Australian Academy of Science

Summer program in Australia for US graduate students in science and engineering

2008 East Asia and Pacific Summer Institutes for US Graduate Students

NSF

Australian Government

Department of Innovation Industry, Science and Research

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Preface

For the fifth year in a row, the Australian Academy of Science was delighted to welcome a group of twenty outstanding students from the United States of America who participated in the 2008 *Summer program in Australia for US graduate students in science and engineering*.

The program, developed in collaboration with the US National Science Foundation, aims to introduce the students to Australian science and engineering in the context of a research laboratory and to initiate personal relationships that will better enable them to collaborate with their Australian counterparts in the future.

The Academy acknowledges the importance of research collaboration that goes beyond national borders and academic disciplines. The Academy places great importance in strengthening exchanges that are both competitive and cooperative among talented young researchers.

The program started on 16 June 2008 and lasted for eight weeks. Participants achieved their immediate research goals, and from their reports I note that they have accomplished much more. Some students have initiated strong collaborative links that will provide the foundation for lifetime cooperative research. Others have gained a broad perspective of the nature of research in Australia, while others have been enriched by understanding another culture. These graduate students and the young Australians with whom they shared their research will play an important role in advancing cooperative research between Australia and the United States in future years.

I would like to extend my thanks to the Australian Department of Innovation, Industry, Science and Research for their continued support in funding this program, and of course to our colleagues at the National Science Foundation. Without their kind assistance and cooperation, this important activity could not be sustained.

The Academy looks forward to welcoming a new group of students in 2009.

Professor Kurt Lambeck FAA, FRS
President
Australian Academy of Science

Contents

Orientation program

Monday 16th June

10.10 Participants arrive in Canberra

10.30 Check–in to University House

13.00 Lunch at Chat's Café, Australian National University

13.45 Administrative details for NSF Summer Program and living allowances for participants

18.30 Dinner at Boffin's Restaurant, University House

Tuesday 17th June

9.50 Arrive at the Shine Dome, Australian Academy of Science

10.00 **Official Opening**

Professor Michael Dopita, ***Australian Academy of Science Council Member and Treasurer***

Michael Dopita is an Emeritus Professor at the Research School of Astronomy and Astrophysics at the Australian National University. He is an expert in interstellar astrophysics and has made fundamental contributions to research on astrophysical plasma diagnostics, star formation in galaxies, the physics of planetary nebulae, supernova remnants, active galactic nuclei and radio jets. He is Editor-in-Chief of the international journal *Astrophysics and Space Science* and has served on a number of NASA committees and peer-review panels.

10.05 **Welcome Address**

Dr Sue Meek, ***Chief Executive, Australian Academy of Science***

Sue Meek has recently taken up the position of Chief Executive of the Australian Academy of Science. Dr Meek held the position of Australia's Gene Technology Regulator since 2001, responsible for administering and enforcing the national regulatory system for the development and use of gene technology. Immediately prior to that, she was Executive Director of the Science and Technology Division at the Western Australian Department of Commerce and Trade. Dr Meek has a PhD in marine biology; an MSc in oceanography; and BSc (Hons) in microbiology. She is a Fellow of the Australian Academy of Technological Sciences and Engineering.

10.10 **Lecture –** ***Australian mammals: Exceeding strange and highly worth observing***

Dr Hugh Tyndale-Biscoe, ***Fellow of the Australian Academy of Science (FAA)***

For more than 40 years Hugh Tyndale-Biscoe has been employed in marsupial research, from brushtail possums in New Zealand, to quokkas in Western Australia, and from tammar wallabies in New South Wales to opossums in South America.

11.00 Morning tea

11.30 **Lecture – *Post-doctoral research opportunities in Australia***

Dr Joe Hlubucek, *Research Project Officer, Australian Academy of Science*

12.05 Group photo

12.30 Lunch at Café in The House, Old Parliament House

14.00 Attend Question Time at the House of Representatives, New Parliament House

15.00 Tour of New Parliament House

18.40 Annual Dinner at Shalimar Restaurant, Canberra City

Wednesday 18th June

9.00 Arrive at Shine Dome

9.15 Site visit of Research Schools, Australian National University

12.30 Lunch at National Museum of Australia

13.30 Tour of National Museum of Australia

16.00 Informal drinks in the Becker Room, Shine Dome

17.00 Free time

Thursday 19th June

8.15 Check out of University House and depart Canberra

Name:	**Melissa Brandon**
University:	University of Wisconsin - Madison
Research advisor(s):	Dr Catherine Steven and Dr Barbara Tillmann
Host institution(s):	University of Western Sydney

Research subject

Implicit learning of auditory temporal patterns

Research description

Implicit learning is learning that occurs without conscious knowledge. The learning takes place through exposure without direction to the material that is to be learned. After the exposure the learner is typically unable to verbalise what they have learned but still shows the behavioural performance markers of learning. A standard task used to assess implicit learning is the serial response task (SRT) (Nissen & Bullemer 1987). This task requires the participant to make a response for every item in the sequence while reaction time and accuracy are recorded. The items occur in a repeating pattern over several blocks of trials before a single test block with a novel pattern is presented. The final block of trials returns to the original order. This novel patterned test block and the return to the previous pattern enables assessment of learning. Evidence of learning is seen in faster response times and improved accuracy over the exposure to the pattern, and an increase in reaction time and errors when the novel pattern is introduced.

The field of implicit learning has focused on learning of sequential patterns such as the patterning of locations in a serial presentation of lights. However the field of implicit learning has not examined the temporal aspects of these serial patterns, and especially not in the auditory modality. Salidis, 2001 is the only paper to examine implicit learning of auditory temporal patterns thus far. Salidis examined the implicit learning of 6-event auditory rhythms using an SRT task and demonstrated that implicit learning of temporal patterns is possible.

But real world events that rely on temporal structure, such as music and language, have far more complex and organised temporal structures. These systems have a hierarchical organisation to their temporal patterns know as meter, which is defined as the organisation of events in time focused around a reoccurring pulse or beat. It is possible the metrical hierarchical temporal organisation in systems such as language and music aid the learning and understanding of these systems. This research project aims to examine the implicit learning of temporal patterns that contain metrical structure. We adapted the SRT task to test for implicit learning of metrical structures in

auditory sequences. In our task participants have to identify syllables (PA, TA, or KA), with the syllables themselves being presented in a random order, but the timing of the presentation of the syllables occurs according to a prescribed metrical structure. The cover task of syllable identification enabled us to have the participants make a key press closely following the metrical timing pattern without directing attention to this timing pattern. To assess the degree to which the metrical structure aids the implicit learning of the temporal structure we incorporated two levels of metricality: strong versus weak. For both conditions, the novel temporal pattern used for the test block was a novel weakly metrical pattern chosen to have no overlap in the interval patterns with either of the trained temporal sequences. Participants were randomly assigned to either the strong or weak condition, and they were not told about the timing aspect of the study until after the implicit learning test. The metrical patterns we used came from well-established interval patterns that have previously been classified as strongly metrical and weakly metrical (Povel & Essen, 1985; Patel et al, 2005).

After the implicit learning task participants also completed a test of explicit memory to asses for any conscious knowledge of the timing patterns. For the test of explicit memory we informed the subjects that there was a regularity in the timing and had them listen to auditory sequences with piano tones in place of the syllables. For every piano tone sequence the participants judged on a 6-point scale if the timing pattern they just heard was like the timing the syllables had occurred in during the previous task. In the explicit memory task the subjects made judgements on six temporal patterns that did occur during the syllable task and nine temporal patterns that did not occur. This design was used so that the same test could be used for both conditions and there would be temporal patterns that had the same meter as the trained patterns, but different local interval patterns. These metric foils allow us to assess if the subjects had conscious knowledge of the temporal patterns on either the local interval pattern level or the higher metrical level.

Data collection for this task was being conducted until the last days of the program, thus the analyses are still being conducted. We predict we will see implicit learning in both conditions, but the learning may take longer or have a smaller behavioural impact in the weakly metrical condition as compared to the strong metrical condition because the hierarchical structure is not as reinforced in the weakly metrical condition. We hope to publish the findings of this experiment.

Research activities

In order to adapt the SRT paradigm to test for implicit learning of metrical structure, I first conducted a literature review of the fields of implicit learning and research on meter.

I used the knowledge I gained in my literature review to help inform our study design which was decided upon in mutual collaboration between Dr Stevens, Dr Tillmann, and myself. In creating my stimuli, I learned to use several new software applications, including a speech synthesiser which I had no previous experience with, and received many helpful tips on creating auditory stimuli from my peers at MARCS Auditory Laboratories. The skills I gained in creating my stimuli here are invaluable skills that I will draw upon in all my future studies as well. Once the undergraduate students returned from break I spent the remainder of my stay collecting data and planning my data analyses.

In addition to the research I conducted I also had the opportunity to participate in the HCSnet Workshop on Speech, Perception, and Action, where I presented a speed paper on a research project I have conducted in the United States. HCSnet is an Australian Research Council funded program to promote interdisciplinary research between scientists that study human communication science. The workshop proved to be a very educational two days. I also gave a full talk on my PhD research at one of the Monday MARCS meetings. Both opportunities to speak produced many fruitful suggestions for the research I have in progress at my home institution.

Perspective of research after this program

My research experience at the MARCS auditory research laboratory at the University of Western Sydney has exemplified to me what a collaborative research environment should be like. During my stay at MARCS, I was one of six international visiting researchers here to do collaborative research with the faculty at MARCS. Being in this hotbed of international collaborative research, both observing the collaborations around me and being personally part of one of these collaborative projects, has helped me see how much knowledge and insight can be gained through collaborative research. From my own experience I have seen personally the advantages of multiple expertises in informing the design of a study and shaping the perspective of the research project. This experience has taught me many practical research skills, and affirmed the benefits of, if not the necessity for, collaborative research in my future.

Advisor's remarks

It has been a delight to host Melissa Brandon's research visit to MARCS Auditory Laboratories through the EAPSI NSF Summer Program.

Melissa has researched and implemented a new experimental paradigm designed to investigate the implicit learning of relatively complex temporal patterns. The paradigm and research topic build on and augment research that Dr Tillmann and I had begun. During the first month of her visit Melissa reviewed relevant literature and prepared a draft manuscript. With the arrival of Dr Tillmann in mid July we finalised the experimental design. Melissa then created the stimuli, programmed and piloted the experiment and, when Semester 2 commenced, ran more than 30 undergraduate participants through the new experiment. We will finalise data collection and analysis over the next few weeks and look forward to working with Melissa in the write up of the findings for publication.

Engaging enthusiastically with students and staff, Melissa has been a committed and energetic member of MARCS Auditory lab over these past eight weeks. She has presented research conducted at her home university at an ARC Research Network Workshop on Perception and Action (**www.hcsnet.edu.au/hcsnetevents/2008/paworkshop**) and at a Monday MARCS Meeting. We look forward to the outcomes of our collaborative research with Melissa and welcome this and future participation in the EAPSI NSF Summer Program.

Name:	**Dylan Burge**
University:	Duke University
Research advisor(s):	Dr Bill Barker
Host institution(s):	State Herbarium of South Australia

Research subject

Evolution of nickel hyper-accumulation in the plant genus *Stackhousia* (Celastraceae)

Research description

Our project aims to produce a molecular phylogeny for the plant genus *Stackhousia*, and to use this phylogeny, in combination with data on tissue nickel (Ni) levels, to elucidate the origin of Ni hyper-accumulation by the species *Stackhousia tryonii*.

Research activities

a) Sequencing of the genes ITS (the internal transcribed spacer regions of the nuclear ribosomal DNA) and trnL-F (from the chloroplast) from a set of 60 *Stackhousia* populations, representing all of the currently recognised taxa. b) Analysis of Ni content from tissue samples of the same plants used for genetic analysis, in addition to 40 other samples not included in the genetic work. c) Field work to obtain broad sampling of *Stackhousia tryonii* for both Ni and genetic research.

Perspective of research after this program

All samples have been analysed for Ni, and gene sequencing is ongoing. The research proceeded rapidly while in Australia, and I am very happy with the amount of work that I was able to accomplish while in the country. The project is not yet complete, but should come to fruition within a few months to a year. I expect to publish one paper with Bill Barker on the phylogeny of *Stackhousia*. Depending on results, we may also publish a second paper on relationships between *S. tryonii* and its closest relatives.

Advisor's remarks

As an experienced plant systematist who yearns for and is on the brink of a return to more active research, Dylan's visit was a very warm, fruitful and educational one for me. He has an excellent grasp of and approach to his science and many strong personal qualities along with a welcome propensity for taking appropriate initiatives. It would be great if opportunities eventuated to develop our collaboration further than the immediate work he undertook while here, which married perfectly with my own research in the phylotaxonomy of *Stackhousia*.

Name:	**Kayla Calvert**
University:	Purdue University
Research advisor(s):	Dr Mark Hoffman
Host institution(s):	University of New South Wales

Research subject

Nanomechanical and structural characterisation of hydroxyapatite coatings on ultrafine grained titanium

Research description

Commercially pure titanium (cp-Ti) and Ti-6Al-4V are biocompatible; however, the use of vanadium and aluminium in Ti-6Al-4V can evoke the foreign body response. Cp-Ti has shown no local or systematic response when implanted in the human body and is thus preferred over Ti-6Al-4V. However, cp-Ti porous implants have low strength for load-bearing application compared to Ti-6Al-4V. Through severe plastic deformation (SPD) processing of cp-Ti, ultrafine grain (UFG) refinement (from ~100 nm to 1 μm) of cp-Ti has shown superior mechanical properties compared to conventional grain size (~50 μm) Ti. Therefore, UFG cp-Ti may potentially be a superior material for orthopaedic devices. Hydroxyapatite (HA), a ceramic coating commonly applied to porous orthopaedic devices, is known to enhance osteointegration (bone ingrowth); however there are no reports of coating properties on UFG materials produced by SPD processing.

Our lab has created a machining process to induce high strains in metals creating an UFG microstructure. In my particular area of research, we have induced severe plastic deformation (SPD) in cp-Ti. With this process, strains of 2-4 are induced into the cp-Ti depending on the specific geometries of the machining.

My study involves the characterisation of three HA application processes to determine the integrity of the coating as well as the thermal effect on the UFG Ti. The proposed research is the first of its kind to examine the feasibility, nanomechanical properties and microstructure of HA coatings on UFG cp-Ti. UFG cp-Ti can lead to better-performing, longer-lasting orthopaedic devices, such as acetabular cups and tibial trays. Orthopaedic devices developed from HA-coated UFG cp-Ti may ultimately improve quality of life in patients with joint replacements.

Research activities

UFG cp-Ti plates (width ~2 cm and thickness ~2 mm) were developed prior to departure and sent to Australia for HA coating via plasma spray. Plasma spray coating can expose the substrate material to high temperatures resulting in the re-crystallisation of the UFG Ti. Two alternative low temperature methods (spin coating of a sol-gel and anodisation in an aqueous calcium/phosphorus solution) were also developed for HA coating.

The characterisation of these coatings involved hardness evaluation of the different HA processing routes. The preliminary hardness data suggests that the hardness of these coatings are approximately 3.5 GPa. The hardness of the plasma spray coatings could not be evaluated by nanohardness; however, are known to be 3.5-4.5 GPa. The nanohardness indentor was not in working condition during parts of my stay; therefore, the data collected is not inclusive of all processing parameters. Metallographic samples were prepared to analyse the microstructure and HA coatings for the different processes.

The focused ion beam (FIB) milling system was used to prepare the coated specimens for transmission electron microscope (TEM) analysis. FIB is a specialised TEM specimen preparation technique that allows for thin foil specimens to be cut out with high spatial resolution, as shown in Figure 1. This system develops very thin (200 nm) sections for TEM analysis. TEM was used to evaluate both the thickness of the coating and the grain size, as shown in Figure 2. The thickness of the coating is 300-500 nm, which is much thinner than the plasma sprayed coatings at 50-75 µm. In addition, in Figure 2, it is shown that the grain sizes are 200-300 nm in diameter, which indicates the grains have not re-crystallised at the HA processing temperature of 350OC. This initially indicates that the temperature required for HA coatings may be suitable for UFG cp-Ti. Confirmation of this observation is pending hardness evaluation, as a decrease in hardness is indicative of re-crystallisation.

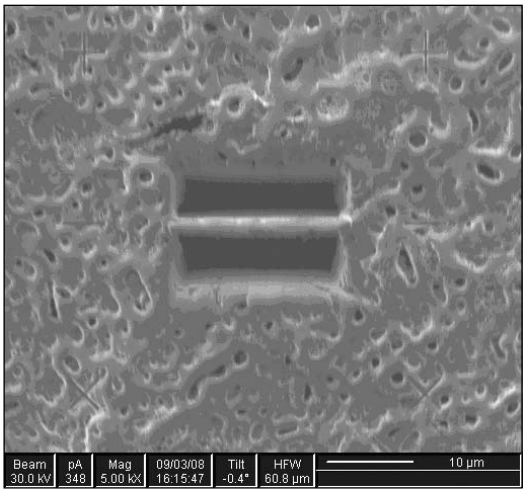


Figure 1. FIB milled anodised sample for TEM

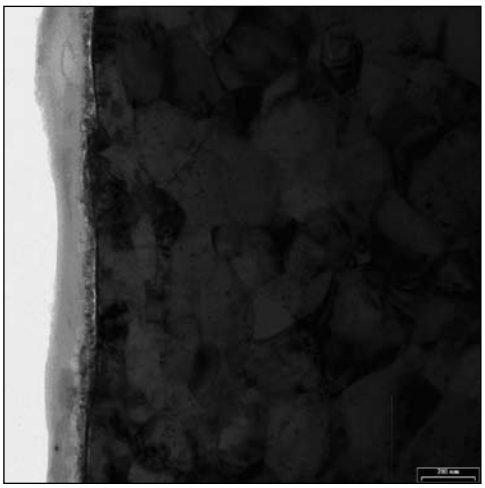


Figure 2. TEM of HA coated cp-Ti, white region indicates HA coating and dark region cp-Ti substrate

Perspective of research after this program

Through the program, I was able to experience the high quality of research conducted in Australia. The time I spent in Australia was amazing, not only did I advance my project, but I was informed of fantastic opportunities available for researchers in Australia. The research conducted through the program allowed for the initial characterisation of HA coated cp-Ti. In addition, I learned skills such as using FIB for TEM sample preparation and testing the nanohardness. My research will continue with the characterisation of the films and evaluation of the substrate to determine the affect of thermal processing.

Advisor's remarks

The project which Kayla sought to undertake was ambitious and exciting. She nevertheless made considerable progress while she was here, attaining some very interesting results. Kayla was certainly a positive contribution to my research group and pleasure to have here.

Name:	**Dawn Carone**
University:	University of Connecticut
Research advisor(s):	Dr Marilyn Renfree
Host institution(s):	University of Melbourne

Research subject

The role of RNA in centromere drive within marsupial interspecific hybrids

Research description

My research project in Australia involved examining the chromosomes of several marsupial interspecific hybrid species for centromere defects arising from incompatibilities in centromere and/or RNA processing machinery. I set out to test the centromere drive hypothesis which is thought to arise from genetic conflict during female meiosis. My previous research in the US indicated a new class of small RNA are produced from marsupial centromeres. My research program in Australia set up to test whether centromere drive and genomic conflict may be mediated by these RNAs.

Research activities

My research involved obtaining rare marsupial interspecific hybrids from another collaborator in Australia. Previous research in Dr Rachel O'Neill's lab had identified several centromere related defects in similar marsupial hybrids. These animals were sent to Dr Marliyn Renfree's laboratory as I arrived in the country and I was able to obtain samples to set up primary fibroblast cell cultures. It is from these cell cultures that I was able to karyotype the hybrid animal's chromosomes to look for centromere specific defects. Once these defects were identified, I performed fluorescence *in situ* hybrisation to look for difference in the amount of DNA at the centromere in addition to a difference in the amount of centromere proteins. I also performed studies to determine if the amount of RNA produced by the hybrids could be correlated with the centromere incompatibility that is seen in the hybrids.

Perspective of research after this program

The research I conducted in Australia through the EAPSI program was very successful and I was lucky to have a host who helped to make my time spent in the lab very productive from the start. I now have a new understanding of how research is conducted in Australia and have fostered and continued many collaborations between my lab in the US and labs in Australia. The research experience through the EAPSI program has been invaluable to my career as a scientist. As I am now completing my graduate studies and beginning to think about conducting my own research, this experience has given me the opportunity to broaden my horizons and to interact with other scientists in my field.

Advisor's remarks

It was a real pleasure to have Dawn Carone visit our laboratory. She had a very productive time, and her visit has significantly strengthened the developing collaboration between the Renfree and O'Neill laboratories. She was able to obtain some unique marsupial material for her research, including samples from some rare hybrids. She has made friends with members of my group, and she would be welcome back here any time. I am delighted that the Academy fosters such programs and I will enthusiastically encourage more visits from participants in the EAPSI NSF Summer Program in Australia.

Name:	**Kristen Casalenuovo**
University:	Virginia Commonwealth University
Research advisor(s):	Mr Dirk König
Host institution(s):	University of New South Wales

Research subject

Optimum computational routes for H- and OH-terminated Si, Ge, and Sn quantum dots

Research description

We explored different theoretical computational routes for studying the electronic structure of atomic clusters containing second, third, and fourth row elements. In particular, the approximants constructed were H- and OH- terminated silicon (Si), germanium (Ge) and tin (Sn) quantum dots. We tested various combinations of hybrid functionals and molecular orbital basis sets for geometric structure optimisations and subsequent single-point energy calculations using the density functional theory (DFT) and Hartree Fock formalism. The goal is to find the optimum route for accuracy with affordable computational expense.

Research activities

Geometry optimisations and subsequent single point energy computational routes (opt//spE) were carried out using the Gaussian03 software package, revision D.01, on a 440 GFLOPS Linux cluster with 72 cores (64 bit) using a maximum of four parallel processors for each single data run. Calculations tested combinations of functional (HF, B3LYP, B3PW91, PBEPBE) with various Gaussian-type MO basis sets. All functionals except for HF are hybrids. Some basis sets used are all-electron (UGBS, 3-21G*, 6-31G(d), and 6-311+G(2d,p), and DGDZVP) thus are only feasible for systems with up to third row elements. The other type of MO basis sets explored contain scalar-relativistic pseudopotentials (LanL2MB, LanL2DZ, CEP-4G, CEP-31G, and CEP-121G) so they can be employed for atomic clusters containing fourth row elements and beyond and are still applicable to systems with less heavy elements although they may not be as accurate there.

Perspective of research after this program

This program really exceeded my expectations in terms of how much I learned and benefited. The ARC Photovoltaics Centre of Excellence is internationally renowned for their solar cell research, and it was exciting to be a part of that effort and work with such esteemed experts. It provided a unique opportunity to see how my particular area of research, DFT, is applied to technology development. Science is a collaborative effort, so being exposed to theory and experiment working hand in hand allowed me to understand the bigger picture of research efforts and to appreciate the importance of such partnerships. Conducting research in Australia was valuable to expanding my awareness of scientific pursuits on a global level. I've learned that optimal research

gives some answers, but leads to more questions. My advisor and I will continue to collaborate to explore these new questions, and share our findings with the scientific community through publications and presentations.

Advisor's remarks

The topic of the summer internship was to investigate density functional theory (DFT) methods which work for chemical elements of the fourth and – to some extend – fifth period of the periodic table of the elements. With increasing atomic number the computation of material properties by DFT become increasingly complex due to relativistic effects as well as the more complex shape of the frontier molecular orbitals (MOs). Relatively few DFT results of heavy elements have been reported in the literature with accuracies not always meeting our demands.

The main test ground for combinations of hybrid DFs with all electron or relativistic effective core potential (ECP) MO basis sets were Si_{10}, Ge_{10}, and Sn_{10} cores terminated with H or OH-groups. While H-terminated approximants present co-valent (standard) systems widely used in the literature, the OH-terminated species are more relevant for practical applications like quantum dots (QDs) embedded in a dielectric as an oxide. The latter termination requires substantially more computation power. The DF/MO basis set combinations were tested for accuracy with the constraint of a minimal computation effort. The accuracy gauge was given by high level reference computations for the 2nd and 3rd (Si and Ge) periods and by experimental values for the 4th (Sn) period.

My initial doubts about the feasibility of an undergraduate student carrying out a total of about 150 program runs for both surface terminations *not* including de-bugging, code optimisations and data post-processing proved to be unfounded due to Kristen having done excellent work. She has been a hard working student who tackled the task with vigour and expertise. The few consultations Kristen asked for were on technically sound topics or syntax/semantics issues of the DFT code used. Her presentation at the end of her internship was of high interest to the research group and gave further momentum to our research work.

The outcome of Kristen's work is being used for evaluating binary compounds involving heavy elements for hot carrier absorbers in 3rd generation solar cell devices. Many of these materials are rather exotic due to their specific material properties. Consequently there are few or no experimental data available which requires DFT for predicting material properties. There is a high chance of a publication in a high-ranking journal about the evaluation of DFT computational routes for heavy elements with Kristen as the first author.

We would be happy to have Kristen back with us after she finished her master's degree for pursuing a PhD at the Photovoltaics Centre of Excellence of the Australian Research Council.

Name:	**Jeffrey Case**
University:	University of California Santa Barbara
Research advisor(s):	Dr Robert Bartnik and Dr Pengzi Miao
Host institution(s):	Monash University

Research subject

Splitting theorems in Lorentzian geometry

Research description

The study of curvature is very important to both Riemannian and Lorentzian geometry. The splitting theorem of Cheeger and Gromoll in the Riemannian case, and Eschenburg, Galloway, and Newman in the Lorentzian case, is an important and powerful rigidity result in the study of spaces with nonnegative Ricci curvature. Roughly speaking, both theorems state that if a complete manifold with nonnegative Ricci curvature contains a line, then it must split isometrically as a product of a hypersurface and the real line. Some care must be taken in the Lorentzian setting, because there are multiple notions of completeness one can take, and one requires only that the manifold have nonnegative Ricci curvature in timelike directions while requiring that the line be timelike.

In the Riemannian setting, using the Cheeger-Gromoll splitting theorem one can easily prove that if such a manifold is disconnected by a compact hypersurface, then it must be isometric to a product of some compact hypersurface and the real line. The analogous question in the Lorentzian case, as posed by Bartnik, is still open, though partial results exist. The difficulty lies in the fact that one can only guarantee the existence of a nonspacelike line, but the Lorentzian splitting theorem requires a timelike line. Hence one must find a way to rule out the existence of a null line, and the partial results are achieved by imposing some additional condition that one can use to show the nonexistence of null lines.

A related question one can ask is to classify static metrics. These are vacuum solutions of the Einstein equations which can be written as a warped product of a Riemannian 3-manifold with the real line, with the warping function defined on the Riemannian factor, and it turns out that this question is only a question of finding a function N on the Riemannian factor, the static potential, which satisfies N*Ric=Hess(N). This problem easily generalises to the question of finding Einstein metrics on any warped product that, as in the case of the static metric equation, reduces to finding a function on the base that has its Hessian proportional to the Ricci curvature in a similar manner. A pseudo-Riemannian manifold together with such a function has been called quasi-Einstein. By understanding these models, we can then return to looking at the larger product manifold and asking if we can't determine when a manifold will split as such a warped product.

Research activities

The majority of my time was spent in learning new techniques of geometric analysis and seeing how they might be applied to the problems of Lorentzian splitting of spatial closed manifolds and finding Einstein metrics on warped products. The proof of the Lorentzian splitting theorem is most easily given by using Bartnik's proof of the existence of maximal hypersurfaces given rough boundary data. This is necessary because one must construct the splitting function, which is done in the Riemannian setting by finding a harmonic function related to the distance function and using the maximum principle, which is only valid for elliptic operators. In the Lorentzian setting, the Laplacian is not elliptic, and one must descend to suitably chosen spacelike hypersurfaces to be able to use the maximum principle. To resolve the question of whether or not one can prove the nonexistence of null lines in a cosmological spacetime will likely require the introduction of other functions or hypersurfaces.

On the other hand, the problem of finding Einstein metrics on warped products is closely tied to the problem of finding static metrics, which has been studied extensively in the literature. Through this connection, I have been able to prove that there are no nontrivial Ricci flat metrics on complete warped products with Ricci flat fibres, which is the natural generalisation of M. Anderson's proof that there are no nontrivial complete static metrics with positive static potential. This work also suggests a way of studying the problem when allowing either the warped product metric or the fibres to be Einstein but not Ricci-flat, as the arguments rely on PDE techniques and volume comparison estimates which are easily proven in those more general settings. The connection to static metrics also suggests considering how horizons in static metrics might arise in the warped products. This question may also be closely related to the study of Poincare-Einstein metrics, where the horizon in static metrics plays a role similar to the role of the boundary of a Poincare-Einstein metric.

This last observation came from attending one of the two conferences I attended while in Australia. These conferences both have led me to see both problems that I am working on in new ways, and led to interesting questions such as the one above. The last question in particular, in considering whether or not it is possible to adapt the techniques of tractor connections used in studying the Poincare-Einstein metric as introduced by Gover, Leitner, and others, is one that I would not have otherwise been exposed to without being in Australia. An answer in either direction will be interesting and perhaps lead to additional insights into the structure of static and quasi-Einstein metrics, and consideration of this question could lead to a fruitful collaborative work with my hosts.

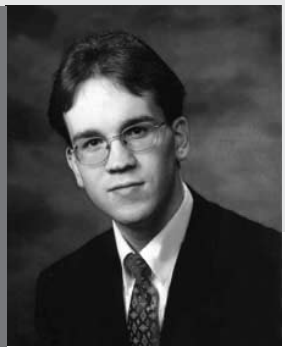
Perspective of research after this program

After my trip to Australia, I have acquired a much more comprehensive view of my research field and both the problems and techniques which lie within it. I've been exposed to many different ideas, and these have led to many questions and possible ideas for solutions to the two problems I am considering. This has been useful not only in providing me with many new insights and possible questions to consider, but in encouraging me to further continue looking at ideas and questions not directly related to my own research topic.

Advisor's remarks

I believe that Jeffery has made the best out of his visit. He and I frequently exchanged ideas concerning various questions relating the properties and existence of quasi-Einstein metrics and their potential relations with static metrics in general relativity. He impressed me with his strong analytical skills and sharp geometric insight. In a less than weeks' time, he was able to generalise a non-existence result of Mike Anderson to quasi-Einstein metrics, about which he is currently writing a paper. He also spoke twice in our geometric analysis seminar at Monash. Many honours students and PhD candidates in our school had shown good interest in his talks.

I think both Jeffery and people at the mathematics school at Monash have benefited from his visit. I hope we can keep having young research visitors like Jeffery each year that can be sponsored by this program.



Name:	**Christopher Drupieski**
University:	University of Virginia
Research advisor(s):	Dr Jie Du
Host institution(s):	University of New South Wales

Research subject

Representations and cohomology of algebraic and quantum groups

Research description

Group structures arise naturally in many branches of mathematics. Roughly speaking, a *group* is a mathematical object that may be realised as a collection of symmetries (eg, the dihedral group is the set of all rigid motion symmetries of the square). *Group theory*, the study of groups, is one of the most important areas of mathematics, with many applications throughout mathematics and science. Key to the advancement of group theory has been the subdiscipline of *representation theory*. Representation theory is the study of the ways in which one mathematical object may 'act' on another. Equivalently, it is the study of the *representations* or *modules* afforded by a particular mathematical object. Studying an object's representations often yields much information about that object's own structure.

A crowning achievement of group theory (indeed, of all mathematics) in the twentieth century was the classification of all finite simple groups. The results of this project will be mined for decades, if not longer, and its implications cannot be overestimated. Still, many problems remain open in the representation theory of finite simple groups. Since the finite groups of Lie type make up the bulk of all finite simple groups, attention naturally focuses in this direction.

Research into the structure and representation theory of finite groups of Lie type is strongly influenced by parallel work in such other areas as algebraic groups, Lie algebras, and quantum enveloping algebras. My research focuses on the representation theory of infinitesimal algebraic groups, and of so-called 'mixed' quantum enveloping algebras (that is, quantum enveloping algebras at a root of unity defined over fields of positive characteristic).

Research activities

The initial goal of my project was to compute the structure of the cohomology ring of the finite-dimensional mixed quantum enveloping algebra corresponding to an irreducible root system of low rank. Prior to embarking for the University of New South Wales (UNSW), I conducted an extensive literature review and performed a few preliminary calculations. I discovered that certain classical as well as some more recent results on the cohomology of non-mixed quantum enveloping algebras could be modified without much difficulty to also work in the mixed case.

With the bulk of the original project seemingly completed before I even arrived in Australia, Professor Du and I decided to pursue a slightly different project during my stay in Sydney.

Providing a connection between the representation theory of quantum enveloping algebras of type A, and of finite general linear groups and Hecke algebras of type A are q-Schur algebras. I devoted most of my time at the University of New South Wales to studying the structure of q-Schur algebras and their connections to quantum enveloping algebras. Topics Professor Du and I discussed included the representation theory and Kazhdan-Lusztig combinatorics of Hecke algebras, cell theory for symmetric groups, canonical bases for Hecke algebras and quantum Schur algebras, and the realisation of q-Schur algebras as homomorphic images of quantum enveloping algebras.

Concurrent with my work with Professor Du, Professor Bangming Deng of Beijing Normal University was a visitor at UNSW. He delivered a series of introductory seminar lectures on the theory of cluster algebras, which I was able to attend. Cluster algebras yield further connections to the theory of quantum enveloping algebras.

Perspective of research after this program

In my original project proposal, I proposed attacking the problem of computing the cohomology of quantum enveloping algebras from the angle of Ringel-Hall algebras and canonical bases. Since I resolved a large part of the cohomology question before arriving in Australia, this was not a topic I spent any time on with Professor Du. I would like to come back to it in the future, especially if I could solicit the help of Professor Du and Professor Deng, who are experts in these areas.

Due to my limited time at the UNSW, I was only able to scratch the surface of what is known about the structure of quantum Schur algebras, and how they relate to quantum enveloping algebras and the representation theory of finite general linear groups. This is a topic I definitely anticipate pursuing as part of my postdoctoral research, and one I hope to work with Professor Du again in the future.

Advisor's remarks

When Chris arrived in Australia, I was working on the final version of a book (joint work with Deng, Parshall and Wang). Since Chris is interested in Hecke algebras, q-Schur algebras and quantum groups, I suggested that he read four chapters of our book. Chris learns things quickly. He made some excellent comments on his findings and we managed to include them before the book went to printing. We very much appreciate his feedback on the book.

He was also actively involved in the seminars series on cluster algebras presented by Professor Deng. His own seminar at UNSW was well received by an audience of postgraduate students, UNSW algebraists and some algebraists from Universities and Sydney and Western Sydney.

It was nice to have Chris here and I enjoyed his visit very much.

Name:	**Steven Gray**
University:	The State University of New Jersey
Research advisor(s):	Dr James Scandol
Host institution(s):	Wild Fisheries Program, NSW Department of Primary Industries

Research subject

Improving the application of risk-based methods in scope, implementation and interpretation of fishery stock assessments for data-poor species

Research description

To assist in the management of data-poor fisheries there is a need to integrate risk-based methods into stock analysis. Fishery stock assessments are the fundamental links between the status of a resource and the manner in which it is managed. Understandably, the methods employ a certain amount of risk-averse strategies, established to determine at what rate resource users can harvest marine capital without disturbing ecological balance. To do this, fisheries scientists and natural resource managers are constantly searching for and modifying methods for stock assessments that maintain marine biodiversity through healthy fish populations while acknowledging the commercial and recreational value of fishing practices.

The way in which risk is interpreted and integrated into fisheries management plays a key role in fisheries science and is often central to the implementation of fishery regulations. In short, fisheries assessment involves three main areas; (1) Scope: identification of species earmarked for stock assessment; (2) Implementation: execution of an assessment using data and various analyses; (3) Interpretation: provide a managerial interface to the outcome of a stock assessment. The interpretation and role of risk within these three phases of assessment differ because the goals, priorities, values, and players of the phases differ. Rather than focus on a simple technical interpretation of risk, the larger project conducted under the Principal Investigator (PI), fisheries scientist Dr James Scandol from the New South Wales (NSW) Department of Primary Industries (DPI), aims to create standards for the application of risk based methods within the assessments of data-poor species that are consistent with the more formal assessments done for target species which are often data-strong.

Research activities

Research for this project required gathering similar data from the United States in order to identify where the concept of 'risk' is being identified within large-scale fishery management systems. Once in Australia, I worked closely with fishery scientists from the NSW DPI to contain 'risk' within qualitative domains in an effort to give further insight into the development of risk-based fishery methods that reflect the professionals involved in the management process.

Perspective of research after this program

I found this program, and in particular working with Dr Scandol, to be extraordinarily beneficial. The NSF EAPSI program has afforded me an opportunity to explore and document trends in the fishery management process on an international scale. My time in Australia also proved to be pragmatically advantageous as it allowed me to collect comparative data for my dissertation while concurrently co-authoring a manuscript intended for publication.

Advisor's remarks

Steven made a great contribution to our project during his time with us. He worked diligently and systematically on a difficult problem examining the interpretation of risk between US and Australian fisheries managers and scientists. I expect the publication that results from this collaboration will be a valuable contribution to the application of risk-based methods in fisheries management in both Australia and the US.

Name:	**Micah Hamady**
University:	University of Colorado at Boulder
Research advisor(s):	Dr Gavin Huttley
Host institution(s):	Australian National University

Research subject

Practical chimera detection for high-throughput sequencing methods

Research description

The Human Microbiome Project (HMP) seeks to understand the microbial symbionts that outnumber us 10 to 1 in our own bodies and that provide many metabolic capabilities that we lack. High-throughput sequencing methods such as pyrosequencing are providing vast amounts of data that allow us to characterise these communities with a depth and scope that could not have been anticipated even three years ago: we can collect for $10,000 what would have cost $4 million with traditional sequencing methods. However, a key challenge of these methods is that the vast number of sequences produced breaks traditional algorithms for building phylogenetic trees, performing sequence alignments, and other necessary tasks.

The goal of this research project was to tackle the problem of chimeric sequences. These sequences are artificial hybrids of genes from different species that occur due to extension of incomplete templates in PCR. No one knows how to remove chimeras from the vast datasets (hundreds of thousands to millions of sequences) produced by pyrosequencing: traditional methods such as Bellerophon and Mallard scale to only a few hundred sequences.

The main approach was to use a method developed by researchers at the Australian National University (ANU) for haplotype detection. Although this method still shows promise, for pragmatic purposes I initially implemented a BLAST-based method that provides less accuracy but has good run-time performance, which we are already using on large-scale datasets. One unique aspect of the EAPSI program was that I was able to interact with a large number of both bioinformatics and lab-based researchers, and used these connections to collect and extract a large number of microbial community samples that I will use to test the techniques I developed. In particular, I was able to visit labs in Canberra, Sydney, and Melbourne, and was able to sample from a wide range of unique Australian wildlife, including marsupials, which will provide extremely valuable phylogenetically independent confirmation of trends that I saw in placental mammals in previous collaborative work for which I did the bioinformatics.

Research activities

My research activities were diverse: I spent the first few weeks working out ideas, initiating collaborations at labs within the ANU, other university research groups and zoos, and designing

and implementing the alternative chimera checking method described above. I also gathered microbial samples from a range of animal-associated and physical environments (including trips to zoos and research stations to collect hundreds of marsupial samples), underwent lab training, extracted microbial DNA from the samples, and prepared the samples for sequencing. I performed preliminary analysis of the data generated from some of these samples. Finally, I redesigned the architecture of the software that forms the basis of my thesis research to enable it to process much larger numbers of sequences, thus benefiting a wide range of collaborative projects.

Perspective of research after this program

I found this program very beneficial both in terms of advancing my current research and in suggesting new research directions and international collaborations. This program provided me with invaluable opportunities to expand my professional network, and enabled me to initiate several new research projects and collaborations. I felt that my Australian colleagues were able to lend a unique perspective to problems that I had been struggling with for some time, and the interaction with both bioinformatics researchers and bench scientists provided a wealth of useful information on practical methods, in terms of collection, sample preparation, sequencing, and data processing that I had thus far not experienced directly. Although the summer was a very short period of time to get much done, it certainly got the ball rolling, and at least one publication crediting the EAPSI support is already in press. The program also reinforced my view of science as a global enterprise in which multiple perspectives are required to arrive at a common empirical truth.

Advisor's remarks

Micah's short time in my laboratory was very beneficial to myself, members of my lab and the broader John Curtin School of Medical Research. It is anticipated this visit will lead to additional research activities and publications. In addition to his efforts on the proposed project, Micah brought with him an impressive amount of experience and new perspectives on application of high performance computing facilities for analysis of the next generation sequencing data which proved to be very beneficial to not just myself, but to many other researchers here. His depth of understanding, work ethic and enthusiasm for science were appreciated by many academics in the department and were a revelation to the postgraduate students with whom he interacted. His time here led to a mutually beneficial exchange of ideas on potential applications of pyrosequencing technologies, microbial ecology and modelling sequence diversity. I look forward to extending our preliminary work on the analyses of these data sets. In summary, it was a very successful and enjoyable experience.

Name:	**Mary la Russa**
University:	University of Alabama at Birmingham
Research advisor(s):	Dr Michael Teubner
Host institution(s):	University of Adelaide

Research subject

Inverse modelling of a multi-layer aquifer system in the Willunga Basin, South Australia

Research description

The flow of groundwater in confined aquifers can be described by the parabolic partial differential equation (1).

$$\nabla \cdot (K(x) \nabla u(x,t)) = S(x) \frac{\partial u}{\partial t} + R(x,t), \qquad (1)$$

where K = hydraulic conductivity (transmissivity in 2-D),
u = piezometric head (height of water in observation well),
S = specific storage (storativity in 2-D), and
R is a sink/source term, referred to as recharge.

The inverse groundwater flow equation consists of recovering the parameters K; S; and R from measured head data. Inverse techniques in common use among hydrologists typically focus on the recovery of only one of these parameters, usually either hydraulic conductivity or recharge, with the other two assumed to be known. My advisor, Dr Ian Knowles, has developed an inverse technique for recovering the parameters of elliptic partial differential equations by the minimisation of a certain convex functional. Since a parabolic PDE can be transformed to an elliptic PDE by doing a Laplace transform over time, this method can be applied to the inverse groundwater problem. In earlier work, Knowles and Yan used this technique to successfully recover all three parameters for an approximately two square kilometre region of the Port Willunga Formation aquifer in the Willunga Basin, South Australia. The goal of my research is to explore further applications of this technique to groundwater questions.

Research activities

My initial research goal for my time in Australia was to model a multi-layer aquifer. In particular, I was hoping to be able to recover leakage between the Port Willunga Formation and Maslin Sands aquifers. This turned out to be an overly ambitious project. There is no good source of data on the amount of pumping that occurs from either of these aquifers. Also, there may be leakage into the Port Willunga Formation aquifer from the Quaternary aquifers lying above it as well as leakage from the Port Willunga Formation aquifer into the Maslin Sands aquifer below it. Head data and

rainfall data alone don't give us enough information to tease out leakage between specific aquifers from the rest of the recharge term.

When it became apparent that the multi-layer problem could not be addressed during the internship, my host researcher, Dr Teubner, posed several questions focusing on establishing the reliability of our method and of our inverse code. Dr Knowles also asked me to investigate whether or not our method, together with rainfall predictions, could be used to accurately predict heads (water levels in wells). I spent most of my time in Australia working on the reliability questions, and doing preliminary work setting up data surfaces needed to address the rainfall-head prediction problem as well as other possible future problems, with assistance from Dr Teubner. The code was found to be very reliable across computers and compilers with data from different wells. I have continued working on the rainfall-head prediction problem since leaving the University of Adelaide. Results are still preliminary.

Perspective of research after this program

As a result of working with Dr Teubner, I am better able to recognise questions that are likely to be asked by hydrologists. In particular, I am taking time to quantify error where possible, and to identify more precisely the conditions needed for our inverse code to work reliably. I am looking at the recoveries we get and trying to ask what the recoveries suggest about the subsurface and if this makes sense from a hydrogeological perspective. I am also trying to consider ways that other kinds of data and/or other inverse groundwater techniques may be used in conjunction with our method. Through Dr Teubner, I met a number of people who live in the Willunga Basin, as well as the owners of area vineyards. I saw large rainwater tanks beside houses throughout the countryside, which are used to supplement the domestic water supply. I also learned how pruning practices have changed in response to decreased water availability. While the specifics of dealing with a severe water shortage will differ from one place to another, learning how the residents of the Willunga Basin are directly affected by a shortage of water and practices they have implemented for dealing with it added a very human perspective to the way I was looking at my research.

Advisor's remarks

I believe the international studentship program is an excellent opportunity for fellowship students from the US to have the opportunity to work with specialists in Australia, and to interact with students at comparable levels in their research programs. This provides the fellowship students with different perspectives that can only be beneficial and, in Dr Mary La Russa's case, the opportunity to actually see and get a first hand feeling for the geographical region she is studying as a part of her research.

Name:	**Stephen Levas**
University:	Ohio State University
Research advisor(s):	Dr Kenneth Anthony
Host institution(s):	University of Queensland

Research subject

Synergistic impacts of coastal eutrophication and elevated ocean temperature on corals and overlying reef seawater chemistry

Research description

There is a dire need to experimentally assess the effect of elevated temperature stress (ie, coral bleaching) conditions under enhanced eutrophication at the species level. Initial work has shown that corals exhibit decreased growth as well as a higher propensity to bleach when reared under elevated temperature and nutrient conditions. However, no study to date has attempted to quantify how changes in coral health might affect seawater chemistry and how such changes feed back to coral health. With the frequency and intensity of bleaching events expected to increase dramatically over the coming decades and continued threats of increases in nutrient and sediment discharge to the coastal ocean due to coastal development the impact on coastal seawater chemistry could be significant. It has been shown that the physiology and biogeochemistry of bleached coral can be significantly different from that of healthy corals, and can also differ significantly among species. Investigating the combined effects of bleaching and nutrient regime on coral physiology and biogeochemistry and seawater chemistry under eutrophic conditions, this research is a novel extension of ongoing research in this area.

Research activities

Three species of corals were kept in a flow through experimental setup. Nutrients were added constantly using a peristaltic pump and were measured every other day to make sure concentrations were those wanted. Colour and health of the corals were assessed every week. To test feedbacks between coral condition and seawater chemistry, I tracked concentrations of total nitrate, ammonia, phosphate and dissolved organic and inorganic carbon concentrations over eight hour incubation periods once the experiment was completed. At Ohio State University lipids, proteins, and carbohydrates will be measured to asses total energy reserves and growth of the corals under each treatment. Densities of photopigments (eg chlorophyll) and algal symbiont (zooxanthellae) will be measured to assess the degree of bleaching in each treatment. I will assay experimental corals for $\delta^{15}N$ of both host and symbionts to track assimilation of nitrogen as nitrate.

Perspective of research after this program

The research that was conducted this summer was really rewarding on a personal level. I will be publishing my results once all of the analysis is completed within the year. I greatly enjoyed this research experience and it will have publishable results.

Name:	**Chris MacDonald**
University:	University of California, San Diego
Research advisor(s):	Professor Marcela Bilek
Host institution(s):	University of Sydney

Research subject

Novel method of cell patterning to study glial signalling pathways

Research description

Creating a patterned biomaterial which would cause cells to arrange themselves into predefined patterns, and then using the patterns to investigate aspects of glial signalling.

Research activities

Working in the physics department of University of Sydney, learning techniques such as photolithography to generate patterns on silicon and the subsequently treating them with various plasmas.

Perspective of research after this program

I learned a huge amount from this project and am still working through the possibilities which the research has created. I would love to continue the collaboration and feel that the experience was invaluable, both from skills learned and meeting so many interested scientists who love what they do.

Advisor's remarks

Chris utilised plasma surface modification techniques available in our laboratory together with patterning methods sourced through collaborations to extend applications of our treatment methods in the biomedical arena. In doing so he benefited both our research activity as well as enhancing his own horizons. It was a great experience hosting Chris in our lab and we hope to continue the collaboration.

Name:	**Samantha Meenach**
University:	University of Kentucky
Research advisor(s):	Dr Penny Martens and Dr Laura Poole-Warren
Host institution(s):	University of New South Wales

Research subject

Fabrication and characterisation of novel degradable magnetic hydrogel nanocomposites based on polyvinyl alcohol and iron oxide

Research description

Polyvinyl alcohol (PVA) hydrogel nanocomposites were synthesised via redox free-radical polymerisations with iron oxide nanoparticles present in the material matrix. The systems were characterised for swelling capabilities, mechanical attributes, and cytotoxicity.

Research activities

Activities consisted of synthesising the PVA macromer, fabricating hydrogels via redox-initiated free-radical polymerisation, characterising gels for swelling and mechanical characteristics, and performing cytotoxicity analysis of the gels and macromer with fibroblast cells.

Perspective of research after this program

I wish I had more time to complete the work I started. One of the most difficult things at the university where I completed my research was the time needed simply for me to learn how they do things (which, of course, is typical). One of the best aspects, however, was learning new techniques in the lab and learning more about the specific work I do.

Advisor's remarks

Samantha was a welcome addition to our group. The time was very limited and thus the ability to generate any publishable results was difficult. However, I do believe that this was a valuable experience for Samantha, and that she would have learned many new things during her time with us.

Name:	**David Murphy**
University:	Georgia Institute of Technology
Research advisor(s):	Dr So Kawaguchi
Host institution(s):	Australian Antarctic Division, Department of the Environment, Water, Heritage and the Arts

Research subject

Schooling behaviour and locomotory biomechanics of Antarctic krill

Research description

Antarctic krill *Euphausia superba* are the keystone species of the Antarctic food web, yet little is known about the biomechanics of their behaviour and, in particular, their locomotion. Of particular interest is the question of why krill form schools, aggregations that can range up to several kilometres wide. One theory is that, by swimming in a certain position relative to other krill, individuals may use less energy to swim (much in the same way that cyclists draft each other or geese expend less energy by flying in a V formation).

By defining the three-dimensional location of a schooling krill relative to the animals surrounding it, any preferred positions relative to other animals can be identified. This knowledge will then give a clue as to whether or not increased hydrodynamic efficiency is a factor in the formation of schools.

A second important question related to krill behaviour is the issue of locomotory biomechanics. Previous work on a related krill species (*Euphausia pacifica*) has shown that krill operate their five pairs of swimming appendages in a metachronal manner. Krill therefore swim by sequentially moving their pleopod pairs, beginning with the most posterior and moving anterior. During the power stroke, setae on the pleopods expand to increase the surface area of the appendages. During the recovery stroke, these setae are contracted. An investigation of this locomotory technique is due because this rowing gait appears to be utterly unique in the animal kingdom. Furthermore, krill are seen to exhibit different swimming modes such as hovering, upright forward swimming, and upside-down forward swimming. It is likely that kinematic parameters such as pleopod stroke frequency and amplitude will change among these various swimming modes. Understanding the biomechanics of krill behaviour and locomotion could also provide insight into the fluid dynamics mechanisms that krill use to sense conspecifics and form schools.

Research activities

The Australian Antarctic Division (AAD) is the only research institution in the world that has been successful in maintaining populations of Antarctic krill. My time at the AAD was therefore divided between the following two goals: 1) To build and employ a stereo camera system capable of filming krill schools within the AAD tanks and 2) To acquire high speed footage of individual krill swimming.

Krill Schooling: I arrived to find that the AAD already had most of the equipment needed to build a stereo camera system, which would allow us to film schools of krill and calculate the 3D positions of individual animals within those schools. I co-ordinated with a researcher at the AAD (Rob King) and with a stereophotogrammetry expert at the University of Tasmania (Dr Jon Osborn) to finalise and implement a design for the two-camera system that would achieve the necessary image resolution and measurement precision. In order to calculate the 3D position of each point in the field of view, it is necessary to calibrate the cameras with an object of known dimensions. I therefore designed a calibration piece using CAD software and had it built in the AAD machine shop. With setup of the system complete, I was able to collect about 15 hours of footage of krill behaviour, including several hours of krill schooling. An example frame from one of the cameras is shown in Figure 1. Finally, I developed a protocol by which the resulting data could be analysed using 3D automatic tracking software to track individual krill.

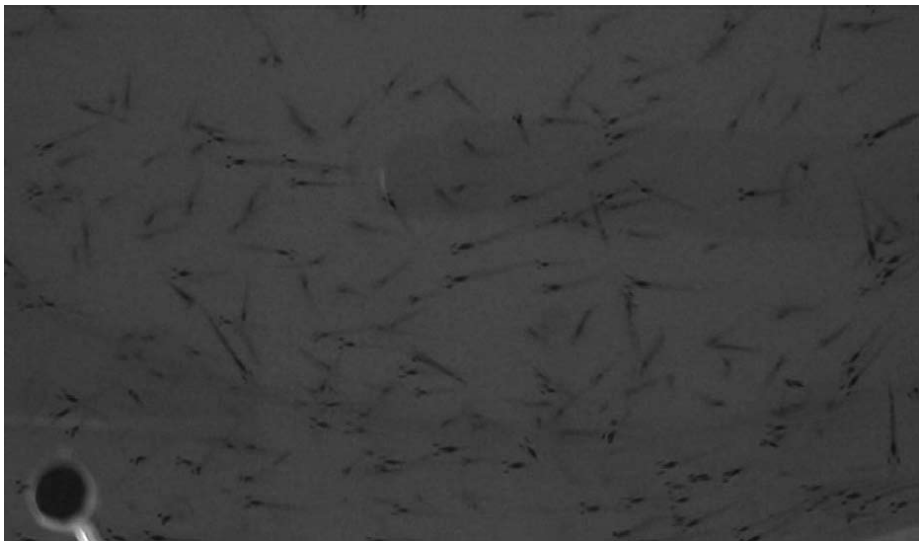


Figure 1: An original image of swimming krill from one of the two cameras comprising the stereo camera setup. Contrast enhancement will be used to assist the automatic tracking algorithm as it tracks krill across the field of view.

Krill Locomotory Biomechanics: The goal of this project was to record high-speed footage of krill behaviour, particularly the various modes of swimming/hovering that krill use to move. A 100 L tank with an optical access window was available for these experiments. About 40 krill were placed in the tank at a time, and it was found that some krill consistently swam around the edges of the tank at the water's surface. A high speed camera (250 fps) was thus aimed at the water-air interface, and the camera was triggered when krill entered the field of view. Approximately 120 movies of krill behaviour were recorded. An example frame of an adult krill is shown in Figure 2. About ten of these movies were of juvenile krill of various sizes that had been hatched at the AAD, and several movies of breeding krill were also acquired. In order to investigate the animal-fluid interaction, I also attempted flow visualisation with the krill using a phytoplankton culture as the tracer. This effort met with limited success. The krill reacted strongly to the phytoplankton, and it was thus difficult to get them to swim through it. Near the end of my time at the AAD, I gained the use of a second high-speed camera from Jon Osborn at the University of Tasmania. I decided to put this to use by trying to synchronously film krill from orthogonal directions in a separate tank. This work was inspired by the obviously three-dimensional nature of the pleopod stroke and was an attempt to gain three-dimensional stroke kinematics. I collected about twenty movies on my

last two days at the AAD. Flow visualisation was also attempted using this 3D setup. In summary, a treasure trove of 2D and 3D data was collected and will provide the basis of many months of analysis.

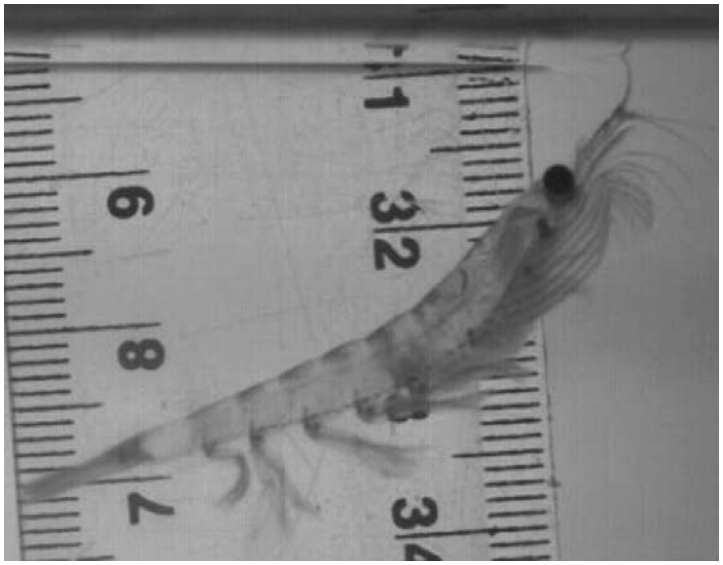


Figure 2: An example image of a krill swimming at the air-water interface. The ruler in the background is in centimetres.

Perspective of research after this program

The EAPSI program was a really fantastic experience that advanced my research by light-years, and I think it also contributed to ongoing work at the AAD. In my mind, this experience has truly highlighted the value of cross-disciplinary collaboration. It was their work in developing the facilities necessary to keep krill alive in the laboratory over the last several years that made my work possible. I was able to provide engineering expertise and equipment (such as a high speed camera) that opened up new insights into the behaviour of krill.

I think that the relationships we formed and the stereo camera system that we developed while I was there will provide the basis for collaboration well into the future. Indeed, I hope to return within the next two years to conduct more experiments on krill schooling. Finally, I was incredibly impressed with the AAD, both the quality of the facilities and the people, and hope to return in the near future.

Advisor's remarks

It was our pleasure to host David, and congratulate what David has achieved during his short stay. He has done a fantastic job not only for his research but also contributed upgrading our setup for krill behaviour study. We are also in agreement that we need to continue and enhance our collaboration into the future to further understand krill behaviour and hydrodynamics of their schooling. It is an excellent example of mutual benefit being generated through international/ inter-disciplinary collaboration. This kind of collaboration format (the visitors provide latest skills and technologies and we provide world class expert advice in krill biology and maintenance) extends our horizon, and is exactly what we are trying to enhance. We are looking forward to having him down to AAD again to further extend our collaboration, if any opportunity arises.

Name:	**Todd Otanicar**
University:	Arizona State University
Research advisor(s):	Dr Gary Rosengarten
Host institution(s):	University of New South Wales

Research subject

Experimental testing of micro-solar thermal collector with direct absorption nanofluids

Research description

The University of New South Wales (UNSW) is developing a novel micro-reactor for hydrogen decomposition to methanol using solar thermal energy. This micro-reactor was used as a test-bed for collecting data on the performance of nanofluids, liquid suspensions of nanoparticles, as direct absorption solar collecting fluids. Different nanofluids were tested to explore the impacts of size, shape and volume fraction on collector performance.

Research activities

Initially my work was going to focus on using infrared thermography to study the temperature profiles of a micro-reactor, but upon further discussions with my host it was decided that testing nanofluids in the micro-reactor would be a beneficial project, especially for my dissertation. The main goal of the project was to collect performance data on the use of nanofluids as a method to directly absorb solar thermal energy. Data was collected for nanofluids that had variations in size, shape, and volume fraction. Particles tested varied from 20 nm to 40 nm, shapes of either spheres or cylinders (nanotubes) and volume fractions from 0.05% to 1.0%. All the particles were suspended in DI water and were sonicated to ensure particle stability. The data collected at UNSW will be used in conjunction with an analytical model to understand the use of nanofluids as solar absorbing liquids. Some of the results will be presented at the EUEC 2009 conference back in the US and with the analytical results will hopefully be published in a journal as well.

In addition to working on a project directly related to my research in the US I was able to participate in other experiments being conducted by graduate researchers in my host's group and present a poster at the opening of the Centre for Energy Research and Policy Analysis (CERPA) at UNSW. This allowed me to develop further contacts within my field and have useful discussions about future opportunities for work relating to nanofluids and solar thermal energy.

Perspective of research after this program

This summer program was a great experience for understanding the research system in a different country. I was able to observe a lot of similarities between research in Australia and the US.

Working with the other graduate students we soon realised that daily problems in research are universal and not just specific to one student. The program also gave me better perspective about my future development as a researcher. In addition I was able to make invaluable contacts through my host and I am now seriously considering coming back to Australia to do further research.

Advisor's remarks

Todd Otanicar's visit has been very useful for our laboratory and I believe Todd has gained a lot from the visit as well. The cross fertilisation of ideas between Todd and my students has given both more perspective on their research.

We set out a short research program that would have mutually beneficial results. Todd has worked diligently and we plan to publish the research that Todd has carried out in his time here firstly in a conference, and with further data as a journal article. His short stay has paved the way for future collaboration between the Arizona State University (ASU) and the NSW in the important area of solar thermal energy. As well as discussing future research for Todd here in Australia I have had discussions with his supervisor Professor Patrick Phelan and another ASU collaborator from Intel Research laboratories, Dr Ravi Prasher. I look forward to having Todd back in our lab in the near future.

Name: **Heidi Renninger**

University: Boston University

Research advisor(s): Dr David Tissue

Host institution(s): University of Western Sydney

Research subject

Do embolisms occur in the petiolar vessels of the palm, *Washingtonia robusta*, and does refilling under tension occur?

Research description

After more than a century of research, there remains a key puzzle about how tall trees restore sap flow when conduits containing the liquid water column inevitably fail and embolise. Embolism formation is a widespread phenomenon that all tree species face to differing degrees and occurs when air is pulled into the water conducting conduits that are under a large negative pressure (the air-seeding hypothesis) or when the water column itself freezes in the vascular tissues of plants (freeze-thaw embolism). These embolism events cause disruption in the water conducting pathways reducing hydraulic conductivity and causing reductions in transpiration and photosynthesis. This research seeks to determine whether and to what extent the petioles of palms of various heights cavitate and embolise under given tensions and if these embolisms are reversible. Palms represent an ideal growth form in which to study embolism repair because they lack a vascular cambium and therefore cannot make new conduits to replace ones that have embolised. Study of the palm *Washingtonia robusta* provided an excellent opportunity to study embolism in a palm species that is naturally subjected to the two main causes of embolism; drought and freezing conditions. Sydney and the surrounding vicinity experience occasional frosts (the historical average is 27 frosts per year; data courtesy of the Australian Bureau of Meteorology, **www.bom.gov.au**) and also water stress conditions due to the very dry climate. Few studies have looked at the rate of embolism formation and reversal in palm species. This research will hopefully lead to published results that will better the understanding of the physiological aspects of water movement in palms, and whether and to what extent embolism avoidance and/or reversal constrain water relations.

Research activities

Petioles and leaves were collected from *W. robusta* palms varying in height from 1 m to 16 m tall. Conductivity was measured and then the petioles were allowed to dry and conductivities were repeatedly measured until petioles were sufficiently dry and the resulting conductivity loss was 90%. The water potential of the petiole was also determined at the points in the dry-down cycle when conductivities were measured in order to create vulnerability curves. These curves could then be used to determine at what water potential petioles in the palm will decrease in

conductivity due to tension-induced air seeding in the vessels. Additionally, on 1 m tall *W. robusta* palms, dye was introduced into the petiole in the afternoon and stained the vessels that had not embolised throughout the day. Then, the following morning, a different colour dye was introduced. If the dye introduced in the morning stained vessels that were not stained in the afternoon, then night-time refilling must have occurred in these vessels. Anatomical measurements of the vessels were also made in order to determine if there is a relationship between vessel size and palm height, and if these sizes correlate with vulnerability to embolism.

Perspective of research after this program

I have had some experience performing fieldwork in the past, and this program has strengthened my willingness to perform research especially in other countries. This program has allowed me the opportunity to work on a research question that would have been very difficult to accomplish elsewhere and allowed me to meet a lot of other interesting researchers working on various research questions within my field. All in all, my perspective of research is a very positive one after this program and my perspective of this particular program is very positive as well.

Advisor's remarks

Heidi did a remarkable job during her research stay in Australia. She tackled a very technologically and logistically difficult question and was able to accomplish her goals in a relatively short two month period. Her primary strength was that she was able to develop solutions to problems that arose during her research, as they always do in field work. She learnt to use new equipment (high pressure flow metre) and perfected the use of more familiar equipment (hydraulic conductivity system and portable photosynthesis system) using both field trees (palms) and glasshouse saplings (Eucalyptus). Heidi collected enough data in her own research project to generate a peer-reviewed manuscript and added to our ongoing research that includes her PhD advisor, Dr Nathan Phillips. In summary, it was a very positive professional and personal experience to host Heidi. Certainly, I would welcome her back for an additional stay.

Name:	**Kimberly Sablon**
University:	University of Arkansas
Research advisor(s):	Professor Chennupati Jagadish
Host institution(s):	Australian National University

Research subject

III-V epitaxial quantum dots (QD) solar cells

Research description

Photovoltaics (PV) technologies are deemed significant to global energy production and consumption. Although silicon (Si)-based devices have been widely investigated, these solar cells are still way below the theoretical efficiency limit of 30%. On the other hand, III-V multijunction solar cells, the preferred cells for space applications, have surpassed the 40% efficiency milestone. Although this is higher than Si-based devices, alternative techniques have been proposed to overcome the efficiency limit of single junction solar cells by utilising low-dimensional structures such as quantum dots (QDs) and quantum wells (QWs).

In this project, various QD structures were thoroughly investigated for the determination of structural parameters (doping and spacer thickness) on the QD electronic band structure, structures were designed to overcome issues of the low absorption cross-section of QDs while minimising strain, structures were designed to overcome issues encountered in varying the band gap of QDs for spectral tuning. This work is geared towards the implementation of the intermediate band (IB) solar cell concept[1], which was proposed about a decade ago but to date has been unsuccessful experimentally. This concept is based on p and n layers with nanostructures (preferably QDs) sandwiched in between. The idea is that, with high density of QDs, the wavefunctions of each dot will overlap due to tunnelling of electrons from one dot to the nearby dot, forming a miniband. This miniband in called the IB. The IB allows the absorption of sub-band gap photons leading to a calculated maximum efficiency of 63%[1].

1. A. Luque and A. Marti, Phys. Rev. Lett., vol 78, pp. 5014, 1997

Research activities

The project consisted of two phases. In phase 1, a matrix of six samples – a GaAs single junction cell as the control sample, dots-in-a-well, coupled QDs, uncoupled QDs, QDs with a stain compensation layer (GaP), and QWs in the active region of the device. These devices were grown by metalorganic chemical vapour deposition (MOCVD). For this phase, there was no doping in the active region. In phase 2, the active region will be doped to realise the intermediate band concept.

Perspective of research after this program

Research is a great way of solving scientific issues and gaining in depth knowledge of the underlying physics involved with different mechanisms. I enjoyed research even before the program and will continue to incorporate the skills (analytical) adapted from Professor Jagadish's group into my everyday approach to solving problems.

Advisor's remarks

Ms Sablon is an excellent visiting student who has curiosity and interest to learn new things in research. She is very friendly and became part of my research group quickly and contributed to our research program on QD solar cells. It was a pleasure to host Ms Sablon in my group.

Name:	**Jennifer Sartor**
University:	The University of Texas at Austin
Research advisor(s):	Dr Steve Blackburn
Host institution(s):	Australian National University

Research subject

Improving performance and space efficiency with arraylets

Research description

Memory is a major bottleneck to computer performance in today's systems – both in embedded devices and in commodity processors. This is especially true for the managed languages in which most modern programs are written; although the languages offer more usability to the programmer, they also add memory overhead. Our goal is to improve the performance and space efficiency of these languages by changing how memory is managed. In this project, we change the way a frequently-used data structure, the array, is stored in memory. We divide arrays into fixed-sized arraylets which can be compressed to save space, and we minimise the overhead to access arraylets. This layout of memory is more flexible, and more efficient in both space and time.

Research activities

I am implementing this project in a tool called Jikes Research Virtual Machine, a significant part of which was built by my Australian host researcher. He helped me design, implement, and debug this redesign of memory layout. His senior graduate student also gave valuable suggestions for this project, and we are now all collaborating together with my advisor and another mentor in the US to finish this project and submit it for publication at a top research conference in our field. Whilst in Australia I was also able to visit and give talks at the University of New South Wales and the University of Melbourne, exchanging ideas for my project with researchers in many areas of computer science.

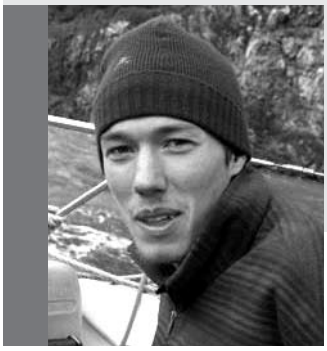
Perspective of research after this program

My research project and career benefited greatly from my participation in this program. The direct collaboration with a top researcher in my field who has thought for years about problems in memory management helped my project progress rapidly. His intimate knowledge of the tool we use, as well as his incremental, small-steps research style helped me change how arrays are represented very quickly, exploring many implementation options and being flexible to new designs. I plan to continue to collaborate with my Australian host throughout my doctoral program to make good progress and solve important problems in our area. I also would like to consider doing post-doctoral research in Australia, perhaps with my host researcher at the Australian

National University. I believe this international collaboration is very important to share ideas and broaden research opportunities.

Advisor's remarks

It was a delight to host Jenn's visit. The visit was a success at many different levels. Jenn was very productive, making the most of her opportunity to work closely with myself and one of my PhD students. We set a very ambitious and aggressive goal and Jenn did a great job in working to meet all our objectives. The technical nature of this work is such that we could not have done this had we not had daily face-to-face discussions. All three of us learned a lot about the problem through this visit, and I feel that this work has opened up an entirely new possibility within this area of work. I am quite excited by it. I continue to work with Jenn now as she prepares this work for publication. Aside from working hard technically, Jenn made a great effort to engage with people while she was here. She engaged with other students in our department and socialised with myself, my student and our families. We were all sad to say goodbye. On the basis of my experience with Jenn, I'd be very happy to host another visitor.



Name:	**Nicholas Swanson-Hysell**
University:	Princeton University
Research advisor(s):	Professor Galen Halverson
Host institution(s):	University of Adelaide

Research subject

Carbon cycling prior to the first Neoproterozoic glacial event–a field and geochemical study

Research description

Paired carbonate and organic carbon isotope values can provide great insight into the behaviour of Earth's carbon cycle throughout Earth history. Data from the late Neoproterozoic, the era (1000 to 542 million years ago) immediately preceding the evolution of animals, suggests an unusual degree of independence in the behaviour of inorganic and organic reservoirs of carbon in the world's oceans. This mode of the carbon cycle has important implications for the way in which Earth's surface became increasingly oxygenated through the Neoproterozoic and for modelling whether or not it is feasible for the entire Earth to have been covered in ice during the Neoproterozoic 'snowball Earth' events.

Using samples from an early Neoproterozoic succession in central Australia we sought to develop high resolution paired carbon isotope data from prior to the first Neoproterozoic glacial event–a period of Earth history where there is a current paucity of such data.

Research activities

Using an EA-IRMS at the University of Adelaide we obtained organic carbon isotope data from insoluble residues separated from limestones and dolostones that had been collected both in outcrop field sections and from stratigraphic drill core. Although variable amounts of organic carbon in the samples required many of the samples to be analysed repeatedly the resulting data sets spanned hundreds of metres of stratigraphy at high resolution.

Furthermore, some of Dr Halverson's samples from previous research expeditions to sediments of similar age in Greenland and Svalbard, Norway, were run during my time in the lab. Additionally, an exchange of samples is allowing for future collaborations on the strontium isotopic composition of these rocks, and volcanic samples I collected during fieldwork in central Australia will be the basis of a geochemistry honours project at the University of Adelaide.

Perspective of research after this program

These new data sets demonstrate that the carbon cycle in the time period leading up to the first Neoproterozoic glacial was not dominated by a large reservoir of fossil organic carbon. This suggests that climate models that use such a carbon cycle, and show that the remineralisation of an organic carbon pool would inhibit the onset of a 'snowball Earth' climate state, are flawed. Sulphur isotope results from an ongoing collaboration between my research group at Princeton, Galen Halverson and Matt Hurtgen at Northwestern University suggest an increase in surface oxygenation contemporaneously. This collaborative research has given us a new perspective on the geochemical evolution of Earth's surface in the early Neoproterozoic.

Advisor's remarks

In his short time in my laboratory, Nicholas succeeded in producing a significant and high quality carbon isotope data set that will soon be published in a high impact paper. Nicholas learned to use the instrument quickly, worked independently, and was a huge asset to the lab. Not only did he mentor and interact with undergraduate students, but he also developed a detailed protocol for using the mass spectrometer for this type of analysis that will be applied in future complementary investigations. Nicholas was also active outside of the laboratory, making a concerted effort to meet other students and researchers at the University of Adelaide, attend seminars, and otherwise integrate with the geology department. I have no doubt our collaboration will continue, and Nicholas is always welcome to return to the University of Adelaide.

Name:	**David Widenski**
University:	Louisiana State University
Research advisor(s):	Dr Ali Abbas
Host institution(s):	University of Sydney

Research subject

Original: Modelling and optimisation of joint cooling and anti-solvent crystallisation.

Host suggested research: A theoretical nucleation study of the combined effect of seeding and temperature profile in cooling crystallisation.

Research description

There had been some difficulty obtaining the chemical compound, paracetamol, for my original experiments due to some administrative challenges. During that span I have been working on a different research problem that my host suggested. The problem is to investigate using classical nucleation theory the effect of both seeding and cooling on the crystallisation process. The current belief is that seed properties are more important than the cooling profile. The aim of the research is to either confirm or disprove this belief using classical nucleation theory. The results so far are promising, and will either be presented at a future conference or published in a journal. In addition, this research has given me further insight useful for my future experiments. Once the paracetamol arrives I will carry out my originally planned crystallisation research.

The planned research consists of running several seeded and un-seeded crystallisation experiments consisting of cooling, anti-solvent, and joint cooling and anti-solvent crystallisation. The resultant data will then be combined with my previously developed crystallisation model to obtain crystallisation parameters for the system. This crystallisation model will then be used to find optimal profiles for different crystallisation objective functions. These profiles will then be validated with further crystallisation experiments.

Research activities

Due to the difficulty of obtaining the paracetamol, I have not carried out any research on my original problem. However, my host and I agreed to extend my stay for a month due to this problem so I will still be able to complete it. My research so far has consisted of testing my crystallisation model for grid dependency, and using my classical nucleation model to determine the importance of seed profile versus temperature profile in the cooling crystallisation of KCl. When the paracetamol arrives I will be able to use the DSC to obtain the calorimetric properties of paracetamol, and utilise the crystallisation lab to run my desired experiments.

Perspective of research after this program

My original planned research is vital to my dissertation. I will be able to utilise the data obtained here to further refine and test my models when I return to the US. In addition, my unplanned research topic has been beneficial, and I have planned further research in this area for the future.

Advisor's remarks

It has been a pleasure to work with David so far. I have found him to be committed and motivated. He adapted rapidly to the new research environment and was in full swing into the research very early on. I proposed a new idea to him to investigate while we were waiting for the arrival of the chemical compound. He undertook this challenge with utmost professionalism and demonstrated his potential as an independent researcher. I continuously am encouraging David to challenge research ideas. Experimental work will provide David with necessary skills to conduct crystallisation research and validate the modelling work.

I recognise the importance of this program for student and host as well as for the collaborative relationship between the academics involved at the two institutions. It will be great to learn about further opportunities for supporting such visits on both sides.

Australian Government

Department of Innovation Industry, Science and Research

If you are interested in hosting a US graduate student, or would like more information about the program, please contact the International Programs section at the Australian Academy of Science, email: is@science.org.au, phone: (02) 6201 9411 or visit: **www.science.org.au/internat/eapsi.htm**

More information on the Summer Program, including application forms and deadlines, is at the NSF website: **www.nsf.gov/funding/pgm_summ.jsp?pims_id=5284**

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