A MILLION IMAGES AND MORE
Digital cultural heritage preservation in the Middle East

PHYSICS WITH A MILLION EYES
Citizen science at the LHC and far beyond

PHYSICS ILLUMINATES BIOLOGY
One molecule at a time

ALUMNI STORIES
Terry Cooper and Georgina Gould reflect on their experiences

EVENTS
Inaugural Meeting of the Moseley Society, Brebis Bleaney celebration and many more

PEOPLE
Five minutes with Merritt Moore; Comings, Goings and Awards

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DEPARTMENT OF PHYSICS
NEWSLETTER

UNIVERSITY OF OXFORD
THE LHC RETURNS
THE SEARCH FOR NEW PHYSICS INTENSIFIES

CROSSING THE DISCOVERY THRESHOLD

After two years of repairs and upgrades the Large Hadron Collider at CERN resumed operation on 5 April and, shortly after, produced the first collisions of its counter-rotating beams at the new world record energy of 13 TeV - 60% higher than in 2012. This success takes us over an exciting threshold in particle physics: the higher energy opens the door to new discoveries that were impossible previously.

Oxford particle physics plays a strong role in two of the LHC experiments: ATLAS and LHCb. Fourteen academics are supported by a team of postdoctoral fellows, postgraduate students and world-leading engineering, technical, and computing teams. Their broad involvement includes pivotal roles in the detector's design, construction and operation as well as the software development, data analysis and management. Notably, the spokesperson for the 800-member LHCb collaboration is Oxford’s Guy Wilkinson.

Located 3.4km apart around the LHC tunnel, ATLAS and LHCb are tasked with observing and identifying each and every 25 ns the showers of particles produced by the colliding beams of protons. In 2012, the ATLAS and CMS experiments identified a few hundred collisions containing a Higgs boson, the particle responsible for the masses of fundamental particles. This discovery completed the Standard Model of particle physics (SM) and justified the 2013 Nobel award to Higgs and Englert.

ENIGMATIC HIGGS Boson

Once discovered, the Higgs boson created a mystery: how can it exist at such low mass? The simplest answer lies in the prevailing assumption of supersymmetry. In ‘SUSY’, every known fundamental fermion or boson has an, as yet unseen, superpartner that is a boson or fermion, respectively. These superpartners provide a balancing act: nature allowing known particles, like the Higgs, to exist at their observed mass and spin without destabilising the universe. Additionally, and excitingly, SUSY naturally predicts a particle that could be the dark matter in the universe.

Supersymmetry is an elegant construction – but is nature really supersymmetric? Prior to the LHC startup (2009) the consensus was that a particularly simple and powerful version of SUSY, called the Minimal Supersymmetric Standard Model (MSSM), was the most likely extension of the Standard Model. Many believers expected to find MSSM superpartners long before the Higgs. That’s not how it turned out.

But great theories do not give up so easily. SUSY is not a single theory but a framework upon which variants can be formulated. Perhaps the superpartners are heavier than expected, or the processes by which they are produced and disintegrate are rarer, or maybe harder to see. Thanks to the boost in energy, the hunt for SUSY has become easier: the higher the collision energy, the greater the frequency that high-mass particles are created; the higher the luminosity, the higher the likelihood that important rare processes will occur.

SEARCHING FOR SUSY WITH QUANTUM LOOPS

Forty-five degrees around the LHC circumference from ATLAS lies LHCb, the premier experiment studying the beauty quark. Instead of searching for the direct production of new particles at high energies, LHCb makes extremely precise measurements of ‘beauty hadrons’, atom-like bound states of a beauty quark with one or more lighter quarks. Beauty hadrons are of great interest because their behaviour is precisely calculable within the SM, yet can be indirectly affected by SUSY. Indirect effects come from the uncertainty principle which allows particles to flicker in and out of existence in ‘quantum loops’. The calculation of many beauty hadron decays depends on loop processes, so deviations from exact SM expectation is the key signature that SUSY could be formulated. Perhaps the superpartners are heavier than expected, or the processes by which they are produced and disintegrate are rarer.

Direct effects come from the uncertainty principle which allows particles to flicker in and out of existence in ‘quantum loops’. The calculation of many beauty hadron decays depends on loop processes, so deviations from exact SM expectation is the key signature that SUSY could be formulated. Perhaps the superpartners are heavier than expected, or the processes by which they are produced and disintegrate are rarer.

Oxford LHCb and ATLAS academics along with their cadre of postdocs and graduate students are, once more, fully engaged in studying the data generated by the high-energy collisions. They join 7,000 scientists from more than 40 countries in this important work. The discovery of Supersymmetry, or some other new physics, perhaps completely unanticipated, could be just months away.

Images clockwise from bottom left: LHCb physicists patiently await the first 13 TeV collisions. Many ex-Oxford personnel are present including the pilot, Mat Charles. All proceeds under the watchful eye of Guy Wilkinson (seated, rear).

A simulated event containing the debris from the evaporation of a microscopic black hole superimposed over a classic image of the ATLAS detector. A computer rendering of one of the first 13 TeV collisions at LHCb. The orange tracks, produced by the proton-proton collisions, stream through the detector, lighting up the tracking system before hitting the calorimeter blocks.

First collisions in the ATLAS control room. Oxford DPhil students Will Kalderon and Will Fawcett are seated second and third from the right.
A NEW ERA IN LIGHT MICROSCOPY

New instruments and methods that help us to visualise microscopic worlds have often marked revolutionary advances in our understanding of life and nature. From the discovery of ‘cells’ and ‘animalcules’ by Robert Hooke and Antony van Leeuwenhoek by means of the first light microscopes, to the fascinating protein structures elucidated by X-ray crystallography, new methods have unlocked intriguing new domains, and helped to answer longstanding questions through direct observation. During the past few years, a new family of microscopy methods is promising once more to revolutionise biology and medicine. These methods, known as super-resolution fluorescence imaging, rely on ingenious molecular machines that control cargo movements.

The potential of these methods is promising once more to revolutionise biology and medicine. These methods, known as super-resolution methods, are based on the ability to detect single fluorescent molecules, and many of these methods rely on the work of Stefan Hell and W.E. Moerner, who introduced powerful methods for a long time: a consequence of the wave nature of light, diffraction limits optical resolution in light microscopy to ~250 nm in the focal plane and ~600 nm along the optical axis. A point-like object that emits light, e.g., a fluorescent dye with a size of ~1 nm, will generate a blurred image of much larger size, the point spread function (PSF), as a result, two emitters present within ~250 nm in the focal plane remain, as in the Rayleigh criterion, unresolved. This inability has always been a source of frustration for biophysicists and biologists, since the dimensions of most cellular molecular machines, information depositories and structural elements are much smaller, ranging from 2 nm (the diameter of a DNA strand) to ~100 nm for large machines that control cargo movements. How does localisation microscopy bypass the diffraction limit? The answer lies in the ability to localise a fluorescent molecule with a precision up to 100-fold better than the PSF width. To localise a single emitter with such precision (which depends mainly on the number of collected photons and the background noise), one can simply fit the PSF of a single emitter with a Gaussian function. Provided that sufficient photons are collected, single fluorescent dyes can be localised with ~1 nm precision—a technique used to visualise the ‘walking’ motion of motor proteins.

A major advantage of localisation microscopy is its ability to detect and track single molecules inside single living cells, as opposed to ‘fixed’ (ie dead) cells or using purified molecules and reconstituted machinery in vitro. This provides a means to record the dynamics of biological processes as they occur in real-time, including the conformational changes and intracellular diffusion of protein machines and other biomolecules.

SINGLE-MOLECULE IMAGING AND TRACKING

Diffraction has been a persistent obstacle for all lens-based optical microscopy for a long time: a consequence of the wave nature of light, diffraction limits optical resolution in light microscopy to ~250 nm in the focal plane and ~600 nm along the optical axis. A point-like object that emits light, e.g., a fluorescent dye with a size of ~1 nm, will generate a blurred image of much larger size, the point spread function (PSF), as a result, two emitters present within ~250 nm in the focal plane remain, as in the Rayleigh criterion, unresolved. This inability has always been a source of frustration for biophysicists and biologists, since the dimensions of most cellular molecular machines, information depositories and structural elements are much smaller, ranging from 2 nm (the diameter of a DNA strand) to ~100 nm for large machines that control cargo movements. How does localisation microscopy bypass the diffraction limit? The answer lies in the ability to localise a fluorescent molecule with a precision up to 100-fold better than the PSF width. To localise a single emitter with such precision (which depends mainly on the number of collected photons and the background noise), one can simply fit the PSF of a single emitter with a Gaussian function. Provided that sufficient photons are collected, single fluorescent dyes can be localised with ~1 nm precision—a technique used to visualise the ‘walking’ motion of motor proteins.

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Fig. 1. High-precision localisation of single molecules. Two-dimensional diffraction-limited images of single fluorescent molecules are blurred images that essentially match the point-spread function of the microscope (left and middle), which has a full width at half maximum of ~200–300 nm; this blurring feature limits the resolution of optical microscopy. However, the centre of the PSF can be determined with high precision (up to 1 nm) when the PSF is fitted with 2-D Gaussian function (right).

Consider the model bacterium Escherichia coli (800 nm in diameter) swimming in cells. We track the displacements of single protein molecules as a function of time, and construct spatial trajectories that capture the diffusion profile of these molecules. This way, we can identify molecules that are either immobile, moving through Brownian motion, or moving in a non-Brownian fashion (eg through confined or anomalous diffusion, as well as directed motion). These motion types are characterised by different functional states of the protein, and different diffusion coefficients, confinement areas, velocities of any direct motion, and the sizes of clusters or corralising areas. To generate an MSD plot, the MSDs of single trajectories are analysed for different time lags; for free diffusion, MSD scales linearly with lag time (MSD = 4Dt), with the slope providing a measurement of the diffusion coefficient D. Matters become more complicated when the molecular density in cells is high, since we cannot discern individual molecules any more due to the overlap of their PSFs. Consider the model bacterium Escherichia coli (800 nm in diameter and 2–8 μm in length); even 10 fluorescent molecules in a single cell create a crowded situation that makes tracking impossible. We overcome this limit by combining single-molecule tracking with photo-activation, a strategy central to many types of localisation microscopy. Since the number of tracks can be enormous (up to 10,000 per single cell), dense diffusion maps can be generated and used for characterising cellular microenvironments and molecular subpopulations even in a single cell.

Fig. 2. High-precision localisation of single molecules. Two-dimensional diffraction-limited images of single fluorescent molecules are blurred images that essentially match the point-spread function of the microscope (left and middle), which has a full width at half maximum of ~200–300 nm; this blurring feature limits the resolution of optical microscopy. However, the centre of the PSF can be determined with high precision (up to 1 nm) when the PSF is fitted with 2-D Gaussian function (right).

One powerful method we use to explore the mechanisms of gene expression and DNA repair is to study the motion of proteins using single-molecule tracking in cells. We track the displacements of single protein molecules as a function of time, and construct spatial trajectories that capture the diffusion profile of these molecules. This way, we can identify molecules that are either immobile, moving through Brownian motion, or moving in a non-Brownian fashion (eg through confined or anomalous diffusion, as well as directed motion). These motion types are characterised by different functional states of the protein, and different diffusion coefficients, confinement areas, velocities of any direct motion, and the sizes of clusters or corralising areas. To generate an MSD plot, the MSDs of single trajectories are analysed for different time lags; for free diffusion, MSD scales linearly with lag time (MSD = 4Dt), with the slope providing a measurement of the diffusion coefficient D. Matters become more complicated when the molecular density in cells is high, since we cannot discern individual molecules any more due to the overlap of their PSFs. Consider the model bacterium Escherichia coli (800 nm in diameter and 2–8 μm in length); even 10 fluorescent molecules in a single cell create a crowded situation that makes tracking impossible. We overcome this limit by combining single-molecule tracking with photo-activation, a strategy central to many types of localisation microscopy. Since the number of tracks can be enormous (up to 10,000 per single cell), dense diffusion maps can be generated and used for characterising cellular microenvironments and molecular subpopulations even in a single cell.

Fig. 3. The displacements of single protein molecules are tracked by single-molecule tracking. Excitation with 405 nm light turns on a single molecule of a photoactivatable version of the protein of interest in a single cell; the two-dimensional position of the molecule can then be tracked with high precision (up to 10 nm) until it bleaches, and its diffusion properties can be analysed using mean-square-displacement analysis. After repeating this activation-tracking-bleaching cycle several times, thousands of trajectories are available, allowing robust statistical analysis and identification of different diffusion species that are assigned to different functional states of the protein of interest.

Fig. 1. Single-molecule fluorescence imaging. The excitation path of a custom-built ultraradial cooling fluorescence microscope that uses three laser lines for the excitation of fluorescent groups introduced on DNA or protein molecules.

Fig. 2. High-precision localisation of single molecules. Two-dimensional diffraction-limited images of single fluorescent molecules are blurred images that essentially match the point-spread function of the microscope (left and middle), which has a full width at half maximum of ~200–300 nm; this blurring feature limits the resolution of optical microscopy. However, the centre of the PSF can be determined with high precision (up to 1 nm) when the PSF is fitted with 2-D Gaussian function (right).

Fig. 3. Photoactivated single-molecule tracking. Excitation with 405 nm light turns on a single molecule of a photoactivatable version of the protein of interest in a single cell; the two-dimensional position of the molecule can then be tracked with high precision (up to 10 nm) until it bleaches, and its diffusion properties can be analysed using mean-square-displacement analysis. After repeating this activation-tracking-bleaching cycle several times, thousands of trajectories are available, allowing robust statistical analysis and identification of different diffusion species that are assigned to different functional states of the protein of interest.
WHAT WE HAVE LEARNED

In our DNA-repair work, published in the journal PNAS in 2013 (Upholt et al., doi: 10.1073/pnas.1307592112), we studied the mechanisms of DNA polymerase, a protein machine that repairs DNA by copying it with remarkable ‘fidelity’, making only one error in 10^9 copying events. To study the function of DNA polymerase in live bacteria, we used tracking to identify molecules of DNA polymerase searching for damaged DNA sites, and molecules repairing DNA. Using custom-built software, we were able to mine our big data sets to find tracks displaying entire repair cycles, including the ‘diffusion-to-capture’ search process by which a DNA polymerase locates a damaged site, copies DNA during repair, and resumes its search.

We were also the first to measure the time for a reaction catalysed by a single protein in living cells, measuring repair times of 2.1 sec for DNA polymerase. This development complemented several in vitro studies that elucidated how the DNA polymerase binds DNA, distinguishes the correct ‘letter’ of DNA to be inserted in the growing DNA strand, and performs DNA synthesis; this is an important contribution, since in vitro studies, despite their exquisite level of control and high sensitivity, could only hint at the actual reaction kinetics in living cells. Our measurements also established a global view for key DNA-repair proteins that can be used by theoretical physicists and systems biologists to construct more reliable predictive theoretical models of DNA damage and repair in cells. Perhaps more importantly, our pioneering study offers a general toolbox that allows the study of intracellular diffusion of any protein, regardless of how many copies it has in a cell.

In more recent work, published on 29 July in PNAS (Stracy et al., doi: 10.1073/pnas.1507592112), we extended our tracking analysis to RNA polymerase; this is the main machine for gene transcription, which is the process that converts DNA information to RNA molecules (which serve both as ‘messengers’ and machines). Despite the fundamental importance of transcription, its spatial organisation within the nucleus (as the bacterial chromosome coated with specific proteins) and the effect of transcription on DNA organisation had remained a mystery. Our work showed that mobile RNA polymerases were homogeneously distributed across the bacterial nucleus, suggesting that all DNA is sampled through random non-specific interactions as the RNA polymerase searches for the start point of a gene.

Surprisingly, we also discovered that RNA polymerases that are actively transcribing DNA were heterogeneously distributed, with the densest RNA polymerase clusters located preferentially at the nucleoid periphery, where the density of DNA is lowest; this finding strongly suggested that highly transcribed genes locate to the nucleoid surface. This striking finding was consistent with entropy acting as a general force that, along with transcription, orchestrates the organisation of the bacterial DNA and the processes operating on it. This confirms the predictions of statistical models of a ‘phase separation’ between RNA polymerases and DNA based on simple entropic considerations for the DNA polymerase (that tries to maximise its conformational entropy) and the large particles associated with it (which try to maximise their translational entropy). Our results will no doubt fuel further theoretical modelling of transcription as it occurs in vivo.

WHAT’S NEXT?

The field of in vivo single-molecule imaging is still very young, with ample room for further method development and with many discoveries awaiting. We are currently working towards measuring distances in and between transcription factors and DNA-protein machines as they function in real time. These capabilities may soon allow us to generate structures of such machines using intramolecular distance restraints obtained in vivo. Such developments, along with the miniaturisation and automation of our single-molecule fluorescence microscopes (through the ERC-funded project NANOIMAGER), make us hopeful that the ‘diffusion-to-capture’ search process by which a DNA polymerase locates a damaged site, copies DNA during repair, and resumes its search.

Dr Alexy Karenowska, the Institute’s Director of Physics, is responsible for coordinating image collection, processing, and the development of the online database. She also played a key role in the development of the low-cost imaging device that lies at the heart of the project. Working in partnership with large multi-national organisations like UNESCO and hundreds of smaller local entities, the aim is to create a permanent record of the monuments and architecture of these important sites. Moreover, the use of 3-D technology will allow the IDA, in collaboration and consultation with local partners, to consider replacing destroyed buildings and objects.
Since the launch of the Large Hadron Collider (LHC) in 2008, the detection of the Higgs boson has been one of its primary goals. The LHC is a particle accelerator that collides protons at extremely high energies to produce new particles. The Higgs boson, which is a particle responsible for giving other particles their masses, was discovered in 2012 at CERN, the European Organization for Nuclear Research, where the LHC is located.

The Higgs boson is a particle that is predicted by the Standard Model of particle physics, the most successful theory in particle physics. It is predicted to be a massive particle, and its discovery would confirm the existence of the Higgs field, which is thought to be responsible for giving particles their masses.

The discovery of the Higgs boson was a significant milestone in the history of particle physics, and it has led to a number of new experiments and collaborations. The LHC is now being used to search for other particles predicted by the Standard Model, such as the Z-boson and the top quark, which are both predicted to decay into the Higgs boson.

The LHC is capable of producing collisions at energies of up to 7 teraelectronvolts (TeV), which is equivalent to the energy of a proton at a speed of 99.9% the speed of light. These high-energy collisions are used to search for new particles that are not predicted by the Standard Model, such as supersymmetric particles, which are predicted by some extensions of the Standard Model.

The LHC is a collaborative project, and it is supported by a number of countries and international organizations, including the European Union, the United States, and Japan. The LHC is currently the largest and most powerful particle accelerator in the world, and it is expected to remain so for many years to come.
IT HAS BEGUN!
In previous columns I have reported on incremental progress towards starting the Beecroft Building. This time I can tell you that the car park has disappeared, the view from the Clarendon Laboratory staircase windows is now dominated by a building site, and that the first major infrastructure development for the Physics Department in over half a century is under way. The process began with the archaeological survey, which revealed the expected English Civil War defence trenches, whose existence and location is described in various contemporary documents, and a possible Roman boundary ditch. Fortunately nothing more startling has been unearthed, so these features were photographed and documented before work continued. You can find the archaeologist’s report, and other project updates including a time-lapse video, at www.physics.ox.ac.uk/beecroft-building. Following on from the archaeology, the construction works to date have centred around the diversion of all the services on from the archaeology, the construction works to date were photographed and documented before work started. To me this marks the centenary of Moseley’s tragic death in the Great War – a death that cut short not only the career of one of Oxford’s most brilliant physicists at the young age of 27, but also the life of a unique and very special individual. Moseley was not only a scientist of extraordinary abilities, but also a man of great personal qualities. He was a gifted and fast-working experimentalist, who was devoted to excellence in educating the next generation of physicists, and the prize cannot be awarded posthumously. Whatever answer to that question one may wish to provide, there is no doubt that within his all-too-brief scientific career the insight that such private donations play in maintaining Oxford’s excellence in Physics.

HENRY MOSELEY
The summer saw the hundredth anniversary of Moseley’s death on 10 August 1915 at Gallipoli, and the Oxford Museum of the History of Science held ‘Dear Harry’ – a special exhibition about his life and work – to which the department was able to contribute his plot of X-ray energy against atomic number, which is usually displayed in the Martin Wood lecture theatre. The exhibition proved so popular that it had to be extended and in May it was also the focus of the inaugural meeting of the Henry Moseley Society (see page 11). Henry Moseley’s short scientific career was informal and opportunistic by today’s standards: having completed an undergraduate degree, someone of his initiative and insight ‘just got on with it’! By contrast, today’s aspiring scientists have to work through a three or four year graduate programme to achieve a doctorate, and typically one or two postdoctoral positions before being in a position to lead their own independent research programme. Each year about 90 young people with outstanding undergraduate records join us from all over the world to study for a DPhil. We aim to admit the very best on the basis of their undergraduate records and the same!) and to learn more about the varied and fascinating paths that lead to undergraduate, master’s and PhD graduation. The reception took place in Trinity’s Danson Room, that looks out over the College’s famous lawns, and just a few yards from the former site of the Trinity/Balliol laboratories, where Moseley carried out experiments as an undergraduate. Head of Department, Professor John Wheater, welcomed members to the event and gave a short update of the status of Clarendon II, and re-stated the department’s gratitude for the generosity of our alumni and the pivotal role that such private donations play in maintaining Oxford’s excellence in Physics.

Oxford Physics has set up the ‘Henry Moseley Society’ to recognise and thank those of our alumni who have pledged donations over and above the £1k level to the department, thereby contributing to the funds needed for the new Clarendon II building. The inaugural meeting of the Society took place on the evening of 19 May with a private showing of the exhibition ‘Dear Harry... Henry Moseley: A Scientist Lost to War’, on display at the Museum of the History of Science in Oxford, followed by a reception and dinner just across The Broad at Moseley’s college: Trinity.

As readers will know from previous editions of this newsletter, this year marks the centenary of Moseley’s tragic death in the Great War – a death that cut short the career of one of Oxford’s most brilliant physicists at the young age of 27, by which time ‘Harry’ (as he was affectionately known by his family), had within a few short months put the ordering of the elements in the periodic table on a firm scientific footing by linking the characteristic frequency of their X-ray line emission to atomic number. By the time you read this, the Oxford Physics Department will have raised about £13.6m of external funding for the laboratory has become very congested so for the time being he had to deal with his mother and surviving sister. One left the museum touched by Moseley’s evident affection for his family, and a realisation that one had been given a privileged glimpse into the private life of one of the past century’s most gifted and fast-working experimentalists.

Four Missing Elements
The Henry Moseley Society now numbers more than 80 alumni and friends, of whom 50 – spanning more than four decades in date of matriculation – attended its first formal event. The curators of the museum divided us into four groups (labeling us after the four elements that Moseley noted above: English Civil War defence trenches and possible Roman boundary ditch found while digging for the new Beecroft Building.

For information on how to join, please see the departmental website (https://www2.physics.ox.ac.uk/alumni) and/or contact the alumni relations officer, Valeria Crowder: alumni@physics.ox.ac.uk.

BUILDING THE FUTURE
The motto of the Henry Moseley Society is ‘Honouring the past, building the future’. It is particularly fitting in this centenary year of his death in Gallipoli that we remember both Henry Moseley’s service to science, and his service to his country. What Moseley might have gone on to achieve had he not been killed by a sniper’s bullet in Gallipoli a century ago is impossible to tell. Many prominent scientists have speculated that he might have gone on to win the Nobel prize in 1916 (it was not awarded that year because of the war, and the prize cannot be awarded posthumously). Whether answer to that question one may wish to provide, there is no doubt that within his all-too-brief scientific career the insight that such private donations play in maintaining Oxford’s excellence in Physics.

By the time you read this, the autumn Alumni Weekend will be in the past but I hope that, over the coming year, many of you will be able to attend one of our alumni events. We always try to put on something special that will entertain and inspire; do please let us know if there is anything in particular you would like to see or hear about. As always, details of upcoming events can be found at www.physics.ox.ac.uk/alumni and I look forward to welcoming old friends and new faces through the year.

The ‘Dear Harry...’ exhibition is on display at the Museum of the History of Science until 31 January 2016, and is well worth the visit.
Richard Feynman famously stated I think I can safely say that nobody understands quantum mechanics. The difficulty in understanding inevitably stems from the fact that the quantum world is so entirely unlike our everyday experience. Objects can be in quantum mechanical ‘superposition’ states – appearing to do two very different things at the same time; and objects can also be ‘entangled’ with each other such that measurement of one object can have ‘spooky’ (Einstein’s word) action on other objects far away.

Feynman realised in the early 1980s that the unnatural properties of quantum mechanics, while difficult to understand, also open up new possibilities for technological applications that would be otherwise unimaginable. He proposed a new type of information processing device, a ‘quantum computer’, which could be put in a complex quantum mechanical state – with bits that are superposed between on and off, and also entangled with other bits. Such a computer would be able to perform calculations that are entirely impossible with any computer design previously conceived.

The seventh instalment of ‘Mornings of Theoretical Physics’ (14 May 2015), attended by over 170 enthusiastic people, was devoted to the ideas of quantum information and their relations to fundamental particle physics. Prof Andrew Spenke, one of the founders of the field of quantum computation, started the morning by explaining what quantum entanglement is, and why this feature of the quantum world makes it behave so differently from our macroscopic world. He then went on to roughly describe what a quantum computer is, how it might operate, and what our progress is towards building such a device.

From a fundamental perspective, the elementary particles that exist in our universe are very much constrained by the laws of quantum mechanics in four dimensions. Consistency under these laws greatly restricts the kinds of physical properties that these particles can have. For example, electrical charges must come in units of the electron charge; spins must come in units of 1/2 of Planck’s constant; and so forth. If our universe were lower dimensional (if we were in a flatland universe for example) the laws would need to be reconsidered, and completely different types of particles would exist. Surprisingly, if we engineer confinement of particles to flat surfaces, these new and different types of particles can be made to exist, and their properties are extremely surprising. If we imagine particles as leaving strings behind them as they propagate through space and time, the knotting of these strings has important physical effects on the properties of the particles – this is quite unexpected since the particles themselves can remain very far away from one another and yet feel each other’s existence from arbitrary distance. Indeed, this effect is another example of Einstein’s ‘spooky’ action at a distance. What is even more surprising is that one can implement quantum computation (as described in the previous paragraph) by simply dragging these new particles around each other.

In the second talk of the theoretical physics morning, Prof Steve Simon described the connection between knotting in space-time and quantum computation. His lecture began with 19th century explorations of the physics of knots and ended by showing how certain unusual particles can be used to build a quantum computer. Following directly from this train of thought, in his third talk of the morning Prof John March-Russell explained how such unusual particles can arise in physics. Starting from the classic Young double slit experiment, he built up the idea of how certain types of spooky ‘action at a distance’ can arise in electromagnetism combined with quantum mechanics. Generalising these ideas, he showed how the unusual particles discussed in the prior talk could arise. Finally he ended on the notion that such exotic particles could be involved in the physics of black holes! »
CUWiP: FIRST UK CONFERENCE FOR UNDERGRADUATE WOMEN IN PHYSICS

The organisation of the conference was spearheaded by Prof Daniela Bortoletto, who had been involved in running some of the highly successful CUWiP programme in the United States, and Jena Meinecke, a graduate student who had attended and enjoyed a US CUWiP. Their experiences gave them the drive and desire to offer the same opportunity to women in the UK. They were joined by a committee of women from across the Oxford Physics department and supported by the Oxford Women in Physics Society, who shared the many tasks involved in bringing Daniela and Jena’s vision to such successful fruition.

Friday 20th March saw two important and rare events for physics in Oxford. The morning’s solar eclipse was impressive, but even more thrilling was the opening of the first UK Conference for Undergraduate Women in Physics (CUWiP). One hundred and twenty women from across the country converged on Oxford in the first event of its kind in Europe, with the aim of meeting, networking with, and being inspired by successful women in physics with whom they could share experiences, advice and ideas.

Over the course of an intensive weekend, the women enjoyed tours of facilities at RAL and Oxford research laboratories to give them a taste of the environment in which research takes place. Lectures from eminent female physicists complemented these with stories of their journeys and explanations of the work they do now. A less formal approach was taken for panel discussions featuring women from both academia and industry, giving participants the opportunity to question all kinds of women in physics. Interactive workshops on assertiveness and improving CVs and applications also offered practical advice to help the participants realise their potential. All of these activities were interspersed with opportunities for the participants to engage with one another over coffee, between lectures or at dinner in the hall at Keble, and some social activities including some university sports and a trip to Blenheim Palace.

The whole weekend was filled with an effusive energy, from the very beginning of the conference, with an open, warm and inviting spirit that made the participants feel welcome and included. The atmosphere was relaxed, yet everyone was fully engaged and committed to the various sessions and activities. The conference was a great opportunity for the participants to meet other women and learn about opportunities within the field, as well as to network with other female physicists and industry representatives.

The conference could not have happened without the generous financial support of a number of institutions and companies. We are particularly grateful for a grant from the Vice Chancellor’s Fund for Equality and Diversity. We plan to run CUWiP UK in Oxford next March to build on the foundations we have in place and to offer another set of women the opportunity to broaden their horizons and be the best women in physics they can be.

These three days are going to become the seed of something much bigger for me, because not only am I going to work harder in my own right, but I am determined to give something back to those who are coming along next. I now see that I’m not isolated, I’m part of a community and each of us can make a contribution in their own way.

CUWiP UK
Conference for Undergraduate Women in Physics UK

BREBIS BLEANEY CELEBRATION

On 27 June some former students, colleagues and family members of Brebis Bleaney gathered to celebrate his life and think about his scientific impact on the occasion of the centenary of his birth. Professor Brebis Bleaney (1915–2006) was head of the Clarendon Laboratory from 1957 to 1977 and one of the pioneers of the technique of Electron Paramagnetic Resonance (EPR). Talks were given by some of those who worked closely with Brebis (Michael Baker, Bill Hayes, Sir Roger Elliott, John Gregg) and those who are now building on the work that Brebis initiated (Andrew Boothroyd, Arzhang Ardavan, Stephen Blundell, Mark Newton and John Gregg).

Brebis was remembered as both an inspiring scientist and a man of great kindness and warmth. The resonance techniques that he developed were a natural outgrowth of his work on radar during the second world war and led to the Clarendon Laboratory becoming a centre for the study of defects in crystals and the magnetic properties of crystals. He pioneered our understanding of the way in which, in certain circumstances, the weak magnetism of nuclei could be enhanced by interactions with electrons, an effect termed ‘nuclear lambs in electronic wolves’ clothing’, and explained in John Gregg’s talk. Other presentations reviewed the way in which techniques borrowed from NMR (nuclear magnetic resonance) can now be applied to EPR to engineer coherent spin interactions, and also how the magisterial treatise on EPR that Brebis wrote with Anatole Abragam has inspired a new generation of researchers who are using Brebis’ insights to develop new magnetic and superconducting materials.

If you would like to be involved with the conference in the future, please get in touch with Daniela Bortoletto: daniela.bortoletto@physics.ox.ac.uk

The conference was followed by a reception at a private residence. This event is possible thanks to the generosity of an alumnus.

INTERSTELLAR

Top: Guests enjoying tea in the common room. Below: Bleaney’s daughter, son and grandchildren at the event.

Department of Physics Newsletter | Autumn 2015 | 15

FORTHCOMING ALUMNI EVENTS

The department offers a series of special lectures, events and other opportunities for alumni to engage and stay connected. The most up to date information and details can be found on the website at www.physics.ox.ac.uk/events.

PHYSICS ALUMNI RECEPTION IN LONDON

2 October, 18:00–21:00
A chance to meet informally and chat with fellow physics alumni and current members of the department, in a beautiful setting on the Southbank, London. Venue details and further information will be sent to those registered, as this is a private residence. This event is possible thanks to the generosity of an alumnus.

CLIMATE CHANGE IN THE RUN-UP TO PARIS: WHAT HAS PHYSICS GOT TO SAY?

6 November, 18:00–21:00, Royal Society, London
Your chance to meet some of the current Oxford faculty in Atmospheric, Oceanic and Planetary Physics engaged in research that underpins the climate change debate – and discuss some physicists’ ideas of what we should be doing about it.

INTERSTELLAR

If you are interested in these events, please visit www.physics.ox.ac.uk/events or contact alumni@physics.ox.ac.uk. All these events are free, but we have limited capacity so tickets will go on a first come, first served basis. To avoid disappointment, visit our website regularly for updates.

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INTERSTELLAR IMAGE WITH THANKS TO SARAH HARRIES AND OLIVER JAMES (DOUBLE NEGATIVE VFX) © WARNER BROS. ENTERTAINMENT INC. AND PARAMOUNT PICTURES CORPORATION
THE PHILIP WETTON ASTRONOMICAL INSTRUMENTATION LABORATORY

On 12 June the department celebrated the contributions to Astrophysics made by Philip and Roswitha Wetton. Their first gift was the Philip Wetton Telescope (PWT) which started life in 1995 in the dome of the old University Observatory. Ten years later it was moved to its present home in the new dome on top of the DWB where it proudly announces to all who look up that astronomy is done here! It is now used extensively for both undergraduate projects and outreach. It has even detected exo-planets!

Philip and Roswitha’s largest gift to the University was the funding of the Philip Wetton Chair of Astrophysics, associated with Christ Church, which I have been fortunate to hold since 2002. When I arrived I realised that they were already part of the fabric of Oxford Astrophysics, eagerly encouraging students, researchers and staff alike through their enthusiastic support – which they continue to do in this day. Over the years they have made several other gifts: a graduate scholarship at Christ Church, funding for the Wetton Lecture & workshop that takes place every three years, and an award for those who make exceptional contributions to the operation and development of the PWT.

In recognition of this sustained support we decided to name one of the laboratories on level three after Philip. On 12 June we opened the Philip Wetton Astronomical Instrumentation Laboratory. We visited the laboratory to see Philip’s latest gift – the Furo arm for precision position measurement – which will play a vital role in two future projects: WAVE, the wide field spectrometer for the William Herschel Telescope and HARMO NI, the first light instrument for the 39m European Extremely Large Telescope. After some brief presentations, the whole of Astrophysics joined in a celebration tea. The day was rounded off with dinner at Christ Church.

THANK YOU PHILIP AND ROSWITHA!

Have you registered as an alumnus/a or friend on our website?
By registering, you will receive advance notice of events and other news, before it is published on the web. There is also a short questionnaire, which will enable us to plan events and services to your liking.
www.physics.ox.ac.uk/alumni/connect

Would you like to host an event for physics alumni?
It could be a drinks reception or dinner, a visit to a special place, to your company, for a small or large group... the possibilities are endless. We may be able to provide financial support and/or assistance, if required, but private sponsorship is always welcomed. Please get in touch for an informal conversation, we’d love to hear from you!

Do you have a photo from your time in Oxford? A story or anecdote that you would like to share?
The alumni office is looking for contributions of this kind, as we are working towards making the archives more accessible and interactive. Send your contributions, no matter how big or small, to Val Crowder, Alumni Officer: alumni@physics.ox.ac.uk

PROF WERNER WOLF VISITED ARTHUR COOKE Awardees

Prof Werner Wolf (New College 1948 and Prof Emeritus at Yale University) and his wife, Elizabeth, visited us last June to meet current awardees of the Arthur Cooke Memorial Prize: Bo Jing, Arni Neniusan and Anne Plochowietz. Prof Wolf was interested to hear what they have been doing, and tell them something about the man in whose name they have been honoured. Arthur Cooke was Prof Wolf’s tutor, supervisor, colleague and friend, and Prof Wolf was very pleased that Arthur Cooke’s memory has been preserved in this way. Sir Roger Elliott, Barrie Ricketson, Mike Wells, Michael Baker and other members of the department shared a lovely occasion, remembering Arthur and swapping stories.

If you would like to know more about, or donate to, the Arthur Cooke Memorial Prize, please contact Olivia Hawkes (Condensed Matter Physics): olivia.hawkes@physics.ox.ac.uk.

HENRY G J MOSELEY: PHYSICIST AND SOLDIER

During 2015 we have been celebrating and honouring the life of physicist and alumnus Henry Moseley, who made incredible achievements for science during his time in Oxford, before going to WWI. He was killed in Gallipoli in August 1915. The new museum ‘Soldiers of Oxfordshire’ in the beautiful location of Woodstock was our venue for an alumni event entitled ‘Henry G J Moseley: Physicist and Soldier.’ Guests enjoyed a joint presentation by Prof Derek Stacey, University of Oxford, and Dr Elizabeth Bruton, Museum of the History of Science, Oxford: ‘Sacrifice of a genius: Henry Moseley, scientist and soldier.’ The event coincided with the museum’s special exhibition ‘Oxfordshire Remembers 1914–18,’ and guests had a behind-the-scenes opportunity, led by historians and members of the museum, to visit the collection, hear interesting talks, and share a drink and nibbles with fellow alumni in this beautiful setting.

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PHYSICIST AND SOLDIER

HENRY G J MOSELEY: PHYSICIST AND SOLDIER
TERRY COOPER, ST PETER’S COLLEGE, 1955–8

A LIFE AFTER PHYSICS?

It must be rare for an Oxford University Physics graduate to have played rugby for a Borstal after graduation but I can claim this particular honour. Of course, I was too old to qualify as a player through the penal system: I was at the Borstal as a student as part of my training to be a social worker. It was, however, because I had chosen social work rather than physics for a career which had surprised some of those now working in the Physics Department and this led to the invitation to write this article.

Coming from a working class area in North London, there was no expectation that I would go to Grammar School, let alone Oxford University. As I progressed through school I continually did better in the sciences than the arts and eventually started in the sixth form doing pure mathematics, applied mathematics, chemistry and physics. I succeeded in getting a good result in all four. But when I had to choose a main subject for university, physics won. However, even before I arrived in Oxford I was thinking I might want to seek a profession in which interpersonal skills played a very significant part, and physics seemed unlikely to offer me that.

Physics appealed to me, however, because I was interested in the fundamental forces which governed the world around us. Separately my tutor was particularly interested in my studying the fundamental aspects of physics and I found that I was looking at the original experiments which had changed our understanding of these forces. My tutorials with Dr von Engels were consequently slightly unusual. Further, he insisted that everything I said had to be precise. In tutorial after tutorial I was challenged. ‘Why? Justify! How do you know that?’ Any mistake in my logic was pounced on. Every tutorial became exciting, confronting and at times, I must confess, annoying. As a tutor I loved him; I hated him. But before I arrived in Oxford I was thinking I might want to seek a profession in which interpersonal skills played a very significant part, and physics seemed unlikely to offer me that.

FROM PHYSICS TO SOCIAL WORK

In Oxford I spent several weekends at a residential school for disturbed young children. At another time I spent two long vacations working in a tented camp on the Isle of Wight run by the Oxford House Settlement for youngsters from Bethnal Green. It was at the first camp that I ‘discovered’ the profession of social work.

The clients? Anybody living in our catchment area could apply for an interview. Very often my clients had financial problems by virtue of over-committing themselves on HP agreements. Some were not getting the state benefits to which they were entitled. Some came with personal and/or family problems and of course many came with housing problems. Often we could do little more than ensure they were getting their entitlements.

In the Family Welfare Association we found we were moving towards offering two kinds of service, an information and advocacy service and a therapeutic service. In the latter, I found as gained more experience that the key skill needed was the ability and the willingness to listen. Listening with my ears, ‘listening’ with my eyes, ‘listening’ to my own body to the feelings clients generated in me and of course I listened for non-sequiturs in the accounts given. Fred, of course, was way ahead of me in this.

LOCAL AUTHORITY SOCIAL SERVICES

I then moved from a comparatively small voluntary organisation into local authority social services. In the late 1960s the latter were subjected to structural changes in order to provide wider ranging services. As a manager – first as a front-line manager and then an area manager – I needed to use the analytical skills I had learnt doing physics to resolve the organisational problems I experienced. On one occasion I had to completely wind-up one committee and replace it with another, to revamped our oversight of Fostering and Adoption. This included redefining the role and required skills of the members of the Adoption and Fostering Panel, which I chaired. Once again, Dr von Engels’s insistence on getting the details right was of paramount importance in this task. It being local government, however, some three years later I was given the task of training a totally new committee where there was no requirement that members of the committee had previous knowledge or experience of fostering and adoption.

During the 1960s, as a committee member of the Association of Family Caseworkers (AFCW), I was involved with the delegates of other professional social work organisations to create a common professional organisation. This was to include hospital social workers (Almoners), probation officers and local authority social workers where the majority of workers were working with children. Virtually all of these workers already had their own professional body so the aim was to persuade the committee and their members to agree on a merger. Eventually we achieved our aims and seven organisations of the original eight joined together in 1971, I was a member of the first executive committee and of the Council.

I then had decided, having done my share in helping set up our professional body, that I would not stand for election to the new Council. Then quite unexpectedly, I was asked if I would stand for an Honorary Officers post in the forthcoming elections. I had no aspirations to become an honorary officer: the first set of Officers had, in effect, been appointed and I thought we now needed full, open elections. Knowing that I was a ‘backroom’ committee member whom very few knew, I agreed for my name to go forward to ensure there was an election. I never mentioned my nomination to anyone outside my family, my immediate colleagues and my boss.

And then, early one morning in the Autumn 1972, the telephone rang. The Director said that as a result of the election procedure I was the new National Chairman of the British Association of Social Workers! The chairman of an organisation open to all qualified social workers working in Northern Ireland, Wales, Scotland and England – and that after all that work that Dr von Engels had done to try to make me into a physicist!...
I’m standing in a small, hot room trying to keep a one-day-old baby alive. The rural Tanzanian hospital has only basic equipment: there’s just one working plug socket, so oxygen and suction have to be alternated. The two other medical students and I are a month away from qualifying as doctors and in theory we’re equipped to handle this resuscitation, but I’m not ready to deal with the reality of a mother losing her newborn child thirty minutes later. There is no privacy, no patient confidentiality, no structuring ‘breaking bad news’ speech. She takes it in silently and moves to the window with a look that’s both stoical and despairing in equal measure. I on the other hand can no longer remain composed, so I walk a short distance from the hospital complex and cry.

GEORGINA GOULD, WORCESTER COLLEGE, 2005

Ten years earlier I’d arrived at Worcester College eager to embark upon a degree in physics. The subject had been an obvious choice for me. I quickly became used to being the only girl out of five physicists in college and for the most part I wasn’t aware of being outnumbered, although the feminist in me does shudder a little when I recall being asked to play ‘mother’ at each of our termly gatherings. Tutorials were a highlight of academic life and I can clearly remember the exhilaration of standing at the blackboard, chalk in hand, racing to expand, rationalise and integrate a sequence of Greek letters. Most of the time my fellow tutees were a source of support, wél quite often get together to dissect problems and share pieces of work. But a competitive streak did sometimes interfere. I’ll never forget one of them intentionally blocking my view of Maxwell’s equations with a strategically positioned pen while I stuttered my way into embarrassment trying to recall them.

We welcome stories from all alumni. Please email: contact@physics.ox.ac.uk

Above: Georgina Gould in Africa.
Below: Worcester College.

Above: Worcester College Ladies Hockey. Georgina Gould is seated front row second from right.

I spent the next 18 months working in the Government Office for Science as a senior policy adviser in the Food, Water and Population team. This involved supporting the Government Chief Scientist with his various meetings and speeches. A particular highlight was accompanying him on a three-day trip to Tinkahure, hosted by a local farming group showcasing their finest produce. They took us on a whirlwind tour that included tasting sessions at an ice-cream plant and a pork pie factory. Despite the perks, however, it was soon clear that a career in the civil service wasn’t for me. In casting about for alternative careers, I stumbled upon the graduate medicine course – an accelerated programme into medicine that is part-funded by the NHS – and I haven’t looked back since.

COLLEGE LIFE

Worcester College is a wonderful place, known for its lake, in which I took annual, illegal dips, and its famous ducks. Our formal hall was well regarded too, particularly on Wednesdays when the menu included, somewhat suspiciously, duck. I spent my first year in the most basic of Worcester accommodation, the ‘Mitchell Building’, graded D3. The rating only went from A to C because the upshot to these stark surroundings was that it brought the 12 occupants closer together and we staged uproarious events such as ‘Mitchellline’ (‘Valentine’s Day’) and ‘Mitchellmir’. I spent a large portion of my university life engaging in various college and university sports. I captained the Worcester hockey squad and played on the football, tennis, cricket, darts and table football teams. Winning any college league or cupper competition entitled the entire team to dinner with the Provost. These were black-tie affairs and involved no less than four courses, finished off with port in the drawing room. Needless to say the women’s hockey team was a particular favourite of the Provost. In fact, one year we were even rewarded with a dinner for losing the cuppers final. This would have been slightly less scandalous had the men’s winning hockey team dinner not been cancelled in order to make space in the diary. Aside from college sport I competed in the University 1st XI hockey squad earning a blue in my final year, as well as taking part in the 50th modern pentathlon varsity match. Modern pentathlon consists of running, shooting, fencing, swimming and show-jumping; I hadn’t come inexperienced at show-jumping and during practice three weeks before the varsity match I managed to break my nose. I’d taken the jump well, sailing over the poles with good height and speed, it was just unfortunate that the horse decided not to come with me.

I saw a baby being born I also cried. The mother was 16 and she clearly didn’t want anything to do with it. The father, who looked even younger, was snap-chatting and covered in tattoos, one of which read ‘Feel No Pain’. Unfortunately my fudged first attempt was so poorly executed he forgot his own tattoo and let out a loud squeal. The first time I verified a death was also the first time I’d ever seen a dead body. I spoke to them to tell them what I was doing as I listened to their silent chest for a whole minute. The first time I saw someone being told their father had died made me cry. I couldn’t help but imagine what I’d do in their position. The first time I saw a baby being born I also cried. The mother was 16 and she clearly didn’t want anything to do with it. The father, who looked even younger, was snap-chatting pictures to his school friends. Obstetrics strikes me as a particularly fascinating specialty; it’s the only branch of medicine in which the patients are not actually suffering from an illness. It is also rarely dull and almost never sedentary. I still have a year until needing to choose a particular direction, but it’s safe to say that obstetrics is currently near the top of the list.

I can clearly remember the exhilaration of standing at the blackboard, chalk in hand, racing to expand, rationalise and integrate a sequence of Greek letters.

I have had the privilege of being an alumnus of the Oxford Physics Department.

Medicine

The last four years have presented me with a host of ‘firsts’. The first time I put a cannula in someone’s arm was in an A&E in Colchester. The patient was enormous and covered in tattoos, one of which read ‘Feel No Pain’. Unfortunately my fudged first attempt was so poorly executed he forgot his own tattoo and let out a loud squeal. The first time I verified a death was also the first time I’d ever seen a dead body. I spoke to them to tell them what I was doing as I listened to their silent chest for a whole minute. The first time I saw someone being told their father had died made me cry. I couldn’t help but imagine what I’d do in their position. The first time I saw a baby being born I also cried. The mother was 16 and she clearly didn’t want anything to do with it. The father, who looked even younger, was snap-chatting pictures to his school friends. Obstetrics strikes me as a particularly fascinating specialty; it’s the only branch of medicine in which the patients are not actually suffering from an illness. It is also rarely dull and almost never sedentary. I still have a year until needing to choose a particular direction, but it’s safe to say that obstetrics is currently near the top of the list.

As I write this I’m just a few weeks into life as a working doctor, and I am loving it. While my ever-fading physics knowledge can sometimes seem far removed from the work I do now, I know that those tutorials taught me a logical approach to problem-solving and have given me the confidence to tackle challenges that require persistence and creative thinking. The friendships I made at Worcester are still strong and I remain a keen sportswoman. My training at Oxford has taken me to some extraordinary places around the world and across a wide spectrum of emotions. I feel privileged to be an alumnus of the Oxford Physics Department.

At the end of three years at Oxford I took the decision not to carry on with physics and instead enrolled on a masters in science communication at Imperial College London. The year involved learning about documentary film-making, radio production and journalism. While there I started a radio podcast called ‘Short Science’, which involved myself and a co-presenter explaining discrete scientific concepts under the guise of normal conversation. We broadcast live each week on the Imperial College radio station and once even had listener numbers in double figures. For some reason we were even rewarded with a dinner for losing the cuppers final. This would have been slightly less scandalous had the men’s winning hockey team dinner not been cancelled in order to make space in the diary. Aside from college sport I competed in the University 1st XI hockey squad earning a blue in my final year, as well as taking part in the 50th modern pentathlon varsity match. Modern pentathlon consists of running, shooting, fencing, swimming and show-jumping; I hadn’t come inexperienced at show-jumping and during practice three weeks before the varsity match I managed to break my nose. I’d taken the jump well, sailing over the poles with good height and speed, it was just unfortunate that the horse decided not to come with me.

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SCIENCE COMMUNICATION

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...
FIVE MINUTES WITH... MERRITT MOORE

**Corpus Christi College, 2012, DPhil student Atomic and Laser Physics**

Tell us a bit about your background...

I grew up in Los Angeles then studied a year abroad in Italy during high school. I studied physics at Harvard, where I had my first experience in research, under the guidance of Charles Marcus, to explore the realisation of Majorana fermions in condensed matter systems. I took breaks from university to dance professionally with the Zurich Ballet, Boston Ballet, and then English National Ballet. Now I am in Prof Ian Walmsley’s research group, studying for a DPhil in Atomic and Laser Physics.

When/how did you decide to become a physicist?

My parents say I never talked much as a kid and that’s why I’ve probably gravitated towards less wordy activities: physics and dance. I remember getting in trouble because I would stay up all night finishing these huge 3-D puzzles that would overwhelm my room. They thought I outgrew those puzzles, but little did they realise that I just found a bigger, more mysterious puzzle (even more dimensional) – physics!

Why do you think it is important to study physics?

One of my favourite quotes is by Robert Musil, ‘It is reality that awakens possibilities, and nothing would trouble because I would stay up all night finishing these huge 3-D puzzles that would overwhelm my room. They thought I outgrew those puzzles, but little did they realise that I just found a bigger, more mysterious puzzle (even more dimensional) – physics!’

Can you explain the work you do?

The general motivation is to harness quantum mechanical phenomena to surpass classical mechanical phenomena to surpass classical limitations. The increased energy and excitement is palpable as collaborations become more meaningful, construction of bigger work spaces begins and more advanced equipment is purchased.

What are the current challenges in this field?

Loss. Photons are susceptible to loss, which causes the probability of an experiment’s success to decrease as the number of photons increase. With my experiment we have ‘upgraded’ to telecom wavelengths, where photons experience less loss in optical fibres, however the problem persists. It’s all part of building the puzzle and piecing together ways to solve various problems.

Can you describe your day to day routine at Oxford?

The dancer in me still wakes up early to stretch for two hours while reading papers before heading to lab. Once there, I’ll discuss the game plan of the day with my lab partner before jumping into experiments. We work long hours so sometimes while aligning light or taking data, we’ll play music or I’ll listen to an audiobook (currently Oppenheimer biography by Ray Monk, which I recommend).

What other interests do you have besides physics?

As you might have guessed – dance. However, I mentally ‘retired’ from my dancing career when I came to Oxford to pursue a DPhil, so I was a bit surprised to find myself back on stage during my winter holiday performing 32 Nutcrackers and 16 Swan Lakes with the English National Ballet at the London Coliseum.

What scientific breakthrough would you like to see in your lifetime?

Quantum computer.

What are your plans in the future?

Taking one month at a time…

Can you share the main positives of being a physics student at Oxford?

Oxford just announced that it will be the leading university for the government funded initiative NQIT (Networked Quantum Information Technologies). The increased energy and excitement is palpable as collaborations become more meaningful, construction of bigger work spaces begins and more advanced equipment is purchased.

Above: Merritt Moore in the laboratory.
Below left: With fellow labmates growing out our Movember mustaches - L-R: Steven Kolthammer, Ben Metcalf, Merritt Moore, Peter Humphreys, Justin Spring.
Centre: Matriculation day.
Bottom: Thinking deep thoughts about ultrafast lasers, photons and trendy lab goggles: Peter Humphreys, Merritt Moore, Justin Spring, Ben Metcalf.

What we got up to before ‘Health and safety at work’ to watch the coronation in 1953

Michael Baker, St John’s College, 1948

Early in 1953 it was announced that the Queen’s coronation would be televised. At that time I was a second year graduate student in Berbis Bleaney’s group, working in room 145 in the Townsend Building. We decided that we would try to set up a television in the lab for friends and colleagues to watch the coronation. I think we used an old television receiver from the electronics practical course. I’m sure that Lee Arundel, who was the group’s electronics technician, must have had work to do on the set. Several of us are shown in the photographs having climbed onto the roof to set up the necessary aerial. I can recognise myself, Lee Arundel and Klaus Bowers, but not the fourth fair-haired person; nor do I remember who took the photographs. The photo with the tower of the Natural History Museum and the roof of the Pitt Rivers Museum in the background is on the flat roof of the High Magnetic Field Lab. We are clearly getting the aerial ready. I don’t know where the second photo is taken. It looks like the steep roof of the Townsend Building, but I don’t recognise the brick structure to which we have affixed the aerial. It must have been straightforwardly reached from the place where we prepared the aerial, so I suspect it may have been demolished in subsequent development of the site.

My recollection is that we had a great party on 2 June, and were able to get a good impression of the coronation, even though the screen was very small for a gathering of I suppose a dozen or more. I attended the coronation on the same roof during my winter holiday performing 32 Nutcrackers and 16 Swan Lakes with the English National Ballet at the London Coliseum.

Let’s take one month at a time…

1. In February, joined the department in 1968 and served Oxford Physics for 44 years before formally retiring in 2012. He was well known internationally for his great expertise in superconducting magnets, which formed the basis of high magnetic field work done in the Clarendon Laboratory over very many years. His legacy is kept alive by the newly formed Oxford Centre for Applied Superconductivity. Our condolences go to his wife Linda, and to his wider family.

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GOINGS...

**PROF SUSAN COOPER** retired from the Chair of Experimental Physics in May 2015. Susan is a particle physicist who worked initially on electron-positron collider experiments and subsequently on experiments aimed at detecting dark matter particles by direct measurement. When she moved here from Munich in 1995 she started the Oxford cryogenic dark matter detector group which flourishes to this day. Susan was Head of Particle Physics from 1997 to 2004 and in that capacity was responsible for managing the finances of the very large PPARC (later STFC) grant which supports all of experimental particle physics. Her science interests expanded with that responsibility; she built up our technical services to meet the challenges of constructing parts of the ATLAS detector and supported the establishment of new groups to work on next-generation accelerators. Ever since she has ensured that we maintain the design and fabrication capabilities necessary to play a leading role in very complex large projects. On stepping down as Head of Particle Physics, Susan became Associate Head of Department – a role she filled for ten demanding years. For most of that time she was in charge of the finances; it has been a roller-coaster ride as the financial crisis hit, the STFC struck its own largely self-inflicted funding crisis, and a cool head and strong nerve were absolutely vital. Altogether Susan has served longer on the Physics Management Committee than anyone else and has played a major role in steering the department through challenging times. In the wider University she was a member of the Mathematical Physical and Life Sciences Divisional Board for several years and an elected member of the University Council. The department owes Susan a debt of gratitude and we wish her a long and happy retirement.

**PROF ISOBEL HOOK** has moved to Lancaster University and will head the Astrophysics group there.

**PROF AMANDA COOPER-SARKAR** was awarded the IoP 2015 Chadwick Medal and Prize for her study of deep inelastic scattering of leptons on nuclei which has revealed the internal structure of the proton.

**PROF FABIAN ESSLER** has been awarded a 2015 MPLS Individual Divisional Teaching Award. The MPLS Divisional Teaching Award Scheme celebrates success and recognises and rewards excellence in teaching.

**PROF CHRIS LINTOTT** was awarded the IoP 2015 Kelvin Medal and Prize for his major contributions to public engagement with science through conventional media (especially through television) and by leading citizen science projects through Zooniverse, opening a new chapter in the history of science by enabling hundreds of thousands of people to participate in the process of scientific discovery.

**PROF SIR CHRISTOPHER LLEWELLYN SMITH FRS** was awarded the Royal Society 2015 Royal Medal for his major contributions to the development of the Standard Model, particularly his success in making the case for the building of the Large Hadron Collider.

**PROF TIM PALMER CBE FRS** has been elected as an international member of the American Philosophical Society (APS). An eminent scholarly organisation of international reputation, the APS promotes useful knowledge in the sciences and humanities through excellence in scholarly research, professional meetings, publications, library resources and community outreach. The USA’s first learned society, the APS has played an important role in American cultural and intellectual life for over 250 years.

**DR CHRISTOPHER PALMER** has been awarded the 2015 MPLS Divisional Project Award for innovative teaching. The MPLS Divisional Teaching Award Scheme celebrates success and recognises and rewards excellence in teaching.

**PROF HENRY SNAITH** has been elected a Fellow of the Royal Society for his pioneering work on the development of hybrid materials for energy and photovoltaics through an interdisciplinary combination of materials synthesis, device development, advanced optoelectronic characterisations and theoretical studies. He has created new materials with advanced functionality and enhanced understanding of fundamental mechanisms.

We hope you enjoyed reading this issue of the Physics Department’s newsletter. To contact the newsletter editor, Prof Fabian Essler, please email newsletter@physics.ox.ac.uk. For latest news on developments at the Oxford Physics Department, see www.physics.ox.ac.uk/about-us. To contact the alumni office, email alumni@physics.ox.ac.uk.