

Mellon Faculty Renewal Grant Final Report

Name of Person (s) Submitting Report: Marcia France

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Institution: Washington and Lee University

Name of project/event: Research at the University of St Andrews: Preparation of Chiral Ligands for Asymmetric Catalysis

Date(s) of Project: June 2009 – August 2009

Amount Awarded: \$5000

During summer 2009, the PI and an undergraduate student, Michael Kuntz, traveled to the University of St Andrews in Scotland to do research in the laboratory of Dr. Matthew Clarke. Our objectives included accessing laboratory equipment not available at Washington and Lee University as well as serving as a pilot program for providing students from St Andrews and W&L with an international research opportunity. In addition, the PI was able to meet with faculty and administrators involved in our study abroad program at St Andrews. The exact research projects that Michael and Dr. France pursued ended up being slightly different from what was in the original proposal. The plans were revised in order to build upon some ongoing research in the Clarke lab. In this way, we could make a positive impact on Dr. Clarke's research as well as our own.

Research. The Clarke group has developed a chiral P,N,N ligand (phosphorus, nitrogen, nitrogen) that is active for the asymmetric hydrogenation of bulky ketones. Michael prepared a derivative of the P,N,N ligand with an electron withdrawing chlorine group on it. He was able to fully characterize this ligand and a ruthenium complex prepared with it. He tested the ligand in asymmetric hydrogenation and demonstrated that the inductive effect of the chlorine almost completely shut down the reaction. This is in contrast to the parent complex without the electron withdrawing group, which gives full conversion. These results provide important mechanistic insight into the nature of the active hydrogenation system. Michael had the opportunity to use instrumentation not available at W&L, including a microwave reactor and high pressure hydrogenation equipment. He was also able to obtain an X-ray crystal structure of the ruthenium complex. Michael's work will be incorporated into a publication currently in preparation, which includes several mechanistic aspects of the hydrogenation. He will also present his research at a poster session at W&L, and we plan to submit an abstract to present a poster at the American Chemical Society National Meeting in March 2010. The original Mellon proposal discussed the preparation of fluorinated P,P and N,N ligands. At W&L we lack the high pressure hydrogenation equipment required to make the desired starting material for such compounds. We now have several batches of this precursor, which are being mailed to us from Scotland so that we will be able to resume this work back at W&L.

Dr. France was also doing experiments designed to provide insight into the mechanism of the hydrogenation system previously developed in the Clarke lab. She looked at the hydrogenation of esters, which are difficult to hydrogenate with homogenous catalysts. She also made progress on the preparation of a derivative of a P,N,N ligand with an electron donating

group, designed to complement Michael's work. In addition, she focused on the preparation of ruthenium hydride species that might be related to the active intermediate in the hydrogenation. These complexes have not yet been fully characterized, but they have been shown to do the desired chemistry with high conversion and moderate enantioselectivities. It is anticipated that this work will also be incorporated into the mechanistic manuscript. Dr. France, like Michael, utilized equipment at St Andrews that is not available at W&L. In addition, Dr. France and Michael both had the opportunity to attend a daylong symposium at the Schering-Plough Corporation. Five well-known chemists presented their work, including two Nobel Laureates. This is an opportunity Michael would not have had back home.

An important goal of this summer's research experience was to serve as a model for summer research opportunities for future undergraduate research students. Matt Clarke was very impressed with the work Michael did. The Head of the School of Chemistry at St Andrews has offered to fund another W&L student to accompany Dr. France for summer 2010. In addition, we discussed the possibility of expanding the program to allow more exchange between the two institutions. Although providing salaries for American students is complicated by work permit issues, the Head of Research in the School of Chemistry at St Andrews has expressed a willingness to cover travel and housing for up to four students if W&L will provide stipends. I will be pursuing this offer with the Provost and the Director of International Education at W&L now that I have returned to campus.

Teaching. I was able to meet with the faculty members involved in our study abroad program. We discussed how we will handle the retirement of one of the two faculty, and I have met the person who will begin teaching the labs this year. We have also discussed some of the changes anticipated when construction of the new undergraduate teaching labs is completed in time for fall 2010. The number of students participating has dropped in the last two years, and I also discussed long-term plans with the head of the School of Chemistry and the Vice-President for External Affairs. We are working on improving our advertising and recruiting, which includes publicity at other ACS schools. All of these interactions will serve to help improve the study abroad program and help attract more students to participate. Both universities have invested a lot into this program and want it to be successful. In addition, it appears that we have paved the way for more undergraduate students to take advantage of summer research opportunities at St Andrews in the future. We will continue to evaluate the study abroad program through course and program evaluations.

Future Work. In addition to the Mellon Faculty Renewal grant, Dr. France and Dr. Clarke also received funding from the EPSRC to support Dr. France's travel expenses. This funding will allow her to return to St Andrews Summer 2010 to continue this work. Dr. France will follow up with both St Andrews and W&L to obtain funding for a student to accompany her again. She will also follow up with both universities to investigate funding for additional students who might work with other St Andrews faculty. Dr. France will continue to investigate the preparation of ruthenium hydride complexes that might be related to the active hydrogenation catalyst. In addition, either Michael or another undergraduate will continue the project to make the fluorinated ligands, now that we have the required starting material available at W&L.

Student Impact. Michael found the experience to be tremendously rewarding and indicated that he felt he had gotten more out of the summer in Scotland than he would have out of a second summer doing research in Lexington. He was able to see how things work in a high-

powered research environment. He worked alongside first year graduate students preparing for their qualifying examinations, older graduate students writing up their Ph.D. theses, highly experienced postdoctoral fellows, and everything in between. He gained a good understanding of what research at a Ph.D. granting institution would be like. The insight and experience has been tremendously valuable to him. The following are his comments on what the experience meant to him:

“Working at St Andrews gave me the chance to experience life in a graduate level lab, which proved to be stimulating in a different way than work in a purely undergraduate lab. Working with graduate students and post-docs gave me the chance to discuss my chemistry with several people in addition to my supervisor. With this came more advice on ways to approach my chemistry, and hence vastly added to my lab experience. Speaking with graduate students and post-docs also gave me the chance to see what chemistry they were working on and gave me more exposure to graduate level chemistry. I was able to use equipment currently unavailable at W&L (microwave reactor, high temperature and pressure vessels for hydrogenation, HPLC), as well as gain access to services unavailable on campus at W&L (x-ray crystallography). These factors combined to give me a greater understanding of how chemistry labs function at the graduate level. By contributing to a project already well developed in the lab, I could see how projects develop over time. I was able to feel a great sense of accomplishment by completing one small piece of the project. Although I am only an undergraduate, I actually felt I was an integrated part of the graduate level lab, and I felt as though I got a truly unique chance to be a graduate student for the summer.”

We believe that this project has paved the way to enable future undergraduate students such an opportunity.

Summary of Work for Inclusion on ACS Faculty Renewal Website

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