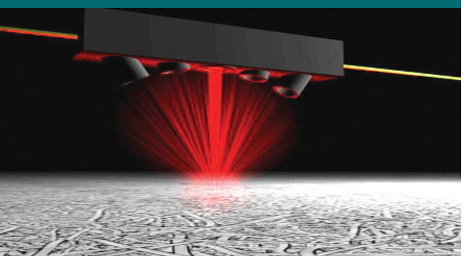
UNIVERSITY OF CAMBRIDGE

CavMag

July 2011 Issue 6

News from the Cavendish Laboratory

Inside...



www.phy.cam.ac.uk

The Opening of the Winton Programme for the Physics of Sustainability

David Harding, Peter Littlewood and David Willetts in the Cavendish Museum viewing posters illustrating the diversity of the Winton Programme for the Physics of Sustainability.

The formal opening of the Winton Programme for the Physics of Sustainability took place on 24th March 2011. It was a day of celebration starting in the morning with the award to David Harding of the Chancellor's 800th Anniversary Medal for Outstanding Philanthropy, presented by the Chancellor, the Duke of Edinburgh.

There followed a special visit to the Cavendish Laboratory by David Willetts, Minister of State for Universities and Science in the company of David Harding, Peter Littlewood and Richard Friend during which the scope of the programme was explained to the Minister.

In the afternoon, the formal opening of the Winton Programme for the Physics of Sustainability took place, chaired by Peter Littlewood as almost his last duty as Head of the Cavendish Laboratory. After the Vice-Chancellor had expressed the University's deep gratitude for his extraordinary generosity, David Harding explained in a light-hearted speech his reasons for the gift. Those which struck your editor were the facts that (a) he had made a great deal of money by employing some of the Cavendish's best physics graduates to work as researchers, (b) he felt a desire to repay to society some of the remarkable gains he had made by introducing innovative approaches to hedge-fund management, in the process hoping to improve the image of the profession, (c) he believed in the sincerity of the Cavendish staff in their desire to use physics for the betterment of society.

The Duke of Edinburgh and David Harding with the University Registrary Jonathan Nicholls at the award ceremony.

The urgency of dealing with energy and environmental problems was emphasised in an impassioned speech by David MacKay, the chief scientific adviser to the Department of Energy and Climate Change and on leave from his professorship at the Cavendish. David was followed by Richard Friend, the Director of the Programme, who described the challenges and steps being taken to deliver the Winton Programme over the next ten years. Already the first appointments are being made to the studentship and fellowship programme which will underpin the research activities.

What is the Physics of Sustainability?

It is simplest to quote the words of Peter Littlewood 'In 2100, the sources of energy on this planet will be either solar or fusion, and the preferred means to transport and use that energy will be electrical. The "magic" technologies needed to deliver this new age and make them available to societies world-wide are: photovoltaics, electrical storage, refrigeration and lighting.

These technologies are particularly important for use in the tropical developing world. There are no basic physical principles preventing breakthroughs in all these areas. Today, solid state lighting is the closest to the appropriate performance. New materials discoveries and the development of new physics concepts are needed to bring this vision to fruition and make resulting technologies available to the worldwide community.'

This vision is very strongly linked to active research programmes in the Laboratory, but the concept is to go beyond these. Some examples do, however, illustrate the enormous potential for imaginative exploitation of basic physical principles.

Designer Materials

Atom by atom manipulation and growth may allow the creation of new chemical environments with desirable properties. Molecular engineering using materials chemistry can be used to grow molecular solids containing functional units. We can further tune properties of materials by applying extreme conditions of temperature, pressure and magnetic and electric fields to search for emergent properties such as superconductivity or magnetism. We are searching for the ultimate limits: a room temperature superconductor for dissipationless electrical wires; a material with a large tuneable entropy change as an ideal refrigerator material; electrical storage densities to rival gasoline; new mechanisms for thermoelectrics to scavenge heat from the environment.

Light and matter

The primary source of energy on the planet is sunlight. Converting incident light to useful electrochemical stored energy needs heterogeneous materials with controlled quantum chemistry, delivered at scale in cheap and robust devices. Patterns of metals and dielectrics on the nanoscale may be used to enhance the sensitivity of molecular detection, and are also a method to manipulate quantum coherence which will be the ultimate efficient computing technology. Photovoltaics require both strong optical absorption and good electrical transport, best arranged in a three-dimensional structure that is largely interface. Future efforts will involve active tuning of structures as well as fully three-dimensional patterns.

Self-assembly

Energy applications will require nanoscale engineering to be delivered by the tonne and by the hectare, which will require the invention of new manufacturing methods. Biology currently holds the only examples of functional and interacting structures at the nanoscale, using nanomachines for everything from photosynthesis to the transfer of energy through cells. We will strive to replace top-down fabrication by bottom-up self-assembly of structures, using natural systems for inspiration and exploiting a mixture of physical processes and programmed methods.

Multiscale modelling

Developing novel sustainable materials and technologies will require an understanding of how quantum mechanical models on atomic scales can be melded with classical modelling on large scales, and to model physical processes on time scales from picoseconds to seconds. Work will strive to integrate modelling with experiment, and eventually use it for the design of complex devices.

The Winton donation will support programmes that explore basic science, which can generate the new technologies and new industries needed to meet the demands of a growing population on our already strained natural resources. The programme will provide studentships, research fellowships, and support for new academic staff as well as investment in research infrastructure of the highest level, pump-priming for novel research projects, support for collaborations within the University and outside, and sponsorship for meetings and outreach activities. There will be a strong emphasis upon fundamental research, which will have importance for the sustainability agenda in the long-term.

The 'bottom-up' parts of the programme are already advertised - studentships and five-year fellowships. The intention is to fund very bright younger physicists. For Fellowships, the emphasis will be on bright and novel ideas that bring new activities to the Cavendish.

'Top-down' activities will involve introducing new areas of research to the Cavendish research programme. In the 'materials' area, programmes may be generated in which the physics is supported by the complementary materials science and materials chemistry that allows us to take new directions.

In carrying out the programme, we will build on our strong existing interactions with various departments in the University. These include:

- the *Department of Chemistry*, including the *Melville Laboratory for Polymer Chemistry*;
- the *Department of Materials Science and Metallurgy*;
- the *Department of Engineering*, particularly through the *Centre for Nanoscience*.

Collaborations will also be developed with cognate departments in other universities where there is complementary expertise.

Peter Littlewood and Malcolm Longair

Peter Littlewood's Parting Shot

Peter Littlewood stood down as Head of Department at the end of the Lent Term 2011 to take up the post of Associate Laboratory Director for Physical Sciences and Engineering at Argonne National Laboratory in the USA. In characteristic exuberant style, he reflects on his tenure of this demanding position. We wish him every success in making the transatlantic transition from the frying pan into the fire.

Life in the Cavendish proceeds with unstoppable momentum. There is the annual cycle of students - inquisitive, stimulating, and demanding; the frenzy of passing business and politics; and the inexorable flow of science, a continually advancing discipline that runs on its own time and to which Cavendish physicists have contributed so much. I have been privileged to chair just half a dozen of these annual cycles and so only a small portion of the Cavendish's history, but in that short time I have had the excitement of hiring a total of 15 lecturers, readers and professors - a turnover of almost a quarter of the academic staff. In the same period we almost completely revamped our undergraduate teaching programme. I am surprised to discover just how much the Department has changed.

Physics is a discipline that continues to address and challenge the ultimate mysteries of science, driving activities from the deeply philosophical to the profoundly practical. The Cavendish remains busy on all fronts. We have thriving research in new areas that barely existed five years ago. Some of my colleagues are literally braiding quantum mechanical trajectories by creating environments where a few particles can be isolated from the rest of the Universe - controlling the quantum behaviour of matter is coming within our reach. Others - in an entirely new endeavour conceived by my predecessor - are applying the methods and tools of the physicist to bring new perspectives to medicine and biology. Ordinary matter turns out not to be so ordinary, and the Schrödinger equation surprises us with its complex adaptations; all you see around you is that simple equation made manifest.

We can claim not only new technologies but also new businesses as we learn to harness and design materials to build devices to solve the pressing problems of the world. We are just embarking on a new programme – the Physics of Sustainability - with the bold goal of providing the physical means to 'solve' major problems of energy and the environment. Particle physics is on the cusp of grand discoveries, or even greater puzzles, as we await the fruits of our labour over two decades of participation in the construction of the Large Hadron Collider. My astrophysicist colleagues are coming to grips with evidence that we have misplaced most of the energy and mass of the Universe - and respond by designing new telescopes that are the size of a continent.

My colleagues are influential – they are awarded not only the expected academic accolades, for example, at least one election to the Royal Society every year, but also:

- the single active PhD scientist in parliament,
- the chief science advisor to the Department of Energy and Climate Change,
- one of the *Guardian*'s top hundred most inspiring women, as well as one of the *Telegraph*'s top hundred most powerful women,
- the UK's most cited researcher in 'chemistry',
- a feature article in FHM magazine,
- a feature article on Oprah's website.

Our students are absolutely everywhere - they are leaders in all walks of life, from hedge funds, to Covent Garden and the High Court.

As well as the expected teaching and research, there are all kinds of things that add delight or bemusement to the office of Head of Department - examples include:

- regular delegations of dignitaries from around the world, with more than once the deadpan request for advice on how to organise a laboratory to win Nobel prizes;
- more benign requests for information, for example, Essex trading standards requesting advice on a "perpetual motion machine";
- a visit from the BBC requesting to "borrow" something from the historical collection;
- massive and popular outreach events – the "Physics at Work" programme is, we believe, now the longest running schools outreach programme from a physics department in the UK;
- a summer school for year 11 students described by its participants as "inspirational".

Running a modern science department is expensive; the Cavendish has an annual research spend exceeding £20M and, although the University does not engage in this kind of accounting, our "turnover" from all activities is about twice that. Setting up a new research activity laboratory can run to £1-2M or more and we are in a competitive global competition for talent and research funding, in a discipline where achievement is readily measured. While I'm distrustful of publication metrics, our citation rates are on a par with Harvard and Stanford, and ahead of all our UK competitors and so we have reason to be proud of where we are.

Our financial indicators are sound - we have excelled in research and teaching assessments and our grant funding grew in good times and is holding up in difficult times. We have been able to make investments in new buildings, new programmes and new staff, frequently helped by the generosity of alumni and donors. Our students remain spectacular, inspiring and - heart-warmingly from a Head of Department's perspective - numerous. And not least, we have an extraordinary administrative support team - we are seen in the University as a model department - our senior administrators deserve wings for the number of initiatives they have piloted.

James Stirling, my successor as Head of Department, is a brilliant scientist but also a very able manager, having been Vice-President for Research at Durham before being lured back to Cambridge, where he was a student, with the promise of being allowed to get on with his own science. Unfortunately for him, he has so many talents that we can't resist exploiting all of them, simultaneously. There are many challenges, in the short term arising from the experiments the government is conducting in funding mechanisms both for student and research support. We are barely started on our plans to rebuild the whole laboratory. But I am sure that what persuaded him to take on the role are the rewarding scientific and educational challenges, and the opportunities we still have to change the world.

I have remarked about my own students that they often fail to recognise that a problem is insoluble, and thus have the enthusiasm and uncluttered minds, as well as the skills, to crack it. The wonderful thing is that as scientific challenges emerge, brilliant people seem to turn up at the Cavendish to solve them.

Peter Littlewood

Passing on the Torch
James Stirling takes over as Head of the Cavendish

It is a pleasure to welcome you as the new Head of Department to this latest edition of CavMag. In the accompanying article, my predecessor Peter Littlewood reflects on the state of the Cavendish Laboratory in its 137th year. He comments on some of our recent achievements and successes, but is too modest to acknowledge his own contributions to these. Peter was a superb Head of Department, and a very hard act to follow. I would like to take this opportunity of thanking him, not just for all he did for the Department in his almost six years as Head, but also for the way he helped and chaperoned me into the job over the last few months. It is a great comfort to me to know that I can tap into his wise advice at any time. And since he will be maintaining a link with the Department, we will of course not be losing him altogether.

When I arrived in Cambridge in 2008 to take up the Jacksonian Professorship, I had no idea that in less than three years I would be sitting in the Head of Department's office. I was deeply honoured that colleagues considered that I was a suitably qualified to lead the Department. Coming from outside has, of course, advantages and disadvantages. On one hand, I hope to be able to bring a fresh perspective and perhaps even some examples of good practice learned elsewhere. On the other hand, my learning curve has inevitably been rather steep, and I have spent much of the time in these first few months visiting the Department's various research groups and administrative and support sections, not just gathering information but also trying to tease out views on what works well and areas where we could do better. The overall impression is of a Department in very good shape – we have an incredibly talented workforce, and a very collegial work environment. Comparisons with other departments are difficult, and probably unfair, but I believe that our policy of recruiting the very best people, and giving them the time, space and support to work to their full potential, is the key reason why we are one of the best physics departments in the world.

What of the future? The Department has recently embarked on a number of major research initiatives. The Winton Programme for the Physics of Sustainability, launched earlier this year and celebrated in this issue, will soon see the arrival of the first cohort of research students and fellows. We have also just received the 'green light' from the University to proceed with plans for construction of a building that will house our new Centre for Experimental Astrophysics. This is the final stage of the process that will see Cambridge's world-leading astronomers, cosmologists and astrophysicists co-located on a single site at Madingley Rise. With the appointment of Ben Simons of the Theory of Condensed Matter research group to the Herchel Smith Professorship, the Physics of Medicine project will enter a new phase. And right across the Department we continue to recruit outstanding research students and research associates. These major developments will greatly enhance our submission to HEFCE's next Research Excellence Framework (REF) assessment in 2014.

We cannot, however, ignore the fact that these are turbulent and challenging times for UK universities. We will need to work even harder, in partnership with the Colleges, to ensure that the much publicised rise in tuition fees does not deter the brightest students from applying to Cambridge. Some 70% of our annual turnover is won through research grants from external sponsors, funding that is particularly vulnerable to the effects of the financial down-turn. Research Council funding provides our core support, and although there was some good news in last year's government Spending Review, with recurrent support for science research maintained at around flat cash, reductions in capital funding for projects and equipment will place extra pressure on departments like the Cavendish in which experimental research figures so prominently. We need to continue to seek funding from other sources.

The Cavendish Laboratory has come a long way since it was established by James Clerk Maxwell in 1874. A few years earlier, a University syndicate had reported 'in favour of founding a Special Professorship, and of supplying the Professor with the means of making his *(sic)* teaching practical; in other words of giving him a demonstrator, a lecture-room, a laboratory, and several class-rooms, with a sufficient stock of apparatus.' Nowadays we have some 30 Professors among a workforce of more than 850 with an annual turnover of almost £40M. We continue with our endeavours to rebuild the Laboratory in a phased programme of construction, details of which are included in the list of projects approved by the School of Physical Sciences in our Development Portfolio*.

It is a challenge to keep everyone fully informed of all that is going on in such a large enterprise, and I will be giving particular priority over the coming months to finding ways of enhancing our internal communications. CavMag is our primary means of communicating with our alumni and friends around the world, and your support is invaluable and strongly encouraging. As noted later in this edition of CavMag, we are always delighted to hear from you - we are continually amazed by the achievements of some of our Alumni. We hope to see you during Alumni weekend – in addition, special visits can be arranged if you happen to be passing through.

James Stirling

* see: **www.phy.cam.ac.uk/development/Development_Portfolio_Final.pdf**

Ben Simons elected Herchel Smith Professor of the Physics of Medicine

We congratulate Ben Simons on his election to the Herchel Smith Professorship of the Physics of Medicine. The endowment of a professorship of physics was bequeathed to the Cavendish in the will of Herchel Smith who pioneered the development of the contraceptive pill. With the founding of the Centre for the Physics of Medicine, the professorship was dedicated to the Physics of Medicine. In this article, Ben describes the remarkable opportunities for physicists to contribute to this key research endeavour for the benefit of society.

Inducible genetic labelling of the small intestine. Following induction, stem cells express one of four fluorescent proteins. The figure shows ribbons of differentiating cells migrating from monoclonal crypts (bottom) onto villi (top) at 4 months post-induction. Image reproduced from Simons and Clevers (2011).

In the late 1940s and 50s the Cavendish played host to the Unit for Research on the Molecular Structure of Biological Systems, established by Max Perutz and John Kendrew. Alongside the structure of DNA, this unit was responsible for several major discoveries from the structure of proteins, such as haemoglobin, and viruses, to the elucidation of the mechanism of muscle contraction. This pioneering group formed the basis of the Laboratory of Molecular Biology, considered by many as the birthplace of modern molecular biology. Half a century later, Malcolm Longair (then Head of the Department of Physics) and Sir Keith Peters (then Regius Professor of Physic) established a new initiative to promote collaboration between the physical and medical sciences. Since then, researchers at the Cavendish and across the University have been engaged in the development of novel imaging and manipulation strategies to probe and perturb living cells, down to the molecular scale.

Although modern technology provides access to data at a resolution and density unimaginable fifty years ago, the pace of its acquisition has far outstripped the rate of its assimilation, and biologists are starting to reassess the directions and challenges of the subject (Nurse, 2008). Soon after the discovery of the double-helical structure of the DNA molecule by James D Watson and Francis Crick at the Cavendish in 1953, the molecular mechanisms of gene replication and transcription were resolved, and the gene became widely accepted as the fundamental unit of biological information. With the advent of cloning and sequencing technologies in the 1970s, geneticists began to gain access to gene sequences of increasingly complex organisms, culminating in the complete sequencing of the human genome just 50 years after Watson and Crick's famous discovery. However, the diversity of genes cannot approximate the diversity of functions within an organism, and the search for mechanism in biological processes has focussed predominantly on the elucidation of complex gene regulatory networks. Unfortunately, such complex, and often incomplete, interpenetrating networks, rarely provide insight into functionality. As Sydney Brenner put it so mischievously, "Sequencing the human genome was once likened to sending a man to the moon. The comparison turns out to be literally correct because sending a man to the moon is easy; it's getting him back that is difficult..." (Brenner, 2010).

Although cell biologists tend to address questions of a much higher intrinsic complexity, the dilemma they face is one that is familiar to physical scientists. The identification of the basic elements of a system, and the resolution of their fundamental interactions, rarely disclose their collective behaviour. Yet, from such complex assemblies, simple, robust, and elementary phenomena frequently emerge. As physicists we know that, when a liquid condenses into a crystalline solid, collective excitations appear involving the coherent vibrational motion of large numbers of constituent atoms. But, despite the complexity of the underlying microscopic interactions, these collective excitations often behave as elementary, particle-like entities governed by simple – universal – physical laws. The generality of this hierarchy was emphasised famously by Phil Anderson in his commentary, *More is different* (Anderson, 1972). By placing emphasis on phenomenology, physicists have cleverly by-passed the curse of complexity and the impossible challenges of bottom-up reasoning. At the same time, they have devised theoretical and conceptual methodologies – kinetic theory, field theory, renormalisation group, hydrodynamics, and so on – to bridge the microscopic and macroscopic world. Inspired by the challenges now facing cell biology, many of us believe that physical scientists have the opportunity to contribute significantly to the conceptual development of the subject, as well as continuing to provide important technological advances.

Recent research in the field of stem cell biology provides a concrete example. Stem cells contribute to both the development and maintenance of multi-cellular organisms. Embryonic stem cells (known as ES cells) form the inner cell mass of the early embryo, and have the ability to differentiate into cell types from any of the three germ layers. The therapeutic potential of these extraordinary pluripotent cells has created interest from both inside and outside the academic community. During development these undifferentiated cells become increasingly restricted in their lineage potential. In adults, many organs such as skin and gut continue to undergo rapid and constant turnover. Their maintenance and repair relies upon adult stem cells. These cells are also defined by their ability to differentiate into multiple cell types and self-replicate. However, unlike ES cells, adult stem cells must achieve something remarkable: to avoid aberrant growth or loss, these cells must maintain a perfect balance between proliferation and differentiation. Resolving the factors that control this balance represents one of the defining challenges of adult stem cell research.

To address this problem, efforts have focused on the identification of stem cell-specific biomolecular markers, with the aim of resolving the transcriptional regulatory pathways that promote stem cell competence and control differentiation. However, the development of transgenic mouse models allows a different approach, which places emphasis on functional (phenotypic) characteristics. The method involves the development of a transgenic mouse model in which the transient expression of a Cre recombinase can lead to the irreversible genetic marking of a cell and its offspring (see Figure). As a result, it has become possible to resolve the fate of individual labelled stem cells and their progeny (termed clones) over the lifetime of an organism.

In cycling tissues, the long-term self-renewal of a stem cell population can be achieved in one of two ways: either each and every cell division results in asymmetric fate with one cell remaining in the stem cell compartment and another committing to differentiation. Or the balance between proliferation and differentiation is achieved on a population basis, with some cell divisions resulting in symmetric multiplication, and others leading to differentiation and loss so that the overall stem cell population remains constant. Intriguingly, lineage-tracing studies combined with insight from non-equilibrium statistical mechanics provides the means to discriminate between these different patterns of stem cell fate. However complex the underlying mechanism of stem cell regulation, in tissues that conform to a pattern of population asymmetric self-renewal, the long-term clonal fate characteristics converge onto a limited set of "universality classes", discriminated by the dimensionality of tissue and the pattern of regulation (cell-autonomous or environmental), and signalled by scaling behaviour of the clone size distribution. Applied to numerous tissue types from testes to epidermis and gut, and across a range of organisms from mice to flies, such studies are beginning to resolve the pattern of stem cell maintenance, raising questions about the biomolecular pathways that promote stochastic fate, and providing a quantitative platform to address factors leading to dysregulation in disease, cancer, and aging.

In modern cell biology, the acquisition of data is too often confused with the accumulation of knowledge. With the challenges now facing cell biology, physical scientists have an unparalleled opportunity to influence the conceptual development of the subject.

Further reading:

Anderson, P.W. (1972). More Is Different. Science 177, 393-396.
Brenner, S. (2010). Sequences and consequences. Philosophical Transactions of the Royal Society B: Biological Sciences 365, 207-212.
Nurse, P. (2008). Life, logic and information. Nature 454, 424-426.
Simons, B.D., and Clevers, H. (2011). Strategies for Homeostatic Stem Cell Self-Renewal in Adult Tissues. Cell 145, 851-862.

Fig 1: Val next to the LHCb experiment. To her right are the magnet coils and to her left is one of the RICH detectors.

Flavour Physics at the Large Hadron Collider

Val Gibson was promoted to Professor of High Energy Physics in 2009 but delayed giving her inaugural lecture to the Cavendish Physical Society until May 2011 when the first results of her major involvement in the LHCb experiment at the Large Hadron Collider were obtained.

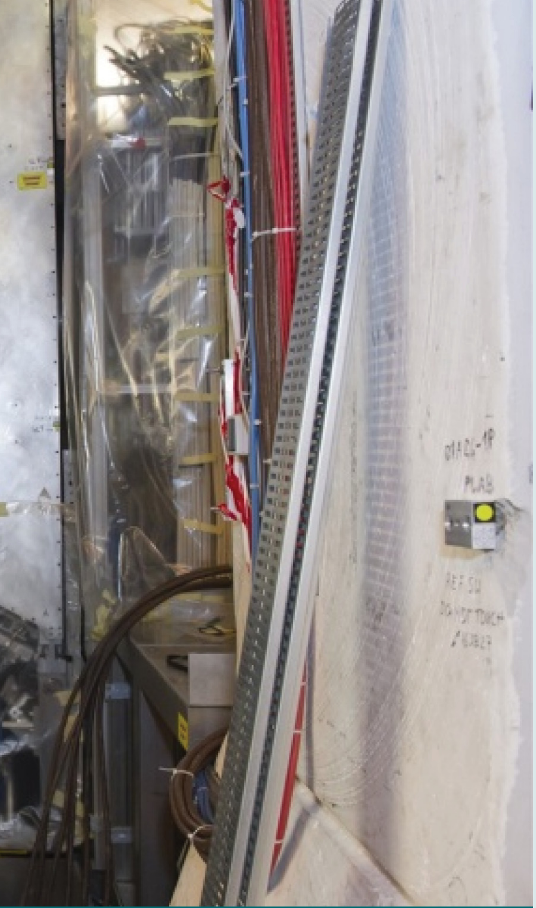
Flavour physics plays a crucial role in the search for new phenomena at the Large Hadron Collider (LHC). The two groups of basic building blocks of matter are the quarks and the leptons. Within each group there are six flavours of subatomic particle. There are six leptons: the electron, the muon, the tau, the electron-neutrino, the muon-neutrino, and the tau-neutrino. There are also six quarks known as up, down, charm, strange, top, and bottom. Flavour physics has made numerous key contributions to the understanding of their particle properties: the first evidence for the existence of the charm quark, the third generation of quarks and leptons, the high mass scale of the top quark and matter-antimatter asymmetries through the discovery of CP violation, meaning the violation of the combination of discrete symmetries, charge-conjugation (C) and parity (P).

The nature of flavour physics is such that it provides access to an energy regime well beyond the LHC energy frontier and therefore offers enormous potential for providing the first evidence for new physics that may hold the key to open scientific questions such as:

- Why are there three generations of quarks and leptons?
- What determines the hierarchy of quark masses?
- What is the origin of CP violation?

Furthermore, two of the very few observations that cannot be accommodated by the Standard Model of particle physics, namely the baryon-antibaryon asymmetry of the Universe and the non-zero neutrino mass, are intimately related to flavour physics.

LHCb is **the** flavour physics experiment at the LHC. It is designed specifically to search for new phenomena in quantum loop processes and to provide a deeper understanding of matter-antimatter asymmetries at the most fundamental level. It does this by studying the decays of hadrons containing bottom or charm (*b* or *c*) quarks. The experiment is configured as a forward single-arm spectrometer with excellent tracking provided by a high precision silicon detector, excellent particle identification provided by two Ring-Imaging Cherenkov (RICH) detectors, a calorimeter system, a muon system and a highly efficient trigger system. The Cambridge contributions to the experiment have involved providing all the RICH off-detector electronics, the RICH data-quality monitoring and the



RICH software, all of which are operating extremely well (Fig. 1).

The LHC has been running smoothly since March 2010 with a rapidly increasing integrated luminosity, which is directly related to the number of potentially interesting events. The first physics publications from the LHCb experiment are based on the proton-proton collision data taken in 2010 and correspond to an integrated luminosity of about 38 inverse pico-barns, corresponding to 10^{10} $b\bar{b}$ pairs (Fig. 2.); the experiment expects to collect more than 30 times these numbers by the end of 2011. In such a short time, the physics results now pouring out of LHCb have already surpassed many of those published by the Tevatron experiments at Fermilab.

What has LHCb achieved so far? With the *pp* collision run in 2010, the LHCb collaboration only expected to understand the operation and calibration of the detector. These expectations have however been far exceeded. The experiment and all its detector components are performing beautifully; the momentum scale is known to 1 part in 10^4, providing mass resolutions of 6-10 MeV/c^2 and the world's best *B* hadron mass measurements, and the resolution of the tracking system provides a proper-time resolution of ~50 fs resulting in some high precision *B* lifetime measurements.

It is only natural that some of the early physics measurements at the LHCb experiment are studies of the production of *b* and *c*-quarks, the fractions of the different *B* species and the search for new *B* decays, especially in the little chartered territory of the B_s^0 (B^0) system. Already with the little data accumulated in 2010, it has been possible to make precision measurements in all these topics and to discover new decay channels, which will be very important for the future study of CP violation.

LHCb expects to provide a solid benchmark for the Standard Model picture of quark flavor interactions against which new physics can be judged by the end of 2012. Indeed, a measurement of CP violation in the B^0 system using $B^0 \to K\pi$ decays has already been made (Fig. 3). The measurement of CP-violation in the $B^0 - \overline{B^0}$ system is extremely important, as any significant enhancement in the CP-violating phase above the small value predicted by the Standard Model would be a clear sign of new physics. Critical to the measurement is the ability to resolve the very fast $B_s^0 - \overline{B_s^0}$ quantum-mechanical oscillations; LHCb has demonstrated this spectacularly by producing a world's best measurement of the B_s^0 oscillation parameter. LHCb has also put together all the elements of the non-trivial extraction of the CP-phase in $B_s^0 \to J/\psi\,\phi$ decays in order to produce a preliminary study of CP-violation in the B_s^0 system.

Although it is not yet possible to extract a value of the CP-phase, the results show that by the end of 2011, LHCb will have the sensitivity to measure the CP-phase with sufficient accuracy to shed light on any new physics contributions.

Finally, the search for very rare $B_s^0 \to \mu^+\mu^-$ decay modes is of paramount importance in flavour physics. In particular, the branching ratio for the decay mode $B_s^0 \to \mu^+\mu^-$ is predicted with good precision in the Standard Model, but large enhancements are possible in many variants of SuperSymmetry and alternative new physics models. As such, the search for this decay mode represents one of the most promising ways of discovering new physics at the LHC. LHCb has recently published the results of the search for this decay based on the data collected in 2010. No signal is yet observed, and an upper limit is placed on the branching ratio of 5.6×10^{-8} at the 95% confidence level. With the data foreseen in 2011-2012 it will be possible to improve the sensitivity such that LHCb will have the potential to discover new physics beyond the Standard Model or to severely constrain viable physics scenarios.

LHCb is now at the forefront of a new era of discoveries and precision measurements in flavor physics. It is a privilege to be part of the exciting times ahead!

Val Gibson

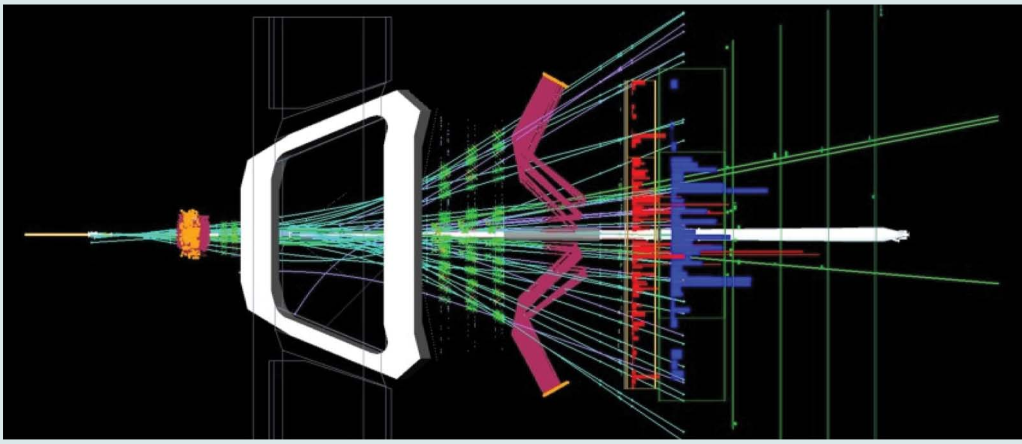


Fig 2: One of the first proton-proton collisions recorded by the LHCb experiment.

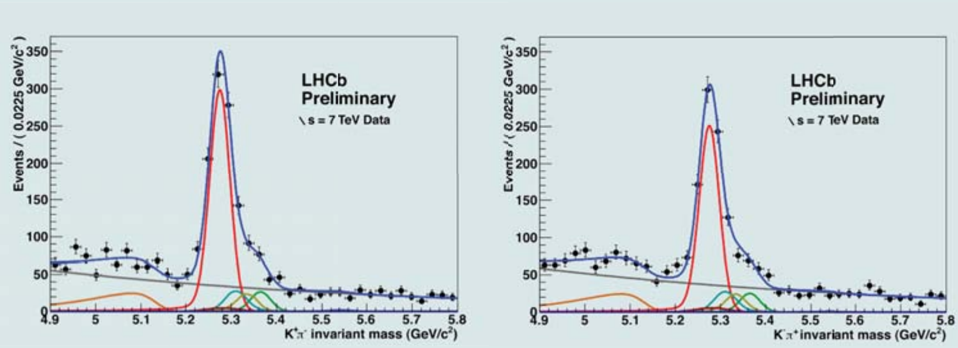


Fig 3: $B^0 \to K\pi$ events selected in the 2010 data (left $K^+\pi^-$ and right $K^-\pi^+$). The fitted signal component is the dominant red curve. The difference in yields between $K^+\pi^-$ and $K^-\pi^+$ is driven by CP-violation.

The Changing Roles of the Assistant Staff

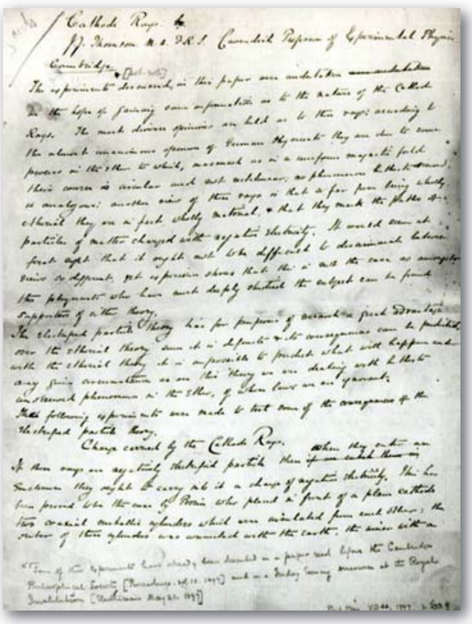
One of the more curious features of the recent history of the Cavendish is that, whilst the number of research staff has grown dramatically over the past few decades, the number of assistant support staff has remained relatively constant at just over 100. But, if numbers have stayed constant, the roles certainly have not.

In a recent edition of *CavMag*, the refurbishment of the mechanical workshops was described. The role of the technicians has evolved considerably as existing, and still very valuable, skill sets have been expanded to embrace the new technologies of computer aided design and computer numerical control. Currently, the Department is investing considerable time and effort into developing a relationship with the software manufacturer Autodesk, to train the next generation of technicians and scientists in industry-standard design tools. Today's mechanical workshop technicians are as likely to be found at a computer screen as at a manual lathe.

The Research Group structure in the Laboratory was introduced by Bragg shortly after the Second World War, with the intention of keeping research teams small and communication lines short. The vision was to have each group with its own assistants acting quasi-autonomously. Whilst in some respects this is still the case, the groups have grown considerably, the types of support required have changed and consequently the roles of assistants have changed also. The individual group workshops have been drawn together, to allow much better use of modern equipment and skill sets. Whilst some support roles have reduced in demand, for example our last glassblower Dick Smith retired several years ago, others have increased. As with many organisations, health and safety consumes significant resources and we now employ a fleet of computer officers. Accountability to the central University bodies and beyond has increased and so inspection and audit are far more regular occurrences.

It is suggested that the first Cavendish Financial Accounts were held personally by J J Thomson in the form of a bank book. He also held the cheque book, which was used to pay some of the staff. Regulation and due process apart, no Head of Department today would appreciate this hands-on approach. The Head of Department is now able to delegate the financial operation to an efficient Accounts section, a Stores team and the Research Group Secretaries and Administrators, under the supervision of the Academic Secretary. Again, these roles have been transformed as one computer system after another has been introduced, requiring a much more professional approach to management accounts and matched inevitably by further regulation. Purchasing large equipment is now a very considerable enterprise, involving the central University Finance team, among others.

In addition to these changes, the roles the secretaries play in the running of the Laboratory have changed dramatically. Originally secretaries worked almost entirely for the head of group, typing up papers and all letters and documents produced in longhand.



Nowadays everyone uses a computer and so there is very little need for the secretary to act as a 'private secretary', typing up documents for others. The secretary now has very significant administrative responsibilities, often having to make decisions in the absence of senior members of staff.

As in all walks of life, one of the major differences is in the use of computers and e-mail, which nowadays occupy a very major part of the Group Administrators' role. These were intended to make life easier and use less paper, but in practice the opposite has proved to be the case. Secretaries' desks are now covered with more and more paper and the pressure for instant replies and the dubious benefits of working right to up to deadlines, with e-mails flying to and fro, have made life much more stressful for the group administrators. What is worse is that they can no longer leave their work at work, as many have computers at home and access e-mail from wherever they are in the world.

The monitoring of finances is a big responsibility for the Group Administrators, keeping track of expenditure on grants and other delegated departmental funds. Decisions need to be made about where to allocate expenditure. All financial work will undoubtedly become more and more vital as finances tighten. The pressure of space in the Department is an ever present problem and it is often down to the Group Administrator to sort out who has which office and to ensure the appropriate academic hierarchy is maintained.

In the area of Human Resources, it was once a simple task of placing an advert and making an appointment, but there are now many hoops to jump through and tightened regulations. The Department, through its Group Administrators, has to attempt to ensure that academics follow the regulations, but given the nature of the academic mind this is a highly non-trivial task.

Whilst recognising the changing roles of the assistant staff, it has to be recorded that they have responded magnificently to these new challenges. They are absolutely indispensible for the success of the research and teaching programme of the Laboratory. As the research context develops, the roles of support staff will undoubtedly evolve further. The goal remains remarkably similar to Bragg's ideal of expert support as close as possible to the frontline of research.

David Peet and Tracey Ingham

Top: Photograph of members of the Assistant Staff in 2010.

Bottom: J.J. Thomson's hand-written draft of the paper on the discovery of the electron written in 1897.

Athene Donald engages with the *Howthelightgetsin* Philosophy and Music Festival

This year I attended the Hay Festival for the first time, not the famous literary one but the more recent ***Howthelightgetsin* Philosophy and Music Festival** running simultaneously. I was invited to take part in a debate on 'human enhancement' and, having agreed to that the organisers threw in a second debate and an invited talk for good measure. Why, you may ask, did I as a physicist get invited to such a meeting and to such a debate? And why did I accept? The answer to the first question to some extent lies in a press release from 2009. In this my work on cell-substrate interactions was 'spun' as relevant to hip replacements: true, but there is a huge gulf between what we do and actual improvements in technology or protocols. Furthermore, our work on protein aggregation, which is relevant to the pathology of Alzheimer's disease, was translated by the *Guardian* into 'revolutionary treatments of Alzheimer's', a statement which is simply quite wrong. Nevertheless, despite these inaccuracies, when issued with what might be seen as the challenge of participating, I decided to accept on the grounds that as a professional scientist I have a duty to engage with non-scientists. I believe it is important both to talk about my work and to demonstrate that scientists are articulate, thoughtful people, not merely geeks who cannot string a sentence together.

What did I learn from the experience? My debating panel consisted of bioethicist and philosopher John Harris from Manchester, who has written a provocative book called *Enhancing Evolution* with which, after I had done my homework of reading it in advance, I profoundly disagreed; Aubrey de Grey, ex-Cambridge biologist but now working for a private enterprise exploring increasing longevity of life; and Mary Warnock, one-time Mistress of Girton and an extremely eminent philosopher – whose 'side', I am pleased to say, I was on. What I learnt is that it is actually extremely difficult to put any serious science into a debate like this. Attempts to discuss the Singularity, the limits of Moore's Law or even brain plasticity and the developments of synapses at different stages of what might, if my opponents had their way, be a very long life, really provoked little reaction. I felt as if the other side simply felt enhancement equates to better, so we don't need to discuss what 'better' means or how it might be achieved. I found this a very frustrating position. I might have believed that I was missing some fundamental philosophical point if Mary Warnock hadn't been so much in agreement with me. I ended up, at the end of the hour's debate, rather irritated. I had survived the experience, but I wasn't sure I had managed to achieve the goals I set myself. Of course I cannot tell how the audience themselves reacted, and whether they were pleased or impressed that an academic physicist had come out of her 'ivory tower' to meet them on their own ground.

The second debate I'm afraid was worse. I was lured into a debate on Western versus alternative medicine on the strict understanding this would **not** be a debate about homeopathy. During my period as Director of our Physics of Medicine initiative I attended a meeting about Chinese traditional medicine and explored a little of the Korean literature on acupuncture. These might have been interesting topics for debate. Unfortunately, we barely got off the topic of homeopathy and the placebo effect, which has been carefully researched by my fellow panel member Dylan Evans, the author of a book on the topic. Again, I made an attempt to introduce science into the debate. For example, I made the rather obvious point that, if you dilute solutions to the point where there are none of the active molecules still present in the vial you give a patient, their activity is necessarily zero because there's nothing there. These arguments were simply ignored as the two homeopathic supporters/practitioners just reiterated their mantra that homeopathy makes patients feel better – which is why the placebo effect is so relevant.

I was at least in full control over my invited talk. This was on the subject of unconscious bias - why are girls often subtly deterred from doing science at every step from birth, why is the pipeline in a subject like physics so particularly leaky once girls enter university and attempt to progress through the academic ranks? These are subjects close to my heart in my role as the Director of Women in Science, Engineering and Technology Initiative (WiSETI) in the University. I felt that the message was heard and well received by the men and women alike in my audience. The video of my lecture can be viewed at **www.iai.tv/video/saving-science**.

Would I go again? I'm not sure, is the honest answer. I'd certainly want to be more convinced that the topic of any debate gave me a better opportunity to speak as a scientist. On the other hand, I am sure that scientists should turn up more regularly at generalist activities and demonstrate what we have to offer. So perhaps it would be self-defeating to turn down a similar invitation should I be asked again.

Athene Donald

Outreach to Students, Young People and School Teachers

By the time you are reading this report, a number of our Outreach events will have taken place, but we also include upcoming events that will be of wide interest and for which early booking is recommended.

School Workshops – Physics of the 3D Illusion

On the 30th and 31st March, 120 students, aged 14 to 16, visited the Cavendish for an afternoon of talks and practical workshops that featured the physics behind 3D movies and current research here at the Cavendish Laboratory. The practical element of the workshop was developed by Dr Eileen Nugent of the Biological and Soft Systems Group at the Cavendish and sponsored by the Institute of Physics. The resources from this and all other workshops are available on our website.

A second workshop on this topic is scheduled on the **8th and 9th December 2011 for 11 to 13 year olds**. The practical workshop of Dr Nugent will still form the central element but the introduction and additional sessions will be changed appropriately for younger students. Places are still available for the **9th December** and bookings can be made online from the school workshop section of our outreach page.

Cavendish Physics Teachers Residential Workshop - Pilot Programme

From the 2nd to 4th July 2011, 20 A-level physics teachers from across the United Kingdom will visit Cambridge for a residential workshop kindly hosted by Churchill College and sponsored by the Ogden Trust. This course is being piloted for the following reasons:

- We are aware that there are many talented students who are unable to attend the Senior Physics Challenge (SPC) as we just do not have the spaces to host them (see below). This is an opportunity to enable teachers to take the SPC back to school and into the classroom by providing attending teachers with all the necessary resources and background materials.
- The teachers will gain first-hand experience of the Cambridge collegiate system and the home of physics research in Cambridge. The programme will include a session on Cambridge admissions from directors of studies in physics and admissions interviewers.
- We are keen to discuss ideas and concepts with teachers to understand better students' conceptual difficulties and to bridge the gap between A-level and university physics.
- We aim to provide access to an inspirational environment in which physics and physics education can be discussed with like-minded teachers with time out from school to refresh, think in alternative ways and experiment.
- The teachers will also observe the Senior Physics Challenge students in action and to see how they respond to the material and environment.

This residential course is a pilot in 2011 and we hope that, if successful, we will be able to increase the number of places available in future years.

Senior Physics Challenge

This annual event ran from the 3rd July until the 7th July 2011 during which the students attended lectures on kinematics and special relativity, and practical laboratory classes on dynamics and optics. Time was also given for students to attend admissions talks and generally discuss physics and socialise with like minded students of a similar age. From over 300 applications of the highest calibre Y12 (AS-level) students, co-director Anson Cheung and I selected 66 students, from all over the United Kingdom.

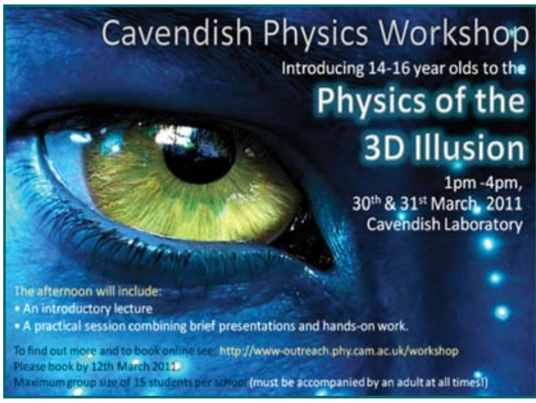
Each year participants are kindly hosted to dinner and accommodated by a number of Cambridge colleges - in 2011 these include Churchill, Corpus Christi, Fitzwilliam, Newnham, Pembroke, Queens', and Trinity.

Student application is initiated by teacher recommendation and, whilst selection for 2011 is complete, **any interested teacher may register online to receive updates and notification of the next application round.** To find out more please see our website.

Undergraduate Open Days

From 2:30pm on the 7th and 8th July 2011 the Cavendish Laboratory opened its doors to the next wave of potential undergraduates. These open afternoons are designed to coincide with the Cambridge University central admissions open days but are stand alone activities to which any year twelve (AS-level or equivalent) students and their families are invited to attend.

One of the aims is to introduce potential students to the variety of experiments that they will undertake as physics



undergraduates, and to provide them with an opportunity to speak with graduate demonstrators and supervisors. To provide insight into the undergraduate experience, Julia Riley will give an example first year lecture on special relativity and as an experienced admissions tutor will follow this lecture with an opportunity for parents and students to ask any admissions questions that they might have regarding entry to study Natural Sciences here in Cambridge. One further session will be on offer to any interested visitors in the form of a museum tour and talk about the history of the ground breaking physics performed at the Cavendish Laboratory. There is no need to register or book for these open afternoons but further information can be found on our website.

Physics at Work 2011 – Bookings now open

Bookings for the 27th annual *Physics at Work* exhibition are now open to schools – and spaces are filling fast! This unique exhibition runs for three days, this year **from 20th until 22nd September**, with two sessions each day (morning sessions begin at 9am and afternoon sessions at 1pm). During each half day session school groups will see six different exhibits selected by the organisers to include 25 internal and industrial exhibitors and to show the many varied ways in which physics is used in the real world.

The exhibition is targeted at 14–16 year olds with some schools bringing their *gifted and talented* year 9 students and others bringing year 12 students who are considering potential careers in physics. Schools are welcome to bring as many students as they are able, provided the student to teacher ratio is about 15 to 1.

Approximately 400 FREE places are available for each half day session and schools travel from all over London and the South East to attend this event. Any teachers interested in attending the 2011 exhibition should book online on our website as soon as possible to avoid disappointment. More details are on the Cavendish Outreach Website: **www-outreach.phy.cam.ac.uk**

More general residential and outreach initiatives are coordinated by the Cambridge Admissions Office in conjunction with the University departments and further information can be found on their website: **www.cam.ac.uk/admissions/undergraduate/events**

Lisa Jardine-Wright

Calling all Alumni

One of the pleasures of editing CavMag is that every so often I receive messages from alumni bringing us up to date about their career progression, as well as the honours and awards they have received. Either that or I receive information from colleagues about the achievements of alumni. Let me give two recent examples.

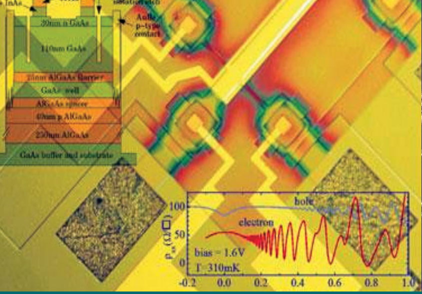
I was delighted to learn from ***Nigel Goldenfeld*** *(above)*, at the University of Illinois at Urbana-Champaign that he was elected to the US National Academy of Sciences, and also to the American Academy of Arts and Sciences in 2010. He writes, `I was in the (first, I think) class you taught that became the basis for your book *Theoretical Concepts in Physics*. It was wonderful!' Your editor is not wishing to use this column to advertise his books, but he greatly appreciates the memory of the exciting days when the course was developed and which continues to thrive under different proprietors. Many congratulations to Nigel on this very significant distinction.

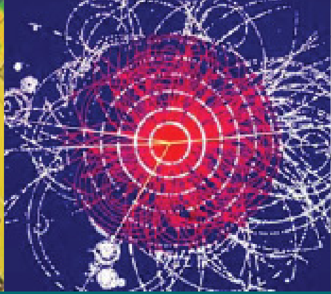
The other case is that of ***John Fulljames*** *(bottom)* who has just been appointed Associate Director of Opera at Covent Garden working with the Director of Opera Kasper Holten and Music Director of the Royal Opera, Antonio Pappano. John read physics in the Cavendish and was at the same time a Choral Scholar at St. John's. John was desperate to carry out a final year project related to acoustics and the best that Alan Walton could do was to develop a project about the physics of the sounds water makes when it is heated in a kettle from room temperature to its boiling point. John's dissertation was an outstanding piece of work and he won the Part III Prize for an Experimental project. We offer John our heartiest congratulations on this wonderful appointment at the Royal Opera.

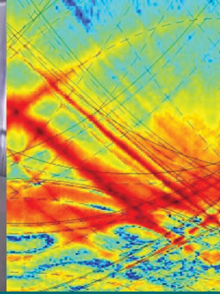
These are wonderful achievements, and I am certain there are many more among the careers of our alumni, which we will be delighted to hear about. We cannot guarantee that all respondents can be included and of course your editor's decision is final. In the last edition we reported on the wide diversity of occupations that Cavendish physicists take up and this is very important in supporting our case that a degree in Physics from Cambridge is excellent preparation for a very widely range of subsequent careers. So, this is an open invitation – ***let us know about your achievements and distinctions*** whether they are in science or all the other disciplines in which you have made your mark.

Malcolm Longair

Below: Claire Booth and John Fulljames rehearse Into the Little Hill (2009) © Gemma Mount








Warmest congratulations to **Michael Hobson** *(top left)* and **Michael Köhl** *(top right)* on their promotions to Personal Chairs.

Likewise, we are delighted that **Crispin Barnes** *(middle left)* and **Mete Atature** *(middle right)* have been promoted to Readerships.

Many congratulations to **Jeremy Baumberg** *(bottom left)* on his election to the Royal Society.

We welcome the following new appointments to the Assistant Staff:

Emily Heavens, Group Administrator in Microelectronics

Rob Smith, Central Departmental Administration

Celia Jones , Group Administrator, Nanotechnology Doctoral Training Centre

Anthony Barnett Technician in the area of Optoelectronics/Nanophotonics.

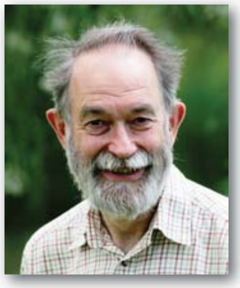
Many congratulations to **Athene Donald** for her recognition by the *Sunday Telegraph* as one of the hundred most powerful women in Britain and by the *Guardian* as one of the world's 100 most inspiring women. She was also winner of the Lifetime Achievement Award, among seven women at the forefront of science, engineering and technology who were honoured by the the *Royal Academy of Engineering*.

Nalin Patel has been appointed Manager of the Winton Programme for the Physics of Sustainability. Nalin, who obtained his doctorate in Semiconductor Physics Group, previously worked with CDT and Toshiba Europe. He will take up his post on 1 August 2011.

Congratulations of **David Ward** *(bottom right)* on being awarded a Pilkington Teaching Prize for excellence in Teaching.





If you would like to discuss how you might contribute to the Cavendish's Development Programme, please contact either Professor Malcolm Longair (msl1000@cam.ac.uk) or Professor James Stirling (HoD@phy.cam.ac.uk), who will be very pleased to talk to you confidentially. Further information about how donations may be made to the Cavendish's Development Programme can be found at:
www.phy.cam.ac.uk/development

Contacts

The Cavendish Laboratory
JJ Thomson Avenue
Cambridge
CB3 0HE

Tel: +44(0) 1223 337200
Fax: +44(0) 1223 363263
E-mail: hod@phy.cam.ac.uk
www.phy.cam.ac.uk

Head of Department
Professor James Stirling
Tel: 01223 337429
E-mail: hod@phy.cam.ac.uk

Director of Development
Professor Malcolm Longair
Tel: 01223 765953
Email: msl1000@cam.ac.uk