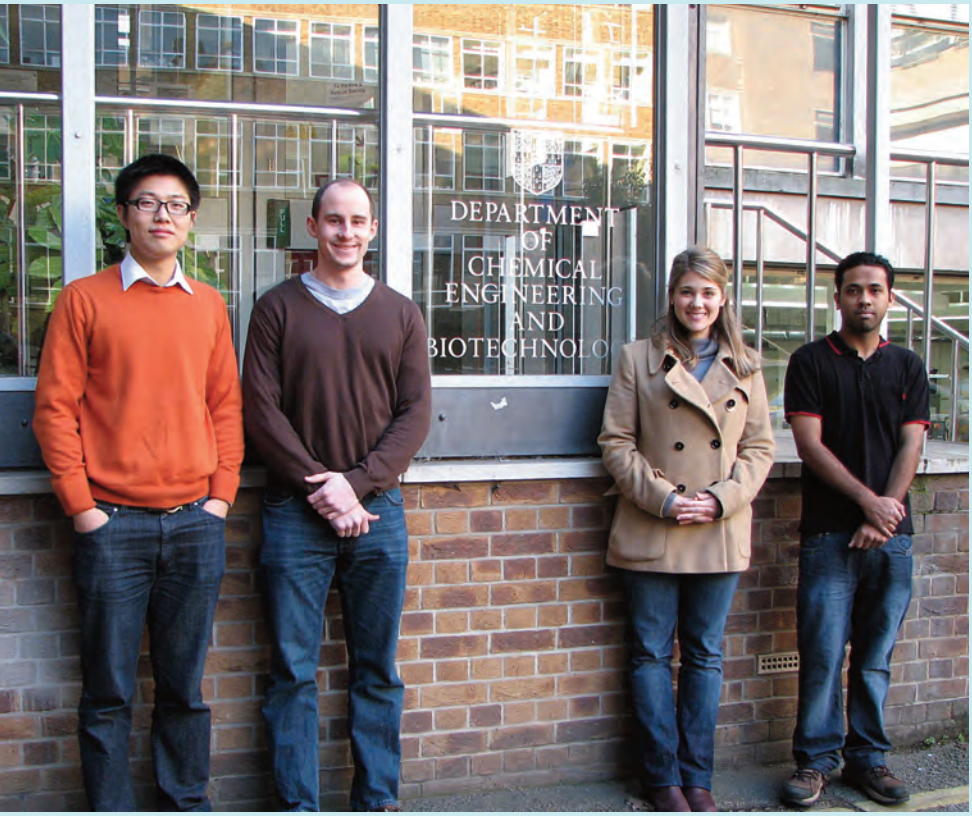
UNIVERSITY OF CAMBRIDGE

CEB Focus

Department of Chemical Engineering and Biotechnology

Lent 2011 Issue 2



Cambridge Trusts support our international students *p.3*

CEB's international PhD students- left to right: Charlie Chen (China), Andrew Lynch and Leslie Mann (USA) and Durga Madras Rajaraman Iyer (India)

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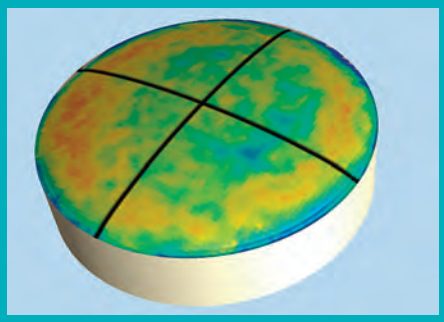

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Welcome

Message from HoD Professor Nigel Slater

On behalf of my colleagues and I in CEB I am pleased to wish all our readers a very happy and prosperous New Year. Amongst our thoughts at this time is the provision of the support and infrastructure that future generations of our students will need to contribute successfully in their chosen fields. We are conscious of the financial pressures that students increasingly face and see a need for CEB to build funds that it can use to maintain access for the very brightest students, regardless of ability to pay. In this regard we are extremely grateful to a former student of the Institute of Biotechnology who has pledged generous personal funding to support access to courses in biotechnology. We are also conscious of the need to continue the excellent work of my predecessor, Lynn Gladden, and to secure the University's firm commitment to proceed with the planned New Building on the West Cambridge Site. It now seems that part of the funding would be in the form of a long-term loan to the Department, which we would need to pay-off through sponsorship, donations and appeals. In addressing both these aspirations we look forward to working with friends of CEB and our alumni throughout 2011.

The Editorial team wishes you all a Happy New Year and welcomes you to the *CEB Focus* Lent Issue

It has been of immense importance to us to get a representative newsletter started, ensuring that the information communicated reflects the new identity of the merged department. We have representatives from the Chemical Engineering, Biotechnology and MRRC sites generating ideas, providing input, and liaising with academics, research groups and students in order to make this possible. We would also like to thank Jeanne Therese Andres for her expert advice in getting the first issue together and her help at the proof-reading stage. Also, we ought to thank Vanessa Blake, Webmaster, for department photography.

We also want to thank Sohini for her help with the first issue. She is sadly leaving the group and the Department in the New Year to focus on her research. Rashmi Tripathi, a Biotechnology PhD student, will be taking over then and we would like to welcome her to the team.

Contributions from department members and corporate partners are much appreciated and it is hoped that this will continue. We welcome our readers to contribute their research and ideas to help us carry on.

If you have any comments or suggestions for articles to be included in the next issue, please get in touch with the Editorial Team on ceb-focus@ceb.cam.ac.uk

We look forward to hearing from you in the future!

For those wishing to receive a regular copy of *CEB Focus* electronically please subscribe by sending a message to ceb-news-request@lists.cam.ac.uk with 'subscribe' as the subject of the message.

Left to right: Sohini Chakrabortee, Fernando Abegão, Elena Gonzalez, Alastair Clarke and Amy Chesterton

Cambridge Trusts support CEB international students

The award of scholarships to talented and well-deserving international students is hugely important. As stated by our new Vice Chancellor Sir Leszek Borysiewicz recently in CAM magazine (Issue 61), *'Since post-graduate recruitment is global, the provision of infrastructure for all disciplines, financial support through globally competitive scholarships and world-class supervisory staff is vital.'*

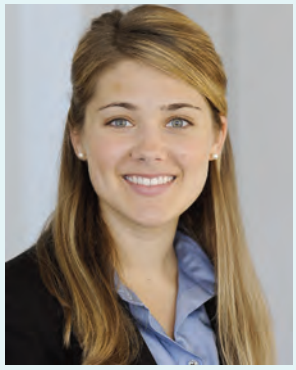
Cambridge international scholarships are prestigious and highly competitive. They are awarded to outstanding graduates outside the UK to study at Cambridge. Some of our current CEB students receive funding from the Gates Trust, the Cambridge Commonwealth Trust (CCT) and the Cambridge Overseas Trust (COT). The overall aim of the Gates Trust and Cambridge is to enable candidates of outstanding academic merit, who would not otherwise be able to take up places at Cambridge, to pursue courses of study or research. The CCT and COT were established as charities by the University in the 1980s in order to provide financial support for international students on degree courses in Cambridge. Professor Slater, HoD values the Trusts highly, *'CEB is extremely grateful for the generous support of the Cambridge Trusts in funding CEB international students. This funding enables the Department to recruit and train extremely able students from across the world, building upon our reputation and that of the University'.*

CEB Focus met with four of our international students to find out how they have benefited from Cambridge Trusts. Their statements below are proof of their worth.

Gates Trust

Lesley Mann
MBE student

Applying to the Gates-Cambridge scholarship was a rigorous process that started for me with an internal review process at the University of Kentucky, 18 months before my eventual start at Cambridge. After which, I spent a few months perfecting my application before being invited to the interview process that happened in early February. The entire process was surprisingly beneficial for me, as it forced me to consider and clearly articulate my reasons for pursuing post-graduate education and my hopes for its application to my future career. I was honoured to be selected from a pool of exceptional people, and now benefit immensely from being in the MBE (Master's in Bioscience Enterprise) programme and belonging to the vibrant Gates society.



Andrew Lynch
Bioscience Engineering PhD student

Pursuing my PhD in chemical engineering at Cambridge would simply not have been possible without the generosity of the Gates Cambridge Scholarship, an award granted to approximately 100 aspiring graduate students worldwide each year. After hearing about the scholarship through advisers at my undergraduate university, I spent several weeks preparing to apply. I was delighted to be invited to interview and impressed with how straightforward the proceedings were. I've had a great time here at Cambridge, both academically and socially, and am incredibly grateful for the opportunity the Gates Trust gave me.

These scholarships are full-cost awards for graduate study and research in any subject available at the University of Cambridge. Application materials for Gates Cambridge Scholarships and graduate admission to the University of Cambridge for 2011-12 entry is now available. For more information visit www.gatesscholar.org/

Cambridge Overseas Trust

Charlie Chen
MRRC, PhD student

Six months ago, choosing between offers from Cambridge and those from Ivy league universities in United States was the toughest choice I had to make in my life. My dream has been to study and live in Cambridge, but the US universities were offering much better financial support. That is until I received a letter of financial assurance from the Cambridge Overseas Trust. With the generous donation from Sun Hung Kai Properties (SHKP)-Kwoks' Foundation, I could finally make my way to this magnificent city. When friends from China saw my photos of sipping port in formal hall, rowing in the gorgeous River Cam, or working with fellow colleagues in MRRC, they joked that I was living in a childhood fantasy. Prof. Gladden brilliantly describes the PhD as a new start from knowing nothing right after seemingly mastering everything at undergraduate level. Due to the support I have received in recent months from both colleagues and the Trust, I am able to start a new adventure both in academia and in life.

'Due to the support I have received in recent months from both colleagues and the Trust, I am able to start a new adventure both in academia and in life'

Cambridge Commonwealth Trust

Durgaprasad Madras Rajaraman Lyer
ACE student

I was delighted to be offered admission to the MPhil (ACE) program at the University of Cambridge. But, I knew that it would have been very difficult to pursue the degree without the required funding, as the University fee for international students is very high. During the course of the application process, I came across the Cambridge Trusts website (www.cambridgetrusts.org).

I realised that the Cambridge Commonwealth Trust is one of the few organisations in the UK that provides complete funding for students from the Commonwealth Group of Nations pursuing their Masters degrees. The application process to CCT was simplified as it was integrated with the application for admission. The people at CCT were extremely supportive throughout the process. They communicated with me regularly and kept me informed about the progress of the application from start to finish. I am grateful to the Trust for funding my studies at one of the world's top-ranked Universities.

The Trusts offer scholarships to students from outside the EU who are starting new courses at the University of Cambridge. The Trusts do not offer funding to students who are part-way through a course of study at Cambridge. Applications are encouraged a year prior to the commencement of studies.

The Spirit of the Students: CUCES

Constantinos Pittas
CUCES President

Michaelmas term has been very exciting for CUCES (Cambridge University Chemical Engineering Society) with a whopping 15 events; most of which had a strong focus on careers. Every single one of the events was well received with record attendance, which has immensely pleased both the committee and the companies alike.

The highlight of the term was the CUCES Christmas Dinner, which was held at the Anchor on the 25th November and kindly sponsored by BP. It is an event that brings together a large portion of the department from Part 1s and MPhils to PhDs and post-doctoral researchers. The spirit of chemical engineering was evident that night as the friendships within and between year groups strengthened further.

At the end of last term, CUCES was named as one of five finalists in the category of Best University Society by the National Placement & Internship Awards 2011 (ratemyplacement.co.uk). The awards ceremony will take place late in January.

During Lent term we hope to shift our efforts to the social aspects of CUCES. Our main events will be the Frank Morton Games in Nottingham in February and the Annual CUCES Dinner at the end of term.

CEB undergraduates enjoying a CUCES Careers Event

Results of UGs Survey on CUCES career programme

Anna Kvarngren
CUCES Events and Careers Officer

In order to represent a group of students, you have to find out what they think and what they want. The CUCES committee decided to carry out a survey amongst the undergraduate student body during Michaelmas term. With responses from nearly 70% of the undergraduates in the department some very interesting results could be seen. These results will help us to make our future events more focused on addressing specific student needs.

One of the main purposes of the survey was to find out what career aspirations the current students have. Approximately 60% of the students see themselves working in the chemical engineering or biotechnology field, either in industry or academia. However, biotechnology and academia clearly did not draw as much interest as the chemical engineering industry. A large portion of the students are undecided about where they see themselves in the future, and for those that already have other career plans, popular alternatives include investment banking, consultancy and accounting. Amongst the large portion of students looking to go into the chemical engineering industry, a relatively even spread was seen between many different industries, such as petrochemicals, pharmaceuticals, food and engineering consultancy.

When asked about what types of events the students want to see organised by CUCES, over 90% of the students wanted more career-related events. In particular, they would like to see more company presentations in the department and have more site visits. On the social event side, there is a need for more opportunities to spend time together outside the department. Formal dinners were by far the most popular option, followed by sporting events and the reappearance of the Department social society, 'The Plumbers'.

Back to (Grad) School ...

Patrick Gordon and Min Zhang
PhD students

As a PhD student, life tends to revolve around your experiments, simulations, or perhaps department tea. You don't often get the chance to take a step back, and ask yourself the questions everyone dreads – why am I doing it this way, what do I want to get better at... and where next?! GradSchools (www.vitae.ac.uk) are run up and down the country to help you do just that.

In October this year, we travelled up to Windermere, in the Lake District, to join 80 other PhD students on a three-day GradSchool. You work in the same eight-person group for the whole course, and work through a program of pretty intense workshops and challenges. The emphasis is on getting you out of your comfort zone, doing things you wouldn't normally do, and then applying this to your work and career. There's almost no writing or lectures, it's all group work and isn't dull!

One of the most useful sessions was an interview workshop. Rather than just having the practice interview, you also get a chance to be the interviewer, and to watch how everyone else in the group handles theirs. Another session involved working as 'interested parties' for new legislation on stem cell research. As a group you're given a role (e.g. Pharma company), and have to research, present and argue your case with the other interested parties, while also dealing with the media. While they may not be for everyone, these GradSchools are great fun. They're funded by the UK research councils (RCUK), so they're free for anyone who gets their funding (EPSRC, BBSRC, etc). Although it's a cliché, you really do get out what you put in, and if you want to improve a few skills and try something new then you'll learn a lot.

Bio PhD students sprout 'staches for Movember

Ollie Wright and Julian Jaros
PhD students

Julian Jaros

The Movember movement has grown year on year ever since, expanding to the UK, US, Canada, New Zealand, Ireland, Spain, South Africa, the Netherlands and Finland. In 2009, global participation climbed to more than 255,000 'Mo Bros' with over one million donors raising £26 million for Movember's global beneficiary partners. The funds raised through Movember's UK campaign benefit the Prostate Cancer Charity (TPCC), UK's leading prostate cancer charity. Participants start clean shaven on 1st of Movember and commit to growing a moustache for 30 days.

For the second year now, Julian Jaros (PhD student at the Bahn lab, Tennis Court Road) was able to raise interest and money towards the charity. Julian raised £80, and you can see his various 'mo' pictures on his official Movember website: http://uk.movember.com/mospace/474025/.

Usually fully-bearded, Ollie Wright (PhD student in the Tunnacliffe lab, Tennis Court Road) also went clean shaven this month to grow a 'stache from scratch. He'd like to thank all those in the department that donated towards the cause. Ollie raised £103, and you can view his Movember website at: http://uk.movember.com/mospace/576528/.

Together their two teams raised a collective ~£2,000, proving that Cambridge is willing to support such a noble cause (or at least pay to ridicule colleagues!)

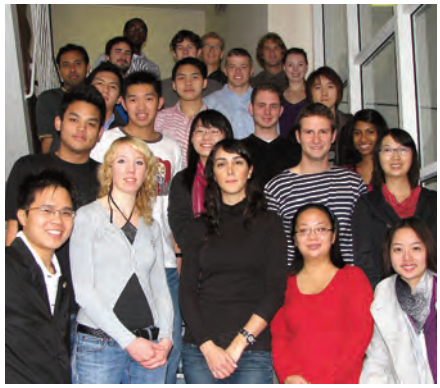
MPhil ACE students update

Prathibha (Micky) Dissanayake

With a record admission of 27 students to the MPhil in Advanced Chemical Engineering (ACE) course this year, I found my first day to be a swiftly passing blur of names and faces. In the past two months, however, the confusion has abated somewhat, despite most of my brain being incapacitated by Matlab coding. The MPhil ACE class is one of the most culturally diverse I have ever been in, with two UK students and the rest hailing from all across the globe.

Mark Deimund undertook an ExxonMobil summer internship in Clinton, New Jersey, in 2010. The research internship, at one of ExxonMobil's Process Research Laboratories, is designed specifically for students who have finished their undergraduate degrees and are intending to move onto graduate level studies. Mark's project involved testing diesel hydrotreating catalysts using a high-throughput reactor system that could test over thirty catalyst configurations simultaneously. *'I really enjoyed industrial research,'* says Mark, on his experience, *'and the opportunity to work in a laboratory instead of a refinery or processing plant as with typical internships.'*

Anna Louise Smith carried out a six month traineeship in the Institute for Transuranium Elements (ITU), in Karlsruhe, Germany, in 2010. ITU, which is a part of the Joint Research Centre of the European Commission, works to further knowledge on the risks associated with the handling and storage of radioactive materials. Anna's research was focused in the area of Sodium-cooled Fast Reactors (SFR) for which sodium acts as a coolant and (U, Pu)O2 fuel is currently considered as a reference. A great challenge for the development of these reactors in the Generation IV project in the future comes from the necessity to introduce minor actinides into the fuel mix.



MPhil ACE 2010-2011 intake

Anna found her internship a *'very rich experience scientifically speaking as well as for my general knowledge. I was able to use many different characterization techniques and I discovered how people worked on a daily basis in such an environment.'*

Baptiste Salley and **Sylvain Caron** carried out summer research at the Harvard School of Engineering and Applied Sciences in 2010. Their research looked at droplets of water bouncing on nano-patterned surfaces at varying temperatures. Developing surfaces with an improved ability to repel water has a variety of practical applications, a useful example is preventing water from freezing on the outside of aeroplanes. *'The burgers were nice,'* they said on their experiences at Harvard. *'And the chicks were friendly.'*

Akin Ali was recently elected as Darwin College Green Officer, and is overseeing projects to reduce the environmental footprint of the college. The work includes the use of solar power for electricity, reducing energy wastage in the ventilation systems and increasing recycling and composting at the college, as well as plans for a beehive in the college grounds.

'Most students find the course a bit of a struggle to start with,' says Sarah Rough, M.Phil. ACE Programme Manager. *'We encourage them to apply their knowledge in new and perhaps unfamiliar ways. This means that answers aren't that obvious, or even definite.'*

Despite the suffering thus inflicted, I find Sarah's next words quite heartening: *'I think the course would be pretty boring and meaningless if the students weren't challenged in this way.'*

CEB's Teaching Consortium of Companies: Strong links with industry

The Department at Cambridge has been running a Teaching Consortium for over a decade. Originally assembled to assist and advise with the transition between the two-year ('Old regulations') and three-year ('New regulations') undergraduate MEng course in the late 1990s, the Teaching Consortium today forms our external industrial teaching advisory board. Consortium members actively support all aspects of process design teaching and professional skills training on the undergraduate MEng course whilst also providing regular advice on MEng curriculum development from an employer's point of view. In addition, Consortium members support graduate research by sponsoring projects and travel bursaries on the doctoral training programme as well as the MPhil ACE course.

In return for their assistance, the following benefits are amongst some of those on offer to member companies:

- preferential access to talented undergraduates for recruitment and internships;
- preferential access to MPhil and PhD students for research and recruitment opportunities;
- an accessible, confidential and free-of-charge point of contact within the Cambridge community to enquire about specific services,expertise or research requests;
- industry needs reflected in the undergraduate MEng curriculum;
- increased awareness of corporate profile by supporting project work;
- positive publicity provided by association with the Department; for example, featuring in the industrial section of *CEB Focus*.

Nigel Slater, HoD, highlighted that *'CEB values the support it obtains from the industrial members of the Teaching Consortium, both in terms of the advice and guidance we obtain that enables us to educate our students in the best possible way to meet the demands of industry and through the financial support that benefits our teaching directly through the provision of resources. By participating in the Teaching Consortium, companies gain the opportunity to present themselves to our students and influence their educational experience so that our students can make better informed decisions about their career choices. In this way the Teaching Consortium benefits both CEB and its industrial members.'*

Bart Hallmark, CEB Design Lecturer added that *'The Teaching Consortium members are a vital part of CEB. From a teaching perspective, they provide us with comment and feedback on our undergraduate MEng course content, which forms part of our quality assurance to ensure that the skills we teach our future graduates are those that are highly sought after by industry. Very often, Consortium members have made invaluable resources available to supplement our undergraduate teaching material; this has included contact with company experts on unit operations, provision of process flowsheets and supporting data for design projects, supply of training material for drafting design documentation and facilitating site visits.*

In addition to this, our undergraduates have a unique opportunity to interact with members of the Teaching Consortium during recruitment evenings and other social events that are organised. This is universally appreciated, as much for the opportunity to talk candidly to active process engineers as for the opportunity to apply for summer internships and employment opportunities.

Also, having a point of contact within the Cambridge community opens up a wealth of resources and expertise that may not be easily found in-house, with the result that a number of MPhil and doctoral research projects, in addition to consultancy contracts,

have been formed with Consortium members over the past few years.

I personally look forward to continuing and strengthening the relationship that CEB has created with its existing Consortium members in addition to building new relationships with future Consortium members.'

Further information on the Teaching Consortium can be obtained from Dr Bart Hallmark on bh206@cam.ac.uk. The statements below show how both CEB and corporate members benefit from this relationship.

ExxonMobil

Sophie Clayton, Site Safety Advisor, Fawley

Though the name ExxonMobil may not be familiar, most people will have heard of our famous brand names, Esso and Mobil. We are the world's largest privately-traded energy company, and every day we help meet the energy needs of millions of people around the world.

ExxonMobil uses innovation and technology to deliver energy to a growing world. We explore for, produce and sell crude oil, natural gas and petroleum products and we are committed to meeting the world's growing demand for energy in an economically, environmentally and socially responsible manner.

Meeting this challenge isn't going to be easy and success will require the dedication and ingenuity of talented men and women. This is where the Teaching Consortium at CEB comes into its own. By enabling ExxonMobil to meet with staff and students, it provides unique access to some of the finest minds in the chemical engineering world, and to future leaders of the energy industry.

The annual Teaching Consortium meeting gives us an insight into the research carried out in the Department and an opportunity to discuss the structure of the undergraduate course.

We have worked with our partners in the consortium to assist in strengthening the design element of the course, which helps to prepare students to tackle the challenges they will face in industry. We also work with CEB to enable students to experience industry first hand, through visits to our refinery and chemicals site at Fawley.

It is a partnership in which both parties benefit - and we look forward to continuing it in future.

Dow

Peter Berns, Site Leader, Kings Lynn

The Dow Chemical Company has been a member of the teaching consortium for three years. Our site at King's Lynn is an hour's drive from Cambridge and has proven to be a convenient location for members of the CEB department to undertake summer internships.

The Cambridge students who have taken placements with us have been of a uniformly high standard and contributed valuable projects whilst gaining worthwhile first hand experience of the realities of working in a chemical production environment.

We were also very pleased to support the recent undergraduate design project at the department, which included hosting a visit by 70 students to see chemical plant at close quarters as part of their project work. It is important to us that we contribute to the professional development of Chemical Engineers and of course this also gives us exposure to potential future recruits.

Dow welcomes the opportunity to be able to influence the content of the Chemical Engineering course by giving our views along with the other teaching consortium members on what we perceive as the needs of our industry, both in terms of chemical engineering knowledge but also personal skills, whether this be thinking skills or the soft skills required to be effective in modern team environments.

Professor Howard Chase – An Academic Profile

Professor Howard Chase, Head of School of Technology

Howard Chase joined the Department of Chemical Engineering in 1981 from the Department of Biochemistry at Cambridge where he had undertaken his undergraduate studies in Natural Sciences and his PhD. in chemical microbiology. The overall aim was to build up the range of research in biotechnology being carried out in the chemical engineering department, by adding to the activities already being undertaken there by Nigel Slater. Howard then became a research assistant sponsored by a Science and Engineering Research Council grant awarded to Dr Kenny. During this period he was awarded a Royal Society 1983 University Research Fellowship but in 1984 he was appointed as an Assistant Lecturer in the Department of Chemical Engineering. Promotion to Lecturer came in 1986, followed by Reader in 1996 and finally he became the Professor of Biochemical Engineering in 2000. He was elected to Fellowship of the Royal Academy of Engineering in 2005 and is a Fellow of the Institution of Chemical Engineers. Initially his research was solely in the area of biochemical engineering and focused on the recovery of a variety of different classes of biomolecules from a variety of different biological sources. In particular, he has championed the technique of expanded bed adsorption for a variety of applications. He also developed a parallel research theme in the area of environmental engineering, originally centred on novel reactors that contained specialised microorganisms capable of treating aqueous wastes by degrading the toxic or recalcitrant molecules present therein.

'The overall aim was to build up the range of research in biotechnology being carried out in the chemical engineering department, by adding to the activities already being undertaken there by Nigel Slater'

The Environmental Engineering theme was also extended to non-biological processes concentrating on the application of microwave heating for the treatment of a variety of wastes that cause environment problems. One such application, the recovery of aluminium and hydrocarbons from aluminium-laminate packaging, has become the business focus of the spin-out company Enval Limited where he is R&D Director.

Howard succeeded Professor John Bridgwater as Head of Department in 1998, a post that he held for a total of eight years. This was a busy time for the Department in terms of refurbishment of laboratory space to meet the department's rapidly expanding research requirements. During his tenure the following research facilities were constructed in the department: the Cambridge Unit for Bioscience Engineering (CUBE), the Cambridge Unit for Responsive Biopolymers (CURB), the Centre for Research in Electrochemical Science and Technology (CREST) and the laser laboratory together with expansion of research facilities at the Magnetic Resonance Research Centre. At the beginning of 2010 he was appointed the Head of the School of Technology (one of the six academic Schools in Cambridge), a post that gives him the responsibility for overseeing the affairs of the constituent departments of that School.

In a parallel with his departmental and academic activities, he has held a variety of tutorial posts at Magdalene College including its Senior Tutorship from 1993-96, a post he had to relinquish upon appointment as a Reader. He was elected to a Fellowship of the College in which he undertook his undergraduate and post-graduate studies in 1984.

Bioresearch: Shaping the future

Rashmi Tripathi, PhD student

We live in an exciting time where emerging technologies continuously shape our lives. This review highlights current research carried at the Institute of Biotechnology (IoB, now part of CEB) where the potential to deliver new biotechnologies is harnessed.

Bio-sensing for consumer electronics is perhaps the next big breakthrough that will impact consumers worldwide. In Prof. Chris Lowe's laboratory, research is currently focused on developing holographic sensors for asthma and diabetes in convergence with electronic devices such as mobile phones. This will empower patients to take better control of their health and well-being and make informed decisions about treatment.

The preservation of cells at ambient temperatures can revolutionise the application of cell-based therapeutics by speeding-up processing, transportation and delivery of biomaterials to patients in emergency situations. Research in Dr Alan Tunnacliffe's laboratory is currently geared towards understanding the principles of anhydrobiosis, or 'life without water', in organisms like rotifers, worms and tardigrades, and applying these principles to preserve cells grown in culture outside -80°C freezers or liquid nitrogen tanks. Proteins involved in anhydrobiosis have also been found to be intrinsically disordered, with special protein anti-aggregation functions. This property could be exploited in the treatment of diseases like Parkinson's, Huntington's and Alzheimer's.

Schizophrenia is a neuropsychiatric disorder with poorly understood disease etiology and progression. The Bahn group is currently busy unravelling the molecular mechanisms of the disease using a proteomics-based approach. The discovery of numerous biomarkers in the blood and cerebrospinal fluid of the patients is expected to result in the development of more reliable diagnostic tests. Latest findings include the evidence of impaired mitochondrial function and oxidative pathways in the brains of schizophrenic patients and the discovery of N-glycans that distinguish first onset, unmedicated schizophrenia patients from healthy individuals. These findings should pave the way for better diagnosis and management of schizophrenia.

Dr Tatsuya Yoshimi in Cell and Organism Engineering lab

The main umbrella of research in the Analytical Biotechnology Group, lead by Prof. Lisa Hall is over heterogeneous analytical systems, with a focus on interfacing biology, electronics, mechanics and optics for new diagnostic and monitoring devices. Current research ranges from fundamental investigations to industry-driven applications. Fundamental bioelectronic and optical studies include: electron and energy transfer between redox proteins and nanosystems; engineering fluorescent biomaterials and studying their interaction with nanoparticles. Integrating an optical transducer into mobile phone technology is at the heart of the lab-on-a-phone project for instant disease diagnosis and monitoring. A further exciting part to the project is interfacing biomaterials with nanowire devices.

Other good blends of academic and applied research include the development of a mycobactin biosensor for tuberculosis and novel drug delivery and diagnostic systems using magnetic and ultrasound contrasting agents.

Research at the Institute of Biotechnology clearly has the potential to shape our futures. For the ingenious and passionate scientists at the Institute benches, the sky is definitely the limit!

Acknowledgements: I would like to thank Dr. Colin Davidson and Dr. Claudia Loechel for their inputs and Dr. Alan Tunnacliffe for his comments.

Enhancing ultrasound therapies using magnetic Nano particles

Vincent Ho, PhD Student

High intensity focused ultrasound (HIFU) is currently being applied for non-invasive ablation of tumors. HIFU works by focusing an ultrasound beam into a small volume inside the patient's body, causing instant cell death within the targeted volume. The destructive effect of HIFU is due to thermal energy deposition or cavitational effects.

The BioScience Engineering group at CEB recently made several discoveries that could enhance the efficacy of HIFU therapies. Magnetite (Fe_3O_4) nano-particle agglomerates were shown to enhance the degree of inertial cavitation induced by HIFU[1]. In a follow-on study using HeLa multicellular spheroids as *in vitro* tumour models[2], the magnetite particles significantly increased the HIFU-induced inertial cavitation, causing cell lysis and disintegration of the whole spheroid (Fig. 1). This suggests that magnetite nano-particle agglomerates can enhance the efficacy of HIFU in tumour ablation and other related therapies. Furthermore, as these magnetite particles can be easily magnetised in an applied field, they could possibly be targeted to tumours *in vivo* using external magnetic field gradients after systemic administration.

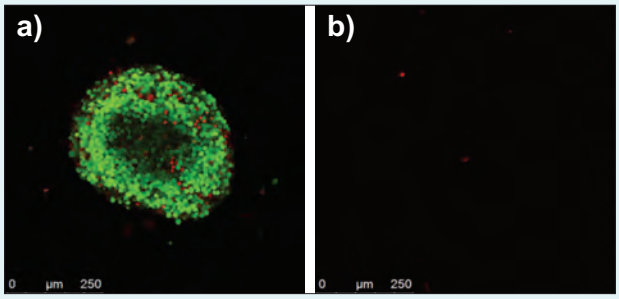


Figure 1. HeLa multicellular spheroids were radiated with high intensity focused ultrasound (HIFU) in the absence (a) and presence (b) of magnetite nanoparticle agglomerates. The magnetite particles were able to enhance the degree of HIFU induced inertial cavitation and caused the disintegration of the entire spheroid (b). Viable cells are stained green, while non-viable cells are stained red.

[1]M. J. Smith, V. H. B. Ho, N. J. Darton, N. K. H. Slater, Ultrasound in Medicine and Biology, 2009, 35(6) : 1010-1014.
[2]V. H. B. Ho, M. J. Smith, N. K. H. Slater, Ultrasound in Medicine and Biology, 2011, 37(1) : 169-175

Understanding CO_2 geological sequestration

Rehan Hussain, PhD student

Geological sequestration of CO_2 in saline aquifers is a potential climate change mitigation technique. One possible sequestration mechanism is the capillary trapping of discrete pore-scale CO_2 bubbles in the rock. At the MRRC, we have been studying these phenomena on a laboratory scale by flowing carbonated brine through model porous media (e.g. random 100 µm glass bead packing and Bentheimer sandstone).

Magnetic resonance (MR) techniques can quantify the spatial distribution and pore environment of the trapped CO_2. MR images of water in the bead packing revealed a macroscopically homogeneous CO_2 entrapment. In order to spatially resolve the bubbles pore environment, a MR technique called PFG was used to acquire probability distributions of the displacement of water, both before and following CO_2 entrapment. The mean displacement of the brine after CO_2 entrapment increased 15%, corresponding with a reduction in brine-occupied porosity of 15%. This observation was quantitatively supported by 1D MR profiles of the water content in the flow direction.

A numerical simulation strategy (based on the Lattice Boltzmann method and random walks) was used to aid the interpretation of the data. By considering various pore environments in which CO_2 could become trapped, comparison between simulated and experimental data suggests that CO_2 is preferentially entrapped in large pores (Fig. 1).

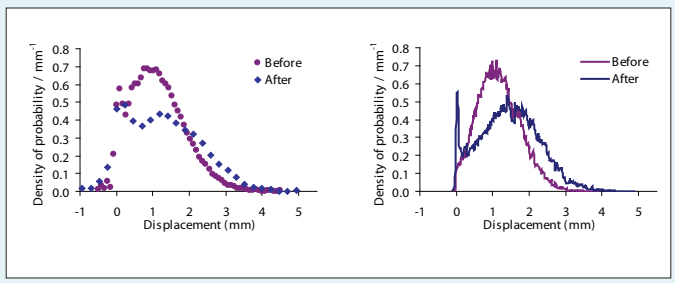


Figure 1. Experimental (left) and simulated (right) probability distributions of displacement for brine flow (20 ml/min) in Bentheimer sandstone, before and after CO_2 entrapment.

Terahertz as a new analytic tool in chemical engineering research: Applications in the field of pharmaceutical sciences

Dr Axel Zeitler

It has been an exciting year for terahertz (THz) research at CEB. The field emerged in Cambridge a few years ago from the Semiconductor Physics Group at the Cavendish Laboratory through Prof. Lynn Gladden. The Terahertz Applications Group has gained momentum and is rapidly expanding. The research is attracting interdisciplinary interest from across the university and industry.

Terahertz radiation is a part of the electromagnetic spectrum between microwaves and infrared radiation. The term terahertz refers to the frequency of the radiation, which centres around 1 THz (10^{12} Hz). This range was difficult to access until, in the early '90s, researchers in Bell Lab managed to emit and detect pulses of THz radiation by firing near-infrared femtosecond lasers on a particular type of semiconductor. Ever since then the field has seen unprecedented growth with first commercial applications emerging recently.

Terahertz radiation easily penetrates through most polymers and is therefore an exciting tool to study materials opaque to visible frequencies. In crystalline materials, THz radiation interacts with vibration modes that extend across large domains of the lattice. This makes it possible to selectively excite crystal lattice vibrations and study the interactions between molecules using low energy THz radiation - qualities that are unique to THz spectroscopy.

The focus in our group is currently on technique development and applications in pharmaceutical sciences and catalysis. However the technique has useful applications spanning the fields from medicine to art conservation.

One of the recent research highlights includes the 3D analysis of the microstructure in polymer film coatings on pharmaceutical tablets. For these measurements, a pulse of THz radiation is focused onto the surface of a tablet and the reflected pulse is measured. The imaging principle is similar to a radar: while a fraction of the pulse is directly reflected from the surface a good proportion of the pulse propagates into the transparent polymer coating. At each change in the refractive index a reflection occurs, which leads to multiple return pulses from a single incident pulse in the time-domain. From the time-of-flight between the multiple pulses the film thickness can be calculated and thickness maps of the distribution of the coating over the surface of a tablet can be obtained (Fig. 1)

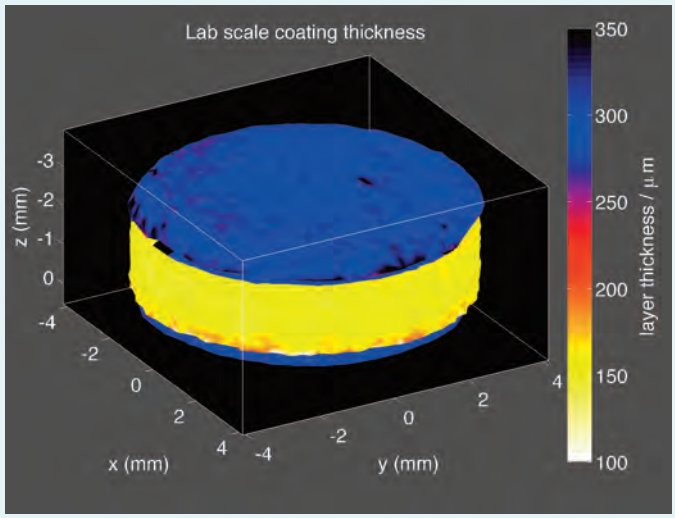


Figure 1. Thickness of the film coating layer on top of a tablet. Note the much thicker film thickness on the top and bottom surfaces of the tablet in comparison to the centre band.

These non-destructive THz images are a useful tool during product development and quality testing in industry. TeraView, a Cambridge company, developed one of the first commercial THz imaging systems for this purpose. Our group is closely involved in the development of this technology and recent research has highlighted the versatility of the imaging approach, which goes far beyond the analysis of coatings (Fig. 2). With the help of CEB and TeraView, we were able to purchase this imaging system earlier this year (Fig. 3), which will

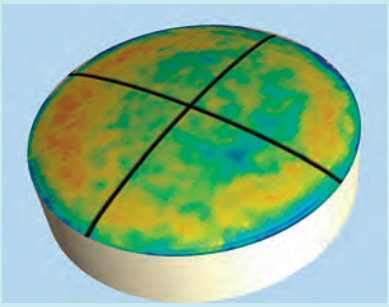


Figure 2. Density distribution on the surface of an uncoated tablet as measured by terahertz imaging. Red areas represent higher density while blue areas exhibit lower density.

form the basis for the future research. This is a pretty unique piece of kit and we are probably the only academic institution in the world to have one right now.

In addition to the imaging work, the Terahertz Applications Group developed the first in-line sensor to measure *in situ* the coating thickness of tablets during the coating process in an industrial unit (Fig. 4). This work was carried out in

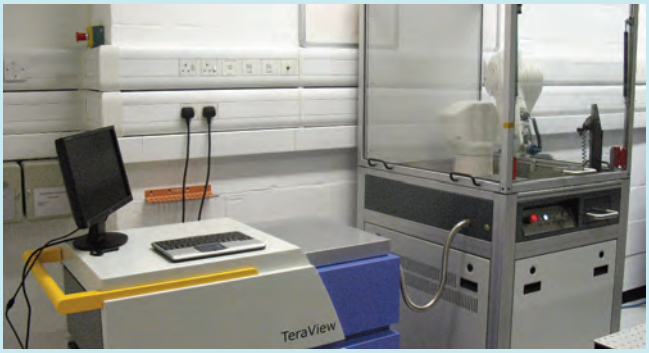


Figure 3. New THz imaging system, equipped with a robotic arm, at the Terahertz Research Group Lab

collaboration with two industrial partners and the Electrical Engineering Department in Liverpool. Due to the short measurement time, the instrument can measure the coating thickness of individual tablets rather than a time average of a large number of samples. It is then possible to determine the thickness distribution of the product, which is a key advantage for applications in process understanding and control.

When used as a spectroscopic technique, THz radiation can be used as a very sensitive probe of the crystal structure in molecular crystals such as drug molecules. In this field, the group has carried out extensive studies into the stability and dynamics of different molecular arrangements, so-called polymorphs, which are increasingly used by pharmaceutical companies to protect patents but also to increase the solubility of poorly soluble drug molecules due to higher lattice energy (Fig. 5). A collaboration with Dr Graeme Day at the Chemistry Department involves the comparison of the experimental spectra with first principle calculations to investigate the molecular nature of the vibration modes that form the basis of THz spectroscopy.

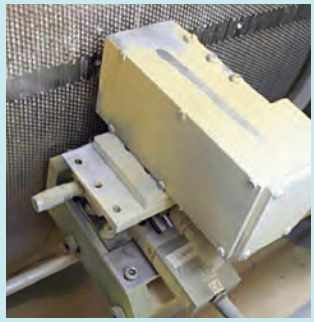


Figure 4. Terahertz in-line process sensor

The group is also very active in the field of catalysis, together with Dr James McGregor at CEB. Here the technique can be used to characterise the nature of coke formed during a catalytic reaction and hence to optimise catalyst selectivity and lifetime.

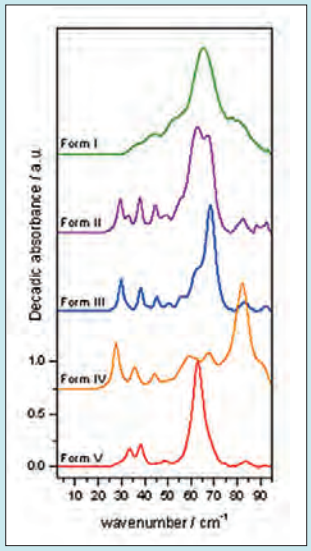


Figure 5. Terahertz spectra of five polymorphic forms of the drug molecule sulfathiazole. Using terahertz spectroscopy it is possible to clearly distinguish between the different forms.

The THz facility in the department is unique: that it combines fundamental research into THz science and technology with a systematic evaluation of new applications in field of chemical engineering. This is reflected by our collaborations within the university and with other internationally leading groups in the fields of THz technology and its applications.

To find out more about what is going on at CEB in this emerging technology please visit our website on www.ceb.cam.ac.uk/thz.php

CEB at Cambridge Phenomenon Conference

Elena Gonzalez

Professor Lowe presenting at the conference

On Tuesday 5 October 2010, three hundred global business leaders, policy makers, entrepreneurs, academics and media converged on Cambridge for ***'The Future Starts Here: The Cambridge Phenomenon 50th Anniversary Conference',*** which took place at Wellcome Trust Conference Centre, Hinxton.

2010 marked the 50th anniversary of 'The Cambridge Phenomenon'. Since 1960 and the founding of Cambridge Consultants Ltd by Chemical Engineering Alumni Tim Eiloart (sadly recently deceased) and David Southward, no end of technology, life sciences and service companies have been established in and around Cambridge. The social and environmental impact of these companies has been recognised and acclaimed globally. In the 'Silicon Fen finds its Feet' article in the Daily Telegraph (30 November 2010), editor Andrew Stone compared Cambridge technology cluster to the Silicon Valley in the US.

Professor Chris Lowe, CEB's Director of the Institute of Biotechnology and serial entrepreneur, gave a talk at the Conference (Novel Point of Care Biomedical Sensors: Future Trends in Technology at the Interface of ICT, Materials Science and Biology). As an academic-entrepreneur, Chris achieves the perfect balance between running the Institute while spinning out a steady flow of successful biotech companies and delivering pragmatic solutions to the problems facing bioscience companies around the world. He commented that *'The days are long gone when academics inhabited ivory towers; today, the knowledge-based economies of the world are intensely competitive and we have to demonstrate that our work has a sustained and practical impact on local, national and global communities.'*

Professor Lowe also contributed to the 'Silicon Valley Comes to Cambridge' event that took place on Friday 19 November 2010.

Theo Koutroukides, one of our Biotechnology PhD students researching on Schizophrenia biomarkers, is a Cambridge Phenomenon Board member who got heavily involved in organising the Conference.

The main objectives of the conference were to project the future of the worlds of IT and Biosciences including the new business opportunities created as these sectors converge and to provide inspiration and guidance to young entrepreneurs.

The day was structured around four themes: IT; Biosciences; Funding; and the Future. Exhilarating presentations and challenging debates were punctuated by one-minute pitches by the CEOs of IT and Biotech companies competing for the title 'Cambridge Phenomenon 2010 Award',

Charles Cotton, architect of the conference, commented, *'I set up Cambridge Phenomenon Ltd to mark the 50th Anniversary of the Cambridge Phenomenon and acknowledge the people, organisations and products behind Cambridge's world-famous Technology Cluster. The conference was a huge success. During the day more than 350 people participated in the event. We had a great cast of speakers and panellists including two University of Cambridge Vice-Chancellors, Sir Leszek Borysiewicz and Lord Broers.'*

Industry Business continued ...

CEO pitches from each of the IT and Biosciences categories also took place and the audience cast their votes before the end of the conference. Dr Darrin Disley, one of our Biotechnology alumni and a former PhD student of Professor Lowe, was one of the stars of the day. His successful company, 'Horizons Discovery Ltd', a local start-up, was awarded the prize for 'Bioscience Enterprise of the Future'.

Alumnus Dr Disley receives his award

Dr Disley commented that *'this award provides recognition for the technical contribution Horizon is making in the pioneering stage of the personalised medicine field. It also recognises the 'eye-opening' commercial performance of the company in what has been challenging economic times'.*

Incidentally, Chemical Engineering alumnus and Founder of the Cambridge Cluster Mr Southward handed Darrin his well-deserved award. The day finished on a great note with a Champagne Reception and 50th Anniversary Cake.

As a result of the conference there are plans under way to publish a book 'The Cambridge Phenomenon' to celebrate 50 years of innovation and entrepreneurship in and around Cambridge. The book launch is expected in the last quarter of 2011. For further information visit www.cambridgephenomenon.com

Photography © cambridgephenomenon.com

Dr Alex Routh awarded the McBain Medal

Alex Routh was awarded the McBain medal for 2010. This medal from the Royal Society of Chemistry and from the Society of Chemical Industry (SCI) is awarded to a researcher who has made a meritorious contribution to the field of colloid and interface science within 15 years of starting his/her PhD. Alex received the award on 8th December during a meeting at the SCI which comprised of talks from Alex's collaborators and colleagues. The meeting culminated in Alex giving a lecture entitled 'Watching paint dry: evaporation mediated self assembly of nanoparticles'. Alex was really moved by the whole day and said, *'To receive this award is fantastic. In addition, to have a meeting with talks from friends and colleagues is simply amazing. I am so grateful'.* The photos show Alex with his group members just after finishing his lecture and with his medal, alongside Dr Pete Dowding who organised the meeting.

Dr Routh at the Award Ceremony

Kiwanuka shines at IChemE Awards

Ssegawa with football pundit Mark Lawrenson

On 4th November 2010, Manchester's Palace Hotel hosted the 2010 IChemE Awards for Innovation and Excellence. Ssegawa-Ssekintu Kiwanuka, a PhD student with the Laser Analytics Group received third place in the category of Young Engineer of the Year. It is a remarkable achievement given that he is the youngest nominee in the award's history. ***CEB Focus*** *met with Ssegawa to find out what the achievement has meant to him.*

Sseg, congratulations! When did you find out you were nominated for the award?
I got an email in September and of course it was a huge surprise. I started the research project for my MEng and only decided after graduation that I wanted to develop this project into a PhD thesis. I didn't expect 12 months down the line I would be even considered for such a prestigious award.

Chemical engineers are not renowned for glitz and glamour. Did the IChemE put on a good show?
As a football fan, I thought having Mark Lawrenson and Ray Stubbs as hosts was an inspired choice by the IChemE. Their decision to host a champagne reception this year, instead of introductory speeches should also be credited. They really put in a lot of effort into everything.

What has been the response from your friends, family and colleagues?
My fellow Laser Analytics Group members were exceptionally pleased and as was my supervisor and Head of the Group, Dr Clemens Kaminski. The fact that I was up against strong competition, four to five years my senior reflects on the international collaborations, responsibility and intellectual freedom Dr Kaminski has given me at an incredibly early stage. Therefore I must thank him first and foremost.

I really hope this sends a strong message to stress the importance of funding scientific research in the UK at all levels. PhD researchers are worth investing in and we can contribute significant work to the wider scientific community and industry. My parents and family were of course really proud.

As for my friends, they too were thrilled and excited, although most think I just make laser discos. I would also like to specially mention Dr Toni Laurila, who led my undergraduate research project and must be credited for making even a simple chemical engineer like myself understand optics and laser physics.

Describe how you felt when they were announcing your category. Did you feel nervous and excited at that point?
Given that the judges had a record number of nominations, I was surprised to have been shortlisted by the judges. To then see my Departmental mug-shot on the big screen announcing my 3rd place was another, less flattering, surprise.

2010, was a great year for you - victorious varsity boxing, sell-out opera tour at the Edinburgh Fringe - what does 2011 have in store?
(Laughs) Hopefully it will be a quiet one! Here is an exclusive for *CEB Focus* - I announce my retirement from boxing at age 23 (although if a call for London 2012 comes up, I may delay this by one year).

Chemical Engineering and the Cambridge Phenomenon

Alumnus David Southward

By common consent the start of the Cambridge Cluster or the Cambridge Phenomenon has been linked to Cambridge Consultants, which Tim Eiloart, who sadly died last year, and I started 50 years ago. Any impression that there was nothing, there was Cambridge Consultants and then suddenly there were hundreds of new technical companies would be completely misleading for there were plenty of scientific companies from all of the Pye Group, Cambridge Instruments, Metals Research etc. But there were no such things as Science Parks.

David at Class of 1957-59 reunion, July 2009

However, to begin when we first met. At school, I knew I wished to be an engineer because I was always making things. It could easily have been any sort of engineer but in the end I was persuaded that chemical engineers would always be in demand. Fortuitously the Ministry of Supply was offering a 5 year student apprentice scheme where I could study chemical engineering and after getting a place at Cambridge this is what I elected to do. Fortuitously also this avoided National Service. Tim Eiloart was a kindred spirit on the same course who also wished to go to Cambridge. After a fairly tedious year making a set of tools at Woolwich Arsenal we both went up to our different colleges in 1955. The Chemical Engineering Department in those days was in a series of temporary buildings behind Old Addenbrookes in Tennis Court Rd . I still have Professor Davidson's Lecture notes from that era although their contents I am sure would now mystify me completely.

Tim postponed his fourth year of Chemical Engineering to cross the Atlantic in the 'Small World' a hydrogen balloon with a small gondola beneath it. They managed to get about halfway across before getting caught in such an updraft that they had to jettison gas and so continue the rest of the way in the gondola. Meanwhile I completed the course and then left the Explosives Factory to spend a year in the city studying accountancy, which I found useful but not really to my liking. In 1960 when casting around for a career move, I spoke to Tim who persuaded me to return to Cambridge. He was working at that time for the Experimental Psychology Laboratory for Richard Gregory but he had started Cambridge Consultants, which operated from offices in Jesus Lane. Although the concept of the company was to make available the scientific expertise in the University to Industry, in fact the only work being undertaken at that time was technical translation.

We decided that I should set up a small workshop and so Cambridge Prototypes was born with a little funding from the Eiloart and Southward families. The workshop was at the back of a firm of printers run by Rodney Dale in Histon Road. We employed a few instrument makers and initially we just manufactured items designed elsewhere for local companies such as Metals Research - then in King Street. Gradually the nature of the work changed and we were then asked to design jobs of ever more complexity for example equipment to investigate the mechanical properties of insect muscles. This sounds simple but it involved vibrating one end of the muscle at varying frequencies over varying amplitudes whilst sensing the reaction at the other end. This had to work at pressures up to 1000psi just to complicate it further. Of course this was in the days before transistors were in common use.

We had no in house electronic expertise to start with and had to rely part time on PhD students such as Colin Fisher. As the nature of the work changed then so we took on staff. Peter Rayner was the first full time electronic engineer to join us. He came to work on electronic petrol pumps. He was later to go back to an academic life taking

a PhD and subsequently became PhD supervisor to Mike Lynch of Autonomy – a $6 Billion per year Cambridge success story.

We had a large Research Contract to explore the manufacture of thin film capacitors. We made a microbalance for a local company and TV audience measuring equipment for AGB. We made typewriter training equipment. For the carpet industry we made a machine for generating Axminster loom spools and produced a demonstration model of a new type of carpet manufacture. There was little common theme to the work we were asked to do.

'We decided that I should set up a small workshop and so Cambridge Prototypes was born with a little funding from the Eiloart and Southward families'

Tim was extremely good at generating publicity for the company both locally and nationally. This brought us in touch with other groups wanting to start their own business. For example, Iann Barron and a group of colleagues worked for Elliott Automation and wished to start a company manufacturing fast computers – to rival the DEC PDP8. We took them onto our payroll and did manage to help raise their finance. Thus Computer Technology which produced the Modular One was born – we had a small shareholding in it. Of more relevance to our background we were also approached by a group of engineers who wished to start a business specialising only in Heat Exchanger design. This lead to the formation of Delta Thermal Technology.

With the naivety and enthusiasm of youth there was nothing we did which while hugely enjoyable also put us back to the start of the learning curve in each new field. Both our clients and ourselves always underestimated the development cost of a project. Thus to have a 'bread and butter' line manufacturing the same item was always something of a dream.

When Gordon Edge joined he produced designs for modular electronic test equipment and so AIM Electronics was born. The premises at Histon Road were now full to bursting and the expansion of the company was straining our financial resources. So we were pleased that Robert Maxwell amongst others then invested in the company and despite his reputation we never had cause to regret his involvement. Gordon also designed the P40 hi-fi amplifier and this led to the formation of a further company Cambridge Audio Laboratories Ltd for which we obtained limited external funding.

When Gordon left in 1970 he went on to start the PA Science and Technology Centre at Royston and subsequently to found Sagentia.

But Aim Electronics and Cambridge Audio were not the only fledgling off shoots, we had a raft of other small ones including Draftmaster, Aim Biosciences. Aim Physical Sciences, Durcam and possibly others I have forgotten. To bring some sort of financial structure to these, the mother company of Cambridge Consultants became the Group Holding Company – Aim Associates and all the others with separate management – including a wholly owned new 'Cambridge Consultants' became operating divisions. The concept was that a failure of any one division would not bring the whole House of Cards down – but in the event this is exactly what finally did happen in 1971.

In 1968 we moved into new premises built for us in Bar Hill (now swept aside by Tescos). We also then took over the Mill at St Ives which became a base for our manufacturing arm – both hi fi and Aim Electronics. The Working Capital demands – especially for the hi-fi side eventually proved our undoing, but at least Cambridge Consultants still thrives and I have never regretted the 'jack of all trades, master of none' education I received – I am sure Tim would say the same. As a colleague said to me the other day 'Know one branch of Science and you know the lot!' – well, not exactly true, but I see and agree with that sentiment.

Return of Friday pub nights socials

Kyra Sedransk, PhD student

Ever wonder who people are outside of your group or office are? Maybe you didn't even know that the department has THREE sites ... Or you are just tired and want a chance to vent out your frustrations with people going through the same thing.

We are kicking off the return of Department Pub Nights!

When: 2nd Friday of the month at 6pm (next one is on 11 February)
Who: Masters, Grad students, Postdocs, and really anyone interested from CEB
Where: each month a different pub (next one in The Anchor pub)
Why: to get to meet and relax, simple as that.

See you all there!

Frank Morton Games

22 February 2011, at Nottingham University.
For further details contact Naveed Kayaam, CUCES Frank Morton rep (onk20@cam.ac.uk)

The Frank Morton Sports Day is an annual sporting competition between the students of chemical engineering departments from UK universities. Some of the sports involved include football, basketball, tennis, netball, squash, rounders and dodgeball. For the non-sports lovers there's a pub crawl followed by a night out after the sports. All in all it is a great day off and an opportunity to get to know fellow chemical engineers from the UK.

Alumni Speaker Series: Lent Term

'Breaking with Tradition: Cereal Processing for the 21st Century'
Dr Grant Campbell, Satake Centre for Grain Process Engineering School of Chemical Engineering and Analytical Science, The University of Manchester
Friday 28 January 2011, 3.30pm.

'Development and Manufacture of an Affinity Filter for the Removal of vCJD from Blood and Blood-Derived Products'
Dr Steve Burton, Prometic Life Sciences
Friday 25 February 2011, 5.00pm

Seminars: Lent Term

'2nd Year PhD Student Presentations and Posters'
Posters from 2pm, Talks from 3.15pm
Chemical Engineering Students, Wednesday 26 January, Tennis Court Road – Level 3
Biotechnology Students, Wednesday 2 February, Lecture Theatre 1, Pembroke St.
Chemical Engineering Students, Wednesday 9 February, Lecture Theatre 1, Pembroke St.

'Technical context for deepwater drilling and oil spill response'
Dr Ellen Williams (Chief Scientist BP), Dr Andy Leonard (Cambridge coordinator BP)
Wednesday 23 February, 2-3pm, Lecture Theatre 1, Pembroke St.

'Inventing apparatus and processes'
Professor Malcolm Mackley, Dept. of Chemical Engineering and Biotechnology, University of Cambridge
Wednesday 9 March, 2-3pm, Lecture Theatre 1, Pembroke St.

A warm welcome to…

Research Associates:
Dr Bob Amess
Miss Eva Brombacher
Dr Man Chan
Dr Natacha Vanatto-Saifoudine
Dr Mikael Winters

Research Assistants:
Miss Rebecca Barner
Miss Sonia Melendi

Visiting academics and research students:
Mr Edward Avezov
Professor Raul Conejeros
Professor Nevin Selcuk
Dr Richard Shaobing

Goodbye to…

PhD Students:
Tamaryn Brown
Ya Ying Cheng
Sarah Creber
Simon Schlachter

Visiting Research academics and students:
Professor Edd Blekkan
Dr John Frank
Nuria Rodriguez Gomez
Professor JoAnn Lightly
Chu Liu
Professor Houston Miller

Visiting Professor JoAnn Lightly

I was on a six-month sabbatical from the University of Utah, where I am Professor and Chair of Chemical Engineering, and have been in the department since June 2010. I was also a By-Fellow of Churchill College in Michaelmas 2010. During my time in the Department, I worked with Professor Markus Kraft on soot oxidation and models that will predict the experimental evidence of particle fragmentation. I also have a research project in process modelling of chemical looping, a common interest with Dr John Dennis.

I have enjoyed my time in the Department and Cambridge. My 15-year old daughter and husband have also loved being here. My daughter has attended Chesterton Community College and played for Cambridge City Football Club. As a family, we will miss the wonderful people; our bike riding adventures; and the amazing history of Cambridge. These are unique features to someone from Utah. A place of too many cars and an age of only 164 years – young in comparison to Cambridge!

Tamaryn Brown
PhD Student

I came to Cambridge in January 2006, having just finished my studies in Chemical Engineering at the University of Cape Town, South Africa. My research topic was on Chemical-looping combustion (CLC) with solid fuels such as coal and biomass. Chemical-looping is an alternative combustion process for generating power whilst at the same time producing a pure stream of carbon dioxide which can be captured and stored underground.

Studying at Cambridge was both a challenging and rewarding experience and I have learnt many lessons along the way. During my time, I was a member of the Cambridge University Yacht Racing Team and sailed against Oxford in the Varsity Regatta two years running, beating them in the first year. I also helped to organise workshops for Engineers without Borders. Since submitting my dissertation, I have begun a post doc in the Policy group of the Grantham Institute for Climate Change at Imperial College in London. In my new role as Mitigation Research Assistant, I am researching technology pathways for low carbon economies.

Dear Dr Sarah

Dr Sarah Rough, MPhil ACE Programme has been listening to the concerns of students and colleagues within the Department for over 10 years. She is a fully qualified practitioner of the Advanced Regression via Sleep Evolution technique, and is a regular contributor to the Bulletin of Social Hierarchies In Teaching.

Dear Dr Sarah,
The research isn't going places. I had big plans but nothing seems to be working. What's the point Dr Sarah? Where am I going wrong? I hope you can help. Phil D

Dr Sarah says ...
First of all, stop worrying. It's perfectly natural to have these types of feelings for your research. Most of us go through what you're describing - it's all part of developing as a researcher.

You probably feel like a little boat on a rough sea - you're doing a lot of tossing about, but you're getting nowhere. What you need to do is to lay anchor and wait for the storm to pass.

One way of achieving this is by meditation - this will focus the mind and invigorate the spirit, and help you become one with your research.

Find a quiet, deserted place - try any of the research labs before 11am. Sit comfortably and start off with a simple one word mantra, e.g. the word 'fugacity'. Say this word over and over in your head. You will soon find that it becomes quite meaningless. Try this for a few seconds every morning.

Once you are comfortable with the whole procedure, move up to the next level - meditation upon an equation, e.g. a Bessel function [Departmental Data book p.17]. Visualise the equation in your mind's eye, and try to hold it there as long as possible without distraction - not as easy as it sounds! Gradually increase the complexity - perhaps choose a set of your data and think about each error bar. If you have no data, then I hear that Excel has an excellent random number generator function.

One can progress through a number of stages, and some adepts can even attain the level of meditation upon contour integration in the complex plane, but you should feel well-grounded before that, and completely at one with your research. The sea should now be calmer, so weigh anchor and off you go!*

**Warning: Do not try this at home.*

If you have concerns that you would like Dr Rough to provide answers for in future issues, email the Editorial Team your questions on ceb-focus@ceb.cam.ac.uk or leave us a note in the comment boxes available in the Department.

Turbulence in a Tea-Cup

Alastair Clarke
PhD student

The last *Tea-time Teaser* caused quite a stir and hopefully this one will also quench your thirst for engineering problems. We look at the turbulent mixing of miscible fluids. When I add milk to my cup of tea-infused water, how long does it take for the two fluids to completely mix without the aid of a stirring spoon?

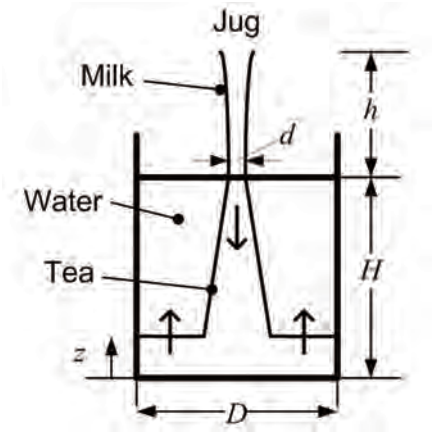


Figure 1: Schematic diagram showing milk being poured from a jug into a cup partially filled with water.

Figure 1 shows the geometry of our problem. Milk is poured from a height *(h)* into a cup of water. The milk jet has a diameter *d* at the water surface, the water has a depth *H* and the cup has an inner diameter *D*. Initially the water is stagnant and we assume it has a uniform density which is equal to the density of milk (actually milk is ~5% denser). As the milk jet streams down the centre of the cup, it drags the surrounding water with it and the two fluids mix. The water enters perpendicularly to the direction of the jet and whilst this causes the volumetric flow-rate *(Q)* to increase, it does not alter the momentum flux *(M)*. *Figure 2* is a photo taken about one second after milk was added to a cup of tea-infused water. When the jet hits the bottom of the cup, it spreads laterally and forms a layer of milky tea. As more milk is added, the tea layer grows. If we assume the velocities of the jet and the tea layer do not vary along the radial direction, then a volume balance in the vertical direction gives the rate of change of the tea layer thickness *(z)* to be:

$$dz/dt = 4(Q-Q_0)/\pi D^2$$

where $\pi = 3.14\ldots$, t is time and Q_0 is the flow-rate of milk from the jug that arrives at the water surface. This approach has also been used in an old Chemical Engineering Tripos question[1]. We further assume that the depth of fluid in the cup does not change much over time compared to the heights h and H. Now, Bernoulli's equation gives the velocity of the milk at the surface ($=\sqrt{(2gh)}$) and the plume equations[2] give $Q = 2\alpha(H-z)\sqrt{(\pi M)} + Q_0$ where α is the entrainment coefficient for a jet (= 0.076), g is gravity and $M = \pi d^2 gh/2$. Combining these equations and integrating the differential equation over the limits $z = 0$ at $t = 1$ second to $z = 0.99H$, gives the time taken for the two fluids to mix. For a typical tea-making scenario where $D = 6$ cm, $h = 4$ cm and $d = 0.5$ cm, our model predicts it will take 13 seconds. Okay if you like cold, milky tea. In future, we may wish to consider buoyancy effects and the overturning of the tea layer at the walls.

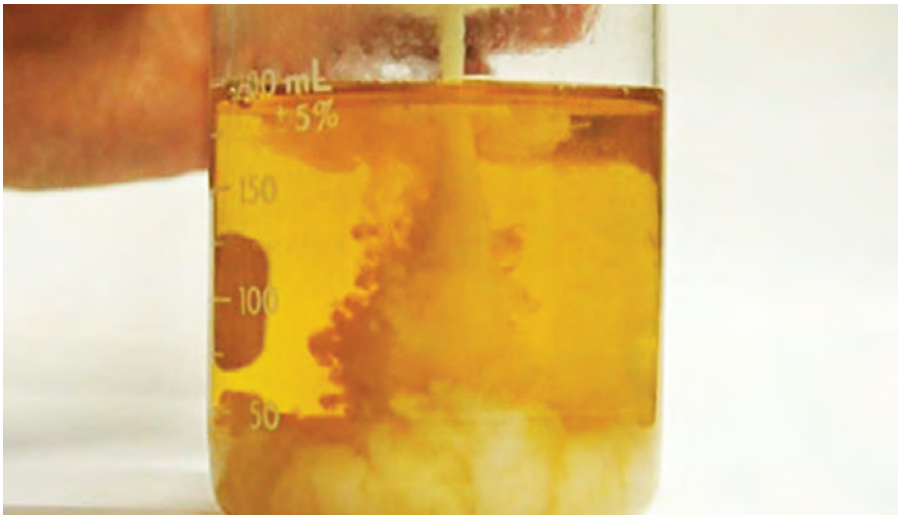


Figure 2: Photograph taken one second after milk was poured into a partially-filled cup of tea-infused boiled water. Here h = 4cm, H = 6cm and D = 6cm.

References

[1] Cardoso, S.S.S., Scott, D.M., 2006. Paper 5 (Fluid Mechanics and the Environment), Chemical Engineering Tripos. Question 3. University of Cambridge.

[2] Morton, B. R., Taylor, G. I., Turner, J. S., 1956. Turbulent gravitational convection from maintained and instantaneous sources. *Proc. R. Soc. London A,* 234, 1-24.

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