

***CHEM4710***

***Honours Project***  
***in***  
***Chemistry or Biochemistry***

***2022/2023 Projects***



**University  
of Manitoba**

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## 1. WELCOME:

Welcome to the 'Honours Project in Chemistry or Biochemistry' (CHEM4710) for the 2022/23 academic year. The 'Honours Project in Chemistry or Biochemistry' is a research project based course providing undergraduate chemistry and biochemistry students with the opportunity to conduct original research as part of an active research group. The research project extends over a duration of 2 consecutive terms (Sep. 2022 – Apr. 2023). Students can request projects based on the list of projects provided in this booklet. Throughout the research projects students will receive guidance and support from their research advisors and other research group members. Notably research environments are very diverse in the Department of Chemistry and naturally individual research groups may operate differently and have different foci. Specifics need to be discussed with the project advisors. The Department of Chemistry at the University of Manitoba is a medium size department and is well situated within the top 15 Canadian Universities (U15). In general the research groups in the Department of Chemistry are highly competitive, recognized in their respective fields and contribute to the large fields of chemistry and biochemistry. The experimental and theoretical opportunities offered in the Department of Chemistry are excellent with well equipped laboratories, state-of-the art instrumentation and outstanding expertise. The majority of the research is being conducted in the Parker Building and additionally many groups collaborate with other departments, faculties/schools and institutes within the University of Manitoba. The majority of research groups maintain national and international collaborations and are part of large scale facilities such as national laboratories and institutes all around the world.

I hope that you will explore the opportunities accessible in the Department of Chemistry by looking at the project descriptions in this booklet and that you will take the opportunity to meet with faculty members and discuss their projects within the framework of CHEM4710.

I am looking forward to a research filled year of CHEM4710 projects for 2022/23.



Dr. Mario Bieringer

Course coordinator for CHEM4710 2022/23

## 2. INTRODUCTORY COMMENTS:

Students interested in taking CHEM4710 should look at all offered projects provided in this booklet and need to contact project supervisors in order to discuss any of the projects listed in this booklet. During those meetings the nature of the projects should be discussed and expectations should be made clear. Please note that project advisors are happy to meet with you in order to discuss their research projects. Students are expected to meet with **at least 3 faculty members** and are required to complete the attached '**Student – Faculty Interviews**' page (Appendix A). Please prioritize your project choices on the attached '**Student Project Choices**' page (Appendix-B). A minimum of 3 choices should be submitted and comments can be added in the provided comment field. In order to be considered for the entire set of advertised projects you are asked to submit the attached '**Student – Faculty Interviews**' page and '**Student Project Choices**' page with your project choices to Dr. Mario Bieringer ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca)) by July 11<sup>th</sup>, 2022. Notably the matching of students with research projects will only occur after July 11<sup>th</sup>, 2022. You can submit your project choices after that date as well, however the number of available projects might be limited by then. Students will be informed about their projects around August 1<sup>st</sup>, 2022.

The projects will start during the first week of the 2022 Fall term. For each project the student and project advisor have to submit a completed and signed '**Student – Advisor Agreement**' (Appendix-C) with a due date of September 16<sup>th</sup>, 2022. Please note that this agreement clearly spells out the obligations of both parties. In addition to the research conducted in the individual research groups there will be mandatory class meetings CHEM4710 which will be held on average once per month. Those meetings will cover general topics relevant to your research activities and will provide you with important skills related to the project course. The dates for the class meetings are tentative and will be updated throughout the terms. Students should reserve Fridays the time from 1:30 pm till 2:20 pm for CHEM4710 meetings for the Fall 2022 and Winter 2023 terms.

It is important for students to communicate regularly with their project advisors, share information about research progress, research needs, administrative needs and talk about upcoming deadlines.

December 9<sup>th</sup>, 2022 is the due date for the progress reports. The expectations for the progress report are clearly stated in the course syllabus. The research projects should be concluded by the end of the 2023 Winter term. On Saturday April 1<sup>st</sup>, 2023 each student will present a 15 minute talk followed by 5 minutes of questions during a conference style presentation day. This will be a public event and faculty members, students, friends, family and other guests are welcome to

attend this event. The final written reports will be due on April 13, 2023. The final report will be graded by an expert reader (suggested by the project advisor) who is familiar with the research subdiscipline and another faculty member (chosen by the course coordinator) as a non-expert reader whose research is in a different subdiscipline.

### 3. IMPORTANT DATES & DEADLINES

Jul. 4 <sup>th</sup> , 2022		Students submit project choices to the course coordinator
Aug. 1 <sup>st</sup> , 2022		Students receive project assignments
Sep. 8, 2022		Students begin research projects
Sep. 9 <sup>th</sup> , 2022		Class meeting #1 - Orientation meeting (all students and supervisors)
Sep. 16, 2022		Signed contracts <b>due</b>
Sep. 23, 2022	<i>tentative</i>	Class meeting #2 (Library resources and literature search)
Oct. 21, 2022	<i>tentative</i>	Class meeting #3 (Academic integrity)
Oct. 28, 2022	<i>tentative</i>	Class meeting #4 (3 min. project presentations)
Nov. 18 2022	<i>tentative</i>	Class meeting #5 (Report writing and proposal development)
Dec. 9, 2022		Written progress report <b>due</b>
Jan. 13, 2023	<i>tentative</i>	Class meeting #6 (Career choices in chemistry and biochemistry)
Feb. 10, 2023	<i>tentative</i>	Class meeting #7 (Academic writing & peer review process)
Mar. 1, 2023		Proposals <b>due</b>
Mar. 10, 2023		Student evaluations of proposals <b>due</b>
Mar. 3, 2023	<i>tentative</i>	Class meeting #8 (Effective oral presentations)
Mar. 27, 2023		Title and abstracts for oral presentations <b>due</b>
April 1, 2023		Oral research project presentation day
Apr. 13, 2023		Final written reports <b>due</b>

### 4. COURSE SYLLABUS

#### CHEM4710: Research Project in Chemistry or Biochemistry:

The University of Manitoba, Faculty of Science, Department of Chemistry

Syllabus for CHEM4710 (2022/2023).

##### GENERAL COURSE DESCRIPTION:

CHEM4710 is a 6 credit hour research project course. You will carry out research as an independent member of a research group in the Department of Chemistry. The course counts for 6 credit hours, and it extends over both the fall and winter terms. Students in CHEM4710 are expected to begin work on the research project at the beginning of September 2022 and to maintain a steady level of work during the entire academic year.

All available course projects will be made available to all students interested in or considering in taking CHEM4710 in Fall 2022 and Winter 2023. Each project will consist of a brief 1 page description. Students are encouraged to read all projects and arrange appointments with supervisors for a brief interview/discussion. Each student needs to meet with 3 potential supervisors. Following those meetings students should submit their preferred project choices to the course coordinator in order of preference (e.g. 1<sup>st</sup> choice: "The investigation of ....", 2<sup>nd</sup> choice: "Synthesis of ...", etc.). Project matching will commence after Jul. 11<sup>th</sup>, 2022 and the project assignments will be e-mailed to the students and supervisors on August 1<sup>st</sup>, 2022.

Students are expected to consult regularly with their advising professor to ensure that adequate progress is being made on the research project. Each student in CHEM4710 is expected to conform to university standards of laboratory safety at all times and will also meet the standards of the research group that they are working in with regard to experimental procedures, notebook keeping, and general laboratory behavior.

The role of the student is to be an active and productive member of the hosting research group. This is not just 'your' project, most projects are integrated in the larger research program underway in the research group. The CHEM4710 project is an excellent opportunity to participate in the "life" of the research group and to learn from the senior members. Your active participation in the group as part of the CHEM4710 experience can also give you a good impression of what graduate studies would be like. More importantly, a good performance in the group will also earn you a positive reference from your advisor for any future applications for graduate studies, other degrees or for entry into the workforce.

The role of your advisor is to help guide your entry into the world of research. This quite often is a markedly different experience than what you have experienced in typical teaching laboratories. The transition into independent research can be challenging in some cases. The role of the advisor is to help you, point you at relevant literature, describe the opportunities and pitfalls, while at the same time avoiding guiding you in minute detail. The success of your research project lies with your ability to work in the research lab in a self-motivated manner and to develop a measure of independence in your abilities. Although your advisor is available to provide guidance on the preparation of your research proposal talk, reports, and presentation, the responsibility for the completeness of these course requirements rests solely with the student.

The role of the project course is to provide students the opportunity to work on a research project in an academic research lab. This is an opportunity to develop practical lab skills beyond those that can be taught in the laboratory portion of an undergraduate course. The CHEM4710 course also provides the opportunity to develop other essential skills such as self-motivation and time management that allow you to be organized in your research. You will also be required to describe your results in a format that is more than a simple 'lab report' in both the written and oral presentation. A major part of the evaluation of your performance is on how well you develop these skills and not necessarily on the perceived success of your project. One meaningful result, generated in September, poorly reported on and described in a rambling talk will not rank the same as a series of carefully recorded experiments repeated several times and described in detail that nonetheless failed to work in the expected manner or at all.



## I) INSTRUCTOR INFORMATION:

### Course Coordinator:

**Name:** Dr. Mario Bieringer  
**Office:** 520c Parker Building  
**E-mail:** [Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca)  
**Phone:** (204) 474 6258

## II) EVALUATION:

3 minute presentation	<b>5%</b>
Written Progress Report	<b>15%</b>
Proposal	<b>10%</b>
Oral Presentation	<b>20%</b>
Research Effort (Evaluated by the research advisor)	<b>15%</b>
Written Final Report (Evaluated by 2 readers)	<b>35%</b>

Final numerical scores will be converted to letter grades. As this is a senior level course, the marking scale will assume that F = less than 50%. Other scores will be scaled appropriately between D and A<sup>+</sup> as described below.

<b>Grade Point Value</b>	<b>Letter Grade</b>	<b>Numerical Score</b>
4.5	A <sup>+</sup>	90.0 – 100
4.0	A	80.0 – 89.9
3.5	B <sup>+</sup>	75.0 – 79.9
3.0	B	70.0 – 74.9
2.5	C <sup>+</sup>	65.0 – 69.9
2.0	C	55.0 – 64.9
1.0	D	50.0 – 54.9
0.0	F	00.0 – 49.9

### III) COURSE PARTICIPATION:

- Students are encouraged to attend the Friday Afternoon Departmental Seminars.
- Attendance of all Friday **CHEM4710 class meetings** (listed in the table below) is mandatory. Class meetings will be scheduled for Fridays from 1:30 pm till 2:20 pm.

Date	CHEM4710 Class Meetings	Presenters
Friday, September 9 <sup>th</sup> , 2022	Orientation Meeting	Mario Bieringer
Friday, September 23 <sup>rd</sup> , 2022	Library and literature searches	t.b.d.
Friday, October 21 <sup>th</sup> , 2022	Academic Integrity	t.b.d.
Friday, October 28 <sup>th</sup> , 2022	3 min presentations	Project students
Friday, November 18 <sup>th</sup> , 2022	Report and proposal writing	t.b.d.
Friday, January 13 <sup>th</sup> , 2023	Career choices in chem. & biochem.	t.b.d.
Friday, February 10 <sup>th</sup> , 2023	Academic writing & peer review	t.b.d.
Friday, March 3 <sup>rd</sup> , 2023	Oral presentations	t.b.d.

### IV) IMPORTANT DATES:

The dates below are fixed and no extensions are possible.

Date	Milestone
Monday, July 11 <sup>th</sup> , 2022	Students submit project preferences to the course coordinator
Monday, August 1 <sup>st</sup> , 2022	Students receive project assignments
Friday, September 16 <sup>th</sup> , 2022	Signed research contract <b>due</b>
Friday, December 9 <sup>th</sup> , 2022	Written progress report <b>due</b>
Wednesday, March 1 <sup>st</sup> , 2023	Proposals <b>due</b>
Friday, March 10 <sup>th</sup> , 2023	Student evaluations of proposals <b>due</b>
Thursday, March 27 <sup>th</sup> , 2023	Title and abstract for oral presentations <b>due</b>
Saturday, April 1 <sup>st</sup> , 2023	Oral presentations
Thursday, April 13 <sup>th</sup> , 2023	Written Final report <b>due</b>

## V) DESCRIPTIONS OF COURSE COMPONENTS:

### a. **Project Descriptions**

Students should read all project descriptions and arrange for a minimum of 3 meetings with potential project supervisors. Supervisors must be full time faculty members in the Department of Chemistry. Please note that potential supervisors cannot promise projects to students.

### b. **Project Preferences** – Due Monday July 11<sup>th</sup>, 2022 for first project selection round

Students should submit their project preferences by July 11<sup>th</sup>, 2022 by e-mail to the course coordinator ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca)). The forms for this submission are part of the project description booklet. Students submitting their project requests after July 11<sup>th</sup>, 2022 may only be able to choose from a smaller (i.e. remaining) set of available projects.

### c. **Project Assignments** – Available Monday August 1<sup>st</sup>, 2022

Students and supervisors will be informed regarding their projects on August 1<sup>st</sup>, 2022. It should be noted that every effort will be made to match students with their highest priority choices. However, this will not always be possible because multiple students may apply for the same project. Students applying for projects after August 1<sup>st</sup>, 2022 may do this up to the late registration deadline, however it is strongly encouraged that students start meeting with supervisors early on and submit their preferences as early as possible.

### d. **Signed Contract** – Due Friday September 16<sup>th</sup>, 2022 (to be provided to Mario Bieringer)

This is a binding contract between the student and the supervisor. The contract clearly defines the responsibilities of the student and supervisor equally. The signed contract should be submitted to Mario Bieringer (520c Parker Bldg.) or alternatively to the Chemistry Department Office (360 Parker Bldg.)

### e. **Written Progress Report** – Due Friday December 9<sup>th</sup>, 2022 (to be provided to Mario Bieringer)

The formal Progress Report will be handed in to the course coordinator by electronic mail for marking ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca)).

The report should consist of:

- a description of the goal(s) of the research project,
- a detailed survey of the relevant literature that puts the project in context,
- a description of the planned methods for the research project,
- a summary of your research results during the Fall term including experimental data.

The progress report should be about 2000 – 3000 words in length with **double-spaced pages** and will include any relevant figures and references (which are not included in the word count). It should conform to one of the formats described below for the Final Report. Students should have your research supervisor review and approve your report before handing it in to the course coordinator. It is essential that the report makes the project **clear to a scientifically literate but non-expert reader**.

The Progress Report is a crucial document that makes sure that projects are progressing, that there are no misunderstandings in terms of expectations and that the relevant literature has been digested. Students will receive the graded progress reports with comments will be important for preparing the final report and the oral presentation. In some cases the progress report may serve as a template for the final report, but this is not always the case. It is well worth the effort to ensure that the progress report is as complete as possible as this effort will pay off at the end of the course in March. Electronic progress reports must be received by e-mail by the end of day on Dec 9<sup>th</sup>, 2022 to be considered for credit in the course.

f. **Proposal** - Due Wednesday March 1<sup>st</sup>, 2023

The proposal is a 3 to 5 page document with additional figures and references based on the students research project. The proposal must address the next step related to the student's research project. There are a couple of possible options for this proposal. For example, if a student has experienced challenges that cannot be addressed in the current research group, the student may choose to write a proposal for access to an external research facility or a request for a collaboration. A proposal could also focus on obtaining specific materials (e.g. isotopes, experimental probes). Alternatively, the proposal can focus on developing the current emphasis of the project towards a new direction etc. Proposals should be discussed with and approved by the course coordinator no later than Feb. 1, 2023. The student will have to prepare a brief outline of the proposal before that meeting. The final proposal will be peer reviewed by 2 students and the course coordinator. The students need to submit their evaluations to the course coordinator by March 10<sup>th</sup>, 2023. Students will receive grades for their evaluations. The total proposal mark will be based on the quality of the student proposal and the 2 evaluations each student has submitted.

g. **Title and Abstract for oral presentation** - Due Thursday March 27<sup>th</sup>, 2023

The Title and Abstract must be e-mailed to Mario Bieringer ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca)) by Thursday March 27<sup>th</sup>, 2023. It is important to meet this deadline in order to create a presentation schedule on time for the oral presentation day.

h. **Oral Presentations** - Saturday April 1<sup>st</sup>, 2023

You will be required to give a 15 minute oral presentation summarizing your research project. The presentation will be followed by 5 minutes for questions. The presentations will be moderated by the course coordinator who will strictly follow the time limits. An oral presentation normally consists of an introduction, a brief description of relevant methods, results and discussion, and conclusions; the last slide is typically an acknowledgment of the advisor and assistance provided by others during the project. It is essential that students prepare and practice their presentations to effectively communicate their project within these time limits. There will be a scoring penalty for exceeding the 15 minute time limit on the presentation. The audience will consist of all professors involved in teaching CHEM4710, as well as all students in the course, plus other students or faculty who wish to attend the presentations. All members of the audience will be allowed to ask questions.

The final presentations are open to all members of the university community as well as the public and will be advertised on campus. Partners, parents as well as other family and friends are particularly welcome to attend.

The use of PowerPoint (or equivalent software) is now the standard for scientific presentations. You should plan to give your oral presentation using the computer that is provided in the room – or with your own laptop if you choose.

Each CHEM4710 advisor, including the course coordinator, will be involved in evaluating your talk. Other CHEM4710 students as well as other faculty members present will also be invited to provide input. However, the majority of the weighting will be given to the evaluations provided by the CHEM4710 advisors.

i. **Final Report** - Due Thursday April 13<sup>th</sup>, 2023 (12 days after the oral presentations)

This is a major part of the evaluation for the project course. It will be marked by two readers. One reader will be close to your research sub-discipline and will be proposed by your supervisor, the second reader will be a faculty member from the Department of Chemistry who is not an expert in your sub-discipline. You need to submit the final report as a properly formatted PDF document to the course coordinator ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca)). The course coordinator will distribute the reports to the two readers. Each reader will give your report a score out of 20 points, for a total of 40 points. It must be emphasized that the report has to be comprehensible to the general scientifically literate reader, and this will be taken into account in marking it. The report must show that you understand the context of the project as well as the actual experiments that you have done. The typical length for the final report is 6000 – 8000 words with double-spaced pages and including figures and references (which are not included in the word count). The exact length will depend on the style of reporting that is specific to the sub-discipline that your project falls in.

The final report must be a formal piece of scientific writing, with Introduction, Results, Discussion, Conclusion and Experimental (Methods) sections. You may find it more effective if the Results and Discussion sections are combined. The report should also include the relevant figures and references as needed to make the report complete and clear. It should follow the style conventions of an appropriate scientific journal, the American Chemical Society (ACS) journals provide good templates to follow. Stylistic rules are found on journal Web pages and students are encouraged to consult the journal (i.e. J. Am. Chem. Soc.; J. Org. Chem. or J. Phys. Chem., Biochemistry) most appropriate to their project. Another useful resource is the ACS Style Guide which is available online and in the library and can offer useful information on formatting and referencing. Consult your advisor before beginning to write, to determine an appropriate approach. Students should have a draft of the report completed by early-March. Advisors are urged to provide constructive comments on their students' draft reports before the final version is submitted.

Written reports should be reasonably free of typographical errors and be checked thoroughly for spelling and grammar. Frequent spelling or grammatical errors detract from the readability of your proposal, report or presentation, generate an impression of sloppiness with the audience, and will often result in a lower grade. The same applies to inconsistent formatting of text and figures in the report and references. Therefore, you are strongly advised to use the spelling and grammar checking functions on your word processing software. In addition, you will find the formatting and document handling features of the word processing software very useful. You are also strongly encouraged to use the "ACS 1996" template for formatting your ChemDraw structures. You should consider asking other members of your research group or another student in the project course to help proofread your documents. Your supervisor will be very willing to provide feedback on the content of your report, and this will be more meaningful on a report free of errors.

The target audience, for your proposal, oral presentation and formal reports, is a student at approximately your stage in the Chemistry or Biochemistry program who may not be familiar with the specifics of your

research project. The use of acronyms and shorthand notations should be kept to a minimum or fully explained. The formal report should attempt to describe in as much detail as possible all of the work you have done during the course of the project. However, in your oral presentation - where you have limited time - you may wish to provide a summary of the most significant results that you generated.

## VI) ADDITIONAL INFORMATION

### Conference Opportunities

- **The 2023 Western Canadian Undergraduate Chemistry Conference**  
It is highly recommended for all CHEM4710 students to consider presenting their research at the 2023 'Western Canadian Undergraduate Chemistry Conference' (WCUCC). This annual conference usually takes place in May in one of the universities west of Ontario. Date and place will be communicated at a later point in time. The format of oral presentations is identical to that used in CHEM4710, so you will already have a talk prepared by the time the course is complete. It is a superb opportunity for you to start some professional networking, and there are cash prizes for outstanding presentations. Interested students need to pre-register in January or February for this conference. There are some travel funds available for students (or groups of students) that intend to present at this conference.
- **Canadian Chemistry Conference and Exhibition (CCCE-2023)**  
The Canadian Chemistry Conference and Exhibition 2023 (CCCE-2023) is the national conference for chemists in Canada with up to 2000 delegates from all over Canada and a significant number of international speakers. The conference will be held in Vancouver from June 4<sup>th</sup> till June 8<sup>th</sup>, 2023 and will provide an excellent opportunity to highlight your research and to network with globally leading researchers. CHEM4710 students are encouraged to present their research at the CCCE-2023. The CHEM4710 project provides an excellent base for presenting a poster at that event. Note that conference registration is expected between the 1<sup>st</sup> week of January and mid February 2023.

## VII) ACADEMIC INTEGRITY POLICIES:

### Academic Dishonesty:

The University of Manitoba treats plagiarism and cheating as serious academic offenses.

- The complete documentation regarding cheating, plagiarism and fraud be accessed in the calendar at: [http://umanitoba.ca/student/resource/student\\_advocacy/cheating\\_plagiarism\\_fraud.html](http://umanitoba.ca/student/resource/student_advocacy/cheating_plagiarism_fraud.html)
- Additional documentation is available on the Faculty of Science website <https://sci.umanitoba.ca/statement-on-academic-dishonesty/>

END OF SYLLABUS

Project: #1

Interplay of Ion Conduction and Redox Processes  
in Tunable Solid State Frameworks

Dr. Mario Bieringer ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca), (204) 474 6258)

INTRODUCTION:

Crystalline solids are widely used in everyday life with applications as electronic, magnetic, optical and mechanical materials in many devices. Material sciences is a trillion dollar economy with a profound societal impact. Rather than viewing crystalline structures as static frameworks we can use parts of those structures as tunable frameworks and engineer interstitial materials. Tuning those materials directly impact electronic and ionic conduction and provides components for green energy applications such as batteries and fuel cells. In order to modify materials and implant functionality we need to be able to follow reactions in real time at high temperature while controlling reactive environments. This approach extends the traditional structure-function relation to structure-reactivity-function relations and thus turns from a static to a dynamic description of materials.

PROJECT:

We will prepare new ternary (A-Ln-O) and quaternary (A-B-Ln-O) lanthanide oxides (A, B = main group cations, Ln = 4f elements) and investigate their redox behavior with the goal to generate highly tunable materials. Ternary and quaternary oxides adopt a wide variety of structures including cation ordered perovskite phases, disordered bixbyites and fluorites, cation ordered zircons and pyrochlores to mention only a few. The goal of this project is to design preparation routes and exploit order/disorder as well as structural phase transitions in order to control physical properties of the target materials. Students will be exposed to solid state synthetic methods, structure determination, physical property measurements and scattering experiments using high temperature X-ray and neutron scattering. Familiarity with inorganic chemistry and willing to determine crystalline structures and characterize materials properties is beneficial. Laboratory skills and data analysis will be one of the many potential learning outcomes of this project.

References:

[1] D. Vrublevskiy et al., *Inorg. Chem.* (2021) **60**, 872-882

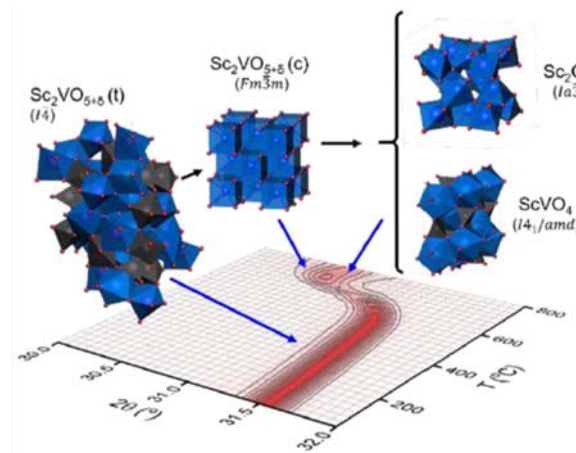


Fig. 1: Illustration of order-disorder structural evolution and product decomposition during oxidation of a reduced vanadate phase, as followed by high-T X-ray diffraction. [1]



Project: #2

# Preparation and Reactivity of $\text{ZrO}_2$ based Oxide Ion Conducting Materials for Solid Oxide Fuel Cell Applications

Dr. Mario Bieringer ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca), (204) 474 6258)

## INTRODUCTION:

Solid Oxide Fuel Cells (SOFCs) are highly efficient and fuel tolerant devices for the conversion of chemical energy directly to electrical energy. Fuel cells are compact and virtually maintenance free if exclusively designed with solid state materials. Currently the major drawback of SOFCs is the high operating temperature of almost  $1000^\circ\text{C}$ . In an effort to lower the operating temperature of SOFCs oxide defect structures based on  $\text{ZrO}_2$  are being synthesized and the formation of the oxide defects are investigated systematically, fig. 1.

## PROJECT:

Yttria stabilized zirconia,  $\text{Zr}_{1-x}\text{Y}_x\text{O}_{(2-x/2)}\square_{x/2}$

(where  $\square$  denotes oxide defects, i.e.

missing  $\text{O}^{2-}$  anions) are cubic fluorite

structures with randomized oxide defects.

In order to investigate the creation and annihilation of these oxide defects it is

proposed to replace  $\text{Y}^{3+}$  with  $\text{Pr}^{3+/4+}$

cations. With the addition of  $\text{Pr}^{4+}$  to  $\text{ZrO}_2$  a

redox active cation allows the reversible

removal of oxide anions during reduction

and repopulation of the oxide defects with

actual oxide ions during oxidation. In this project  $\text{Zr}_{1-x}\text{Pr}_x\text{O}_2$  will be prepared using high temperature

reactions. The reversible oxide uptake and removal will be investigated using in-situ powder X-ray

diffraction experiments and thermogravimetric analysis in order to determine structural details and

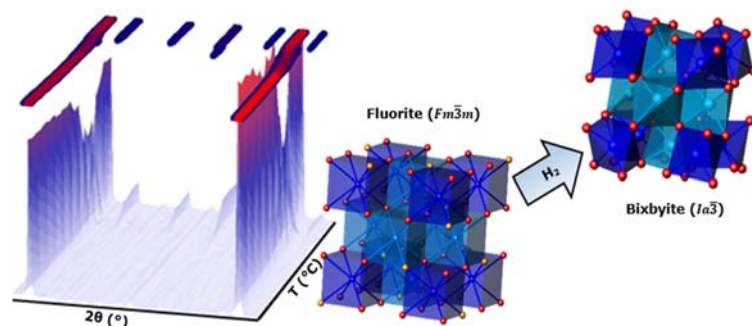
oxygen stoichiometries as a function of reaction conditions. Ion conductivities will be measured for this

system under redox conditions. Students carrying out this project should be familiar with inorganic

chemistry and willing to learn structure determination techniques for crystalline solids and be interested in

characterization of physical properties. Laboratory skills and data analysis will be one of the many

potential learning outcomes of this project.



**Figure 1:** Real time *in-situ* X-ray diffraction experiments illustrating the selected oxide removal from the disordered fluorite structure (right structural diagram) during reduction of  $\text{Y}_{(1-x)}\text{Pr}_x\text{O}_{3.5}$ .

## References:

- [1] J.A. Lussier, G. Devitt, K.M. Szkop, M. Bieringer, *J. Solid State Chem.*, (2016) **242**, 126–132
- [2] J.A. Lussier, K.M. Szkop, A.Z. Sharma, C.R. Wiebe, M. Bieringer, *Inorg. Chem.*, (2016) **55**, 2381–2389
- [3] J.A. Lussier, D.H.P. Souza, P.S. Whitfield, M. Bieringer, *Inorg. Chem.* (2018) **57**, 14106–14115



Project: #3

Preparation of Novel Quantum Magnets

Dr. Mario Bieringer ([Mario.Bieringer@UManitoba.ca](mailto:Mario.Bieringer@UManitoba.ca), (204) 474 6258)

INTRODUCTION:

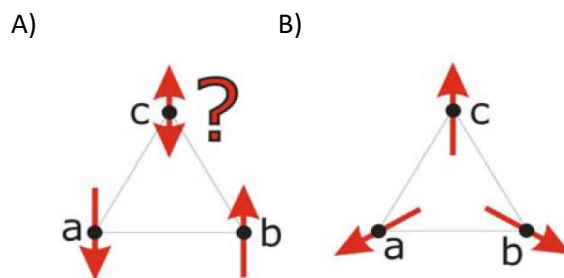
Materials science is largely based on solid state materials. Among magnetic materials particularly interesting are examples that do not show classical long range magnetic ordering at low temperatures. Magnetic ordering can be manipulated by disorder and competing magnetic exchange paths. E.g. a triangle of paramagnetic cations (e.g.  $V^{4+}$  or  $Ti^{3+}$ ) with antiferromagnetic coupling results in magnetic frustration, i.e. at least one of the magnetic moments is not able to satisfy all interactions simultaneously, see figure 1. For large magnetic moments a  $120^\circ$  compromise structure may be observed. In contrast small magnetic moments (e.g.  $d^1 \rightarrow S=1/2$ ) may form exotic magnetic ground states enhancing our fundamental understanding of magnetic interactions. This concept can be further expanded to tetrahedral motifs, see fig. 2. Quantum magnets fall into this category and are under intense investigation for quantum computing applications.

PROJECT:

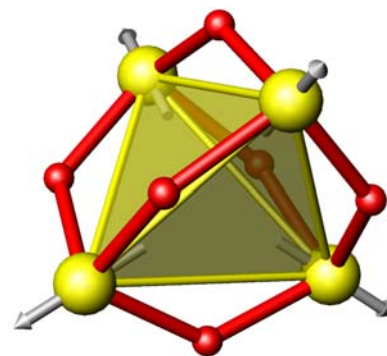
In this project novel materials with triangular and tetrahedral magnetic lattices will be synthesized and the transition metal oxidation states will be fine-tuned in order to realize quantum behaviour. The work will be based on  $ABO_3$  and  $ABO_4$  structures where A is a diamagnetic cation (Ca, Sr, La, Y, Lu etc.) and B is a redox active cation such as Ti, V, Cr, Mn or Fe etc. Notably the  $ABO_3$  and  $ABO_4$  samples are chosen in order to further reduce or oxidize the parent compounds under mild conditions (use of buffer gases and solid state hydrides in particular). This project consists of a synthetic component, a structure determination (diffraction) part in order to establish the newly generated phases and advanced physical property measurements. The advanced characterization will potentially include magnetic measurements, neutron scattering (NPD), X-ray photoelectron spectroscopy (XPS) and related EXAFS and XANES experiments. This project will provide students with a strong background in materials chemistry coupled with materials characterization.

REFERENCES:

- S. Nishimoto et al., *Nature Communications*. (2016) **7**, 10273
- B. Hernden, J.A. Lussier, M. Bieringer, *Inorg. Chem.* (2015), **54**, 4249–4256
- D. Vrublevskiy et al., *Inorg. Chem.* (2021) **60**, 872–882



**Figure 1:** A) Geometric magnetic frustration. 3 spins on a triangular lattice cannot align antiparallelly with respect to each other. B)  $120^\circ$  magnetic structure for large spins.



**Figure 2:** Tetrahedral spin arrangement on metals (yellow) with oxide (red) bridges responsible for magnetic exchange.

## Project: #4

### Adaptive laboratory evolution (ALE) of *Escherichia coli* and other microbes relevant to biocompatible plastic degradation

Prof. Dr. Ned Budisa ([nediljko.budisa@umanitoba.ca](mailto:nediljko.budisa@umanitoba.ca), <http://chemsynbio.com> )

#### INTRODUCTION:

Organofluorine and organohalogens compounds, which are used massively in industry, agriculture and human households, are also known as "inert" substances that have a strong tendency to accumulate and persist in soil and water, and are therefore extremely difficult to remediate. Microorganisms, and in particular bacteria, which have an exceptional ability to develop rapid metabolic or genetic responses to chemical stresses (such as *Escherichia coli* and *Pseudomonas putida*), are the most attractive research vehicles to develop new solutions to detoxify halogenated compounds, for example, by acquiring them as substrates for cellular biotransformations and growth. Our approach can also be considered as a strategy of biocompatible plastic degradation, as it is based on structures and processes found in nature.

The planned research should create a state-of-the-art environment for students and trainees to learn the discipline of synthetic biology and to provide the necessary infrastructure to supplement the existing faculty.

#### PROJECT:

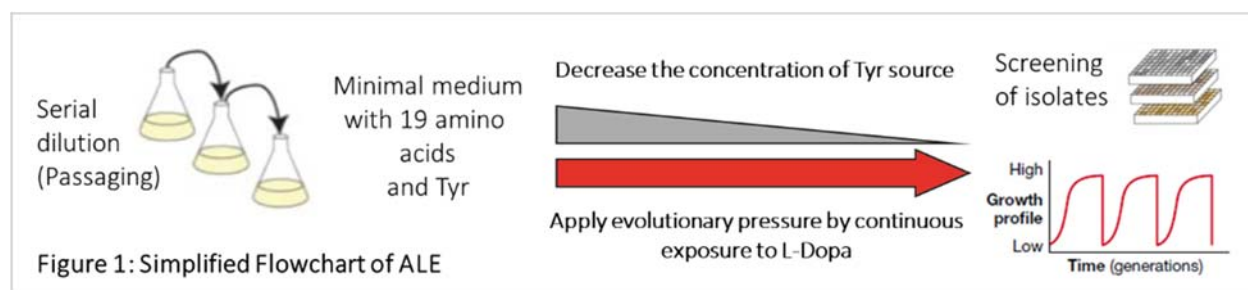
As the simplest experiment, we will set up adaptive laboratory evolution of *E. coli* cells thriving in an artificial medium containing fluorinated amino acids (e.g., fluoroprolines or fluoro-tyrosines) as an example of currently widely used aromatic and aliphatic organofluorine compounds. We will develop microbial cultures that are fully adapted to defined media containing fluorinated amino acids as environmental stressors in relatively short periods of time.

ALE experiments will be set up to evolve suitable auxotrophic *E. coli* strains to incorporate halogenated amino acids (Fig. 1). ALE experiments will be performed with multiple lineages (at least 4) so that adaptive mutations can be distinguished from hitchhiker mutations with properly designed control experiment. The analysis genomic mutations (UofM DNA Sequencing Services), dynamics of proteome (SILAC/TMT, in collaboration with Manitoba Centre for Proteomics and Systems Biology) and metabolomes of the adapted strains will enable us to set forward working hypotheses that need to be tested experimentally.

#### Reading:

M.G. Hoesl, S. Oehm, P. Durkin, E. Darmon, L. Peil, H-R. Aerni, J. Rappsilber, J. Rinehart, D. Leach, D. Söll, N. Budisa, *Chemical Evolution of a Bacterial Proteome*, *Angew. Chem. Int. Ed. Engl.* **2015**, 54, 10030–10034.

F. Agostini, L. Sinn, D. Petras, C.J. Schipp, V. Kubyshkin, A. A. Berger, J. Rappsilber, P.C. Dorrestein, N. Budisa, B. Kokschi, Multi-omics analysis provides insight into the laboratory evolution of *Escherichia coli* towards the metabolic usage of fluorinated indoles. *ACS Cent. Sci.* **2021**, 7, 1, 81–92.

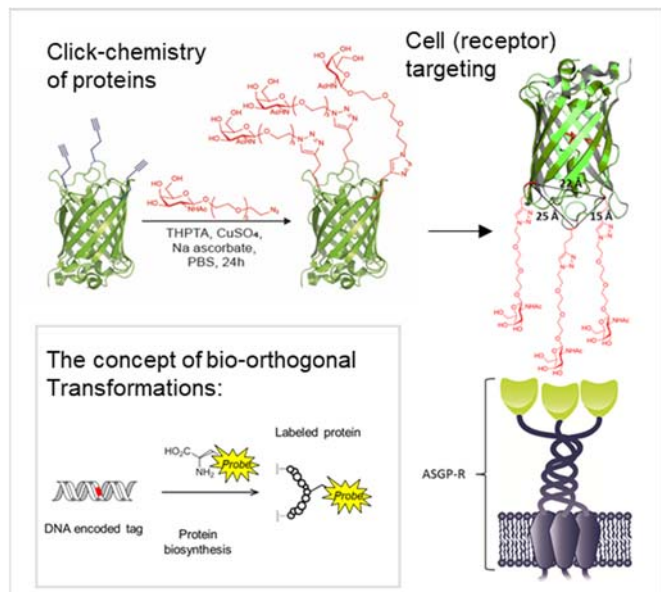


## Project: #5

### Design of therapeutic proteins by using click chemistry and an expanded genetic code

Prof. Dr. Ned Budisa ([nediljko.budisa@umanitoba.ca](mailto:nediljko.budisa@umanitoba.ca), <http://chemsynbio.com> )

#### INTRODUCTION:



Green fluorescent protein (GFP) is one of the most commonly used markers in molecular and cell biology. Its native fluorescent properties provide a functional read-out during cell targeting. The high stability and intrinsic fluorescence properties of the  $\beta$ -barrel structure makes GFP an ideal protein scaffold for the rational engineering of therapeutic proteins.

In particular, the GFP scaffold provides an efficient tool for investigation of multivalent receptors in living cells due to a simple, precise, and reproducible functional read-out: measurements by cell microscopy or flow cytometry of GFP fluorescence ensures the structural and functional integrity of the protein scaffold in live-cell experiments.

Furthermore, unlike synthetic polymers, nanogels and nanoparticles, the GFP scaffold is biocompatible, structurally robust and customisable, facilitating site-specific incorporation of unnatural amino acids (i.e., expanded genetic code) for the chemical conjugation of

different ligands via click-chemistry.

#### PROJECT:

We will synthesize protein-based therapeutic agents with protein scaffolds genetically competent for bioorthogonal ("clickable") conjugations. To establish the overall methodology, "clickable" green fluorescent protein (GFP) scaffolds will first be decorated with various ligands (e.g., commercially available lycopetide moieties) by genetically encoded click chemistry, and their activities will be monitored by flow cytometry and fluorescence microscopy. In the second stage (in collaboration with various groups from campus), we will use this technology to incorporate unnatural residues into the sequences of the target protein (e.g., GFP, bioadhesives, collagens, etc.) that would allow ligation of external components via click chemistry. Click chemistry (via the azide-alkyne reaction) is a common tool to ligate functional elements to biochemical scaffolds (see figure). The modular hybrid material produced as a result of this project should meet requirements important for clinical applications such as non-invasive monitoring.

#### Reading:

Y. Ma, H. Biava, R. Contestabile, N. Budisa, M. L. di Salvo, *Coupling Bioorthogonal Chemistries with Artificial Metabolism*, *Molecules* **2014**, *19*, 1004–1022.

D. Lauster, S. Klenk, K. Ludwig & et. al, N. Budisa, R. Netz, C. Böttcher, S. Liese, A. Herrmann, C.P. Hackenberger, *Phage capsid nanoparticles with defined ligand arrangement block influenza virus entry - an antiviral strategy*. *Nat Nanotechnol*, **2021**, *15*, 373–379.

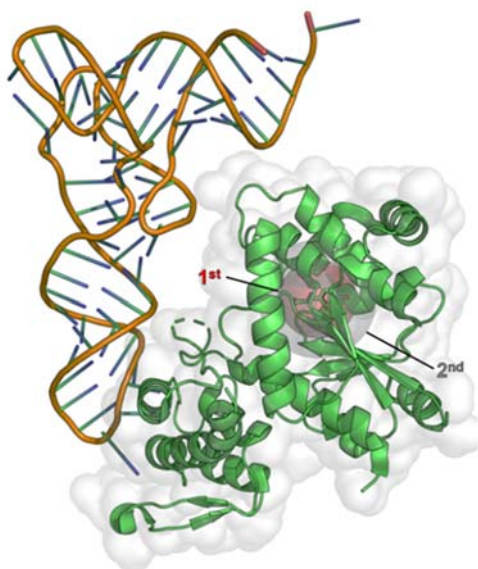
## Project: #6

### Orthogonal aminoacyl-tRNA ligases - crucial enzymes for the expansion of the genetic code

Prof. Dr. Ned Budisa ([nediljko.budisa@umanitoba.ca](mailto:nediljko.budisa@umanitoba.ca), <http://chemsynbio.com> )

#### INTRODUCTION:

Aminoacyl-tRNA synthetases (aaRSs) are an important class of enzymes crucial for maintaining accuracy during translation of the genetic code (i.e. they are responsible for the attachment of specific amino acids to their cognate tRNAs). The natural genetic code dictates which canonical amino acids are allowed for ribosomal translation. The expansion of their number beyond the canonical 20 requires a change in the substrate specificity of an aaRS, since these enzymes are crucial interpreters of the genetic code.



We are interested in expanding the genetic code by adding new unnatural amino acids to the existing amino acid repertoire to provide proteins and cells with new and unusual functions for specific applications. For example, this method enables the functionalization (e.g. cross-linking, conjugation, metal binding, conductivity, adhesiveness etc.) of protein structures in combination with genetic engineering and chemical methods (such as click chemistry).

#### PROJECT:

To determine the efficiency of such an unnatural translation, we need to know parameters related to the recognition and activation of unnatural amino acid substrates. We will take advantage of the fact that most aaRS enzymes can activate their amino acid substrate in the absence of tRNA. In particular, we will first express, purify and analytically characterize these enzymes. Next, we will determine the thermodynamic parameters of substrate binding by isothermal titration calorimetry and resolve high-resolution crystal structures of mutants. With these data in hand, we will gain important insights into how these molecular machines work. Finally, these parameters are also used to design optimally engineered, unnatural enzymes with good efficiency and improved accuracy.

#### Reading:

T. Baumann, M. Hauf, F. Schildhauer, K.B. Eberl, P.M. Durkin, E. Deniz, J.G. Löffler, C.G. Acevedo-Rocha, J. Jaric, B.M. Martins, H. Dobbek, J. Bredenbeck, N. Budisa. "Observation of Site-Resolved Vibrational Energy Transfer Using a Genetically Encoded Ultrafast Heater." *Angew. Chem. Int. Ed. Engl.*, **2019**, 58 (9), 2899-2903. doi: 10.1002/anie.201812995.

F. Agostini, J-S. Voller, B. Kokschi, C.G. Acevedo-Rocha, V. Kubyskhin, N. Budisa, Xenobiology meets enzymology: Exploring the potential of unnatural building blocks in Biocatalysis, *Angew. Chem. Int. Ed. Engl.*, **2017**, 56 (33), 9680-9703. doi: 10.1002/anie.201610129.

Project: #7

Synthetic Methodology Development targeting Highly Functionalized Furan Derivatives

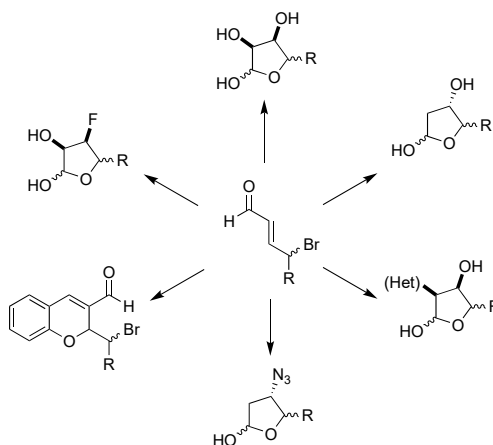
Dr. Rebecca Davis ([Rebecca.Davis@umanitoba.ca](mailto:Rebecca.Davis@umanitoba.ca))

INTRODUCTION:

Facile functionalization of five-membered heterocycles has long been a challenging task for organic synthesis. Asymmetric organocatalysis has emerged as a powerful synthetic methodology that has provided access to a variety of previously unachievable stereoselective transformations, resulting in a diverse array of chiral molecules. Currently, remote functionalization using dieneamine and trienamine activation are state-of-the-art in aminocatalysis, with a great deal of effort being devoted to the expansion of the scope of substrates available.<sup>1</sup> Using a combination of the a recently developed regioselective Wohl-Ziegler reaction and aminocatalysis we have devised a method for achieving functionalized five-membered heterocycles. This methodology will allow for rapid, scalable access to pharmaceutically relevant carbohydrates/nucleosides from cheap starting materials.

PROJECT:

The Davis lab recently developed a methodology for  $\gamma$ -functionalization of conjugated carbonyls that has brought forth a new route to create enantioselectively enriched heterocycles. Using these  $\gamma$ -functionalized carbonyls along with robust asymmetric aminocatalysis to add substituents to the  $\alpha$ - and  $\gamma$ - positions, cyclization of these compounds will allow us to create a simple method for production of enantioselectively substituted heterocycles. This work will provide efficient new routes to a wide range of natural product and has the potential to produce novel small molecule pharmaceuticals. The student involved in this project will learn advanced synthetic techniques as well as small molecule characterization techniques including HPLC-MS, GC, polarimetry, and NMR spectroscopy.



REFERENCES:

1 a) Kiler, L.; Tur, F.; Poulsen, P. H.; Jorgensen, K. A. *Chem. Soc. Rev.* **2017**, 46, 1080. b) Reboredo, S.; Parra, A.; Aleman, J. *Asymm. Cat.* **2014**, 1, 24.



## Project: #8

### Drug Discovery with Machine Learning

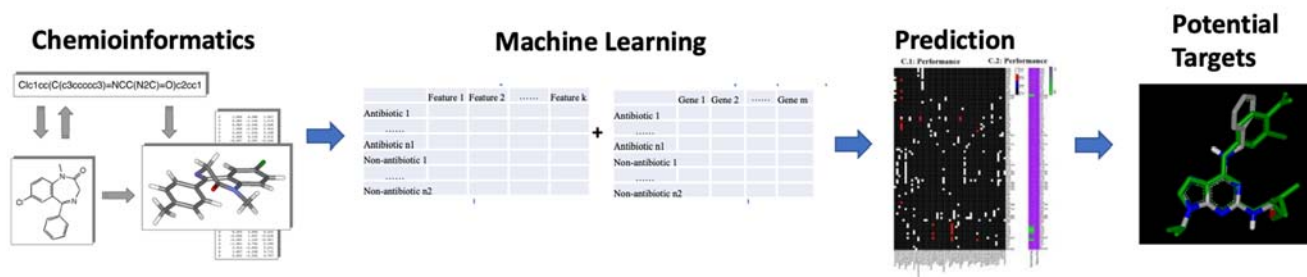
Dr. Rebecca Davis ([Rebecca.Davis@umanitoba.ca](mailto:Rebecca.Davis@umanitoba.ca))

#### INTRODUCTION:

The emergence of multidrug-resistant bacterial infections is a major modern health threat. Infections caused by Gram-negative bacteria are more worrisome as their cell envelopes are less permeable to antibiotics. Consequently, the development of novel antibiotic discovery strategies tailored to Gram-negative bacteria is a pressing need. As part of a multidisciplinary team, the Davis group is working to develop a deep learning tool to predict antibiotic activity.

#### PROJECT:

The proposed work aims to both work on the generation of small molecule libraries for screening and identification of potential antibiotics as well as to determine what features of molecules are necessary to determine antibiotic activity (helping to answer the question: How do we teach computers chemistry?). The student involved in this project will learn a variety of chemioinformatic tools to analyze small molecule libraries. This includes everything from standard ADMET property generation to the many features implemented in RDKit. We will also use 3D structure -specific features to describe antibiotics and non-antibiotics and link the compounds' 3D structures with chemogenomic profiles by using AI-based deep learning model.



#### REFERENCES:

- 1) Ji Lv, Senyi Deng, Le Zhang, "A review of artificial intelligence applications for antimicrobial resistance" (2021) *Biosafety and Health*, 3, 22-31.

Project: #9

Synthetic Development of High Order Cycloadditions

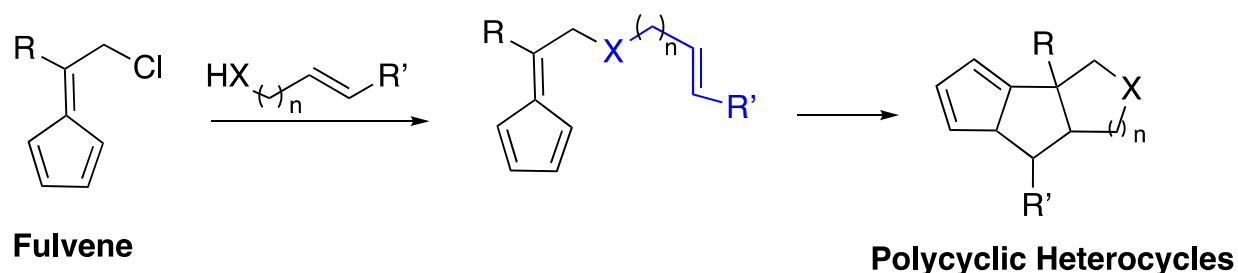
Dr. Rebecca Davis ([Rebecca.Davis@umanitoba.ca](mailto:Rebecca.Davis@umanitoba.ca))

INTRODUCTION:

Pericyclic reactions have long been a crucial element in facilitating complex molecule construction and the total synthesis of bioactive compounds. While early work in this area focused on small conjugated systems to form small ring systems in a predictable manner, cycloadditions involving higher conjugated systems have become the new target as they allow for the simultaneous construction of multiple rings. Building upon previous work in the Davis group, focused on understanding the behaviour of complex conjugated systems, new scaffolds for the construction of complex functionalized heterocycles has been devised.

PROJECT:

This project will explore the extended conjugated pi-system of fulvenes in order to perform higher-order cycloadditions. This methodology is based on a simple fulvene synthesis which will allow us to obtain a wide range of tricyclic structures bearing heteroatoms or full carbon skeletons. This work will provide efficient new routes to a wide range of natural product scaffolds and has the potential to produce novel small molecule pharmaceuticals. The student involved in this project will learn advanced synthetic techniques as well as small molecule characterization techniques including HPLC-MS, GC, polarimetry, and NMR spectroscopy.



REFERENCES:

1 a) Dourado, J.; Singh, S.; Davis, R. L.\* "Exploring the Role of Aminocatalysts in the Dearomatization and Regioselectivity of Heteroaromatic Aldehydes" *J. Org. Chem.*, **2021**, *86*, 11673

Project: #10

# FTIR spectrochemical imaging analysis of saturated fatty acid esters in ice algae from the Northwest Passage of the Canadian Arctic

Dr. Gough ([Kathleen.Gough@UManitoba.ca](mailto:Kathleen.Gough@UManitoba.ca), (204) 474-6262)

## INTRODUCTION:

Increasing Arctic temperatures, declining sea ice extent and thickness, later freeze-up, and an earlier but longer ice melting season are rapidly changing the environment of sea ice algae. Their photosynthetically-driven growth in the early Arctic spring is of key importance to the ecosystem, as they constitute a food source for larger organisms, contributing nearly half of the total annual primary production. In collaboration with Professor CJ Mundy (Environ & Geo, CEOS), students in the Gough research group have been analysing bio-nutrient composition with Fourier Transform InfraRed (FTIR) imaging.<sup>1</sup> We have shown that nutrient limitation, light alteration and changes in sea ice affect the normal health and population dynamics of sea ice diatoms.<sup>1,2</sup>

## PROJECT:

The project is focussed on the FTIR spectrochemical analysis of diatoms acquired from Cambridge Bay and Dease Strait, Nunavut, through the course of the Arctic spring. Typical methodology is described in [1] and N Pogorzelec, MSc (2020). We have established a reliable method for analysis of bulk samples. We also discovered that the diatom *Nitzschia frigida* stored salts of fatty esters (FAS) and the production of one specific FAS (Oravec et al, *MS in prep*). In this project, the student will conduct a controlled study to determine the influence of increasing light on biomass composition of *N. frigida*, and other species under low nutrient conditions, through FTIR imaging and analysis of diatoms that are currently stored at -80C. The student will prepare samples and use our FTIR microscope to obtain statistically significant data for their report (& publication). The goal is to gain a clearer picture of the winter to spring transition and their response to environmental stressors, thus helping to establish accurate ecosystem predictions with respect to climate change.

## REFERENCES:

1. NM Pogorzelec, CJ Mundy, CR Findlay, K Campbell, A Diaz, JK Ehn, S Rysgaard, KM Gough. *Marine Ecology Progress Series*, **69**:77-88 (2017).
2. K Campbell, CJ Mundy, C Belzile, A Delaforge, S Rysgaard *Polar Biol*, **41**:41-58 (2018).

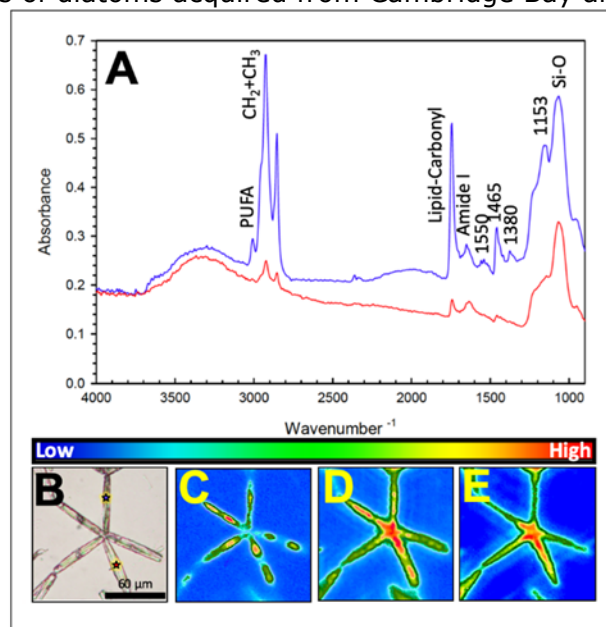


Fig. 1. Characteristic IR spectra and images of *N. frigida*. [1]



Project: #11

FTIR of Collagen in Self-Assembled Materials

Dr. Gough ([Kathleen.Gough@UManitoba.ca](mailto:Kathleen.Gough@UManitoba.ca), (204) 474-6262)

INTRODUCTION:

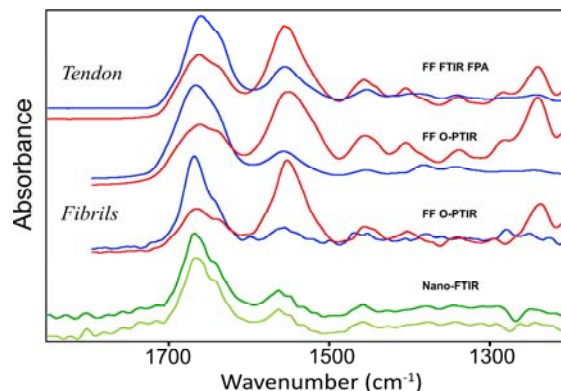
The functional properties of collagen-based mammalian tissues are determined by their complex hierarchical structures, chemical cross linking and post-translational modifications. Establishing the relationship between their structure and mechanical properties is key to understanding injury, scar formation, healing and remodelling events in mammals, and to the development of biomimetic scaffolds.

PROJECT:

Members of the Gough lab have been studying collagen in scar tissue and in tendon for many years. Collagen's unique triple helical structure at the molecular level translates into an unusual and very characteristic IR spectrum [1] that is conformation- and orientation-dependent in normal tissue and measurable in fibrils at the micro- and nano-scale (Figure 1). The proposed project is a new collaborative study of biomimetic scaffolds. With a collaborator at the University of Toronto, we are studying in vitro self-assembled scaffolds with polarized IR spectroscopic imaging. An important question that we aim to answer is how the aging process and the formation of advanced glycation end products affect inter-fibrillar cross-linking and the mechanical properties of collagenous materials. Synthetic scaffolds also offer tremendous scope for exploring disease processes [2].

The student will conduct experiments in spectrochemical imaging with the Agilent FTIR microscope in Dr. Gough's lab, and correlate results with students conducting AFM and other experiments in our collaborator's group. If feasible, some nanoFTIR experiments will be conducted remotely at the Advanced Light Source, Berkeley CA, USA.

The student will gain hands on experience with IR imaging and analysis, as a member of a collaborative interdisciplinary team. They will be a co-author on a publication, anticipated to be the outcome of this study.



**Fig.1:** Representative polarized IR spectra from Agilent Far-field IR microscope (top), Optical-PhotoThermal IR (middle) and near field IR (bottom) offset for clarity, illustrate the power of polarized IR studies to characterize collagen. Fig. 5 in *Molecules* 2020. [Ref.1],

REFERENCES:

1. G Bakir, BE Girouard, R Wiens, S Mastel, E Dillon, M Kansiz, K Gough, *Molecules* 25:4295 (2020).
2. CM Schuc, B Benso, PA Naulin, NP Barrera, L Bozec, S. Aguayo, *J. Dental Res.* 100:82-89 (2020).

## Project: #12

### Designer Molecules for Sustainable Energy Capture and Conversion

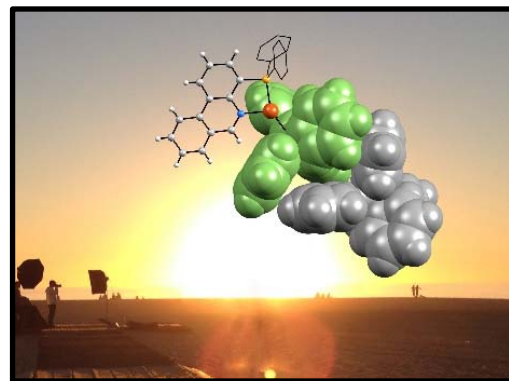
Dr. David Herbert ([david.herbert@umanitoba.ca](mailto:david.herbert@umanitoba.ca), <http://home.cc.umanitoba.ca/~dherbert/>)  
(204) 474-7535)

#### INTRODUCTION:

As the world's population grows, so too does the global demand for materials and energy. The ability to harvest solar energy (solar cells) and manipulate light output (display technologies and low-cost/energy usage lighting) using *abundant* materials will be key to providing a high global quality of life to as many people as possible, while limiting the impact of making and using these materials on our climate and environment.

#### PROJECT: *Designing emissive molecules and materials for solar energy capture and conversion*

As part of our group's broader efforts to target new dyes to harvest solar energy based on abundant elements such as iron (Fe), and new emissive materials based on copper (Cu) and zinc (Zn), we are designing ligand motifs for transition metals and constructing their transition metal coordination complexes, where we modify the molecular structure of **ligands** through **chemical synthesis** in order to tune the photophysical and electrochemical properties of complexes. In doing so, we target molecules that can absorb a broad range of the electromagnetic spectrum across the visible and, ideally, into the near-IR, and allow for tuneable emission from complexes of abundant metals.



This project requires an enthusiastic and engaged student interested in **sustainable chemistry** and learning about **synthesis**, how to manipulate air- and moisture-sensitive reagents, and characterization techniques including single-crystal X-ray diffraction, cyclic voltammetry, multi-nuclear NMR and absorption/emission spectroscopy. A 4710 student will work directly alongside Dr. Herbert and a graduate student mentor to construct their own novel ligand and form coordination complexes. Working as part of this team, the student will evaluate their complexes' properties to examine their suitability in energy and sustainable chemistry applications.

#### REFERENCES:

- I.B. Lozada, J.A.G. Williams, D.E. Herbert *Inorg. Chem. Front.* **2022**, 9, 10-22  
C.B. Larsen, J.D. Braun, I.B. Lozada, K. Kunnus, E. Biasin, C. Kolodziej, C. Burda, A. Cordones, K. Gaffney, D.E. Herbert *J. Am. Chem. Soc.* **2021**, 143, 2064  
R.J. Ortiz, J.D. Braun, J.A.G. Williams, D.E. Herbert *Inorg. Chem.* **2021**, 60, 16881

Project: #13

Scaffold Hopping by Photochemical Carbon Deletion  
from Benzannulated Azaarenes

Dr. David Herbert ([david.herbert@umanitoba.ca](mailto:david.herbert@umanitoba.ca), <http://home.cc.umanitoba.ca/~dherbert/>)  
(204) 474-7535)

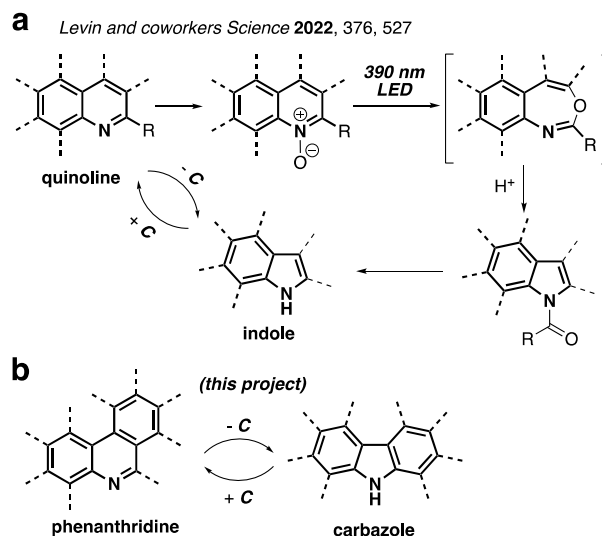
INTRODUCTION:

Chemists often identify molecular structures that show promise for a specific application, for example, as chemotherapeutics, molecular electronics, or solar materials. The preparation of each new candidate molecule in a series can often require a completely new synthetic approach if the **core** of the molecule needs to be altered. Synthetic methodologies that can easily and directly interconvert between molecular cores are tantalizingly attractive ways to streamline molecular discovery.

PROJECT:

Very recently, chemists at the University of Chicago reported<sup>[1]</sup> an exciting new approach to 'hop' directly between chemically distinct heteroaromatic scaffolds, namely quinoline *N*-oxides and *N*-acylindoles (**a**). We have developed synthetic routes to functionalized phenanthridines, also known as benzo[*c*]quinolines,<sup>[2]</sup> and demonstrated their use in diverse applications including as emissive materials.<sup>[3]</sup> This project will involve applying this scaffold hopping protocol to convert **phenanthridine *N*-oxides** to **carbazoles** to investigate the extension of this exciting work to *benzannulated azaarenes* (**b**).

This project requires an enthusiastic and engaged student interested in **sustainable chemistry** and learning about **chemical synthesis**, in particular the use of **photochemistry**. A 4710 student will work directly alongside Dr. Herbert and a graduate student mentor to develop an **optimized protocol** for ring-contraction starting with 6-methyl phenanthridine *N*-oxide. The starting materials will be characterized using multinuclear NMR and UV-Vis absorption spectroscopy. A photochemical protocol using an LED photoreactor will be developed, and products isolated and analyzed chemically. Once an optimized procedure is established, the 4710 project will then look to establish a **substrate scope** for this transformation using a library of phenanthridine *N*-oxides prepared using our pre-existing library of available substituted phenanthridines.



REFERENCES:

- [1] J. Woo, A.H. Christian, S.A. Burgees, Y. Jiang, U.F. Mansoor, M.D. Levin *Science* **2022**, 376, 527
- [2] P. Mandapati, J.D. Braun, I.B. Lozada, J.A.G. Williams, D.E. Herbert *Inorg. Chem.* **2020**, 59, 12504
- [3] I.B. Lozada, R.J. Ortiz, J.D. Braun, J.A.G. Williams, D.E. Herbert *J. Org. Chem.* **2022**, 87, 184

Project: #14

Interactions of the snR30 RNA with proteins during ribosome assembly

Dr. Ute Kothe ([Ute.Kothe@UManitoba.ca](mailto:Ute.Kothe@UManitoba.ca), (204) 474 9265)

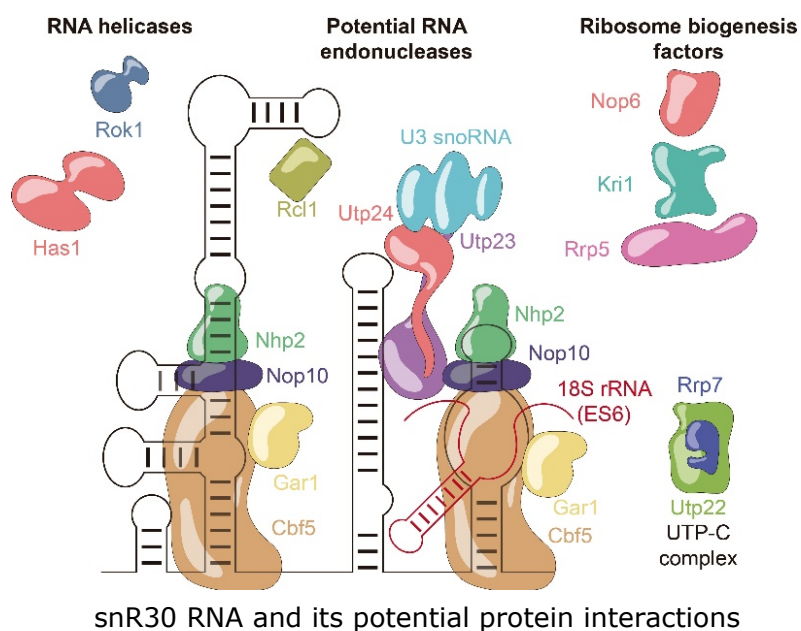
**INTRODUCTION:**

Ribosome assembly is a multistep process that generates the cell's protein synthesis machinery called ribosome which is composed of both large ribosomal RNAs (rRNA) and many proteins. In addition to rRNA and ribosomal proteins, hundreds of additional proteins and small nucleolar RNAs (snoRNAs) assist with ribosome biogenesis by transiently interacting with ribosome precursors. The Kothe group aims to understand the molecular mechanisms how these proteins and snoRNAs facilitate ribosome assembly with the long-term goal of identifying strategies to inhibit ribosome formation in rapidly growing cancer cells.

**PROJECT:**

The objective of this project is to identify the importance of different regions in the snoRNA called snR30 for the interaction with other proteins involved in ribosome assembly. snR30 is the only essential H/ACA snoRNA in yeast and is required for the processing of rRNA from a long precursor to its mature form. However, the molecular mechanism of snR30 and its interactions with the precursor ribosome remain poorly understood [1].

This project is based on previous work in the Kothe lab where we have identified mutations in the internal hairpin of snR30 that cause temperature sensitivity suggesting that this region is functionally important. Here, we will take a predominantly biochemical approach to identify the interactions of the internal hairpin in snR30 with purified proteins [2, 3]. Towards this goal, you will in vitro transcribe and purify snR30 variants harboring mutations, and you will also purify selected proteins such as Utp23. RNA-protein interaction assays will be completed together with an experienced lab member. If time permits, we may also assess snR30-protein interactions in baker's yeast through co-purification.



**REFERENCES:**

- [1] Vos TJ, Kothe U. snR30/U17 Small Nucleolar Ribonucleoprotein: A Critical Player during Ribosome Biogenesis. *Cells* 2020, 9(10):2195. doi: 10.3390/cells9102195
- [2] Caton EA et al. Efficient RNA pseudouridylation by eukaryotic H/ACA ribonucleoproteins requires high affinity binding and correct positioning of guide RNA. *Nucleic Acids Research* 2018, 46(2):905-916. doi: 10.1093/nar/gkx1167.

### Project: #15

## Polymer Batteries: Intercalation in Conducting Polymer – Polyanion Composites

Dr. Christian Kuss ([Christian.Kuss@UManitoba.ca](mailto:Christian.Kuss@UManitoba.ca), (204) 486 1823)

### INTRODUCTION:

Climate change is one of the most pressing global issues and emission reductions are the only long-term sustainable solution. This requires a transition from fossil fuels to renewable energy sources. Since these are less mobile and less controllable, batteries are a key enabling technology. Recognizing the importance of battery technology, the 2019 Nobel Prize in Chemistry went to John Goodenough, Stanley Whittingham and Akiro Yoshino for the development of lithium-ion batteries. Yoshino was the first to put a full lithium-ion battery together, and he used polyacetylene, a conducting polymer, as first anode<sup>1</sup>.

### PROJECT:

In my group, we are developing nano-composites of conducting polymers with polyanions for their application as binders in battery electrodes<sup>2</sup>. These composites have a number of advantages over standard binders, of which their contribution to charge storage is the topic of this honours project.

Standard lithium ion battery electrodes consist of the charge-storing material and an electrochemically inactive matrix. Conducting polymer – polyanion composites replace this inactive matrix with one that can contribute to the charge storing mechanism and reduce dead weight and volume<sup>3</sup>. This project will involve a combination of finite-element models and experiments to investigate the capacity, rate and depth of charge of these materials. Chemically sensitive electron microscopy and electrochemical experiments will allow determination of the empirical capacity, its charge rate dependence and the distribution of these charges within the material. The experimental performance measures can then be compared to expected behavior from a microscopic model, improving our understanding of charge storage in these composites.

Lithium-ion batteries have massively improved in performance in the past two decades, based on new and optimized charge-storing materials. Further improvement hinges on more than just the charge-storing materials: new electrode matrices and electrolytes are critical enablers of the next generation of batteries. This work will inform the design of a novel class of electrode matrix that can minimize dead weight and improve cycling life of new batteries.

### REFERENCES:

1. A. Yoshino, *Angew. Chemie - Int. Ed.* (2012).
2. V. A. Nguyen and C. Kuss, *J. Electrochem. Soc.* (2020).
3. G. Bidan, B. Ehui, and M. Lapkowski, *J. Phys. D. Appl. Phys.*, **21**, 1043–1054 (1988).



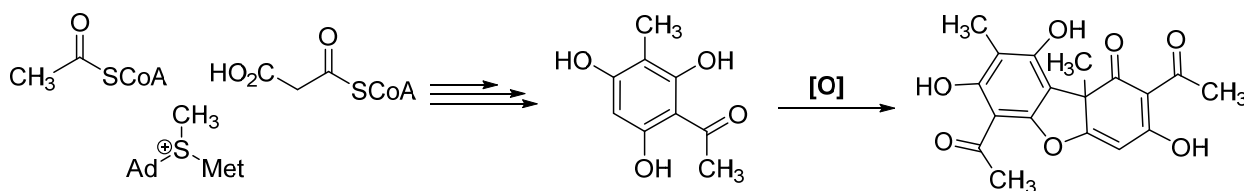
Project: #16

Investigation of Usnic Acid Biosynthesis by Electrochemistry

Dr. Sabine Kuss ([Sabine.Kuss@umanitoba.ca](mailto:Sabine.Kuss@umanitoba.ca), (204) 272 1693)  
 Dr. John Sorensen ([John.Sorensen@umanitoba.ca](mailto:John.Sorensen@umanitoba.ca), (204) 474 9504)  
 Group Website: [www.bioanalyticschemistry.com](http://www.bioanalyticschemistry.com)

INTRODUCTION:

This project presents a synergy of research in the fields of bio-organic chemistry and electrochemistry and aims to contribute to the understanding of the biosynthesis of usnic acid in lichens. Usnic acid is a polyketide produced by lichen species native to Northern Manitoba and displays antibacterial activity as well as the ability to halt the growth of cancerous cells.[1] Unfortunately, lichens grow extremely slowly, making them unsuitable for commercial production of Usnic Acid. A full understanding of the biosynthesis will allow us to develop efficient large scale production methods.



Scheme 1: The biosynthesis of Usnic Acid.

PROJECT:

Usnic acid is biosynthesised in lichens by the oxidative coupling of two molecules of methylphloroacetophenone which in turn is produced from acetyl-CoA, malonyl-CoA and a methyl group from SAM. [2] The dimerization step is carried out by a member of the cytochrome P<sub>450</sub> family of enzymes. However, very little is known about the mechanism of how this reaction takes place. In this project, electrochemistry will aid to understand details of this biosynthesis, such as the step-by-step mechanism, and aims to identify the oxidative enzyme involved. The student on this project will be trained in electrochemical methods, such as voltammetry and amperometry [3] to get insight into electrochemical sensing techniques, as well as the characterization techniques mass spectrometry and scanning electron microscopy.



Figure 1: Lichens collected by the Sorensen Lab. Picture taken by Dr. Horace Luong.

REFERENCES:

1. Cardarelli, M., *et al.*, Cellular and Molecular Life Sciences CMLS, 1997. 53(8): p. 667-672.
2. Taguchi, H., *et al.* Tetrahedron Letters, 1966. 7(42): p. 5211-5214.
3. Compton, R.G. and C.E. Banks, Understanding voltammetry, 2nd edition. 2010. 1-430.

Project: #17

## Detection of Cytochrome C Oxidase Deficiency by Electrochemistry

Dr. Sabine Kuss ([Sabine.Kuss@umanitoba.ca](mailto:Sabine.Kuss@umanitoba.ca), (204) 272 1693)

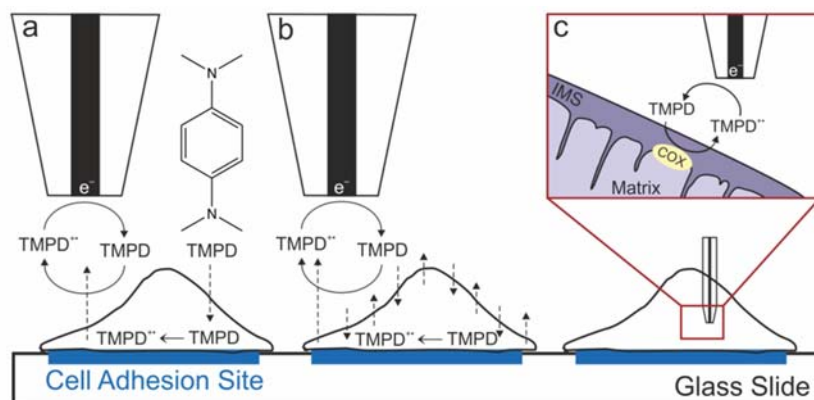
Group Website: [www.bioanalyticschemistry.com](http://www.bioanalyticschemistry.com)

### INTRODUCTION:

Cytochrome c Oxidase (COX) deficiency represents the most common childhood mitochondrial disorder [1] and results in a variety of health issues affecting the brain, the heart, the intestinal tract system and other crucial body functions.[2] There is currently no cure for COX deficiency related diseases. The long term goal of this project is to develop an early, accurate, rapid and cost efficient electrochemical biosensor for COX deficiency.

### PROJECT:

COX detection will be based on the principle of the electrochemical sensing of COX in living bacteria using N,N,N',N'-tetramethyl-para-phenylene-diamine (TMPD), which serves as COX indicator.[3] This concept will be transferred to mammalian model systems, such as skeletal muscle cells, which will be analyzed by Scanning Electrochemical Microscopy (SECM). SECM is a bioanalytical instrument, employing a micro- or nanoscale electrode, which is rastered across a surface to analyze its electrochemical activity. An integrated optical microscope allows cell observation at the same time as performing electrochemical measurements.[4] Immobilized cells will be analyzed in different approaches, summarized in Figure 1. A microelectrode will be positioned in close proximity to a living cell to recognize COX activity. Alternatively, a nanoelectrode will penetrate a cell to detect COX activity intracellularly.



**Figure 1:** COX monitoring in single mammalian cells by SECM. a) TMPD diffuses into an immobilized cell, and is converted intracellularly to TMPD<sup>••</sup>. Leaving the cell, TMPD<sup>••</sup> can be recognized at an electrode. b) Permeabilization of the cell membrane results in an enhanced species transport in and out of the cell. c) Nanoelectrodes can penetrate a cell and recognize TMPD<sup>••</sup> in close proximity to mitochondria.

The quantitative sensing of COX activity has the potential to improve future medical diagnostics and shorten the recognition time of COX deficiency in patients. This is a challenging interdisciplinary project connecting analytical chemistry, electrochemistry and medical research.

### REFERENCES:

- [1] M. Bohm et al. *Pediatr Res*, 2006, 59, 21.
- [2] P. F. Chinnery, in *Goldman's Cecil Medicine: Twenty Fourth Edition*, 2011, vol. 2, 2409.
- [3] S. Kuss et al. *Chem. Sci.*, 2017, 8, 7682.
- [4] J. Mauzeroll et al. *Scanning Electrochem. Microsc.*, 2012, 379.

### Project: #18

## Structural Characterization of RNA-Protein Complexes that Regulate Translational Control

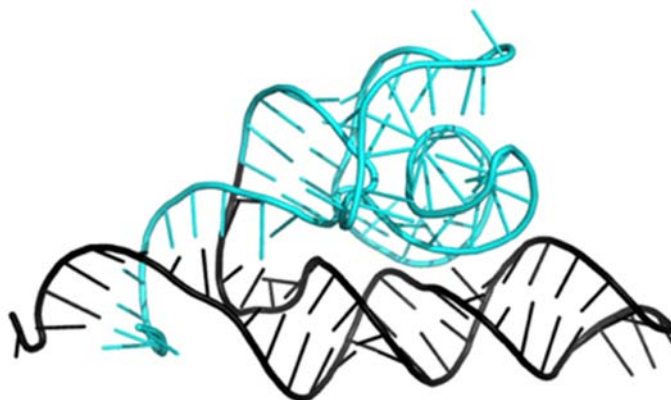
Dr. Sean McKenna ([Sean.McKenna@UManitoba.ca](mailto:Sean.McKenna@UManitoba.ca))

### INTRODUCTION:

Brain Cytoplasmic RNA 1 (BC200) is a 200 nucleotide long non-coding RNA that is hypothesized to regulate protein translation. We have begun to define the BC200-containing protein complexes that mediate BC200 function through immunoprecipitations of the RNA coupled with mass spectrometry analysis of bound proteins. From hundreds of potential hits, we have cross-validated a small subset of proteins that we suspect directly interact with BC200. Our current hypothesis is that BC200 acts as a scaffold for a protein regulatory complex that interacts with messenger RNAs to regulate translation.

### PROJECT:

The proposed research project will use a combination of biochemistry, structural biology, and molecular biology to characterize the direct interactions between BC200 and target proteins identified from our screen. Molecular biology approaches coupled with bacterial/eukaryotic expression systems will be used to produce the BC200 binding partners (starting with one initially and building to more as time permits). Expression/purification protocols will need to be individually developed for each protein. BC200 will be produced (using an established protocol) using *in vitro* transcription, as will a series of BC200 truncations (to probe the specific regions responsible for binding). RNA-protein binding affinity and complex stability will be evaluated. Promising complexes will be structurally characterized using cryo-electron microscopy approaches.



### REFERENCES:

- Booy, E.P., *et. al.* (2021) "BC200 associates with polysomes to positively regulate mRNA translation in tumour cells." *Journal of Biological Chemistry*. 296: 1000-36.
- Booy E.P., *et. al.* (2018) " Comprehensive analysis of the BC200 ribonucleoprotein reveals a reciprocal regulatory function with CSDE1/UNR." *Nucleic Acids Research*. 46(21): 11575-11591.



## Project: #19

### Characterization of Viral RNA-Protein Interactions Central to Innate Immunity

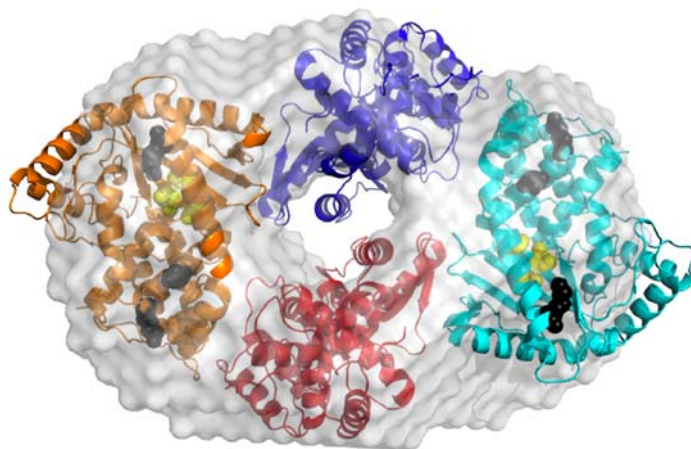
Dr. Sean McKenna ([Sean.McKenna@umanitoba.ca](mailto:Sean.McKenna@umanitoba.ca))

#### INTRODUCTION:

Host detection of viral pathogens by the innate immune response is an effective first line of defense against infection. The innate immune system relies heavily on protein recognition of evolutionarily conserved viral nucleic acid structures to stimulate interferon production that prepares neighboring cells for attack. Viral double-stranded RNA (dsRNA) from the viral genome serves as a potent stimulator of the interferon response. The interferon response then up-regulates the transcription of additional antiviral effector proteins to enhance the initial innate immune response. My laboratory studies one such effector protein family in humans, the 2'-5'-oligoadenylate synthetases (OAS), and these enzymes specifically bind viral dsRNA and ultimately restrict viral protein translation through their catalytic activity. However, an understanding of how these enzymes discriminate viral from similar host dsRNA remains a key unresolved feature of this system.

#### PROJECT:

The proposed research project will use a combination of biochemistry, structural biology, and molecular biology to characterize the interaction between OAS enzymes and the highly structured ends of viral RNA genomes. Our group has already characterized these interactions for a flavivirus, West Nile virus, and would like to extend these studies to include similar regions from other flaviviruses and coronaviruses. We have produced safe, short, structured dsRNA regions, and we have established methods to express/purify OAS enzymes. RNA-protein binding affinity will be measured using a combination of gel-based approaches, microscale thermophoresis, and isothermal titration calorimetry. OAS enzyme activity upon viral RNA binding will be measured using a colorimetric assay. Time permitting, minimal RNA-OAS complexes sufficient for binding and catalytic activity will be investigated using cryo-electron microscopy. The potential results from the project represent an important step in understanding how innate immunity enzymes can recognize viral RNA.



#### REFERENCES:

- Koul, A., *et.al.* (2020) "Structural and hydrodynamic characterization of dimeric human oligoadenylate synthetase 2". *Biophysical Journal*. 119(11): 2726-40.
- Koul, A., *et. al.* (2019) "Impact of double-stranded RNA characteristics on the activation of human 2'-5'-oligoadenylate synthetase 2". *Biochemistry and Cell Biology*. Bcb-2019-0060.

## Project: #20

### Probing the Structure-Function Relationship of Dynamic Bacterial Proteases

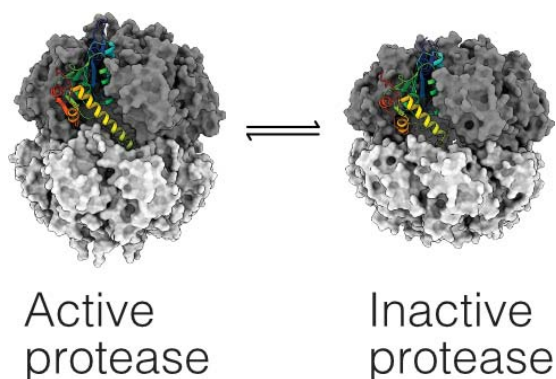
Dr. Zev Ripstein ([Zev.Ripstein@UManitoba.ca](mailto:Zev.Ripstein@UManitoba.ca), (204) 474 8504)

#### INTRODUCTION:

Macromolecular protein degradation machinery assumes a central role in cellular physiology, from the timing of cell division, to stress responses, and the removal of damaged or aberrantly folded proteins. As such the protease machinery responsible for these functions are critical factors in the virulence pathways of many pathogenic organisms. ClpPs are a conserved family of serine proteases that collaborate with ATP-dependent translocases to degrade protein substrates.

#### PROJECT:

Drugs targeting these enzymes have attracted interest for the treatment of cancer and bacterial infections due to their critical role in mitochondrial and bacterial proteostasis, respectively. As such, there is significant interest in understanding structure–function relationships for this protein family. This research project will focus on producing and characterizing small peptides that interact with the ClpP machinery. This project will complement my lab's ongoing work using structural information from **cryoEM**, coupled with other biochemical and biophysical tools to gain insight into how ClpPs exploit their rugged energy landscapes to enable key conformational changes that regulate their function.



#### REFERENCES:

1. Ripstein ZA, Vahidi S, Rubinstein JL, Kay LE. A pH-Dependent Conformational Switch Controls *N. meningitidis* ClpP Protease Function. J Am Chem Soc. 2020 Dec 9;142(49):20519-20523. PubMed PMID: 33232135.
2. Vahidi S, Ripstein ZA, Juravsky JB, Rennella E, Goldberg AL, Mittermaier AK, Rubinstein JL, Kay LE. An allosteric switch regulates *Mycobacterium tuberculosis* ClpP1P2 protease function as established by cryo-EM and methyl-TROSY NMR. Proc Natl Acad Sci U S A. 2020 Mar 17;117(11):5895-5906. PubMed Central PMCID: PMC7084164.

## Project: #21

### First Principle Design and Development of Multifunctional van der Waals Solids

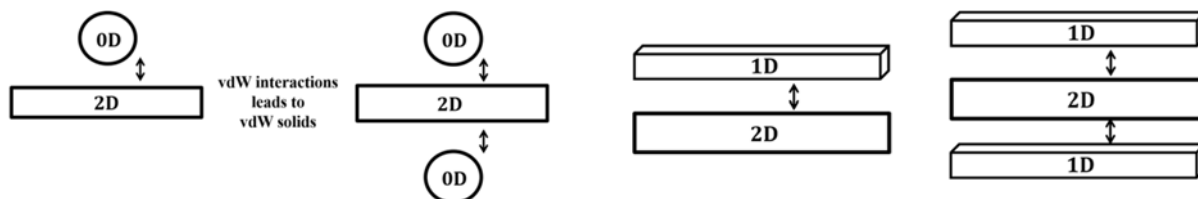
Dr. Georg Schreckenbach ([Georg.Schreckenbach@umanitoba.ca](mailto:Georg.Schreckenbach@umanitoba.ca), (204) 474-6261)

#### INTRODUCTION:

2D van der Waals (vdW) layered materials, which have a strong covalent bonding within the layer and weak vdW interaction between the layers, possess unique layer-dependent features distinct from bulk materials.<sup>1</sup> It is well known that the interaction between any two layers in 2D materials is due to the van der Waals interaction. The feasibility to extract individual layers from these solids has created new avenues in the designing of new materials.

#### PROJECT:

The development of new mixed dimensional van der Waals solids is an emerging topic of research owing to their exceptional electronic, physical and chemical properties. The inherent covalent connectivity and the interlayer non covalent interactions make these materials interesting to the scientific world. Though some of the 2D materials of this kind are explored both experimentally and theoretically, there are room for many novel materials.



Schematic representation of Designing mechanism of Novel 0D-2D and 1D-2D materials

0D models under consideration: Quantum Dots of various carbon, metal oxides and pure metals especially Au and Pt and biologically important molecules like porphyrin etc.

1D models under consideration: various nanoribbons for example, graphene nano ribbons, h-BN etc.

2D models under consideration: MoS<sub>2</sub> and its analogues, CrI<sub>3</sub> and various 2D magnetic materials.

#### REFERENCES:

1. A. K. Geim and I. V. Grigorieva, Nature, 499, 419 (2013)

### Project: #22

## Piezoelectricity in Two-Dimensional Materials: A DFT Study

Dr. Georg Schreckenbach ([Georg.Schreckenbach@umanitoba.ca](mailto:Georg.Schreckenbach@umanitoba.ca), (204) 474-6261)

### INTRODUCTION:

Two dimensional (2D) materials exhibit unique properties and applications different from their bulk counterparts. This has been demonstrated by various experiments and theoretical works. Since the exfoliation of graphene from graphite, numerous 2D materials have been successfully exfoliated from bulk layered solids such as hexagonal boron nitride (h-BN), transition metal dichalcogenides (TMDs) and phosphorene.

### PROJECT:

2D materials are promising materials in the field of piezoelectricity as they can sustain large deformation<sup>1</sup> which is favourable for energy conversion between electrical and mechanical energy. Good piezoelectric materials require non-centrosymmetry and a band gap.<sup>2</sup> Hence, the current project aims to explore the various van der Waals and lateral heterostructures of TMDs for piezoelectric application using computational tools. It also intends to understand the relationship between piezoelectric coefficients and polarizabilities of the anion and cation in various TMDs.

### REFERENCES:

1. Alam, M. N. A., and Nolan, M. Negative Piezoelectric Coefficient in Ferromagnetic 1H-LaBr<sub>2</sub> Monolayer. ACS Appl. Electron. Mater., 4, 850-855 (2022)
2. Duerloo, K.-A. N., Ong, M. T. and Reed, E. J. Intrinsic piezoelectricity in two-dimensional materials. J. Phys. Chem. Lett. 3, 2871-2876 (2012).

## Project: #23

### Computational Actinium Chemistry

Dr. H. Georg Schreckenbach ([schrecke@cc.umanitoba.ca](mailto:schrecke@cc.umanitoba.ca), 204-474-6261)

#### INTRODUCTION:

"Theoretical actinide molecular science", quantum-chemical modeling of actinide complexes, is motivated by fundamental and practical considerations. [1] Fundamental interest arises because of the unique chemistry of these elements. For instance, it is only in this part of the periodic table that f-orbitals contribute significantly to bonding. A novel practical application comes with the proposal to apply the actinium isotope  $^{225}\text{Ac}$  (half-life 10 days) as a radiotherapeutic agent for cancer treatment, particularly for difficult to treat late-stage cancers. [2, 3]

#### PROJECT:

The chemistry of actinium is not very well known [4] since all of its isotopes are highly radioactive, and the element occurs naturally only in trace amounts. (The most stable isotope,  $^{227}\text{Ac}$ , has a half-life of about 22 years.) Therefore, it is the **goal of the project** to use *computational chemistry* to fill in some of these knowledge gaps. Actinium is quite intriguing chemically in that it behaves essentially as a transition metal but has empty 5f orbitals that are in principle available for bonding as well.

Following a recent study from our group [5] and using the known [2] Ac aquo complex as reference point, the project student will model complexes with various small, biologically relevant compounds (e.g. amino acids) as ligands. The project student will use these systems as model systems to further establish bonding patterns, addressing questions such as participation of f orbitals in bonding, the nature of bonds (covalent vs. ionic contributions), or the equatorial coordination number in solution (i.e. the number of bonds around actinium – this is particularly difficult to determine experimentally) and its relationship to bonding and thermodynamic stability. Thus, we will add to the knowledge of actinium chemistry, in relationship to that of its neighbors in the periodic table.

#### REFERENCES:

- [1] G Schreckenbach, GA Shamov "Theoretical Actinide Molecular Science" *Acc. Chem. Res.* **2010**, *43*, 19.
- [2] MG Ferrier et al. "Spectroscopic and Computational Investigation of Actinium Coordination Chemistry" *Nature Communications* **2016**, *7*, 12312.
- [3] NA Thiele, JJ Wilson "Actinium-225 for Targeted  $\alpha$  Therapy: Coordination Chemistry and Current Chelation Approaches" *Cancer Biother Radiopharm.* **2018**, *33*, 336.
- [4] HW Kirby, LR Morss "Actinium", In: *The Chemistry of the Actinide and Transactinide Elements*; 3<sup>rd</sup> ed.; LR Morss et al., Eds.; Springer: Dordrecht, 2006; Vol. 1; 18-51.
- [5] J Tomeček, C Li, G Schreckenbach "Actinium Coordination Chemistry: A DFT Study with Monodentate and Bidentate Ligands", *J. Comp. Chem.* **2022**, *in print*.

## Project: #24

### Evaluating the CV- $\Delta$ SCF methods

Dr. H. Georg Schreckenbach ([schrecke@cc.umanitoba.ca](mailto:schrecke@cc.umanitoba.ca), 204-474-6261)

#### INTRODUCTION:

Density-functional theory (DFT) is the “workhorse” of current computational quantum chemistry. For excited state calculations specifically (e.g. simulation of UV-Vis spectra), the method of choice is time-dependent DFT (TDDFT) [1, 2]. While TDDFT works well for many systems and hence is part of the computational chemistry “toolbox”, it also clearly has its shortcomings and failures [2]. Therefore, various theoretical chemist groups are trying to develop novel DFT-based approaches for excited state calculations that go beyond TDDFT or are otherwise different from it. Amongst those, there is the family of constricted variational  $\Delta$ SCF (CV- $\Delta$ SCF) methods of Ziegler et al. [e.g. 3–5].

#### PROJECT:

The **goal** of the project is to further test (*benchmark*) different variants of the CV- $\Delta$ SCF method [3–5]. Thus, the student will run systematic calculations over existing benchmarking databases [2] which will allow getting a better and more systematic understanding of the scope, applicability and limitations of different levels of the CV- $\Delta$ SCF methods, in comparison to more standard TDDFT.

In practical terms, the project student will systematically run, manage, and analyze large numbers of quantum-chemical computations, working relatively interdependently (but in collaboration with a graduate student). In conjunction to this, it would be beneficial for the student to also take a strong interest in the physics/ quantum mechanics underlying TDDFT and CV- $\Delta$ SCF. Thus, this project might be particularly well suited, for instance, for students with strong interests in math or computer science, or those enrolled in

the joint physics-chemistry degree.

#### REFERENCES:

- [1] Casida, M. E.: “Time-Dependent Density Functional Response Theory for Molecules” In *Recent Advances in Density Functional Theory*; Chong, D. P., Ed.; World Scientific: Singapore, **1995**; p. 155.
- [2] Laurent, A. D.; Jacquemin, D.: “TD-DFT Benchmarks: A Review” *Int. J. Quantum Chem.* **2013**, *113*, 2019-2039.
- [3] Krykunov, M.; Ziegler, T.: “Self-consistent Formulation of Constricted Variational Density Functional Theory with Orbital Relaxation. Implementation and Applications.” *J. Chem. Theory Comput.* **2013**, *9*, 2761-2773.
- [4] Park, Y. C *et al.*: “Self-Consistent Constricted Variational Theory RSCF-CV(infinity)-DFT and Its Restrictions To Obtain a Numerically Stable Delta SCF-DFT-like Method: Theory and Calculations for Triplet States.” *J. Chem. Theory Comput.* **2016**, *12*, 5438-5452.
- [5] Ziegler, T. *et al.*: “Constricted Variational Density Functional Theory Approach to the Description of Excited States.” In *Density-Functional Methods for Excited States*; Ferre, N., Filatov, M., HuixRotllant, M., Eds., 2016; Vol. 368; p. 61.

Project: #25

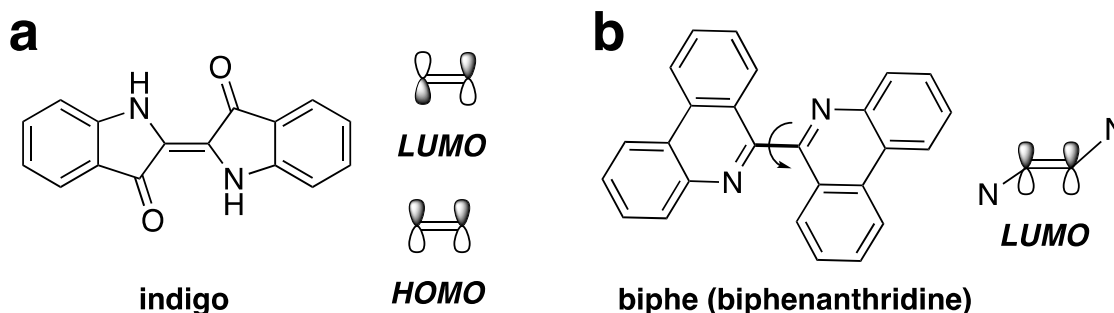
Using Computational Chemistry to Predict the Properties of Biphenanthridines

Dr. H. Georg Schreckenbach ([schrecke@cc.umanitoba.ca](mailto:schrecke@cc.umanitoba.ca), 204-474-6261)

Dr. David E. Herbert ([david.herbert@umanitoba.ca](mailto:david.herbert@umanitoba.ca), 204-474-7535)

INTRODUCTION:

Aromatic compounds in general, and substituted aromatics such as N-heterocycles in particular, are of great interest in their own right. Extended aromatic systems are of interest as singlet fission materials for solar energy harvesting. [1, 2] In addition, they can serve as ligands in transition metal complexes. Recently, we have developed synthetic methods to coupled benzannulated N-heterocycles such as "biphe" (6,6'-biphenanthridine).[3] Compared to well-known dyes such as **indigo** (**a**) which joins two chromophores via a C=C double bond and as such has a lowest unoccupied molecular orbital (LUMO) comprised of C=C *anti*-bonding character, the LUMO of biphe has C=C **bonding** character (**b**). Filling this orbital with electrons should thus introduce **conjugation** between the two phenanthridine units and drastically change its optical properties.



PROJECT:

The goal of this project is to use computational chemistry to predict the structural and optical properties of biphe and its analogs, as both neutral complexes and in their (di)anionic forms. The interested student would work primarily in the Schreckenbach group, but in close contact with the Herbert group, to simulate the absorption spectra of these compounds and evaluate their lowest lying singlet and triplet state structures and energies for potential application in singlet fission and related applications.

REFERENCES:

[1] Smith, M. B.; Michl, J.: Singlet Fission. *Chem. Rev.* **2010**, *110*, 6891-6936.

[2] Match, C.; Perkins, J.; Schreckenbach, G.: Simple computational screening of potential singlet fission molecules. *Theor. Chem. Acc.* **2018**, *137*.

[3] Nemez, D.B.; Lozada, I.B.; Braun, J.D.; Williams, J.A.G.; Herbert, D.E. *Submitted* **2022**.



Project: #26

# Design, Synthesis and Biological Properties of Outer Membrane Permeabilizers: Short Polybasic Peptidomimetics to Overcome Antibiotic Resistance

Dr. Frank Schweizer ([Frank.Schweizer@UManitoba.ca](mailto:Frank.Schweizer@UManitoba.ca), 204 474 7012)

## INTRODUCTION:

To address the rising threat of multidrug-resistant (MDR) bacteria, new therapeutic strategies must be developed. One of the major challenges in developing new antibiotics is the restrictive bacterial outer membrane (OM) in Gram-negative bacteria (GNB) which prevents accumulation of many antibiotics in GNB. To overcome this barrier, the project will investigate the design and synthesis of polyamine-based peptidomimetics as outer membrane permeabilizers (OMPs).<sup>1-3</sup>

## PROJECT:

Polyamines are a class of compounds that recognize lipid A in the OM of GNB. The binding of polyamines to lipid A destabilizes the OM by replacing bivalent metal ions like  $Mg^{2+}$  with positively charged ammonium ions. This process perturbs the packing of the OM and enables the passage of OM-impermeable agents (antibiotics) into bacteria leading to a higher intracellular concentration (FIG. 1). In this project, polyamine-based peptidomimetics that are inert to proteolytic cleavage and lack the naturally occurring amide backbone of antimicrobial peptides will be assembled by using solid phase organic synthesis. The compounds will be characterized by various 1D- and 2D-NMR methods and purified by automated reverse phase chromatography. The antibacterial activity of the peptidomimetic-based OMPs alone and in combination with clinically used antibiotics against a panel of clinically relevant and antibiotic-resistant bacteria will be determined.

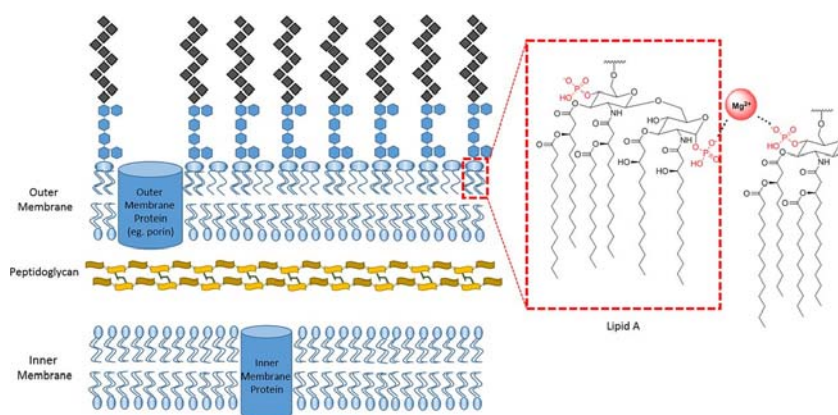


FIG. 1. The outer membrane (OM) barrier prevents accumulation of antibiotics in GNB.

## REFERENCES:

1. *ACS Infect. Dis.* **2020**, 6, 1413-1426.
2. *Front. Microbiol.* **2021** Dec 23, 12:803309.
3. *Antibiotics* **2022**, 11, 335.



Project: #27

## Design, Synthesis and Biological Properties of Outer Membrane Permeabilizers: Amphiphilic Aminoglycosides

Dr. Frank Schweizer ([Frank.Schweizer@UManitoba.ca](mailto:Frank.Schweizer@UManitoba.ca), 204 474 7012)

### INTRODUCTION:

To address the rising threat of multidrug-resistant (MDR) bacteria, new therapeutic strategies must be developed. One of the major challenges in developing new antibiotics is the restrictive bacterial outer membrane (OM) in Gram-negative bacteria (GNB) which prevents accumulation of many antibiotics in GNB (Fig. 1). To overcome this barrier, the project will investigate the design and synthesis of amphiphilic aminoglycosides as outer membrane permeabilizers (OMPs).<sup>1-3</sup>

### PROJECT:

Aminoglycosides are a class of antibiotics that self-promote their uptake into GNB by recognizing lipid A in the OM of GNB. The binding of aminoglycosides to lipid A destabilizes the OM by replacing bivalent metal ions like  $Mg^{2+}$  with positively charged ammonium ions of aminoglycosides. This process perturbs the packing of the OM and enables the passage of OM-impermeable agents (aminoglycosides or other antibiotics) into bacteria leading to a higher intracellular concentration of antibiotics. In this project, amphiphilic aminoglycosides with no or poor antibacterial activity but enhanced OM permeability will be developed. The compounds will be prepared and characterized by various 1D- and 2D-NMR techniques and purified by automated reverse phase chromatography. The antibacterial activity of the amphiphilic aminoglycosides alone and in combination with clinically used antibiotics against a panel of clinically relevant and antibiotic-resistant bacteria will be determined.

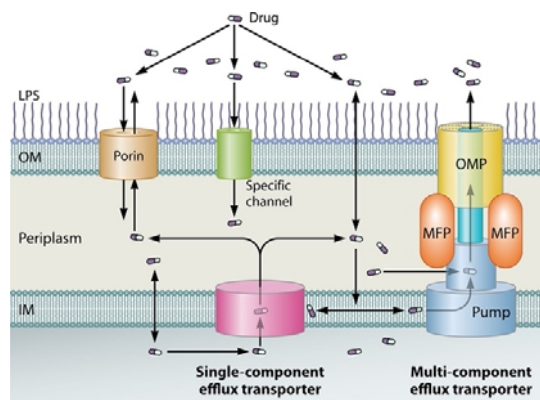


Fig. 1. Challenges drugs face to enter the bacterial cell in Gram-negative bacteria (GNB).

### REFERENCES:

1. *J. Med.Chem.* **2019**, 62, 9103-9115.
2. *Future Medicinal Chemistry* **2019**, 11, 1519-1522.
3. *Journal of Antibiotics* **2019**, 72, 816-826.

Project: #28

The discovery of new drugs from lichen fungi

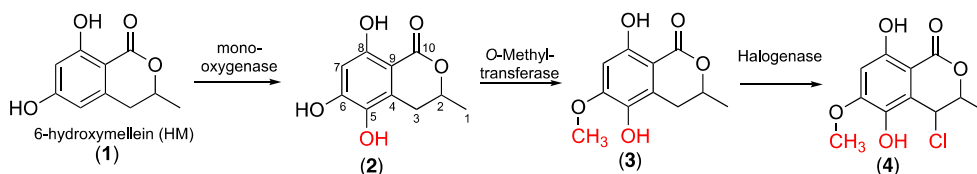
Dr. John Sorensen ([John.Sorensen@umanitoba.ca](mailto:John.Sorensen@umanitoba.ca), (204) 474 9504)

INTRODUCTION:

The Sorensen lab is working at the interface between chemistry and biology by exploring the biosynthesis of biologically active organic molecules produced by lichen and other fungi.<sup>1,2</sup> We have discovered over 40 biosynthetic gene clusters in a *single* strain of the lichen *Cladonia unicalis*.<sup>3</sup> These clusters, comprising of anywhere from 2 to 10 (*or more*) genes appears to each code for a unique natural product.<sup>4</sup> Our focus is now on assigning function to each of these gene clusters by expressing individual genes in a heterologous host. Our overarching goal is to discover new biologically active molecules that can be used as lead compounds for the design of new pharmaceuticals.

PROJECT:

This project will offer a student a unique opportunity to combine molecular biology with synthetic chemistry in a way that will allow us to probe individual chemical steps in natural products biosynthesis in fungi. One of the pathways that we have discovered in the lichen fungi appear to involve the conversion of 6-hydroxymellein (1) to a



halogenated isocoumarin (4). However, this pathway is a speculative assignment of function based on homology of the individual genes in the identified cluster. This project will aim to assign function to each of the individual genes that we have identified. Our initial focus will be on the gene that codes for a cytochrome P<sub>450</sub> monooxygenase that we suspect is involved in the conversion of (1) to (2). In order to accomplish this a polymerase chain reaction (PCR) method will be used to amplify and clone this gene in to an appropriate vector that will allow for expression in *E. coli* bacteria (*or some other suitable host*) in a manner that allows for the production of functional enzyme. In addition, the project will also focus on the expression of enzymes that convert (2) to (3) (*likely an O-methyltransferase*) and (3) to (4) which is a halogenase. This project will also require the chemical synthesis of molecules that can be used as substrates to test the biochemical function of the purified enzyme. For example, a chemical synthesis of compound (2, 3 and 4) will be required in order to test if it is indeed a substrate for the *O*-methyltransferase. Successful completion of this project would then set the foundation for the investigation of the other genes that we have discovered in *C. unicalis*.

REFERENCES:

1. Abdel-Hameed, M.; Bertrand, R.; Piercey-Normore, M.; Sorensen J. L. *Fung. Biol.* **2016**, *120*, 306-316.
2. Abdel-Hameed, M.; Bertrand, R.; Piercey-Normore, M.; Sorensen J. L. *J. Nat. Prod.* **2016**, *79*, 1645-1650.
3. Bertrand, R. L.; Abdel-Hameed, M.; Sorensen J. L. *J. of Nat. Prod.* **2018**, *81*, 723-731.
4. Bertrand, R. L.; Abdel-Hameed, M.; Sorensen J. L. *J. of Nat. Prod.* **2018**, *81*, 732-748.

## Signature Sheet for Student – Faculty Interviews

Student: \_\_\_\_\_  
(print name) (student #)

e-mail: \_\_\_\_\_  
(University of Manitoba e-mail address)

Program: \_\_\_\_\_  
(e.g Honours Chemistry) (year in program on Sep. 8, 2022)

### Interview #1:

Faculty member: \_\_\_\_\_  
(print name)  
\_\_\_\_\_  
(signature) (date)

### Interview #2:

Faculty member: \_\_\_\_\_  
(print name)  
\_\_\_\_\_  
(signature) (date)

### Interview #3:

Faculty member: \_\_\_\_\_  
(print name)  
\_\_\_\_\_  
(signature) (date)

### Notes:

1. Each student should interview at least 3 faculty members willing to offer CHEM4710 projects. During the meeting the nature of the project should be explored and expectations of the student and advisor should be discussed. You can interview as many faculty members as you wish.
2. Students should prioritize their project choices, a minimum of 3 projects are required. Note that every student can apply for any project. Students are strongly discouraged from only choosing projects from a single advisor.

## Student Project Choices

**Student:** \_\_\_\_\_  
(print student name) (student #)  
\_\_\_\_\_  
(student signature) (date)

### Project choices (1 = highest priority, 2, 3,...)

**Choice 1:** Project title: \_\_\_\_\_ Project # \_\_\_\_\_  
Supervisor: \_\_\_\_\_  
I, the student, have carried out research with this research group before. YES\_\_\_\_ NO\_\_\_\_

**Choice 2:** Project title: \_\_\_\_\_ Project # \_\_\_\_\_  
Supervisor: \_\_\_\_\_  
I, the student, have carried out research with this research group before. YES\_\_\_\_ NO\_\_\_\_

**Choice 3:** Project title: \_\_\_\_\_ Project # \_\_\_\_\_  
Supervisor: \_\_\_\_\_  
I, the student, have carried out research with this research group before. YES\_\_\_\_ NO\_\_\_\_

**Choice 4:** Project title: \_\_\_\_\_ Project # \_\_\_\_\_  
Supervisor: \_\_\_\_\_  
I, the student, have carried out research with this research group before. YES\_\_\_\_ NO\_\_\_\_

**Choice 5:** Project title: \_\_\_\_\_ Project # \_\_\_\_\_  
Supervisor: \_\_\_\_\_  
I, the student, have carried out research with this research group before. YES\_\_\_\_ NO\_\_\_\_

**Student comments:**

## CHEM 4710 Research Project in Chemistry or Biochemistry 2022/23

Course Coordinators:	Mario Bieringer
Office:	520c Parker Building
Email:	<a href="mailto:Mario.Bieringer@UManitoba.ca">Mario.Bieringer@UManitoba.ca</a>
Phone:	204-474-6258

### *Student - Advisor Agreement*

This agreement is between

1. \_\_\_\_\_  
a **student** registered in CHEM 4710 "Research Project in Chemistry or Biochemistry", hereafter called "the Student"
2. \_\_\_\_\_  
a **professor** at the University of Manitoba, and an advisor of a CHEM 4710 student, hereafter called "the Advisor"

The Student agrees to carry out a research project, as described in the attached research proposal, under the direction of the Advisor. The student agrees to meet the goals and expectations that have been set out by the advisor. These goals and expectations will include not only the scientific aims of the project, but also the time commitment that is required of the student to achieve these goals. The student agrees to a schedule of attendance at regular meetings with the advisor and the research group. The student is expected to become an active member of the research group and will assume responsibility for maintaining a safe work environment in the laboratory. The student may also be expected to assume various duties in addition to those directly associated with the project in order to maintain the safe laboratory environment. The student understands that the main goal of the Research Project is to gain experience in the process of scientific research and that effort is evaluated as much as obtaining research results. The student agrees to meet the deadlines for reporting for both written reports and the oral presentation as set out in the course outline.

The Advisor pledges to support the student in the research project by making available to the student the full resources of the research group and department. In addition the advisor will provide the scientific and intellectual guidance to ensure the success of the project. The advisor agrees to hold regular meetings with the student to discuss the current progress and results. The advisor will encourage the student to develop skills in critical thinking and help to develop a sense of scientific independence. The advisor will provide the necessary training in lab techniques and ensure that the student has received adequate safety training relating to the project. The advisor will also provide the student with timely advice on the content and style of both written reports and oral presentations. The advisor also agrees to give the student appropriate credit for the results generated during the project. This may also include authorship on publications that are generated from the results of the project.

The Student: _____ Date: _____	The Advisor: _____ Date: _____
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Please sign this form and submit to the course co-ordinator by September 16<sup>th</sup>, 2022.