THE UNIVERSITY OF MELBOURNE

FACULTY OF SCIENCE

SELBY RESEARCH AWARD
END OF AWARD YEAR REPORT
Dr Lars Goerigk 2014

Awardee information

Name: Dr Lars Goerigk

School: Chemistry

Research title: Quantum chemical optimization of DNA structures and related compounds

Research and budget report

Please report on your research during the past year including the following headings (no more than two pages):

- A summary of your original aims and objectives (as outlined in your application)
- Progress made during the year against these objectives, including notable results and findings
- Scholarly outcomes, including titles of publications, conference publications etc.
- Budget – a summary of your use of the funds requested in your original application
- Any other information

Certification

Name Lars Goerigk

Signature.....Date.....3 June 2015.....

Submit your report by 29 May 2015 to

Linda Richardson, Faculty of Science E: science-awards@unimelb.edu.au T: +61 3 8344 5949

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End of award year report for the Selby Research Award 2014

Dr Lars Goerigk
School of Chemistry
The University of Melbourne

Project title: Quantum chemical optimization of DNA structures and related compounds

1. Summary and outcomes

The aim of this project was to develop a methodology that allows the efficient structural optimisation of large biomolecules with quantum-chemical procedures. One particular aim was to develop this optimiser for DNA structures with the potential to be used to complement the standard X-ray crystallographic macromolecular refinement technique, which is a key step in a crystallographic structure determination.

Very early during this project it became necessary to modify the original aim and instead of DNA, the project initially dealt with protein structures. The reason for this was that protein crystal structures can usually be obtained at much higher resolutions and therefore they serve as a much better benchmark to assess the applicability of the newly developed optimiser. This part of the project was carried out successfully in collaboration with Prof. Jeffrey Reimers (Shanghai University, China) and A/Prof. Charles A. Collyer (The University of Sydney) and it resulted in a publication in December 2014 (reference 1 in the publications list at the end of this document). This paper deals with protein optimisation and quantum refinement and we demonstrated that standard optimisation techniques are not adequate in this area and that they are outperformed by a newer approach presented in the publication. Its peer-reviewers received the publication very well and they shared our hopes that it can have an important impact on the quantum-chemistry community. The results of this paper were also presented at the National Congress of the Royal Australian Chemical Institute in Adelaide in December 2014. This study forms an important basis for the next step of the project, which is a similar investigation on common structural features of DNA. This work is currently in progress. The outcomes can then be transferred to existing crystal structures of various forms of DNA, e.g. B-DNA, Z-DNA or G-DNA.

As I had arrived at the University only a couple of weeks prior to the award of the Selby Research Award, the provided funds were crucial in building a functioning research infrastructure. This infrastructure helped me not only with my main project, but it was highly beneficial in establishing four collaborations with other researchers that have all resulted in publications. In all cases, funding from the Selby Scientific Foundation has been appropriately acknowledged. My collaboration with Dr. Amir Karton (The University of Western Australia) on the quantum-chemical treatment of barrier heights of pericyclic reactions showed surprisingly large errors for some popular quantum-chemical protocols, and the editors of the *Journal of Computational Chemistry* acknowledged the importance of our study by featuring it as a front-cover article (reference 2). This paper was also the eighth most-read of this journal in February 2015.

Two separate collaborations with experimentalists Dr. Chris Ritchie and Prof. Evan Bieske – both from the School of Chemistry – have also resulted in recently published articles (references 3 and 4). A paper written in collaboration with Dr. Bun Chan and Prof. Leo Radom (The University of Sydney) has been accepted for publication in the *Journal of Computational Chemistry* and we hope that it will be featured as a front-cover article (reference 5).

In summary, the past months have been very successful. Further publications are planned and also in those the Selby Research Award will be acknowledged. Finally, I would like to thank the Selby Scientific

Foundation for supporting my research and for laying the foundation of a flourishing research environment that will also guarantee success in my future projects.

2. Statement on the spent budget

A large portion of the awarded $15,000 were spent for computer hardware, i.e. an Apple MacPro as a local workstation for quantum-chemical calculations and an Apple iMac as a workstation to access high-performance computer clusters in Melbourne and in Canberra (total costs $7,672). The Selby Award also allowed me to support an international visiting student from the Indian Institute of Technology Roorkee, who worked with me for seven weeks from November 2014 until January 2015 (combined cost of $3,573.57). Publication costs for the front-cover article in the Journal of Computational Chemistry were USD 495 (about $640.5). As of 3 June 2015, there are still $3,113 left, which will be spent until the end of July 2015, i.e. until the end of my 12th month after having been granted the Selby Award. This money will be spent for conference registration to PACIFICHEM 2015 in Hawaii – as outlined in my award application – and for the expected front-cover publication costs of reference 5. Also, as the already purchased hardware turned out to be less expensive than anticipated at the time of my grant application, I am able to purchase additional hardware that will guarantee the continuation of this successful project.

3. Publications

1. **L. Goerigk**, C. A. Collyer, J. R. Reimers, "Recommending Hartree-Fock theory with London-dispersion and basis-set-superposition corrections for the optimization or quantum refinement of protein structures", *The Journal of Physical Chemistry B* **2014***, 118*, 14612-14626.

2. A. Karton, **L. Goerigk**, "Accurate reaction barrier heights of pericyclic reactions: surprisingly large deviations for the CBS-QB3 composite method and their consequences in DFT benchmark studies", *Journal of Computational Chemistry* **2015,** *36*, 622-632.

3. M. R. Healey, S. P. Best, **L. Goerigk**, C. Ritchie, "A heteroaromatically functionalized hexamolybdate", *Inorganics* **2015,** *3*, 82-100.

4. P. B. Markworth, B. D. Adamson, N. J. A. Coughlan, **L. Goerigk**, E. J. Bieske, "Photoisomerization action spectroscopy: flicking the protonated merocyanine-spiropyran switch in the gas phase", *Physical Chemistry Chemical Physics* **2015,** published online, DOI: 10.1039/c5cp01567g.

5. B. Chan, **L. Goerigk**, L. Radom, "On the inclusion of post-MP2 contributions to double-hybrid density functionals", *Journal of Computational Chemistry* **2015,** in press (accepted on 22 May 2015).

4. Conference presentations

1. **L. Goerigk**, "Efficient alternatives for the quantum-chemical treatment of peptides and proteins", talk at the 2014 RACI National Congress, Adelaide.

NB: Postscript note from Lars Goerigk 16 July 2015: Accepted article has been published with DOI 10.1002/jcc.23972