CHURCHILL COLLEGE
UNIVERSITY OF CAMBRIDGE

2015
CONFERENCE ON EVERYTHING

Saturday 25 April 2015

13:00 to 19:00

FELLOW'S DINING ROOM, COCKCROFT ROOM & SCR CORRIDOR

PROGRAMME

13:00	***Registration*** – SCR Corridor	
13:30	***Plenary Talk*** – Fellow's Dining Room	
	Mathematical Modelling of Visual Illusions Prof. Ian Stewart, FRS	
14:30	***Break***	
14:40	***Talk Session 1*** – Fellow's Dining Room	
	Solar Fuels from Photoelectrochemical Water Splitting: Architectures for Advancement David W. Palm	
	Targeting the Untargetable: On Developing Drugs That Bind to Intrinsically Disordered Proteins Gabriella Heller	
	Genome Mining for Magnesidin Biosynthesis in *Vibrio Gazogenes* Constance Wu	
	Reaction Engineering Concepts for Selectivity Improvement in Partial Oxidation of Hydrocarbons Samson M. Aworinde	
	Identifying Small Molecules That Inhibit Non-Homologous End Joining DNA Repair Shannon R. Esswein	
	Non-decaying Hydrodynamic Interactions in Narrow Channels Karolis Misiunas	
15:35	***Poster Exhibition*** – Cockcroft Room	
16:05	***Talk Session 2*** – Fellow's Dining Room	
	Engendering Children's Movement: A Participatory Technique to Unveil the Subjectivities and Multiple Realities of Young Migrants in Ghana Thomas Yeboah	
	Three-Dimensional Imaging Patterns Reveal Survival Trends in Patients with Glioblastoma Natalie R. Boonzaier	
	Funery Choices of Ancient Egyptians – A Statistical Approach Barbora Janulíková	
	Calibration and Utility of Low-Cost and Highly-Portable Gas Sensors for Atmospheric Composition Measurement Joshua D. Shutter	
	Excess Spaces, Political Violence and Political Sovereignty in Modern German Autonomie Ali Jones	
	Machine Learning in Materials with Long-Range Interactions Max Veit	
17:00	***Poster Exhibition*** – Cockcroft Room	

17:30	***Talk Session 3*** – Fellow's Dining Room Nuclear Air-Brayton Combined Cycle Alisha Kasam A Gentle Introduction to Compressed Sensing Alexander Bastounis Fine-Tuning and the Future of Fundamental Physics David Kolchmeyer The Human Need For Space Exploration Carson F. Woodbury The Quantum Revolution Frederik Floether What Is Music and Why Should We Study It? Malinda J. McPherson
18:30	***Poster Exhibition*** – Cockcroft Room
18:45	***Awards Reception*** – Cockcroft Room

POSTER EXHIBITION

Judged at 15:35[a], 17:00[b]

#1[a]	Exploring Quantum Effects in Biologically Inspired DNA Origami Nanostructures Philip Mair
#2[a]	Reinforced Concrete Crack Analysis Tahreer M. Fayyad
#3[a]	Modelling Fracking: Role of Ground Disorder John Kam-wing Wong
#4[a]	Hybrid Monopiles for Offshore Wind Turbines Aliasger Haiderali
#5[a]	Separation and Analysis of α-synuclein Strains as Distinguished by Differential Elongation Kinetics Ashley Fidler
#6[a]	Evolution of Linear Optimal Perturbations in Stratified Shear Layers Alexis Kaminski
#7[b]	Sustainable Concrete Using Industrial By-products and Reactive Magnesia (MgO) Ahmed Abdalqader
#8[b]	Understanding the Origin of Epithelial Neoplasia by the HPV16 E6 and E7 Oncoproteins Diane Libert
#9[b]	A Bioinformatics-Based Analysis of Neandertal and Denisovan Genetic Introgression into Modern Human Genomes Evelyn Jagoda
#10[b]	Call and Response: The Blue Lotus in the Discourse of the National Characteristics Zhiyuan Pan
#11[b]	How We Design Beijing's Greenbelts? : Insights from a Model of Urban Growth Dynamics Mingfei Ma

PLENARY TALK

Mathematical Modelling of Visual Illusions

Prof. Ian Stewart, FRS

13:30 – 14:30

ABSTRACT

There are at least three types of visual illusion: ambiguous figures (where the same image can be interpreted in several ways), rivalry (where different images are represented to each eye), and impossible figures (where an image appears to depict a 3-dimensional object that can't exist).

The talk will report some recent research (By Golubitsky, Diekman, and Stewart) using simple networks of neurons ('Wilson networks') to model the decision-making process involved in interpreting ambiguous images and rivalry. No technical knowledge assumed.

BIOGRAPHY

Ian Stewart was born in 1945 and educated at Cambridge (MA) and Warwick (PhD). He is an Emeritus Professor in the Mathematics Department at Warwick University. Stewart is best known for his popular science writing—mainly on mathematical themes. His awards include the Royal Society's Faraday Medal (1995), the IMA Gold Medal (2000), the AAAS Public Understanding of Science and Technology Award (2001), and the LMS/IMA Zeeman Medal (2008). Jointly with Martin Golubitsky, he won the 2001 Balaguer Prize. He was elected a Fellow of the Royal Society in 2001. His book Nature's Numbers was shortlisted for the 1996 Rhone-Poulenc Prize for Science Books, and Why Beauty is Truth was shortlisted for the 2008 Royal Society Prize for Science Books. His iPad app *Incredible Numbers*, a collaboration with TouchPress and Profile Books , won the DigitalBookWorld Award for adult nonfiction in 2015 and was selected as one of the 24 'Best Apps of 2014' in the US and Canadian App Stores. He is an active research mathematician with over 180 published papers, and currently works on pattern formation, chaos, network dynamics, and biomathematics. He lives in Coventry, UK, and is married (44 years and counting) with two sons and three grandchildren.

TALK SESSION 1

14:40 – 15:35

Solar Fuels from Photoelectrochemical Water Splitting: Architectures for Advancement

David W. Palm[1], Tânia Lopes[2], Yi-Hsuan Lai[1], Erwin Reisner[1]
Department of Chemistry, University of Cambridge[1], Department of Chemical Engineering, Faculdade de Engenharia da Universidade do Porto[2]

Sunlight and water are two of the most abundant and most basic resources available on Earth. Photosynthetic organisms adapted to this reality long ago, evolving means of harnessing these two resources (along with carbon dioxide) to provide for their energy needs – now humans are trying to follow suit. Chemists and materials scientists are developing photochemical and photoelectrochemical techniques for splitting water, in order to store solar energy as hydrogen fuel. With the goal of producing a technology that has industrial application, there is now heightened interest in investigating the feasibility of commercial-scale solar fuels reactors. My project involves standardizing, scaling-up, and rethinking the current methods of reactor design and materials fabrication. Utilizing novel architectures for both the photoactive materials and the reactor itself, I am seeking to optimize the solar energy conversion from well-established thin film semiconductor materials.

Targeting the Untargetable: On Developing Drugs That Bind to Intrinsically Disordered Proteins

Gabriella Heller[1], Carlo Camilloni[1], Massimiliano Bonom[1], Aleksandr Sahakyan[1], Kris Pauwels[2], Peter Tompa[2], Michele Vendruscolo[1]
Department of Chemistry, University of Cambridge[1], Vlaams Interuniversitair Instituut voor Biotechnology Structural Biology Department, Vrije Universiteit Brussel[2]

In Biochemistry classes, one learns the cardinal principle of protein biology is "structure defines function". According to this rule, a protein's unique, well-defined structure defines a similarly unique, well-defined function. Recent discoveries, however, have shown that about one-third of eukaryotic proteins largely lack singular structures, and yet remain fully functional. Proteins with these properties are referred to as intrinsically disordered proteins (IDPs), which have spurred an exciting revelation in biochemistry, one that stretches the traditional "one structure-one function" paradigm. Unlike structured proteins, which are essential for catalysis and transport, IDPs appear to be crucial for regulation and signalling, acting as network hubs which interact with a wide range of molecules, rather than just one. Dysfunction in disordered proteins gives rise to a diverse set of diseases, including cardiovascular disorders, cancer, and neurodegenerative disorders, such as Alzheimer's disease. IDPs exist in a dynamic equilibrium between many energetically similar but conformationally distinct states, rendering them effectively untargetable by current drug design practices. Currently only one example of an IDP which has been targeted by drugs exists, despite enormous efforts. We combine molecular dynamics simulations with experimental techniques, such as Nuclear Magnetic Resonance (NMR), to understand the dynamics of IDPs and their interactions with small molecules and develop novel therapeutics. I will present our current understanding of the mechanism of these interactions and insights we have on developing novel drugs to target these "untargetable" proteins.

Genome Mining for Magnesidin Biosynthesis in *Vibrio Gazogenes*

Constance Wu[1], Yong-jun Zhou[1], Peter Leadlay[1]
Department of Biochemistry, University of Cambridge[1]

The wide range of biological activity displayed by secondary metabolites is attributed to the diversity of their chemical structures. As such, the study of the enzymes and biosynthesis pathways that produce this diversity is important for the discovery and development of compounds with useful pharmaceutical properties. The main aim of our project is to use genome mining to examine the biosynthesis pathway for the model tetramate magnesidin, so that the mechanism of ring formation can be compared with that of tetronates. Towards this end, bio-informatics work with Antismash 2.0 and other programs has identified a candidate gene cluster for magnesidin production in the marine bacterium *Vibrio Gazogenes*; efforts to conduct gene knockouts and heterologous expression are currently underway. Insights into this pathway will aid future attempts to engineer the production of novel natural antibiotics by synthetic biology approaches. A second aim of our project is to decipher the biosynthetic potential of *Vibrio Gazogenes* for secondary metabolites, as this species of bacteria is one of many marine microorganisms that hold potential as new bacterial sources of bioactive compounds. Bio-informatics work has identified a gene cluster that produces an iron-chelating siderophore; the production and structure of this siderophore is currently being investigated experimentally.

Reaction Engineering Concepts for Selectivity Improvement in Partial Oxidation of Hydrocarbons

Samson M. Aworinde[1], Alexei A. Lapkin[1]
Department of Chemical Engineering and Biotechnology, University of Cambridge[1]

Catalytic partial oxidations are of great industrial importance because of their role in the conversion of hydrocarbon feedstocks such as alkanes, olefins and aromatics into numerous valuable petrochemicals, polymers and liquid fuels. These chemical reactions are generally problematic because of their highly exothermic nature and large heat release, requiring good temperature control. Achieving high product selectivity in these reactions is important for several reasons, including economic benefits through cost savings on raw materials and downstream purification, improved process efficiency as well as environmental benefits through reduction in the formation and emission of greenhouse gases (mainly CO_2). All of these are crucial as the chemical industry shifts towards more sustainable chemical processing.

This project deals with the investigation of a novel chemical reactor concept for the partial oxidation of *o*-xylene to phthalic anhydride (PA). PA is an important chemical intermediate used in the production of plasticizer for polyvinyl chloride (PVC) polymer and resins, which are used in the automotive, construction and manufacturing industries. The concept involves the use of a microreactor (i.e. miniaturised reactor with characteristic dimension of <1000 μm) with oxygen distributed along the reactor length as an alternative to conventional fixed-bed reactors. Using mathematical modelling and simulation of this process, the feasibility of improving PA selectivity above 70-75% currently achieved in industrial processes is explored.

Identifying Small Molecules That Inhibit Non-Homologous End Joining DNA Repair

Shannon R. Esswein[1], Takashi Ochi[1], Tom L. Blundell[1]
Department of Biochemistry, University of Cambridge[1]

Non-homologous end joining (NHEJ) is one of two systems that repair DNA double strand breaks (DSBs), which result from exogenous sources such as ionising radiation and virus infections, and endogenous sources such as nucleases, reactive oxygen species, and DNA replication across nicks. Mutations in NHEJ proteins result in immunodeficiency, radiosensitivity, cancer predisposition, and growth retardation indicating that NHEJ is important for genome stability. DNA Ligase IV is an essential protein known to function in NHEJ only. This suggests that Ligase IV is a promising drug target to specifically inhibit NHEJ. Using differential scanning fluorimetry we identified several small molecules that may bind Ligase IV and serve as the basis for designing drugs that prevent DSB repair in cancer cells. Used in combination with radiation therapy, NHEJ inhibition may improve the effectiveness of cancer treatments.

Non-Decaying Hydrodynamic Interactions Inside Narrow Channels

Karolis Misiunas[1], Stefano Pagliara[1], Eric Lauga[2], John R. Lister[2], Ulrich F. Keyser[1]
Cavendish Laboratory, University of Cambridge[1]
Department of Applied Mathematics and Theoretical Physics, University of Cambridge[2]

Particle-particle interactions are of paramount importance in every multi-body system as they determine the collective behaviour and coupling strength. Many well-known interactions like electrostatic, van der Waals or screened Coulomb, decay exponentially or with negative powers of the particle spacing r. Similarly, hydrodynamic interactions between particles undergoing Brownian motion decay as 1/r in bulk, and are assumed to decay quickly in small channels. Such interactions are ubiquitous in biological and technological systems. Here we confine two particles undergoing Brownian motion in narrow, microfluidic channels and study their coupling through hydrodynamic interactions. Our experiments show that, in contrast to expectations from current theoretical understanding, the hydrodynamic particle-particle interactions are long-range and non-decaying in these channels. This new effect is of fundamental importance for the interpretation of experiments where dense mixtures of particles or molecules diffuse through finite length, water-filled channels or pore networks.

TALK SESSION 2

16:05 – 17:00

Engendering Children's Movement: A Participatory Technique to Unveil the Subjectivities and Multiple Realities of Young Migrants in Ghana

Thomas Yeboah[1]

Centre of Development Studies, University of Cambridge[1]

Although migration is known to be principally positioned in the youthful stage of lifecycles, young people and children's migration geographies were sidelined in social science research until recently. In situations where research has paid attention, it is largely dominated by international and advocacy concerns which are squeezed towards migrant children in problematic and abusive circumstances- trafficked situations, orphans and refugee children – which invisibilises those who may not fall among these categories. The reconceptualisation of childhood and the recognition of children as worthy research participants have in recent decades spearheaded calls for novel research methods in relation to exploring children's perspective in migration. However researching migrant children lives may mean having to strive to redress power asymmetries resulting from their highly vulnerable position. This paper focuses on conceptual difficulties associated with studying migrant children as well as a child-centred participatory methodology that has been developed for a study on the gendered processes and outcomes of children's rural to urban migration in the Ghanaian context. It explicitly assesses the strengths and weaknesses of a child-focused multiple – a technique/approach that has been developed for fieldwork in Ghana. I argue that one effective means to successfully gain an in-depth picture of children/young migrants complex, multiple and diverse realities, and to be able to attend to each situation as it turns out, is for independent child/young migrants to be seen as active agents in the migration process, and for inclusion of their own views, perceptions and experiences within migration studies through the use of child-friendly participatory techniques.

Three-Dimensional Imaging Patterns Reveal Survival Trends in Patients with Glioblastoma

Natalie R. Boonzaier[1,2], Jiun-Lin Yan[1,2], Timothy J. Larkin[3], Stephen J. Price[1,2,3]

Department of Clinical Neurosciences, Cambridge[1], Wolfson Brain Imaging Centre, Addenbrooke's Hospital, Cambridge[2], Division of Neurosurgery, Addenbrooke's Hospital, Cambridge[3]

Glioblastomas (GBM) are the most common and aggressive of the primary brain tumours in adults. Their characteristic invasive nature results in tumour cells resisting chemo-radiotherapy and infiltrating healthy brain. This leads to tumour recurrence and inevitable patient death. GBM also demonstrates marked intratumoural heterogeneity, where one finds many cell subtypes within a single tumour, making treatment and analysis difficult. The gold standard of regional analysis in GBM is invasive biopsy sampling. As these are unsafe for patients, non-invasive methods are needed to better understand these tumours. This study aimed to use non-invasive, advanced magnetic resonance imaging to characterise GBM regional heterogeneity. This was done by assessing regional features of diffusion (water movement) and perfusion (blood supply) in 42 patients. Findings were correlated to regional metabolic activity to confirm whether regions of interest were, indeed, tumourous. Thereafter, three-dimensional (3-D) visual analyses revealed that specific spread patterns of these regions were associated with poor survival in patients. As the neuroradiologist relies on qualitative, visual data (images), and not quantitative data, to assess the "picture", 3-D, volumetric studies of this nature may eventually lead to non-invasive diagnosis, assessment and strategy-planning of GBM at 'first glance'. This, too, may be a link to personalised treatment of GBM.

Funerary Choices of Ancient Egyptians - A Statistical Approach

Barbora Janulíková[1]
Department of Archaeology and Anthropology, University of Cambridge[1]

The city of Memphis (modern Cairo) was supposedly the first capital of the newly formed Ancient Egyptian state. Unfortunately, very little is currently known about this settlement and its inhabitants during this period of Egyptian state formation (ca. 3100 – 2700 BC). What we do know is mostly based on cemeteries surrounding the Memphite Nile valley, as the original Early Dynastic remains are not accessible for archaeological investigation anymore. Besides this mortuary focus, another bias within the current knowledge of the early Ancient Egyptians stems from the lens of purely elite burials through which we tend to look at them.

This perspective is now being recalibrated through the excavation of the Early Dynastic cemetery at Helwan on the Memphite Eastern Nile bank, which is committed to archaeological exploration of the lower and middle classes of the Memphite population that have been buried there.

Through a statistical study of people´s graves at Helwan, I aim to achieve a better understanding of the decision making that was involved when equipping these dead for the afterlife, while at the same time exploring the hierarchy within different types of funerary provision. Finally, the extent to which individual preferences, socially ascribed practice and stately norms were existent is also of great interest to my research.

Calibration and Utility of Low-Cost and Highly-Portable Gas Sensors for Atmospheric Composition Measurement

Joshua D. Shutter[1], Olalekan A. M. Popoola[1], Adam J. Durant[2], Ray A. Freshwater[1], Roderic L. Jones[1]
Centre for Atmospheric Science, Department of Chemistry, University of Cambridge, Cambridge[1],
Meteorology and Oceanography Section, Department of Geosciences, University of Oslo[2]

The recent availability of low-cost, compact, and lightweight gas sensors with high temporal resolution (on the order of seconds) that are highly sensitive to concentration changes down to sub-parts-per-million (ppm) volumes provides a novel measurement device for atmospheric composition measurements. While the precision of these sensors have not yet reached the levels of bulkier, more expensive, lab-based spectrometers, the fact that they are easy to manufacture and readily portable in field studies more than compensates for this drawback. Furthermore, when the gas sensors are linked together in a network, the spatial information provided by the sensor network far surpasses that of a single point measurement from a highly accurate and precise spectrometer placed in the same environment.

In this study, the calibration and use of long path length (LPL) non-dispersive infrared (NDIR) gas sensors are discussed. With an effective path length of 128 centimetres, the LPL sensors are capable of measuring carbon dioxide and methane concentrations down to tenths of a ppm as demonstrated when sensor measurements are compared to the readings of a cavity ring-down spectrometer (CRDS). Data collected by these sensors at the Sidoarjo mud flow (also known as the Lusi mud volcano) in Indonesia show how the sensors can be used to capture and quantify eruption events and emissions from around the site. The use of the LPL NDIR sensors in such locations demonstrates the utility of the sensors for environmental monitoring and suggests their usefulness in measuring gaseous emissions for the improvement of climate models.

Excess Spaces, Political Violence and Political Sovereignty in Modern German Autonomie

Ali Jones[1]
Department of German, University of Cambridge[1]

Post-War West Germany witnessed a veritable explosion of New Social Movements and international terrorism, particularly after 1968. The most famous of these include the Red Army Faction, but many others also built upon these foundations, while radically altering their focus from large spectacles of violence to smaller, individualist and deeply subjective acts of resistant self-formation. The most visible and enduring of these movements were the Autonomen.

As the flagship of the German Autonomist identity and movement, Hamburg's Rote Flora cultural centre has been squatted since 1989. A site of deep spatial contestation, it represents an alternative conception of culture, democracy, and political engagement.

Within this space, language and the social contract are refused, in favour of a spatial occupation and embodied performance of political protest. I will examine this refusal of discourse and look at the creation of an alternative form of political sovereignty. This negation occurs viscerally, corporally, and symbolically through the occupation of specific spaces, or "autonomous zones". These squatted places represent an "excess" space, not in the sense of citizens being stripped of their sovereignty by a state, but rather of those activists who refuse citizenship, and instead create their own site of political contestation. As such, this "danger zone" represents a state of exception, where state power and Autonomists each rely exclusively upon the performance and embodiment of political violence, outside of the realm of language, law, and sovereignty

Machine Learning in Materials with Long-Range Interactions

Max Veit[1]
Department of Engineering, University of Cambridge[1]

Materials are the building blocks of our everyday lives, from the familiar examples of concrete, steel, and glass to more recent developments such as solar cells and battery cathodes to things we may not usually think of as materials, like petroleum, cell membranes, and even water. For as long as humans have been using these substances, scientists have been trying to understand what makes them work. I investigate materials by simulating how they behave at the atomistic scale; from there, we can gain insights into how a material behaves at the macroscopic scale of our everyday experience. For example, to investigate a material, say, jet fuel, we might try to solve the quantum mechanical equations that describe how its atoms interact. However, if we want to calculate this material's macroscopic properties, the full quantum mechanical approach is often far too slow. A recent alternative is to use a relatively small sample of quantum mechanical calculations to learn how an atom interacts with its neighbours with the help of rigorous statistical methods. I am working to make this approach more accurate by accounting for the interactions an atom can have with other atoms outside of its immediate neighbourhood. These interactions are especially important if the molecules that make up the material have their electrons unevenly distributed; this could happen, for example, if we mixed our jet fuel with water. I am testing a method that can account for these long-range interactions by again employing machine learning, thereby expanding fast, accurate atomistic simulation to a new class of materials.

TALK SESSION 3

17:30 – 18:30

Nuclear Air-Brayton Combined Cycle

Alisha Kasam[1], Geoff Parks[1]
Department of Engineering, University of Cambridge[1]

Nuclear power, while a promising low-carbon energy source, currently has high capital costs and low operating costs so it is designed to operate at a full capacity that matches only base load electricity. Hybrid energy systems can enable us to use nuclear energy while meeting variable electricity demand and significantly improving nuclear plant revenues. The Nuclear Air-Brayton Combined Cycle (NACC) couples the heat output from a Fluoride-salt-cooled High-temperature Reactor (FHR) operating at base load with a natural gas powered "topping" cycle operating at intermediate and peak modes, achieving efficiency far above the best modern stand-alone natural gas cycles. Analysis and understanding of the NACC is still in the early stages, but the FHR with NACC has the potential to be the most efficient method of electricity production from combustible fuel. I will use computational modelling and optimization of design options and thermodynamic limitations to explore how the NACC should be configured for different modes of operation.

A Gentle Introduction to Compressed Sensing

Alexander Bastounis[1]
Cambridge Centre for Analysis[1]

One of the most important mathematical developments of the last decade is the introduction of compressed sensing. The basic idea is to use the inherent compressibility of real world objects (e.g. images) to increase the speed of a scanning device. This has benefits across a wide range of fields including (but not limited to) MRI scanning, CT scanning and fluorescence microscopy. The mathematical theory behind compressive sensing is both deep and interesting, but it is also incomplete. In particular, there are a variety of models for compressed sensing which produce very elegant mathematics but do not correlate closely to real world observations. I shall discuss the general ideas behind compressed sensing and elaborate on some of the remaining challenges facing the field.

Fine-Tuning and the Future of Fundamental Physics

David Kolchmeyer[1]
Department of Applied Mathematics and Theoretical Physics, University of Cambridge[1]

I will briefly describe the Standard Model of particle physics and explain how general theoretical considerations tell us that the mass of the Higgs boson is "unnatural." I will then describe the implications of this for possible new phenomena we might discover at the Large Hadron Collider or elsewhere.

The Human Need For Space Exploration

Carson F. Woodbury[1]
The Gurdon Institute and Department of Genetics, University of Cambridge[1]

In a climate of austerity, underemployment, and violence at home and abroad, many people struggle to justify human space exploration. Why, they ask, should we spend billions to claw our way out of Earth's gravity well just to take a few pretty pictures and maybe make a few bootprints on alien dirt? Shouldn't we focus our energies on this world with its countless cruelties and inequalities? Media's tendency to play up the loftier, less tangible motivations for spaceflight reinforces this perspective. Grand notions of humankind's place in the universe matter little when one's family is suffering. I argue that human spaceflight is – and should be portrayed as – a wise investment. It focuses brilliant minds on solving apparently insurmountable problems, leading to new technologies that benefit society. Perhaps most significantly, space exploration inspires young minds to dream, kindling scientific curiosity, and encouraging many to pursue careers in science and engineering. Human space exploration is a powerful tool to improve life on Earth. We must use it.

The Quantum Revolution

Frederik Floether[1,2]
Cavendish Laboratory, University of Cambridge[1], Toshiba Research Europe Limited[2]

A particle is in two places at once. Things without mass carry information. Communication is 100 % secure. Do these visions sound like science fiction? They have already become reality and are the topics I have been researching in my PhD in quantum physics. In this talk, I will describe how we have used photons, massless particles that can be in multiple places at once and carry information, to enable lightning-fast computing as well as implement communication channels which are impossible to hack. These advances pave the way towards a quantum revolution of our everyday lives.

What Is Music and Why Should We Study It?

Malinda J. McPherson[1]
Centre for Music and Science, Faculty of Music, University of Cambridge[1]

In most dictionaries, music is defined as a sound. However, in order for people to hear a musical sound, a performer must first create that sound. The concept of music as a fundamentally auditory capacity is culturally specific, largely resulting from Western concert culture and recording technology. For most of human history, people had to perform music (often in social contexts) in order to hear it. Musical sounds are the product of a complex set of human behaviours, including rhythmic coordination, relative pitch perception, theory of mind, and others. Studying music as a social, multi-dimensional and evolved behaviour, rather than as a sound, is crucial to determining the function of music, and developing music therapies and medical interventions.

POSTER EXHIBITION

Judged at 15:35-16:05[a], 17:00-17:30[b]

Poster #1[a]: Exploring Quantum Effects in Biologically Inspired DNA Origami Nanostructures

Elisa A. Hemmig[1], **Philip Mair**[1], Celestino Creatore[2], Florian A.Y.N. Schröder[3], Andy Parker[4], Akshay Rao[3], Alex W. Chin[2], and Ulrich F. Keyser[1]

Biological and Soft Systems, Cavendish Laboratory, University of Cambridge[1], Theory of Condensed Matter, Cavendish Laboratory, University of Cambridge[2], Optoelectronics Group, Cavendish Laboratory, University of Cambridge[3], High Energy Physics, Cavendish Laboratory, University of Cambridge[4]

The DNA origami technique has emerged as a powerful 'bottom-up' approach for the assembly of two- and three-dimensional nanostructures with tailored geometries and chemical addressability. Our research efforts are focused on the functionalisation of DNA origami structures by attaching fluorescent dye molecules with base-pair accuracy. Our aim is to explore the possibilities of DNA origami as a versatile platform to design sophisticated, multicomponent nanoarchitectures for the study of quantum effects underlying light-harvesting in photosynthesis. Here, we introduce a biologically inspired DNA origami design consisting of a ring of donor fluorescent dyes surrounding an acceptor core on a flat, square-shaped DNA origami platform. Steady-state fluorescence analyses of various donor-acceptor geometries revealed that the light-harvesting ability is highly enhanced by increasing the number of adjacent donors. Furthermore, we demonstrate the possibility of fine-tuning the observed antenna effect by varying the concentration of Mg^{2+} ions in the buffer solution. In conclusion, these initial results clearly show the potential of the DNA origami technique to build artificial mimics of light-harvesting complexes with exquisite control over donor-acceptor geometry.

Poster #2[a]: Reinforced Concrete Crack Analysis

Tahreer M. Fayyad[1], Janet M. Lees[2]

Department of Engineering, University of Cambridge[1], Civil Engineering, Department of Engineering, University of Cambridge[2]

The construction industry, together with the materials industries which support it, is one of the major global exploiters of natural resources and this contradicts with the sustainable development concept. Therefore, the construction industry should adapt its practices in ways that take sustainability into consideration. Repair, renovation and strengthening of concrete structures are some of these practices to reduce demolition waste and save construction resources. During the last decade, new materials have been used to repair cracks or strengthening structures. So, an understanding of the mechanism of concrete cracking in reinforced concrete structures and its effect on the strength of the structures can help to assess old buildings and identify the best material properties to be used to enhance structures. Over the last decade there has been rapid development in image processing techniques as well as in high resolution digital cameras. New advances in this field provide new tools to measure fracture processes and provide insight into the concrete cracking process. This research aims to provide an improved understanding of concrete cracking in order to better assess the strength of existing reinforced concrete structures and to encompass strengthening systems. A non-destructive digital image correlation technique (DIC) is used to analyse the experimental results which then used for theoretical modelling verification.

Poster #3[a]: Modelling Fracking: Role of Ground Disorder

John Kam-wing Wong[1], Kenichi Soga[1], Xiaomin Xu[1], Jean-Yves Delenne[2]
Department of Engineering, University of Cambridge[1], The Ingénierie des Agropolymères et Technologies Emergentes, Montpellier, France[2]

Fracking is a technique to create fracture in rock by injection of high pressure fluid. Fracking has wide applications such as hydrocarbon extraction, geothermal energy and disposal of liquid waste. However, how fractures grow kilometers below ground is not well understood because of the disorder of ground from natural fracture network constituted by discontinuities in different scales (e.g. fissure, joints, and faults). Interacting with natural fracture networks, fractures created by fracking, is tortuous and clustered. Without including disorder nature of ground, current simulators can only generate idealized fractures which do not match the observation (e.g. microseismic monitoring) on site. The research studies the role of disorder in fracking. Rock is modelled by lattice network where geometric disorder is incorporated. Fracturing is modelled by simple removal of lattice. Pipe network is used to model fluid flow along fractures. Fractures formed in this model are clustered and fluid flow is tortuous. Some initial results are presented to show how different degrees of disorder affect the fracture formed. The model is an ideal tool for understand fracking by statistical physics on disordered system. The microseismic data collected on site can be compared with simulation results in meaningful ways.

Poster #4[a]: Hybrid Monopiles for Offshore Wind Turbines

Aliasger Haiderali[1], Gopal Madabhushi[1]
Department of Engineering, University of Cambridge[1]

Offshore wind, a proven source of clean, renewable and affordable energy, is vital to a future energy supply that is secure, environmentally friendly and less dependent on fossil fuels. In the EU, it is forecasted to provide 24 GW of power by the year 2020 representing phenomenal growth from its current capacity of 8 GW. Monopiles, which are large diameter (4-6 metres) tubular piles subjected to high magnitude lateral loads from wind and ocean waves, are the most popular foundation type for offshore wind turbines in waters of up to 30 metres in depth.

The capital cost of an offshore wind farm is approximately thrice that of an onshore wind farm. Hence, project developers strive to maximise energy output through the use of bigger turbines that are located in deeper waters to tap into consistent winds of higher speeds. This has led to the current trend of the monopile diameter being continually increased to withstand the ever increasing structural and environmental loads. However, monopiles with a diameter greater than 7.5 metres would be impractical to install using current technology.

Using three-dimensional finite element analysis, a study was undertaken to assess the improvement in the lateral capacity of a 5 metres diameter monopile in medium dense to dense sand when used in combination with reinforced concrete footings. The influence of surcharge load due to a gravel armour was also examined. Findings indicated favourable interaction between the monopile, footings and the gravel armour resulting in increased lateral capacity of hybrid monopiles.

Poster #5a: Separation and Analysis of α-Synuclein Strains as Distinguished by Differential Elongation Kinetics

Ashley Fidler[1], Dora Pinotsi[1], Gabriele Kaminski Schierle[1], Clemens Kaminski[1]

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The aggregation of normally soluble proteins into amyloid structures is a pathological characteristic of many neurodegenerative disorders, including Alzheimer's and Parkinson's disease. Amyloids, or highly regular, self-propagating protein aggregates, form through a sequential process initiated by the misfolding of native proteins into conformations containing metastable β-sheets. Furthermore, recent studies have demonstrated that, like prions, amyloid aggregates are able to spread from cell to cell and initiate fibril formation. To better understand this phenomenon, my research group has utilized super-resolution microscopy to compare the growth rates of individual amyloid fibrils generated by the addition of monomers of α-synuclein, a protein strongly associated with Parkinson's disease, to template oligomers *in vitro*. They have demonstrated that fibrils from the same sample vary significantly in their degree of growth over the same time period, indicating that oligomers differ in their ability to recruit monomers. My project attempts to explore this heterogeneity of elongation rates further. My first objective is to expand upon the body of work detailing the kinetics of α-synuclein fibril growth through more extensive *in vitro* elongation assays. In particular, I am employing super-resolution microscopy to perform generational studies that more closely examine the inheritance of polarity and elongation rates in discrete time intervals. Concurrently, I am developing a microfluidics-based methodology for the accurate sorting and release of individual α-synuclein fibrils by degree of elongation. When completed, this technique will allow us to employ distinct classes of fibrils in experiments that identify structural polymorphisms.

Poster #6ᵃ: Evolution of Linear Optimal Perturbations in Stratified Shear Layers

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Stratified shear flows are ubiquitous features in the ocean and atmosphere, and the study of such flows is a canonical problem in fluid dynamics. Classical normal-mode stability analysis has given rise to many results for such flows; one of the most famous is the Miles-Howard stability theorem, which states that a necessary condition for normal-mode instability in parallel, inviscid, steady stratified shear flows is that the gradient Richardson number, Ri_g is less than 1/4 somewhere in the flow. However, non-normal modes may undergo substantial transient growth at finite times even when $Ri_g>1/4$ everywhere in the flow. We have calculated the "optimal perturbations" which maximize linear perturbation energy gain for a stably-stratified shear layer. We then give these optimal perturbations a small but finite initial amplitude and use them to initialise direct numerical simulations. The optimal perturbations are observed to grow at the predicted linear rate initially, but in some cases experience sufficient transient growth to become nonlinear and susceptible to secondary instabilities which break down into turbulence. We will describe the nonlinear evolution of the optimal perturbations, as well as the resulting turbulence and mixing.

Poster #7[b]: Sustainable Concrete Using Industrial By-Products and Reactive Magnesia (MgO)

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A system of alkali-activated fly ash (FA)/slag (AAFS) mixtures as a clinkerless cement was investigated with different dosages of Na_2CO_3, as a sustainable activator. The effect of incorporating various proportions of reactive magnesia (MgO) was also examined. Mechanical, mineralogical, and microstructural characterisation of the cement pastes was carried out using the unconfined compressive strength, X-ray diffraction, thermogravimetric analysis, infrared spectroscopy and scanning electron microscopy. It was found that the strength of Na_2CO_3 activated FA/slag mixtures generally increased with time and the Na_2CO_3 dosage. The hydration products were mainly C-(N)-A-S-H gel of low-crystallinity, which is rich in Al and may have included Na in its structure, and hydrotalcite-like phases. Adding reactive MgO in the mixes showed an accelerating effect on the hydration rate as suggested by the isothermal calorimetry data and reduction of drying shrinkage. Additionally, findings revealed variations on the strength of the pastes and the chemical compositions of the hydration products by introducing reactive MgO into the mixtures.

Poster #8[b]: Understanding the Origin of Epithelial Neoplasia by the HPV16 E6 and E7 Oncoproteins

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Papillomaviruses comprise a group of nonenveloped DNA viruses that infect vertebrates at epithelial sites. Most types of human papillomaviruses (HPVs) are “low-risk,” causing warts and other benign self-limiting skin lesions. However, a subset of “high-risk” types are involved in the development of cancer and give rise to over half of oropharangeal cancers and 99% of cervical cancers. There have been widespread efforts to explain the molecular pathways that underlie cancer progression, but the way that HPV infection initially disrupts proliferation and differentiation to bring about neoplasia remains unclear. High-risk HPV types express viral oncoproteins E6 and E7 during early infection, which can disrupt the normal functions of the tumour suppressor proteins p53 and pRb respectively. Using an isogenic normal immortalized keratinocyte (NIKS) cell line containing HPV episomes, we have now studied the impact of E6 and E7 on cell proliferation, differentiation, and contact inhibition, which are functions that are important for the development of neoplasia. Our studies suggest that while E7 is not required to enhance basal-cell proliferation, the E6 protein plays a role in overcoming normal contact inhibition signals, allowing cells to grow to a higher cell density. We find that E6 expression reduces activation of NICD1, a keratinocyte differentiation determinant, and inhibits the commitment of basal cells to differentiate. Our current work is now expanding on these findings to produce a coherent picture of how E6 promotes proliferation and delays differentiation in the context of its role in p53 degradation. This mechanistic insight will improve clinicians’ understanding and treatment of HPV infection.

Poster #9^b: A Bioinformatics-Based Analysis of Neandertal and Denisovan Genetic Introgression into Modern Human Genomes

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When modern humans left Africa, they faced environmental obstacles for which their millennia of adaptation in Africa left them sorely unprepared. To survive in these new climates, they had to adapt and acquire physiological adaptations. They may have been aided in this process by an unlikely source, archaic hominins such as the Neanderthals and Denisovans. These populations had been living throughout the world in harsh climates long before modern humans arrived. By interbreeding with these now-extinct hominins and receiving genetic contributions from them, our ancient human ancestors may have acquired gene variants that helped them to survive in these new environments. I am currently conducting a study that aims to use bioinformatics techniques to find such alleles and determine their present-day biological significance in human populations.

Poster #10^b: Call and Response: *The Blue Lotus* in the Discourse of the National Characteristics

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Taking place in 1930s Shanghai, *The Blue Lotus* is one of the stories in the cartoon *The Adventures of Tintin* by Belgian cartoonist Hergé. This story is regarded by many Chinese as a remarkable work, not only because the storyline is exciting, but more importantly, collaborating with a Chinese arts student called Zhang Chongren in Brussels at that time, Hergé changed his previous depictions of Chinese people. In the story, this is reflected in a conversation on the stereotypes of Chinese: Tintin talked about some impressions held by people in Europe at that time, while a local Chinese boy laughed and rejected them completely. By analysing the formation of one specific image, I will point out the role of the discourse of "national characteristics" in this process. When the "Chinese national characteristics" became an object studied and defined by the foreigners, meanwhile in China, some intellectuals learning about these descriptions, grew uneasy and took actions to change the negative parts. "To transform the national characteristics" thus became their weapon to attack the "old" ethics and customs domestically. Viewed from the perspective of the discourse of the "national characteristics", the conversation in *The Blue Lotus* reflected this transnational process. It is like a call and response: on one hand, this discourse gave rise to some stereotypes formed outside China to describe its people; on the other hand, some Chinese intellectuals tried hard to change these national images by launching radical movements from within.

*Poster #11^b^*: How We Design Beijing's Greenbelts? : Insights from a Model of Urban Growth Dynamics

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Urban greenbelts (such as established in London and other UK cities) are considered a key instrument for improving the urban environment, public health and social equity. However, attempts to establish greenbelts in the emerging economies tend to falter. Beijing is a good example: its first greenbelt of the 1990s disappeared under the urban expansion and its second is under a similar threat.

We use the Recursive Spatial Equilibrium Model for Beijing to simulate the patterns of urban growth which not only represent the equilibrating interactions between work, living and travel but also the temporal dynamics of growth.

This model builds upon representation of two cross-section models for the year of 2000 and 2010, and the recursive structure enables the reproduction of the evolution trajectory from 2000 to 2050. We first calibrate the 130-zone Beijing model using observed datasets for 2000, which provides insight into the drivers of the distribution patterns of households and businesses. In addition, we test alternative scenarios to the current greenbelt design to predict 2050 patterns, including stringent greenbelt, green wedges, urban densification and transit-oriented development (TOD).

The analyses suggest that under rapid urban change, the configuration of urban land use policy has a significant impact on the economic performance of the city. A full realisation of the greenbelt plan may not necessarily be the highest performing scenario. The insights can help to reconsider the design of major urban green space provision in fast growing cities.

Research Funding Bodies

Alfred Toepfer Foundation

Arts & Humanities Research Council

Cambridge Trust

Canon Collins Trust

Commonwealth Scholarship Commission

Deutscher Akademischer Austauschdienst

Edmonton Churchill Scholarship

Energy @ Cambridge

Engineering and Physical Sciences Research Council

Gates Cambridge Trust

The Hong Kong Institute of Engineers

Medical Research Council UK

Natural Sciences and Engineering Research Council of Canada

Phi Beta Kappa

Royal Dutch Shell

Social Sciences and Humanities Research Council

The Solar Fuels Network

The Thouron Award

The Winston Churchill Foundation of the United States

Special Thanks to

Jill Hay
Carol Robinson
Shelley Surtees

Chris Cummins & AV Team
Livia Harriman
Naomi Morris

Jan Freyberg & Sonke Hee
Barry Kingston
Justin Palfreyman
Alex Webb

MCR Committee Volunteers

Cambridge Trophy and Engraving Center
PLAN-IT Reprographics Ltd