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ALFRED WERNER FUND, MASTER'S STUDENT SCHOLARSHIPS

The Alfred Werner Fund of the SCS Foundation, established in 2014, continues the initiatives and projects of the former foundation 'Stiftung für Stipendien auf dem Gebiete der Chemie', also known as the 'Alfred Werner Stiftung'. The SCS Foundation offers this scholarship program in collaboration with the Swiss chemical and pharmaceutical industry (see below for supporting companies).

The program supports Master degree studies for excellent students from foreign countries in Chemistry or Biochemistry at a Swiss University or at a Federal Institute of Technology. The Foundation offers up to ten scholarships of CHF 25,000 each year for students selected by the partner universities (see box). The goal of the scholarship program is to bring in young talent to Swiss Universities or the Federal Institutes of Technology.

See *https://scs-foundation.ch/* for information about the Alfred Werner alumni.

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Summary of the Master Theses from Students of the Term 2017–2019

Jessica Caldwell
Nationality: *United States*
Bachelor at: *Indiana University Purdue University Columbus (IUPUC), USA*
Master at: *Adolphe Merkle Institute*
Master thesis supervisor: *Prof. Barbara Rothen-Rutishauser*

Creation of Fluorescent Micro- and Nanoplastic Particles Which Can be Tracked in Mammalian Cells

Work presented in this thesis demonstrates the design of fluorescent microplastic and nanoplastic particles composed of representative polymers such as polyethylene terephthalate and polypropylene. Material production is completed utilizing standard material processing techniques such as melt-processing and milling, and thorough particle characterization via light scattering, microscopy, calorimetry, and infrared spectroscopy is conducted. Fully characterized plastic particles are then exposed to relevant in-vitro mammalian cell models to investigate the interaction of these plastic particles with the cells.

Plastic-based products, from packaging for food to construction materials to automotive components,[1] have become an everyday part of life. As a result of their popularity, the production of plastic-based materials has skyrocketed since their introduction, with annual production in 2017 alone reported to be 348 million tons.[1] As production values continue to rise, so, too, does the amount of plastic waste being discarded. While many countries have turned to disposing of this waste *via* recycling and energy recovery methods, recent estimates for the worldwide management of plastic waste indicate as much as 79% of all plastic waste is in landfills or the environment.[1,2]

These macro-sized plastic products (>20 cm) which have entered into the environment have been shown to undergo degradation as a result of their exposure to UV radiation from the sun and mechanical forces from wind or waves.[3] This degradation leads to the formation of smaller plastic particles at the meso (20 cm – 5 mm), micro (5 mm – 1 µm), and even nano (< 1 µm) size ranges.[4a,b] Once at these smaller size ranges within the environment, the plastic particles are known to be more bioavailable; with organisms, such as fish, bivalve mollusks, and birds, known to ingest small plastic particles.[5a,b,c]

Despite the increasing prevalence of plastic particles within the environment leading to an increasing possibility that micro- and nanoplastic particles will be ingested or inhaled by humans, to date relatively little work has been done to assess the impact of these particles on human health. The predominant reason for this lack of experimental data is the technically challenging detection of real plastic particles in humans and/or human cells.

This thesis aimed to address the lack of relevant study materials by creating micro- and nanoplastic particles which could be detected in cell culture through state-of-the art methods such as fluorescence microscopy. For this, fluorescent molecules were introduced into the bulk plastics, and then micro- (<300 µm) and nanoparticles

(<200 nm) were produced. Subsequent laser scanning microscopy imaging confirmed that the fluorescent particles could be observed in (i) their initial dry powder or dispersion state without alteration and (ii) after their exposure to cell cultures (Fig. 1).

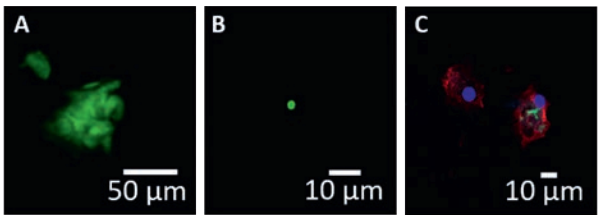

Fig. 1. Representative images from the characterization of fluorescent polypropylene particles. Confocal laser scanning microscopy images were used to confirm the fluorescence of the microplastic particles (A) and nanoplastic particles, which were detected predominantly in an aggregated state (B). An additional LSM image for the polypropylene particles after a 24-hour exposure in a macrophage cell culture indicates the fluorescence of the particles is strong enough for them to be detected efficiently (C). Cell nuclei were stained with DAPI (blue) and the actin present in cell membranes was stained with rhodamine/phalloidin (red) to allow for visual observation of cellular interaction with the particle aggregates.

[1] PlasticsEurope, 'Plastics – the Facts 2018', **2018**.
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[5] a) O. Güvena, K. Gökdağa, B. Jovanović, A. Erkan Kıdey, *Environ. Pollut.* **2017**, *223*, 286; b) E. R. Holland, M. L. Mallory, D. Shutler, *Sci. Total Environ.* **2016**, *571*, 251; c) L. Van Cauwenberghe, M. Claessens, M. B. Vandegehuchte, C. R. Janssen, *Environ. Pollut.* **2015**, *199*, 10.

Future Plans

Upon completing my Master's, I plan to pursue a doctorate degree in the Bionanomaterials group of the Adolphe Merkle Institute. I look forward to being able to continue my work with micro- and nanoplastic particles, and I am excited to see what new collaborations and opportunities this work will bring.

Asma Mansouri
Nationality: *Algeria*
Bachelor at: *USTHB, Algeria*
Master at: *University of Geneva*
Master thesis supervisor: *Prof. Hans Hagemann*

Structural and Luminescent Properties of M_4OX_6 Crystals Doped with Europium (II)

The alkaline earth oxyhalides M_4OX_6 (M= Ca, Sr, Ba and X= Cl, Br) are thermally stable compounds. When doped with europium (II), they become effective blue-emitting phosphors that can be excited by a near-UV LED chip, which makes them candidates to be used as blue components in white LEDs.[1,2] In this work, crystals of M_4OX_6 doped with europium are synthesized, characterized and their luminescence properties are studied. Low-temperature measurements are used to gain a deeper understanding of the relationship between the environment of the luminescent center and its emission properties. Periodical DFT calculations are performed to have an accurate spectroscopic signature of these systems and were carried out using the Crystal14 code with different functionals.[3]

The unit cell parameters of the six compounds, computed using LDA[4] and GGA[5] type functionals, were compared to the experimental ones. The agreement is good; the error is within 1–2% for GGA and 2–3% for LDA calculation.

Most of the frequency modes of the Ba_4OX_6 compounds were successfully reproduced. For the Ca_4OX_6 and Sr_4OX_6 compounds, the high-frequency bands associated to the four stretching modes of the tetrahedra computed in GGA are higher than the experimental ones by more than 60 cm^{-1} due to the presence of couplings between the vibrational modes of M-O bonds with M-X modes that lower the experimental frequencies of the M-O bonds. The results were improved by 10 cm^{-1} by adding dispersion interactions using the Grimme D2 scheme.[6]

The luminescence measurements were performed at RT, 200, 100 and 5 K. All samples exhibit a broad blue emission band, with maxima at around 450 nm under excitation in the near-UV region and the excitation spectra consist of a broadband in the region from 250 to 445 nm (Fig. 1).

This study gave the spectroscopic signature of these systems and evidenced the problem of accurately describing the vibrational modes of the tetrahedra in the Ca_4OX_6 and Sr_4OX_6 compounds. The changes in the emission properties as a function of the temperature of $M_4OX_6:Eu^{2+}$ crystals were explored and a new phosphor in this family, $Ca_4OBr_6:Eu^{2+}$, has been characterized, and its crystal structure has been determined.

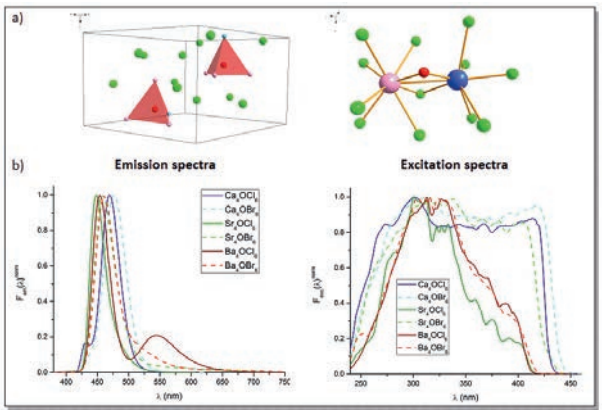

Fig. 1. a) Representation of the coordination of the two crystallographic sites M1 (pink) and M2 (blue) and the anion centered tetrahedra. b) Excitation and Emission spectra of the six M_4OX_6 compounds at 5 K.

[1] Y. Chen, F. Pan, M. Wang, X. Zhang, J. Wang, M. Wu, C. Wang, *J. Mater. Chem. C*, **2016**, *4*, 2367.
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[3] R. Dovesi, R. Orlando, A. Erba, C. M. Zicovich-Wilson, B. Civalleri, S. Casassa, Y. Noël, *Int. J. Quantum Chem.* **2014**, *114*, 1287.
[4] K. Burke, L.O. Wagner, *Int. J. Quantum. Chem.* **2013**, *113*, 96.
[5] J. P. Perdrew, K. Burke, M. Ernzerhof, *Phys. Rev. Lett.* **1996**, *77*, 3865.
[6] S. Grimme, *Int. J. Quantum. Chem.* **2006**, *27*, 1787 .

Future plans

After my graduation, I will pursue a PhD degree at the Ecole Normale Supérieure (ENS) de Paris under the supervision of Prof. Christian Serre. The objective of this PhD project is the development of a methodology allowing the use of precession electron diffraction tomography (PEDT) for the structural elucidation of beam sensitive nanocrystalline materials, primarily, MOFs.

Alena Budinská
Nationality: *Czech*
Bachelor at: *University of Chemistry and Technology (UCT), Prague, Czech Republic*
Master at: *ETH Zürich*
Master thesis supervisors: *Dr. Dmitry Katayev, Prof. Antonio Togni*

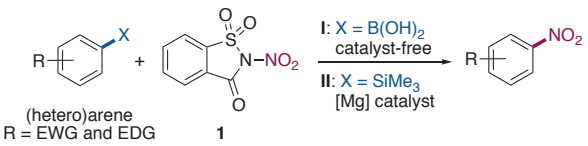
Application of *N*-Nitroheterocycles in the Synthesis of Nitro(hetero)arenes

*An efficient protocol for regioselective ipso-nitration of arylboronic acids using N-nitrosaccharin (**1**) as the nitrating reagent was developed. General features of the methodology include mild reaction conditions, ease of scale-up and recyclability of the saccharin scaffold. Furthermore, the first example of a highly chemo- and regioselective ipso-nitration of arylsilanes was also achieved with this reagent.*

Nitroaromatic compounds find various applications as building blocks and intermediates in the synthesis of dyes, explosives or pharmaceuticals.[1] In light of the development of mild and practical methods for their synthesis, the Katayev group recently introduced *N*-nitrosaccharin as a bench-stable electrophilic nitrating reagent for arenes and heteroarenes with exceptionally broad substrate scope.[2] Yet, the problem of poor regioselectivity, generally associated with electrophilic aromatic nitration, remained unsolved. Therefore, the goal of the thesis was to explore the suitability of reagent **1** for *ipso*-nitration, a strategy that allows for regioselective introduction of the NO_2 group starting from commercially available prefunctionalized arenes.[3]

In the first part of the project, a procedure for *ipso*-nitration of arylboronic acids with **1** was established, and the functional group tolerance was demonstrated on 17 different aryl boronic acids. In addition, the reaction could be easily performed on a two-gram scale with the same efficiency, and the recyclability of saccharin was also shown.

Secondly, arylsilanes comprise a thoroughly studied, yet rarely utilized class of organometallic compounds for *ipso*-nitration due to their poor chemo- and regioselectivity.[1] Intrigued by the lack of efficient methodologies, we studied the use of **1** for nitrodesilylation, which we successfully accomplished using $Mg(NTf_2)_2$ as the catalyst. The protocol is currently used by the Katayev group and has already been utilized for the nitration of more than 30 aryl- and heteroarylsilanes.



Scheme 1. *Ipso*-nitration of arylboronic acids and arylsilanes using *N*-nitrosaccharin (**1**).

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[2] R. Calvo, K. Zhang, A. Passera, D. Katayev, *Nat. Commun* **2019**, *10*, 3410.
[3] G. Yan, M. Yang, *Org. Biomol. Chem.* **2013**, *11*, 2554.

Future Plans

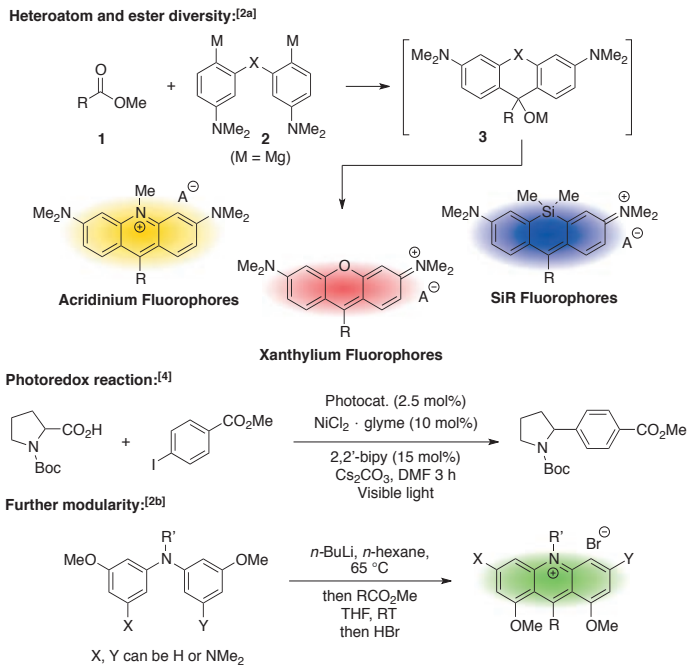
I am currently doing an internship in the Roche Center of Excellence for Catalysis working on the synthesis of transition metal catalysts and their application in hydrogenation reactions. After finishing my internship, I will start my PhD under the supervision of Prof. Helma Wennemers at ETH Zürich. My research will focus on further development of peptidic catalysts for various asymmetric transformations.

Dragan Miladinov
Nationality: *Serbian*
Bachelor at: *University of Novi Sad, Serbia*
Master at: *University of Basel*
Master thesis supervisor: *Prof. Christof Sparr*

Preparation of Modular Heterocyclic Fluorophores directly from Esters

Visible-light-driven photochemical reactions have, in recent years, unequivocally demonstrated their utility in academic and industrial laboratories. Otherwise challenging or even impossible transformations are feasible under mild conditions through activation with photocatalysts. Unlike polypyridyl transition metal complexes, whose photochemical properties can be readily tuned by variation of their ligand structure, organic fluorophores remained limited in their synthetic modularity. Therefore, we focused on increasing the structural diversity of heterocyclic fluorophores and their catalytic performance.

Apart from photocatalysis, organic fluorophores have important roles in the fields of bioimaging and optoelectronics. Thus, there is an increasing demand for tailor-made dyes.[1] In order to address the need for modularity, we developed methods to directly transform carboxylic acid esters into acridinium, xanthylium and SiR fluorophores (Scheme 1).[2]



Scheme 1. Formation of diverse heterocyclic fluorophores along with a Ni-dual catalytic cross-coupling reference reaction.[2a,b,4]

Gratifyingly, the combination of 1,5-bifunctional organomagnesium reagents[3] with abundant, stable and structurally diverse carboxylic acid esters allowed the direct formation of heterocyclic dyes. A heteroatom-bridged, 1,5-dimetallic, dianilide (**2**) undergoes double addition to an ester (**1**) yielding intermediate **3** which is dehydrated during an acidic work-up. The formed fluorophores were successfully used

as photoredox catalysts in a dual catalytic C(sp^2)-C(sp^3) cross-coupling reaction[4] and other benchmark transformations.

In order to further increase the diversity of the acridinium rings, the 1,5-bifunctional organometallic reagents were formed by dilithiation of *bis*(3-methoxyphenyl)amines by a double directed *ortho*-metalation, resulting in 1,8-dimethoxy-acridinium salts. Current efforts in our group focus on the modulation of the photophysical properties of the substituted heterocyclic fluorophores and in collaborative efforts, the characterization, scale-up and use of the photocatalysts.

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[3] a) A. Link, C. Fischer, C. Sparr, *Angew. Chem. Int. Ed.* **2015**, *54*, 12163; *Angew. Chem.* **2015**, *127*, 12331; b) A. Link, C. Fischer, C. Sparr, *Synthesis* **2017**, *49*, 397.
[4] Z. Zuo, D. T. Ahneman, L. Chu, J. A. Terrett, A. G. Doyle, D. W. C. MacMillan, *Science* **2014**, *345*, 437.

Future Plans

After graduation, I began my PhD studies in the Sparr group at the University of Basel, being part of an NCCR Molecular Systems Engineering project involving the Lörtscher group from IBM Research – Zurich.

Kevin M. Jablonka
Nationality: *Germany*
Bachelor at: *Technical University of Munich*
Master at: *EPFL*
Master thesis supervisor: *Daniele Ongari, group of Prof. Berend Smit*

Making Simulations of Gas Adsorption in Porous Materials Comparable and More Useful for Data-Driven Modeling

In large-scale molecular simulations interaction potentials often need to be truncated to make the systems explored computationally feasible. For liquids, it has been known for a long time that one can add a correction term to remedy the shortcomings introduced by truncation but it is still debated if this correction can also be used for gas adsorption in porous materials. We showed that molecular simulations of gas adsorption in porous materials with such corrections show a more desirable convergence behavior than those using simple truncation. This also makes simulations more comparable, and the data generated are more useful for machine learning approaches.

Chemical separations have the power to change the world.[1] One important example is the removal of dilute emission of greenhouse gases, like carbon dioxide or methane, from the air. Porous crystals are a promising way to attack this separation challenge. In the last decade, several classes of porous materials have been created based on the principles of reticular chemistry, which means that the compounds, and hence their pore geometry and chemistry, can be designed by combining building blocks (like different metal nodes and linkers connecting these). But this raises another problem: How can one find the best material from all possible pairings of building blocks?

Molecular simulations have become an indispensable tool in this process[2,3] and more recently, researchers also try to leverage data from *in silico* high-throughput screenings to build machine learning models to expedite further the discovery process.[4]

In simulations, we usually only consider Van der Waals interactions between particles within a cutoff radius for reasons of computational feasibility. In homogenous liquids it is well established that one can correct for this truncation using homogenous tail corrections which assume that the particles are randomly displaced beyond the cutoff region. But in porous materials their applicability is still debated as the particles are not randomly displaced.[5]

To probe the influence of the tail corrections in more detail, we selected an array of geometrically diverse porous materials and performed adsorption simulations of various alkanes at different cutoff radii with and without tail corrections. We found that tail corrections make the results much less sensitive to the choice of the cutoff radius—for all of the materials investigated (*cf.* Fig. 1).

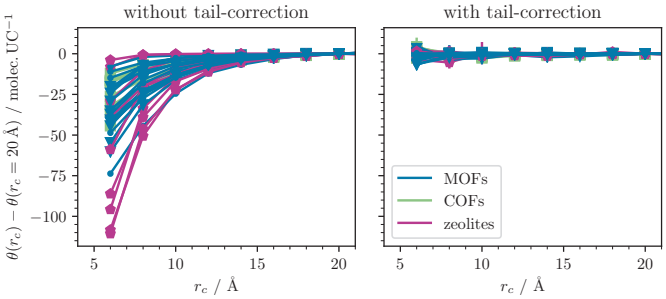

Fig. 1. Convergence of the methane uptake with the cutoff radius in different materials at low pressure for simulations with and without tail corrections in different materials classes such as metal-organic frameworks (MOFs), covalent organic frameworks (COFs) and zeolites. Simulations with tail corrections are less sensitive to the truncation radius.

This result is important, since there is no cutoff radius the community has agreed on. Further, it bypasses the need to converge this parameter for each structure in high-throughput screening experiments. Finally, tail corrections make it easier to combine different datasets into one training set for machine learning. The results of this investigation were recently published.[5]

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[2] P. G. Boyd, Y. Lee, B. Smit, *Nat. Rev. Mater.* **2017**, *2*, 17037. doi.org/10.1038/natrevmats.2017.37.
[3] A. Sturluson, M. T. Huynh, A. R. Kaija, C. Laird, S. Yoon, F. Hou, Z. Feng, C. E. Wilmer, Y. J. Colón, Y. G. Chung, D. W. Siderus, C. M. Simon, *Mol. Simulation* **2019**, *45*, 1082, doi.org/10.1080/08927022.2019.1648809.
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[5] K. M. Jablonka, D. Ongari, B. Smit, *J. Chem. Theory Comput.* **2019**, doi.org/10.1021/acs.jctc.9b00586.

Future plans

After my graduation, I will continue working towards a PhD in the same group, further exploring the beautiful, but challenging universe of porous materials based on *in-silico* approaches.

Luka Milosevic
Nationality: *Serbian*
Bachelor at: *University of Belgrade, Serbia*
Master at: *EPFL, Lausanne*
Master thesis supervisor: *Prof. Jeremy Luterbacher*

Synthesis and Stabilization of Highly Dispersed Palladium Catalytic Sites by Alkoxysilane-Metal Complex Deposition and Metal Oxide Overcoating

Highly dispersed heterogeneous catalysts have recently gained increasing attention because of their high metal atom utilization efficiency and well-defined active sites for mechanistic studies. However, specific synthesis conditions are typically required in order to prepare ultra-small nanoparticles. For instance, the metal precursor often needs to be strongly anchored on the support by electrostatic or metal-support interactions, so the screening of different metal precursors and supports are generally needed. Such 'trial and error'-based strategies can be extremely time consuming. Another challenge involves stabilizing these nanoparticles and preventing particles from sintering after synthesis, during catalytic processes. We have developed a novel strategy for synthesizing a sinter resistant and nearly atomically dispersed supported palladium catalyst. We have explored the use of an inexpensive alkoxysilane structure functionalized with amine groups, which has a high affinity to noble metal ions and leads to the formation of alkoxysilane-metal complexes. This complex can be grafted onto silica support to form isolated metal sites. Subsequently, liquid phase sol-gel overcoating method was applied, in order to immobilize these isolated Pd sites and/or stabilize very small (<1 nm) metal nanoparticles (Fig. 1).

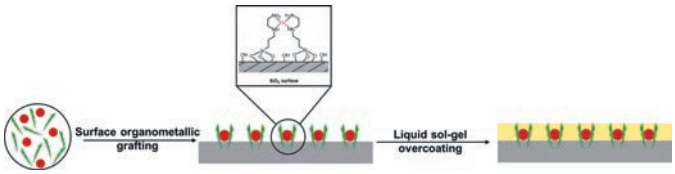


Fig. 1. Synthesis pathway of overcoated palladium catalysts.

The goal of this step was to prevent sintering during thermal reduction treatment, which is the major mechanism behind the formation of larger particles and decreasing activity due to reduction in the atom efficiency. Properties of the coated and uncoated catalysts have been examined by XRD spectroscopy, TEM, as well as chemical and physical adsorption methods. This simple approach was found to be very effective in protecting particles from sintering. As a test case, we used hydrogenation of cinnamaldehyde to show the effectiveness of both grafted and overcoated metal catalysts. Both overcoated and uncoated catalysts demonstrated high activity and selectivity for the probe reaction, however only coated samples retained their activity after thermal treatment.

Future Plans

In the near future, I will begin doctoral studies in Chemical engineering at EPFL as a member of Jeremy Luterbacher's group. My research will be focused on catalysis and novel material synthesis.

Brett Garabedian
Nationality: *United States*
Bachelor at: *UC Berkeley*
Master at: *University of Basel*
Master thesis supervisor: *Dr. Johannes Rebelein*, *Prof. Thomas Ward*

Artificial Metalloenzyme Directed Prodrug Activation on Tumor Cells

Cancer is a leading cause of mortality worldwide. Contemporary treatment strategies rely on the ability to target cytotoxic payloads to specific disease markers. Excluding bystander effects, methods based on antibodies, nanoparticles and small molecules are stoichiometric in their mode of action. This study aimed to overcome this limitation by retrofitting the cancer cell surface with transition metal-based artificial metalloenzymes (ArMs) that catalytically activate cytotoxic payloads in situ. This study highlights significant progress in the Ward lab and in the broader field of bioorthogonal catalysis.

This study aimed to selectively target an endogenous tumor marker with a transition metal-based catalyst, generating a cell-surface ArM that catalytically activates chemotherapeutic agents in cancer cell populations (Fig. 1). A surface marker was chosen that is uniquely expressed on solid tumor cells and was targeted on human cancer cells using a fluorophore conjugated to a commercial inhibitor. The probe localized on the surface of marker(+) cells, but not marker(–) cells (Fig. 2). Targeting was supported further with (i) the use of anti-marker antibodies (Fig. 2A–C) and (ii) competition of the probe in the presence of excess inhibitor (Fig. 2C). These observations were confirmed using flow cytometry (data not shown), and marker expression was validated and quantified by western blot and flow cytometry, respectively (data not shown).

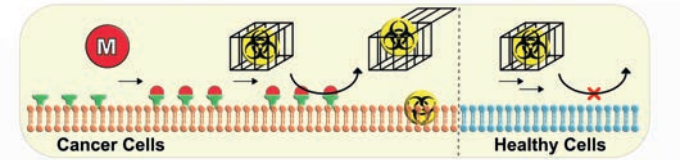


Fig. 1. ArM Directed Prodrug Activation on the Cancer Cell Surface. Cancer cells (orange) uniquely expressing a disease marker (green) are fixed with metallocofactors (M), affording surface ArMs that catalytically activate prodrugs (yellow) on cancer cells and not healthy cells (blue).

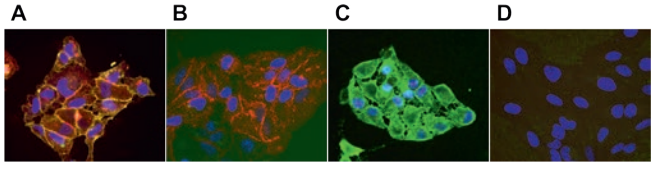


Fig. 2. (**A-C**) Marker(+), (**D**) Marker(-) Cells. (**A**) Probe and anti-marker 1°/2°-fluorescein antibodies. (**B**) Probe and 2°-fluorescein antibody alone. (**C**) Probe and anti-marker 1°/2°-fluorescein antibodies, in the presence of 1000-fold excess inhibitor. (**D**) Probe and anti-marker 1°/2°-fluorescein antibodies. Red, probe; Green, 2°-fluorescein; Blue, nuclei. Red, Green and Blue channels merged in (**A-D**).

We next selected a series of chemotherapeutic agents spanning various modes of action. Each drug was appended with a protecting group (PG) to generate its cognate prodrug (Fig. 3A). By measuring 72 h cell viability, half-maximal inhibitory concentrations (IC_{50}) were calculated for each prodrug using a panel of solid tumor-derived cell lines, including HeLa, A549

and HT29 cells. The fold-increase in IC_{50} engendered by 'caging' the drug, defined as Log(IC50*), is expressed in Fig. 3B as the logarithmic ratio log(IC_{50}prodrug/IC_{50}drug). These data indicate an approximate 155-fold IC_{50} increase in HT29 cells exposed to **pro1** relative to **1**. Though less pronounced, **pro5/5** showed a similar trend with the largest IC_{50} shift in HT29 of nearly 25-fold.

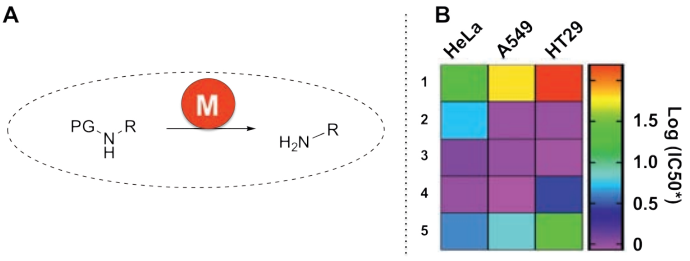


Fig. 3. (**A**) Prodrug activation using transition metal (M). (**B**) Fold-increase in IC_{50} of prodrug/drug pairs **1–5**.

The Ward lab is using the data generated in this study to finalize cancer cell-surface catalysis using marker-based ArMs. This approach represents an exciting new tool for targeted therapies *in vivo*,[1,2] and serves as a superstoichiometric alternative to traditional drug delivery platforms.

[1] J. G. Rebelein, Y. Cotelle, B. Garabedian, T. R. Ward, *ACS Catal.* **2019**, *9*, 4173.
[2] W. Ghattas, V. Dubosclard, A. Wick, A. Bendelac, R. Guillot, R. Ricoux, J.-P. Mahy, *J. Am. Chem. Soc*. **2018**, *140*, 8756.

Future Plans

I am currently pursuing my PhD with Prof. James Paulson at The Scripps Research Institute in La Jolla, California where I am using the skills gained through the Alfred Werner Scholarship, developing small molecule- and protein-based reagents to study **s**ialic acid binding **i**mmuno**g**lobulin **lec**tin**s** (**Siglecs**) and their roles in cancer as glyco-immune checkpoints.

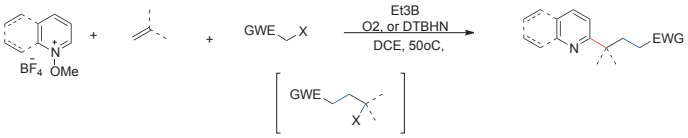
Kleni Mulliri
Nationality: *Albania*
Bachelor at: *University of Tirana, Albania*
Master at: *University of Bern*
Master thesis supervisor:
Prof. Dr. Philippe Renaud

A Radical Multicomponent Approach for Functionalization of Pyridines and Related Systems

A multicomponent protocol for the functionalization pyridine has been developed. In contrast to the classical Minisci reaction that uses pyridinium salts and a stoichiometric oxidant, this method is based the use of N-methoxypyridinium salts. This transition metal free method allows the preparation of substrates which are suitable precursors for the synthesis of the core structure of quinolizidine alkaloids.

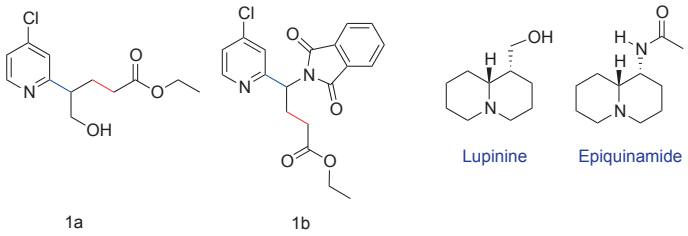
Due to their biological properties, pyridines and related heterocycles are of great importance and have found many applications in pharmaceutical and agrochemical sector.[1,2] Developing new and efficient ways of functionalizing pyridines and related heterocyclic compounds remains a challenging field.[3]

My work focused on developing a multicomponent approach for the functionalization of pyridine under mild conditions.[4] Pyridines were converted to *N*-methoxypyridinium salts and treated with α-iodoesters and alkenes in the presence of triethylborane as a chain transfer reagent. Under these conditions, no oxidant is required. After extensive optimization, it was found that the reaction proceeds efficiently using either thermal initiation or employing oxygen from air (Scheme 1).



Scheme 1. Multicomponent approach for the functionalization of pyridine and related heteroaromatic compounds.

With the optimized conditions at hand, a family of substituted pyridines was synthetized. Typical representatives such as compounds **1a** and **1b** were prepared (Scheme 2). These compounds represent key intermediates for the synthesis of lupinine and epiquinamide. Conversion of these compounds into the natural products is currently under investigation.



Scheme 2. Key intermediates (**1a** and **1b)** for the synthesis of lupinine and epiquinamide.

[1] 'Quinolizidine Alkaloid - an overview', ScienceDirect Topics, *https://www.sciencedirect.com/topics/chemistry/quinolizidine-alkaloid*, accessed May 13, **2019**.
[2] T. Kubota, T. Nishi, E. Fukushi, J. Kawabata, J. Fromont, J. Kobayashi, *Tetrahedron Lett.* **2007**, *48*, 4983.
[3] J. Tauber, D. Imbri, T. Opatz, *Molecules* **2014**, *19*, 16190.
[4] S. Rieder, PhD Thesis, 'Harnessing the Reactivity of Organoboranes Towards the Generation of Alkoxyl Radicals and Homolytic Aromatic Substitution of N-Methoxy Pyridinium Salts', University?, Year?.

Future Plans

After I finished my thesis, I started an internship in the group of Prof. Dr. Philippe Renaud working on the total synthesis of quinolizidine alkaloids. I would like to extend my knowledge and continue my studies as PhD student.