IOP Institute of Physics
Biological Physics Group

NEWSLETTER

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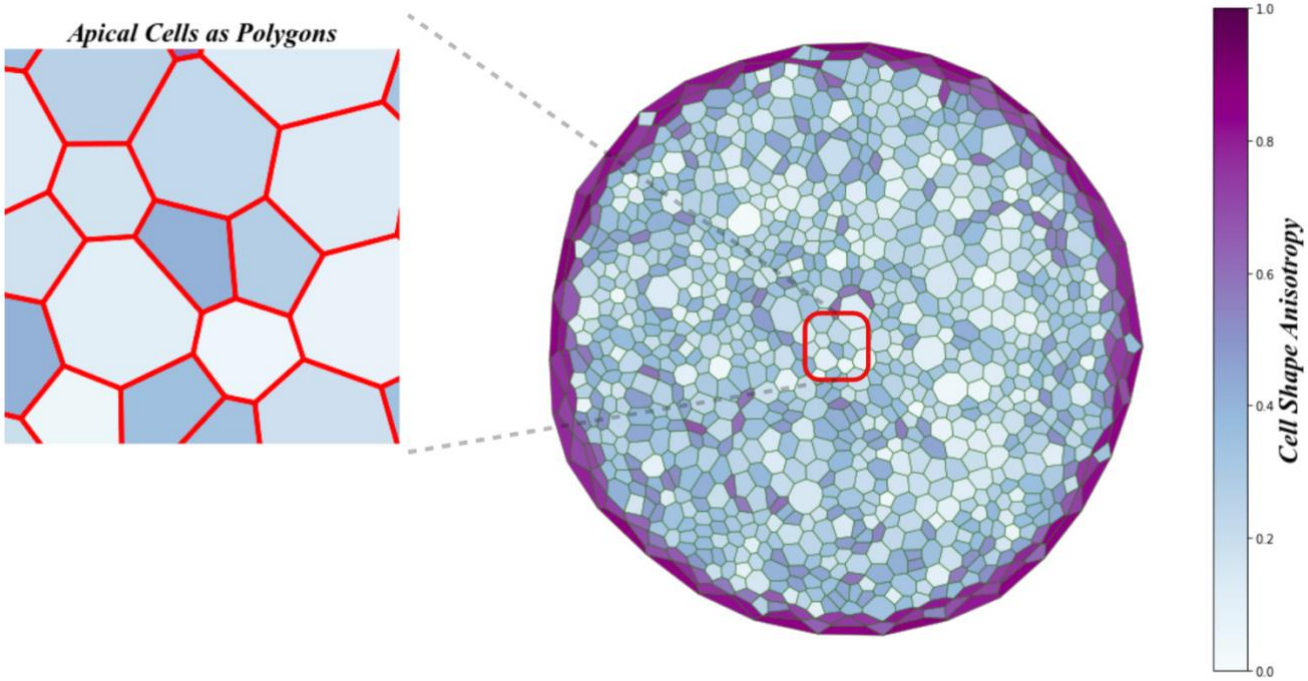


Cover Image

Vertex model of 2D growing tissue generated using Tyssue. Colour coding represents anisotropy of cell shape. Inset shows close up of a group of cells at centre of tissue.

Image credit: Yi Ting Loo, Timothy Saunders – University of Warwick

Contents

Items for the newsletter should be e-mailed to Diana Fusco (df390@cam.ac.uk)

Websites
www.iop.org/physics-community/special-interest-groups/biological-physics-group#gref
sites.google.com/view/biologicalphysicsgroupuk/home

The Chair's commentary

Dear Biological Physics Group Members,

As the the nights draw in, and the turkey farms fall eerily silent, we hope you enjoy this first newsletter of 2023 from the Instute of Physics Biological Physics Group. You will see that since our last newsletter the Group has support four fantastic meetings, reports detailed in full in this issue below for your reading pleasure, and already has plans for five further meetings in the new year, which we implore you to investigate. We have such an enormously vibrant and engaged community of researchers across the UK and Ireland, and indeed with international members further afield, a real fountain of inspiration with such a broad catalogue of interests manifest in these absolutely brilliant workshops and conferences. I hope you you gain real inspiration from reading about these meetings, and if this inspires you to help to organise a meeting yourself, please do drop us an email – we want to support you, we want to help you make these happen! I feel so truly proud to Chair such a collegiate group of execeptional and enthusiastic indivudals.

On behalf of the committee may I wish a happy and healthy break, and all the best of good fortune in your wonderful biological physics endeavours in 2023!

Mark Leake, BPG Chair.

The current committee

Professor Mark Leake (Chair)
University of York
Develops new biophysical instrumentation to apply to open biological questions

Professor Mark Wallace
(*Treasurer)*
KCL
Mark's group builds artificial mimics of cell membranes

Professor Michelle Peckham
(Secretary)
University of Leeds.
Interested in the cytoskeleton, molecular motors, super-resolution imaging.

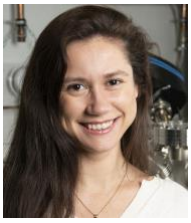
Dr Marco Mazza
University of Loughborough
Uses theory and computer simulations across scales to identify the driving mechanisms of complex matter organization

Dr Chiu Fan Lee (Website).
Imperial College London:
Works on universal behaviour in biology, protein amyloid self-assembly and pathogenesis, phase separation in the cell cytoplasm, and active matter

Dr Diana Fusco (Newsletter Editor*)*
University of Cambridge
Physics of microbial ecology and evolution

Dr Margarita Staykova,
University of Durham
Interested in understanding the functional principles of biological membranes and capture them in artificially designed smart interfaces

Dr Bartlomiej Waclaw,
(Website Editor)
University of Edinburgh,
Interested in applications of statistical and soft matter physics to biological evolution



Dr Nirvana Caballero,
University of Geneva,
Theoretical Physicists, specialises in statistical and computational physics

Dr Timothy Saunders,
University of Warwick,
Quantitative Developmental Biologist

Dr Peter Adams,
University of Leeds,
Nanoscale Physics

Dr Massimo Vassali,
University of Glasgow,
Mechanobiology

Meeting reports

Imperial Quantitative Biology Meeting, June 2022, London

Organizers: Vahid Shahrezae (Imperial)i, Philipp Thomas (Imperial), Ruben Perez-Carrasco (Imperial) and Peter Swain (Edinburgh)

From 23rd – 24th June 2022, a group of quantitative biologists, biophysicists and mathematical biologists met at Imperial College London for a 2-day workshop. The meeting was organised by Vahid Shahrezaei, Philipp Thomas and Ruben Perez-Carrasco from Imperial and Peter Swain (Edinburgh) and funded by Quantitative Sciences Research Institute (Imperial College) and a UKRI Future Leaders Fellowship (Philipp Thomas). The meeting had a "no-slides" policy, with all talks taking place on a large whiteboard. A large TV was provided to show a few experimental images to motivate the work, but all speakers spent >90% of the time at the board. Talks were each 45 minutes long, allowing plenty of time for questions and concepts to be explained in depth.

Day 1

Martin Howard (John Innes Centre) kicked off the meeting, discussing his lab's work on coarsening during meiotic crossover. Through a combination of stochastic modelling and theory, he was able to explain the frequency and positioning of crossovers following double-strand DNA breaks. This work showed the power of statistical physics in explaining seemingly complicated biological phenomena within a simple framework.
See: https://www.nature.com/articles/s41467-021-24827-w

Chris Barnes (UCL) discussed the importance of microbial engineering. In particular, given the huge array of potential inputs into cells state and the subsequent diverse range of phenotypes, can modelling help to identify trends in multidimensional data that can be applied to therapeutics? Machine learning can help, but the output is a "black box", so he has been trying to develop a generalised Lokta-Volterra model for describing the data, utilising Bayesian approaches to handle the numerous parameters. The challenge of understanding the multidimensional data that biology produces looks like being a challenge for years to come.
See: https://www.biorxiv.org/content/10.1101/2022.03.18.484889v1

George Constable (York) outlined his work on understanding sexual reproduction in Leishmania, a parasite spread by sand flies. It has recently been discovered that Leishmania undergoes rare sexual reproduction in the sand fly host. This may play a role in drug avoidance by the parasite. He developed probabilistic models of inheritance including both sexual and asexual reproduction.

Omer Dushek (Oxford)'s lab focuses on quantitative and operational understanding of T cell responses. He focused on T cell receptors and other co-signalling receptors that shape T cell receptor signalling. His group has experimentally quantified how different receptors fine-tune the signal. While these signalling networks are very complex, simple coarse-grained and phenotypic mathematical models of such signalling provides insights on how signalling works at an operational level.
See: https://www.science.org/doi/abs/10.1126/scisignal.aay9363

James Locke (Sainsbury Laboratory) works both on bacterial and plant systems. In this talk he focused on some recent work on the role of molecular stochasticity in the variation in decision making dynamics in plants. They have observed significant natural variation in the timing of Arabidopsis seed germination. This variation could be explained by a simple stochastic mathematical model involving feedbacks within the plant hormonal system that exhibits bistability.
See: https://elifesciences.org/articles/59485

Alexis Barr (Imperial) gave an overview of her lab's work on cell cycle regulation and how her work with quantitative biologists has guided her research. She focused on cellular senescence. This has typically been investigated in healthy cells but what about in cancer? She discussed how modelling helped in analysis of large potential drug libraries, to see how to stop healthy cells undergoing senescence while cancerous cells avoid it.
See: https://febs.onlinelibrary.wiley.com/doi/full/10.1002/1873-3468.13867

Daniel Hebenstreit (Warwick) described his work on understanding the phenomenon of Pol2-pausing at the transcription start site (TSS) of a gene. Yet, what underlies this process remained unknown, and in particular the

relevant time scales. Daniel outlined how ProSeq gave access to temporal information during transcription. Surprisingly, they found that Pol2 was *more rapid* at the TSS. The large peak in CHiP seq was in fact due to aborted transcription, not Pol2 pausing. These results are consistent with recent independent experimental evidence.
See: https://www.cell.com/cell-reports-methods/fulltext/S2667-2375(21)00138-7

Mamen Romano (Aberdeen), nicely following on from the previous talk on transcription, discussed the dynamics of translation. She outlined the Totally Asymmetric Simple Exclusion Process (TASEP) model and its application to translation across a finite domain. By considering the effective entry and exit rates, parameter spaces can be formed to understand the rate of translation under different constraints.
See: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.105.034117

Day 2
Omer Karin (Cambridge) covered the exciting topic of epigenetic inheritance. *C. elegans* has become a model system for exploring this biological phenomenon. By using fluorescent readout, experiments can follow the level of gene silencing over multiple generations. Yet, the mechanism underlying epigenetic silencing remains poorly understood. Omer developed a stochastic autocatalytic model with negative feedback to describe the emergence of memory. Under certain parameter regimes, this model can capture the long-tailed distributions observed experimentally.

Timothy Saunders (Warwick) described a new model for cell migration. During development cells can undergo long-ranged migrations across and between tissues. Meanwhile, the tissues often grow and alter morphology. While cell migration has been studied in detail, how cells migrate within changing spatial environments remains unknown. Motivated by work from his experimental collaborator Tom Carney, Timothy outlined a model of echolocation. Here, migrating cells generate a signal that is received at the tissue boundary. This induces a response that alters the local mechanical environment around the cells, thereby altering the cell migration speed. This model of echolocation was able to replicate observed fibroblast migration in the developing zebrafish fin.
See: https://www.biorxiv.org/content/10.1101/2022.05.13.491825v1

Andrea Rocco (Surrey) outlined mechanisms for noise-induced transitions in gene circuits. He explained how transcription factor binding could generate extrinsic noise in gene expression, leading to long-lived temporally correlated states. Such memory can have counter-intuitive consequences; noise can create bimodal distributions in regions of the parameter space where otherwise it would be deterministically monostable. Interestingly, in the toggle switch, this effect is observed only for one of the genes involved but not the other.
See: https://arxiv.org/abs/2206.01955

Wenying Shou (UCL) showed her experimental set up to study evolution in synthetic communities by continuously diluting and mixing populations of competing bacteria. She demonstrated that varying the dilution and carrying capacity across the experiments resulted in counterintuitive behaviours. Such behaviour could be understood within a mathematical formulation of the temporal evolution of the system. This provides evidence that problems such as antimicrobial resistant require the development of tools from stochastic dynamical systems.
https://www.nature.com/articles/s41467-021-26647-4.

Ruth Baker (Oxford) described a high throughput imaging based experimental set up to test the function of different genes in cell motility. A relatively simple agent-based (individual based) mathematical model of cell motility was used to assist relating the images to mechanisms. As such mathematical models can only be simulated, an approximate Bayesian computation approach was utilised to fit the model to data. However, such approaches are computationally expensive, particularly when applied to a high-throughput experimental setting (*i.e.* lots of different gene knock-out experiments). She described an elegant solution to this computational challenge motivated by the method of Stochastic Gradient Descent, proposing a *minibatch* approach to approximate Bayesian computation.
https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1010191

Bruno Martins (Warwick) gave an exciting talk about the impact of the circadian clock on cell division in cyanobacteria. His data demonstrated that the clock generates two subpopulations of fast and slow-growing cells dependent on a cell's perceived time of day. These subpopulations differed in their cell size, which could be explained through a simple model coupling division with cell size control and the circadian clock. Bruno further

elaborated how he now plans to disentangle the mechanisms behind these dynamics using sophisticated time-lapse microscopy experiments in combination with fluorescent reporters.

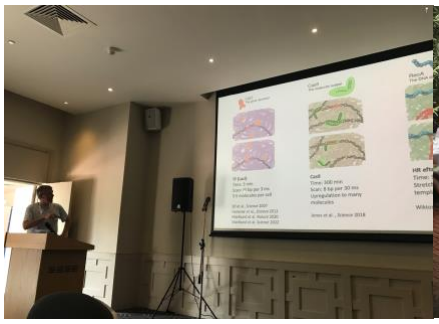
Orkun Soyer (Warwick) challenged our current view of cell behaviour as a dynamical system by proposing a new level of abstraction to tackle the dynamics of metabolism. In particular, he tackled the Warburg effect in saturation of glucose and how we can use dynamical system theory to understand the switching between respiration strategies of the cell. He proposed details of this modelling that required taking into account energy fluxes incorporated in a replicator model.

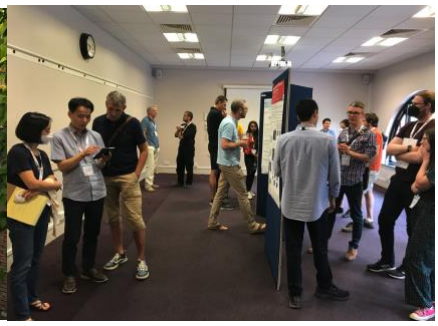
Robert Endres (Imperial) closed the workshop with an overview of Turing patterns. The talk celebrated the anniversary of Turing's 1952 paper 'The chemical basis of morphogenesis'. Robert used the chalkboard to derive the mathematics behind Turing's mechanism of pattern formation. He then showed how the theory is applied to study the emergence of synthetic pattern formation in the lab. To this end, Robert used physics-based machine learning methods to accurately classify patterns and mechanisms without requiring time-consuming simulations. Robert emphasised how Turing's mechanism keeps inspiring researchers 70 years after its inception, not just in developmental biology but nowadays in synthetic and quantitative biology.
Ruben Perez-Carrasco, Timothy Saunders, Vahid Shahrezaei, Philipp Thomas

Single-molecule bacteriology, July 2022, Oxfordshire

Organizers: Achilles Kapanidis (Oxford), Meriem el Karoui (Edinburgh), Stephan Uphoff (Oxford) and Jie Xiao (Johns Hopkins)

The first "Single-molecule Bacteriology" meeting, also the 87th Harden conference (sponsored by the Biochemical Society), took place near Oxford on July 11-14, 2022 at Milton Hill House, Oxfordshire. The meeting attracted 92 attendees and included 22 invited talks, 22 talks chosen from the abstracts and 16 posters. The meeting was co-organised by Achillefs Kapanidis, Meriem el Karoui, Stephan Uphoff and Jie Xiao, and received generous sponsorships from the BBSCR, the IoP, as well as from other academic, industrial, publishing, and industrial sponsors.





The conference concentrated on studies of the spatial organization and mechanisms of living bacterial cells by using single-molecule experimental methods and complementary theoretical modeling approaches. The conference also covered new quantitative in vivo techniques applicable to bacteria, single-molecule studies of clinical and commercial significance, and applications of machine learning in controlling gene expression in bacteria. A large number of talks were dedicated with mechanisms related to the processing of nucleic acids, ranging from transcription and translation to CRISPR-based recognition and search processes on the bacterial chromosome.

The meeting opened with a lecture by Professor Johan Elf (University of Uppsala, Sweden; see photo below) who presented exciting recent results on how different DNA-binding proteins locate their targets inside bacterial cells. The conference also included the 2022 Biochemical Society Colworth Medal Lecture on the "Structural biology of prokaryotic cell surfaces", given by Dr Tanmay Bharat (MRC Laboratory of Molecular Biology).

The conference ended with discussions about the possibility of a third such conference in the Oxford area; since the participants enthusiastically supported such an option, it is very likely that the 3rd "Single-molecule bacteriology" meeting will be held around September 2024.
Achilesfs Kapanidis

The physics of infection, September 2022, online

Organizers: Phil Marsden (Unitive Design), Tom Waigh (University of Manchester), Bahdar Bhatia (Sandwell Hospital NHS Trust) and Mark Leake (University of York)

This was a joint Biological Physics and Medical Physics group event. The *Physics of Infection* was a one-day meeting planned to encourage interactions between our two groups. Originally intended as an in-person event in London, the Queen's funeral and uncertainty regarding the rail strikes meant it needed to be held on-line. Nevertheless, the talks were of an excellent standard.

The first talk was given by a consultant doctor in infectious diseases, *Dr. Matthew Inada-Kim*. It provided a fascinating introduction to the real-world problems associated with infectious diseases from someone working on the front line in a hospital. He stressed a wide range of important topics such as: speed of diagnosis, previous failed attempts to automate diagnosis, the conservative nature of medicine in the face of litigation, guidelines for the safe use of general antibiotics and the revolution provided by digital patient records.

The next speaker, *Dr. Neciah Dorh*, discussed his perspective based at a spin out company from the University of Bristol. His company had developed an automated platform to diagnose bacterial diseases based on the aggregation of bacteria with suitably functionalized colloidal probes.

Next in the programme were *Mr. Emmanuel Akabuogu* (University of Manchester) and *Dr. Rachel Bennett* (University of Bristol) who considered electrical signalling in *E. coli* and colonisation strategies of *P. aeruginosa* respectively, from a pure biological physics perspective.

After lunch, there were three more fascinating biological physics talks on cellular immunology, malaria and viruses by Dr. Huw Colin-York (University of Oxford), Prof. Pietro Cicuta (University of Cambridge) and Prof. Rediun Twarock (University of York) respectively.

In the final session *Dr. Robyn Pritchard* (Cellular Highways) described his company's award-winning microfluidic device for sorting cells. He provided many valuable insights into how they have provided a state-of-the-art piece of instrumentation to sort cells at extremely high rates. The final speaker was Prof. Thomas Krauss (University of York) who considered the detection of bacterial infections using nanophotonics. Refractive index measurement could be performed relatively cheaply using miniaturized photonic devices e.g. spectrometers.

In summary, there is some excellent research being performed on the physics of infectious diseases in the UK. Although the meeting encouraged dialogue between medics and biophysicists, I found there continues to be a culture gap between researchers working in universities on the biophysics of infections and those treating patients in clinics. Translational research is clearly key to increase the impact of research in medically relevant biophysics, but there are a series of hurdles that need to be overcome for this to succeed. It is hoped that dialogue will continue between the two groups (biological physics and medical physics) and a series of future meetings on the physics of infection can be held to help bridge the gap between the two cultures.

Tom Waigh

From polymers to biomolecules: celebrating Dame Athene Donald's contributions to science and policy, September, 2022, Cambridge

Dame Athene Donald has been a driving force in developing the growth of biological physics research and teaching in the UK, and indeed was the IoP Biological Physics Group's (BPG) inaugural Chair at its inception a decade ago. This September, delayed multiple times due to the pandemic, we finally celebrated Athene's contributions both to science and to policy in a 2 day meeting at Churchill Collage, Cambridge, at which she is the Master, jointly host by the Polymer Physics Group and BPG, with participants and speakers drawn from Athene's many academic friends and colleagues.

Richard Jones (University of Manchester) gave a wonderful overiew of AThene's career, starting from here early work investigation the material properties of industrially-extruded starch matrices (the "Cheesy Wotsits Years") through to her more recent research on biopolymer physics. We then had contributions from Paul Meredith (University of Swansea) talking on aspects of microscopy, and Aline Miller (University of Manchester) and Jamie Hobbs (University of Sheffield), both previous BPG committee members, talking on the alignment of Athene's work with modern

biological physics from their perspectives. Richard Jones then chaired a really valuable panel discussion focussing on the benefits of interdisciplinary working for science, and the institutional and cultural barriers that stand in its way, with panellists Matin Durrani (Editor, Physics World), Veronica Strang (Durham University) and Mark Leake (University of York, and current BPG Chair). Day 1 was concluded with a fantastic college dinner, and some heart-felt reflections from Athene afterwards, in particular talking candidly of the challenges of women progressing in STEM, and more personally of her own experiences of imposter syndrome. Day 2 started with valuable research insights into biological physics from Alison Smith (John Innes Centre, Norwich) and electronic materials from Sir Richard Friend (University of Cambridge), then followed with a valuable panel discussion on raising the profile of equality, diversity and inclusion in science, asking the questions how far have we come, and what remains to be done, with panellists of Dame Julia Higgins (Imperial College, London), Beth Bromley (Durham University) and Helen Gleeson (University of Leeds). We then concluded the meeting with polymer physics insight from Joe Keddie (University of Surrey) and Tony Ryan (University of Sheffield).
A really super celebration of an enormously valuable career that has not only transformed the biological physics landscape in the UK, but really helped to improve the diversity of researchers more generally in physics.
Mark Leake

This two day conference celebrated the work of Dame Professor Athene Donald on her retirement from the department of physics at the University of Cambridge. Athene was the founding chair of the biological physics group of the IOP and was instrumental in its creation. She has a huge list of other achievements: fellow of the Royal Society, first female professor in the Cavendish laboratory, L'Oréal award for women in science 2009, ……
I was a PhD student in Athene's group in the late 1990s and, from a purely selfish perspective, I really enjoyed the event, because I met a number of old friends I had not seen in 20 years. It reminded me of how much I had enjoyed working under Athene's guidance and the great environment for research she had created at the Cavendish laboratory.
The speakers for the conference were illustrious and they gave excellent overviews of their research careers and the key role Athene had played in their lives. In addition to keynote talks on areas to which Athene has directly contributed (polymer mechanics, electron microscopy, starch, food and polymer electronics), two panel discussions were held on *interdisciplinary working in science* and the *profile of equality, diversity and inclusion in science*; key areas in which Athene has been an important voice in our community. Much progress has been made in these two areas, but much more is still required and the whole community needs to be active in their development.
It was heart warming to see the esteem and affection held for Athene by our community and we hope she will continue to contribute to the field of biological physics in the UK and beyond.
Tom Waigh

Upcoming meetings

Physics of Life 2023, Harrogate UK

Abstract submission deadline: 23 January 2023: https://iop.eventsair.com/physics-of-life/
Featuring early career event and satellite meetings.

Motility in microbes, molecules and matter: *23 January 2023, Edinburgh*
We're looking forward to a bilateral programme of talks on biological topics, including dynamic structures within biofilms, and computational physics approaches, including dynamic density functional theory, multiparticle collision dynamics, agent-based bacilliform models, machine learning and phase-field models.

Physics of Emergent Behaviour: *30-31 March 2023, Harrogate*
Satellite meeting to Physics of Life 2023.
The Physics of Emergent Behaviour (PoEB) IV conference is the fourth edition of the successful IOP PoEB conference series. There will be four themes: i) tissues & organs, ii) membranes, iii) cytoskeleton, and iv) cytoplasm and nucleoplasm.

Interdisciplinary Challenges: from non-Equilibrium Physics to Life Sciences: *17-23 April 2023, Rome*
This is a workshop organized by early-career researchers, for early-career researchers who are tackling interdisciplinary challenges in Physics, Biology, and Chemistry.
https://www.interchall2023.com/

Organoids on a chip: *21 April 2023, IOP, London*
Recent years have witnessed rapid progress in the development of "lab-on-a-chip" devices which combine microfluidics and cell culture techniques to create model systems of healthy and diseased tissues. This meeting is intended to bring together researchers from physics, biology, and engineering who develop and use organoid-based models to study biomedical and biophysics problems. The meeting will offer an opportunity to learn about recent technological advances in setting up organoid models in microfluidic devices, and novel questions that can be addressed using such systems.

Super-resolution imaging workshop: *7 July 2023, Leeds*
https://www.rms.org.uk/rms-event-calendar/super-resolution-workshop-.html