistic cooperativity effects in bimetallic main-group complexes.^[5] One such example is shown in Fig. 2 **B**, detailing the hydroboration of a benzophenone imine catalyzed by ate complex **2**. The influence of the alkali metal as well as the ligand set on the ensuing aluminium reactivity is critical for this catalytic transformation. The mechanistic details of the chemistry exemplified in the two reactions shown above are remarkably unexplored. This project will bring together the expertise of the above (independent) experimental groups and the Kraemer group (theory) in order to develop a fundamental understanding of the remarkable chemical reactivity of the main-group species studied in their respective groups. Mechanistic details of the above and related reactions will be studied on the atomistic level, using state-of-the-art quantum chemical computations. Insight into the electronic structure of key intermediates on the potential energy surface will be obtained from orbital (MO, NBO) and energy decomposition analysis, in concert with theoretical spectroscopy. This project is thus both fundamental and applied in scope, and will aid the rational design and development of new main-group catalyst platforms with tailored control of catalytic ability and selectivity, in concert with improving our fundamental understanding of how chemical bonds can be manipulated by these systems.

[1] G. Ertl et al. *Handbook of Heterogeneous Catalysis*, 2nd Edition, Wiley-VCH, Weinheim, 2008

[2] P. P. Power *Nature*, **2010**, 463, 171.

[3] Legare et al. *Science*, **2018**, 359, 896.

[4] Manuscript in preparation.

[5] Mulvey et al. *Chem. Rev.*, **2019**, DOI: 10.1021/acs.chemrev.9b00047.

Project 4: New Mussel-inspired adsorbents with applications in Environmental Chemistry

Supervisor: Prof. Carmel Breslin

Polydopamine is often described as a Mussel-inspired polymer. It was first described in 2007 and since then it has been used in several applications as a biomaterial, as it contains amine, imine and catechol groups. These facilitate covalent and non-covalent linkages with different biomolecules and transition metal ions, making polydopamine essential in several bio-related applications. However, these properties also make it interesting in Environmental Chemistry and the applications of polydopamine as an adsorbent for the removal of environmental contaminants are now beginning to emerge. The metal binding properties can be exploited to uptake and remove metal ions from the environment, while at pH values below approximately 4.5, polydopamine is positively charged and therefore it can be used to uptake and remove anionic species, such as organic dyes.

In this research programme, polydopamine will be formed on polymerisation of dopamine at porous membranes, porous graphite electrodes and within hydrogels with the aim of forming polydopamine coatings with a high surface area. Other catecholamine compounds will be considered, polymerised and compared with polydopamine. These new materials will be characterised using scanning electron microscopy (SEM) coupled with energy dispersive X-ray analysis (EDX) and FTIR spectroscopy and then used for the uptake of heavy metal ions, such as Cu^{2+} , Zn^{2+} , Ni^{2+} , Ag^+ , Cd^{2+} , and hexavalent chromium, phosphates, nitrates, methyl orange and orange II. The kinetics of uptake will be monitored using UV-visible spectroscopy or chromatography to monitor the removal of the dye molecules, while a combination of conductivity, atomic absorption spectroscopy (AA) and UV-visible spectroscopy will be employed to study the uptake of the heavy metal ions. The adsorption capacity of the various adsorbents will then be determined. The selectivity of uptake and removal will also be considered and finally de-adsorption will be studied to determine if these materials could be used to both remove and recover essential elements, such as phosphorous, which is being rapidly depleted from the earth.

Carmel Breslin, Electrochemistry/Materials lab

<https://www.maynoothuniversity.ie/chemistry/our-people/carmel-b-breslin>

Project 5: A Combined Theoretical and Experimental Evaluation of Novel Squaraine Dyes and their Application as Stimuli Responsive Fluorescent Sensors

Supervisors: Dr. John McCaffrey & Dr. Rob Elmes

The squaraine dyes, all consisting of a central four-membered ring system, possess structural rigidity and aromaticity and display unique photophysical properties characterised by intense absorption associated with strong fluorescent emission in solution. Currently, both squaraines (**SQs**) and squaramides (**SQa**) are finding wide ranging use in applications at the interface of materials science and biology where new materials, molecular sensors and new drug candidates aimed at treating a diverse set of diseases, have all been reported. Because of its central location in the molecular structure of the squaraines, squarate dianion holds the key to understanding the optical characteristics of these novel dyes which ultimately determines their fluorescence properties. While much experimental work has been carried out on the absorption and emission spectra of squaraine dyes (e.g., squarylium), very little is known about the fluorescence characteristics of the squarate dianion itself. Moreover, the vast majority of the existing work on the squaraine dyes has been done in room temperature solutions which exhibit large solvent shifts and lack any resolved vibrational structure. Both of these factors greatly limit the information that can be extracted from solution phase spectra. In the current work we will undertake a fundamental study of the fluorescence of squarate dianion and related **SQs** both theoretically and experimentally and aim to extend this work to involve the synthesis of designed dyes having applications as novel fluorescent sensors.

In order to conduct an analysis of the energy levels of the moderately-large polyatomic **SQs** molecules, vibronic bands must be fully resolved in the recorded absorption and emission spectra. To achieve this, spectra must be recorded at the lowest possible temperatures. Two experimental approaches can be adopted to record spectra under these conditions that greatly improve the resolution of the acquired data. One involves the use of supersonic jets, a gas phase technique – the other is matrix-isolation, a solid phase method. The latter involves the use of rare gas solids to isolate the molecules in a chemically inert environment. Because of the cryogenic temperatures used ($T < 10$ K), hot bands are completely absent which greatly simplifies the recorded matrix spectra. This method has the additional benefit over gas phase spectroscopy since rotational motion of the molecule is quenched in the solid. As a result, the vibrational band origins that appear in the recorded spectra can be directly compared with theoretical predictions.

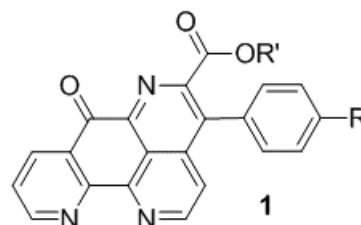
An understanding of **SQs** dyes derived from such fundamental studies is crucially important for the rational design of new fluorescent materials. High-level quantum chemical calculations of the energy levels in **SQs** will provide an invaluable and independent method to simulate low temperature spectroscopy. In particular, calculations done at the DFT level of theory have proved to be a very reliable method to obtain ground state vibrational frequencies that can be compared with experimental data. This project will call upon the complementary supervisory expertise of Dr. John McCaffrey and Dr. Rob Elmes. In the past decade, Dr. McCaffrey's group has extensive experience with these calculations running on stand-alone Linux-based workstations at NUI-Maynooth using the Gaussian-03 suite of programmes. Previous calculations have involved determination of the vibrational frequencies for high symmetry tetra-pyrrole molecules, in the ground electronic state which have been used to simulate infra-red absorption and normal Raman scattering spectra. Dr. McCaffrey's group has also recorded matrix-isolation spectra (MIS) in the and visible spectral regions for a variety of similar dye molecules *viz* the porphyrins and phthalocyanines. The Elmes group has research expertise in the synthesis and experimental evaluation of squaramides and fluorescent materials where their application as sensors and as anion transporters has been reported recently.

Project 6: Design and synthesis of novel metal-based anti-cancer therapeutics

Supervisors: Dr Denise Rooney and Prof. Frances Heaney

This is an exciting project in the area of **Bioinorganic Chemistry** with a goal to make and study the biological activity of a series of novel metal complexes with potential anti-cancer activity.

We are interested in chelating ligands like **1**, which have close structural resemblance to a family of naturally occurring anti-cancer compounds with DNA binding properties¹. These compounds can only be isolated in tiny amounts from nature and are very hard to synthesise, but we have already found a robust synthesis to structures like **1**. In this project you will develop the synthesis of a family of similar ligands, make and characterise their metal complexes and study the anti-cancer activity of both the free ligands and the complexes.



In undertaking this project, you will receive an excellent training in modern inorganic chemistry, gaining expertise in core techniques which will allow you to develop as a research chemist. Additionally, in working with biological collaborators, you will have the possibility of conducting biological assays. You will have the opportunity to disseminate your results through research papers and by presenting at research meetings and conferences.

You will be working with Dr Denise Rooney and Prof. Frances Heaney who have successfully supervised many PhD students. The presentation of the 2019 Maynooth University Doctoral Supervision Award to Dr Rooney reflects the quality of supervision on offer with this project. Both supervisors are members of the newly established Human Health Institute at Maynooth University, which will enable the student on this project to access a large network of active researchers within the university. Moreover, Dr Malachy McCann, who has extensive expertise in bioinorganic chemistry, will be associated with the project. Your supervisors will be committed to supporting your professional development and helping prepare you for a future as a highly skilled scientist in an academic or industrial setting.

1. G-quadruplex and duplex DNA binding studies of novel Ruthenium(II) complexes containing ascididemin ligands M. Wumaier, J-J. Shi, T-M. Yao, X-C. Hu, R-R. Gao, S. Shi, *Journal of Inorganic Biochemistry* (2019), 196, 110681.

Project 7: Targeting Anticancer Metallo-drugs with sugar mimetics

Supervisors: Dr. Diego Montagner and Trinidad Velasco-Torrijos

Metal-based drugs such as cis-platin are one of the most important and effective class of therapies in the fight against cancer. Although they started to be used clinically several decades ago, they remain extremely efficient drugs for the treatment of many types of tumors. One of the main drawbacks of the of cancer drugs is the severe side effects for the patient undergoing treatment. Targeted cancer therapies which aim to kill only cancerous cells, but not healthy cells, have been investigated in order to minimize toxic effects of cancer chemotherapy and improve its efficacy. [1] Some cancer cells overexpress certain receptors at the cell surface compared to healthy cells. Thus, the modification of a cancer drug with an epitope which are recognized by these abnormal receptors can direct the drug more selectively to the cancerous cell, sparing healthy ones. Galactose residues have been attached to anti-cancer drugs in order to increase the cytotoxicity of the drug towards hepatocytes and other cancerous cells, since it is know that during cancer, these cells overexpress asialo receptor in the cell surface. This receptor recognizes and binds compounds featuring terminal galactosides, providing the basis to develop targeting anti-cancer therapies (Figure 1).[2]

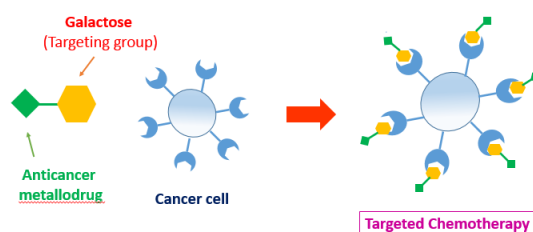


Figure 1: Schematic representation of the use of carbohydrates and metallodrugs in targeted anti-cancer therapies.

The proposed project builds on the expertise developed by Dr Diego Montagner (metallo-based anti-cancer drugs, [3]) and Dr Trinidad Velasco-Torrijos (carbohydrate synthesis, [4]): we intend to prepare derivatives of cis-platinum both in the oxidation +2 and +4 that are modified with galactose derivatives that mimic the structure of the epitopes recognized by the receptor in the cancer cells. A representative example of the structure of a proposed target compound is shown in Figure 2. We expect that this targeting strategy may improve the anticancer activity and selectivity of this class of metallodrugs.

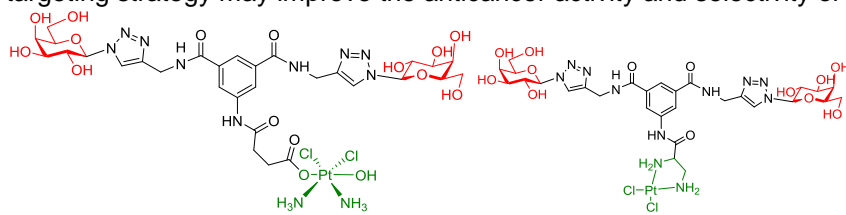


Figure 2: Chemical structure of target galactosylated metallodrugs.

The project will combine (i) a chemical part with the synthesis of a library of metal complexes: structural features of the ligands such as the type of sugar or the linker group will be varied, and (ii) a biological part where the anticancer activity of the compounds will be evaluated in collaboration with collaborators at MU and in other research institutes.

[1] Marmion, C. J. *et al* (2017), *Eur. J. Inorg. Chem.*, 1596-1612.

[2] Gao Q. *et al* (2016) *Eur. J. Med. Chem.*, 110: 32-42.

[3] Montagner, D. *et al.* (2018), *ChemComm*, 54, 8324.

[4] Velasco-Torrijos T. *et al* (2018). *Eur. J. Med. Chem*, 160: