UK–JAPAN
FRONTIERS OF SCIENCE MEETING

17 – 19 JUNE 2025

Organised by the Royal Society and the
Japan Society for the Promotion of Science.

THE ROYAL SOCIETY

JAPAN SOCIETY FOR THE PROMOTION OF SCIENCE · FOUNDED 1932 ·

FRONTIERS OF SCIENCE

This meeting is part of the Royal Society scientific programme – connecting scientists from around the world in discussions which influence their field and inspire future research opportunities.

The abstracts in this booklet are provided by the presenters and the Royal Society takes no responsibility for their content.

Cover image

Botanical study of box-leaved holly, also known as Japanese holly, *Ilex crenata* (*Bruscus vel ruscus*). The plant is native to Japan and Korea. Plate 155 from Elizabeth Blackwell's (1707 – 1758) *Vermehrtes und verbessertes Blackwellisches Krauter-Buch*..., volume two, 1750; the German version of her *A Curious Herbal* (1737 – 1739), a reference work on medicinal plants.

June 2025 DES9247_3

Welcome

Dear participant,

Welcome to this UK-Japan Frontiers of Science meeting organised by the Royal Society and the Japan Society for the Promotion of Science.

We are delighted to be partnering to deliver this meeting; an early career researcher (ECR) focused three-day scientific workshop taking place in London on Tuesday 17 – Thursday 19 June 2025.

The meeting programme has been planned by an organising committee made up of the following Planning Group Members:

- Dr Dimitra Kosta, University of Edinburgh, UK
- Dr Kaneko Miki, Kyushu University, Japan
- Dr Mitsuaki Takemi, Hiroshima University, Japan
- Dr Chris MacDonald, University of York, UK
- Dr Ross Anderson, University of Oxford, UK
- Dr Hideko Takayanagi, Tohoku University, Japan
- Professor Yoshifumi Nakata, Kyoto University, Japan
- Dr Youngchan Kim, University of Surrey, UK
- Dr Alice Bowen, The University of Manchester, UK
- Professor Keiichi Inoue, The University of Tokyo, Japan
- Professor Masato Yamamichi, National Institute of Genetics, Japan
- Professor Thomas Gorochowski, University of Bristol, UK

Frontiers of Science meetings are designed to bring together outstanding ECRs providing them with the opportunity to showcase their work and gain insights into cutting-edge research taking place in other academic disciplines. Our objective is to build and strengthen scientific ties between ECRs from the UK and Japan, and to provide opportunities for knowledge sharing, networking and peer-on-peer scientific discussion on areas of scientific strength and where further collaboration might be possible.

We appreciate your time and hope that this meeting proves insightful, enjoyable and collaborative.

Contents

The Royal Society

The Royal Society is a self-governing Fellowship of many of the world's most distinguished scientists drawn from all areas of science, engineering, and medicine. The Society's fundamental purpose, as it has been since its foundation in 1660, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity.

The Society's strategic priorities emphasise its commitment to the highest quality science, to curiosity-driven research, and to the development and use of science for the benefit of society. These priorities are:

- The Fellowship, Foreign Membership and beyond
- Influencing
- Research system and culture
- Science and society
- Corporate and governance

For more information, visit: **royalsociety.org**

The Japan Society for the Promotion of Science

Japan Society for the Promotion of Science (JSPS) was established in 1932 with an endowment from the Emperor Showa for the promotion of science. After undergoing changes of its legal status, it is currently the core research funding agency in Japan which supports scientific research of all fields established under the national law.

At present, JSPS's program rests on five pillars: (1) creating knowledge in diverse and profound fields; (2) fostering next generation of researchers who challenge the creation of new genres of knowledge; (3) strengthening the support base for science promotion in universities and research institutions; (4) strengthening of international research networks; and (5) strengthening the support base for science promotion.

Various programs of JSPS are operated on a budget issued from Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) and are implemented by fair and impartial peer review by top researchers. To be selected for JSPS programs is considered achieving high status among researchers.

Main programs of JSPS

- Grants-in-Aid for Scientific Research (KAKENHI): These grants support research based on the free ideas of researchers. Every year, there are about 90,000 applications, and through impartial selection, about 80,000 projects are implemented each year, including continuing ones. It is the most important grant which supports the research activities of researchers in Japan.
- Research Fellowships for Young Researchers: These are the core fellowship programs which foster top-class researchers in Japan, who are about to obtain or have just obtained their doctoral degree. Recently, this fellowship has been granted every year to more than 5,000 researchers who have been selected through highly competitive selection, allowing young researchers to conduct research in a self-directed way. For students in Japan aspiring to become researchers, acquiring this fellowship is considered a gateway to success.
- International Collaboration Programs: JSPS implements programs for international research activities based on cooperative relationships with 97 counterpart organizations worldwide. These include programs supporting the formation of international research hubs, fellowship programs for foreign researchers to conduct research activities in Japan, and symposiums where internationally active young researchers discuss and create networks. Under these programs, about 3,000 foreign researchers are invited to Japan and about 5,500 researchers are sent overseas from Japan in 2019.
- JSPS Prize: JSPS awards the JSPS Prize to about 25 young Japanese researchers who play an active part in the world's top-level research arena and encourages them to advance their research.
- JSPS Overseas Offices: JSPS Overseas Offices in 10 cities in 9 countries, such as the JSPS Washington Office, JSPS San Francisco Office and the JSPS Bonn Office, cooperate with science promotion organizations in each country. They also support the international activities of Japanese universities.

In addition to the above, JSPS provides various programs for researchers both in Japan and overseas to advance scientific research. For details, visit the following site: https://www.jsps.go.jp/english/

Programme

Tuesday 17 June 2025

9am	**Registration**
9.30am	**Welcome and introduction**
10am	**Session 1: Maths/Applied Maths/Informatics: Singular learning theory** Chaired by Dr Dimitra Kosta, University of Edinburgh, UK and Dr Kaneko Miki, Kyushu University, Japan
10.05am	**Introduction of Singular Learning Theory and Algebraic Geometry** Dr Kenji Nagata, National Institute for Materials Science, Japan
10.25am	**Tropical Geometry in Statistics, Machine Learning, and AI** Dr Anthea Monod, Imperial College London, UK
10.45am	**On assessing generalisation performance in various predictive scenarios** Professor Keisuke Yano, The Institute of Statistical Mathematics, Japan
11.05am	**Discussion**
12pm	**Publishing and grants presentation**
12.30pm	**Group photo**
12.45pm	**Lunch**
1.45pm	**Session 2: Medical/Neuroscience: Non-conventional organismal biology** Chaired by Dr Mitsuaki Takemi, Hiroshima University, Japan and Dr Chris MacDonald, University of York, UK
1.50pm	**Unlocking biological time: insights from the naked mole-rat and the turquoise killifish** Professor Kyoko Miura, Kumamoto University/Kyushu University, Japan
2.10pm	**Genome evolution of Germline restricted DNA in fungus gnats** Dr Kamil Jaron, Tree of Life Programme, Wellcome Sanger Institute, UK
2.30pm	**Chrono-Developmental Biology: Exploring the Blueprint of Time via Killifish Diapause** Dr Oginuma Masayuki, RIKEN, Japan
2.50pm	**Discussion**
3.45pm	**Break**
4.15pm	**Poster flash talks 1** Odd poster numbers presenting
5pm	**Poster session 1** Odd poster numbers on display
6.30pm	**Formal networking dinner**

Wednesday 18 June 2025

8.30am **Session 3: Earth Science/Environment: Resourcing society: metals for the future**
Chaired by Dr Ross Anderson, University of Oxford, UK and Dr Hideko Takayanagi, Department of Earth Science, Graduate School of Science, Tohoku University, Japan

8.35am **From Rocks to Renewables: Earth Science and the Future of Metals**
Dr Frances Cooper, University College London, UK

8.55am **Critical metal resources on the seafloor as a key to a sustainable future**
Dr Kazutaka Yasukawa, The University of Tokyo, Japan

9.15am **Microbes as mineral engineers: sustainable pathways for resource recovery and advanced material synthesis**
Professor Julie Cosmidis, University of Oxford, UK

9.35am **Discussion**

10.30am **Poster flash talks 2**
Even poster numbers presenting

11.15am **Poster session 2**
Even poster numbers on display

12.45pm **Lunch**

1.45pm **Session 4: Physics/Astrophysics: Quantum information science and technology 2025**
Chaired by Professor Yoshifumi Nakata, Yukawa Institute for Theoretical Physics, Kyoto University, Japan and Dr Youngchan Kim, University of Surrey, UK

1.50pm **Quantum Biology in Photoactive Proteins**
Dr Youngchan Kim, University of Surrey, UK

2.10pm **Simulating Quantum Systems with Quantum Computers: New Approaches for Understanding Materials and Fundamental Physics**
Dr Kosuke Mitarai, The University of Osaka, Japan

2.30pm **Development of Quantum Sensors for the detection of human biomagnetism**
Dr Anna Kowalczyk, University of Birmingham, UK

2.50pm **Discussion**

3.45pm **Out of venue group event**

7pm **Dinner**

Thursday 19 June 2025

8.30am **Session 5: Chemistry/Material Science: Experimental and computational exploration of three-dimensional biological structures**
Chaired by Dr Alice Bowen, The University of Manchester, UK and Professor Keiichi Inoue, The University of Tokyo, Japan

8.35am **Cinematography of enzymatic reactions at atomic resolutions**
Dr Junpei Yamamoto, The University of Osaka, Japan

8.55am **Inhibition of fusidic acid resistance through restricting conformational flexibility in domain III of EF-G identified using NMR methyl relaxation dispersion**
Dr Jennifer Tomlinson, University of Leeds, UK

9.15am **Computational Protein Structure Prediction and Design**
Dr Takahiro Kosugi, Institute for Molecular Science, National Institutes of Natural Sciences, Japan

9.35am **Discussion**

10.30am **Break**

10.45am **Session 6: Biology/Life Science: Experimental evolution to understand and engineer life**
Chaired by Professor Masato Yamamichi, National Institute of Genetics, Japan and Professor Thomas Gorochowski, University of Bristol, UK

10.50am **Experimental evolution as a guide to building predictable adaptive paths**
Professor Tiffany Taylor, University of Bath, UK

11.10am **Exploring life's origins through experimental evolution**
Dr Ryo Mizuuchi, Waseda University, Japan

11.30am **Predicting bacterial evolution to engineer novel biotechnologies and understand AMR**
Professor Harrison Steel, University of Oxford, UK

11.50am **Discussion**

12.45pm **Closing session**

1.15pm **Farewell lunch**

2.15pm **Meeting close**

Meeting day 1
Tuesday 17 June 2025

Welcome and introduction

Sir Mark Walport FRCP FMedSci HonFRSE FRS
Foreign Secretary and Vice President, the Royal Society, UK

Sir Mark Walport is Foreign Secretary and Vice President, the Royal Society. He chairs Imperial College Health Partners, Imperial College Academic Health Sciences Centre and the Kennedy Memorial Trust. He is a non-executive board member of NHS England, and trustee of the British Museum, the Daiwa Anglo-Japanese Foundation, and Health Data Research UK.

Previous career highlights include:
Founding Chief Executive of UK Research and Innovation 2017 to 2020
Government Chief Scientific Adviser 2013 to 2017
Member and latterly co-chair of the Prime Minister's Council for Science and Technology
Director of the Wellcome Trust
Professor and Head of the Division of Medicine, Imperial College London
Founder Fellow and first Registrar of the Academy of Medical Sciences
Member of the Advisory Board of Infrastructure UK

Dr Mizumoto Tetsuya
Executive Director, the Japan Society for the Promotion of Science, Japan

Mizumoto Tetsuya was awarded a Bachelor of Engineering degree in Electrical and Electronic Engineering in March 1979, a Master of Engineering degree in Physical Electronics in March 1981, and a Doctor of Engineering degree in Electrical and Electronic Engineering in March 1984, all from the Tokyo Institute of Technology (Tokyo Tech), Tokyo, Japan.

He began working for Tokyo Tech in April 1984 as a research associate in the Faculty of Engineering and became an associate professor in March 1987. He was promoted to full professor with the Graduate School of Engineering in April 2004. From October 2012 to March 2018, he served as Vice-President for Education at Tokyo Tech, and became Executive Vice-President for Education in April 2018. In October 2021, he began serving as Executive Director at Japan Society for the Promotion of Science (JSPS), while working at Tokyo Tech. He retired from Tokyo Tech in March 2022. Currently, he is serving as Executive Director at JSPS.

His research fields are applied optics, photonic circuits, and information and communication engineering. His research activity has been concerned mainly with waveguide optical devices, especially magneto-optic devices and all-optical switching devices based on the third-order optical nonlinearity.

Dr Mizumoto received the Treatise Award in 1994 and the Best Letter Award of Electronics Society Transactions in 2007 from the Institute of Electronics, Information and Communication Engineers (IEICE). He was awarded the Institute of Electrical and Electronics Engineers (IEEE) Photonics Society Distinguished Lecturer Awards in July 2009, IEEE Fellow grade for “Contributions to investigations of waveguide optical nonreciprocal devices for optical communications” in January 2012, and IEICE Achievement Award for “Pioneering work on optical nonreciprocal circuits” in May 2012. He is a fellow of IEICE, member of the Japan Society of Applied Physics, and the Magnetic Society of Japan.

Session 1
Maths/Applied Maths/Informatics: Singular learning theory

PGM: Ms Miki Kaneko
Kyushu University, Japan

Miki Kaneko is an Associate Professor of Graduate School of Information Science and Electrical Engineering at Kyushu University. Her key areas of work and research focus on bio signal processing, medical informatics, life sciences and biomedical engineering. Her work focuses specifically on the healthcare monitoring with wearable biosensors. Bio signals include electrocardiogram (ECG), electroencephalogram (EEG), electromyography (EMG), respiratory signals, body and gaze movements, and daily behavioural patterns. These signals constantly carry an important information about the mental and physical health and are used to assess mental workload states, emotional states and health states. Her research aims are to investigate the characteristics and the mechanisms of bio signals through the analysis of the signals and to develop novel methods for applying life sciences, medicine, education, artistic culture and sports.

PGM: Dr Dimitra Kosta
University of Edinburgh, UK

Dimitra Kosta is a Royal Society Dorothy Hodgkin Research Fellow at the School of Mathematics of the University of Edinburgh. Her research initially focused on birational geometry; however, over time, her interests have evolved to encompass the intersection of algebra, geometry, and statistics. She has broadened her research scope to include areas such as algebraic statistics, phylogenetic algebraic geometry, computational commutative algebra, and applied algebraic geometry.

Her education and research experience span several institutions, the University of Ioannina, the University of Edinburgh, the University of Vienna, and the University of Glasgow, where she has engaged in training and research at undergraduate, doctoral, postdoctoral, and independent researcher levels. She is a founding member of the Applied Algebra and Geometry UK network, which seeks to bring together UK-based academics interested in applications of algebra and geometry.

Introductory speaker: Dr Kenji Nagata
National Institute for Materials Science, Japan

Kenji received his PhD in Engineering from Tokyo Institute of Technology in 2008. The title of his dissertation is Theory of Exchange Monte Carlo Method and Application to Bayesian Learning. Since then, he has worked at the University of Tokyo and the National Institute of Advanced Industrial Science and Technology and will join the National Institute for Materials Science in 2019. His original research theme was the development of algorithms for Bayesian inference via singular learning theory and MCMC methods, but he has also been actively working on data-driven approaches for experimental and measurement data in the natural sciences. He is currently working on the development of data-driven methodologies in materials development.

Introduction of Singular Learning Theory and Algebraic Geometry

It is fresh in our minds that the Nobel Prizes in Physics and Chemistry for 2024 were awarded in the field of AI [1]. The main technology of those prizes was the proposal and utilisation of deep neural networks. The term “Learning Theory” in this session title refers to the field of mathematics and statistics that attempts to theoretically analyse the learning efficiency and learning performance of such deep neural networks.

In learning from given data, the amount of data naturally leads to the stability of the estimation. This is similar to the behaviour of thermodynamics with respect to temperature. At low temperatures, the motion of atoms and other elements tends to be smaller, and the overall system tends to have a stable structure like a solid. Such a picture can be equated with the fact that estimation becomes stable when more data is available, leading to a theoretical clarification of the learning properties of statistical models. By taking advantage of this fact, conventional Learning Theory has been advanced by utilising Gaussian approximation around one point of model parameter when there is a sufficient amount of data.

However, a problem arises when trying to utilise it directly for neural network training. In neural networks, there is no one-to-one correspondence between parameters and model behaviour. Therefore, the model parameters are not fixed at a single point when there is a sufficiently large amount of data. Furthermore, the parameter set forms a manifold including singular points in the parameter space. The learning theory of such neural networks requires a departure from analysis centred on Gaussian approximation. This is a very difficult subject. The name “Singular Learning Theory” was coined as a field to discuss learning theory for models with such singularities. Professor Sumio Watanabe, a pioneer in this field, used algebraic geometry as a technique for this analysis [2]. Algebraic geometry is a field of mathematics that discusses manifolds as solutions to (polynomial) = 0. It has a high affinity as a technique for handling manifolds in the parameter space of neural networks.

In this talk, I will introduce Professor Sumio Watanabe's contributions to Singular Learning Theory. As an example, I will introduce his work on Bayesian inference, in which he clarified the asymptotic behaviour of Bayesian free energy under the condition that the number of data is sufficiently large [2], and the information criterion, WAIC [3] and WBIC [4], which were proposed based on his theory.

[1] https://www.nobelprize.org/all-nobel-prizes-2024/
[2] S. Watanabe, Neural Computation, Vol.13, No.4, pp.899-933, 2001.
[3] S. Watanabe, Journal of machine learning research, Vol.11, No.12, pp.3571-3594, 2010.
[4] S. Watanabe, Journal of machine learning research, Vol.14, pp. 867-897, 2013

Session speaker: Dr Anthea Monod
Imperial College London, UK

Anthea Monod is a mathematical data scientist specialising in the application of pure mathematics to machine learning and data analysis. Her work leverages algebraic topology and algebraic geometry to address challenges in deep learning, neural networks, biomedical image analysis, viral and cancer evolution, social networks, and beyond. As a Lecturer in the Department of Mathematics at Imperial College London, she leads a dynamic research group of 14 postdoctoral researchers, PhD and MSc students, and undergraduate researchers. Anthea is also the Imperial Principal Investigator for the £10m EPSRC grant focused on establishing the Mathematical and Computational Foundations of Artificial Intelligence.

Tropical Geometry in Statistics, Machine Learning, and AI

Tropical geometry is a piecewise linear, polyhedral and combinatorial variant of classical algebraic geometry and has been a powerful tool in modern challenges arising in geometric statistics, machine learning, and deep learning. In this talk, I will overview some recent advances where tropical geometry has been used in statistical analyses for phylogenetic trees; modelling neural networks; understanding aspects of theoretical machine learning including expressivity and adversarial machine learning; as well as proposing novel graph kernels that outperform existing methods.

Session speaker: Professor Keisuke Yano
The Institute of Statistical Mathematics, Japan

Professor Keisuke Yano is interested in statistics and its applications. Keisuke's research topics include Bayesian methodologies, information geometry, machine learning, predictive densities, seismology and geodesy, and stochastic processes. His theoretical work includes extending Widely-applicable information criterion (WAIC) to various predictive settings, analysing WAIC in overparameterized models, information-geometrical characterization of posterior distributions, constructing Bernstein--von Mises theorem and prediction theory in high dimension, and analysing an embedding structures in determinantal point processes in seismology and geodesy, he contributes to detecting short-term slow slip events and developing graph-based convolutional networks for earthquake detection from seismic waveform data. Keisuke likes bridging theoretical statistical advancements with practical applications, addressing real-world problems while advancing statistical methodologies.

On assessing generalisation performance in various predictive scenarios

Assessing generalisation performance is a central concern in data-science research. Since Akaike introduced the information criterion (AIC), many techniques, most notably cross validation, have been developed to estimate out-of-sample predictive accuracy. Yet, the recent success of deep neural networks has put singular learning machines, whose parameterisations are not uniquely determined, and unfortunately, classical criteria often break down in this setting.

Watanabe's Widely Applicable Information Criterion (WAIC) [1] provides the first theoretically sound assessment tool for singular models. WAIC relies only on the posterior variances of sample-wise log-likelihoods, so it can be obtained from a single Bayesian simulation on the full data set; this avoids the repeated retraining required by conventional cross validation.

In this talk, I survey several recent extensions of WAIC that accommodate modern predictive scenarios: Weighted inference like covariate-shift adaptation; Learning with over-parameterised models that has overabundant model parameters [3]; Evaluation with general loss functions that move beyond log-likelihood to task-specific risk measures [4].

[1] S. Watanabe. Equations of states in singular statistical estimation. Neural Networks, 23:20–34, 2010.
[2] Y. Iba and K. Yano, Posterior Covariance Information Criterion for Weighted Inference, Neural Computation, vol. 35, 1340–1361, 2023.
[3] A. Okuno and K. Yano, A generalization gap estimation for overparameterized models via Langevin functional variance, Journal of Computational and Graphical Statistics, vol. 32, 1287-1295, 2023.
[4] Posterior Covariance Information Criterion for arbitrary loss functions (with Y. Iba; arXiv:2206.05887; in minor revision)

Session 2
Medical/Neuroscience: Non-conventional organismal biology

PGM: Dr Mitsuaki Takemi
Hiroshima University, Japan

Mitsuaki Takemi is an Associate Professor in the Biological Systems Engineering Laboratory at Hiroshima University. His research focuses on the neural process of learning and control of physical movement and on the potential of non-invasive neural stimulation to enhance these processes. Neuroimaging, kinematic analysis, and computational modelling are also his main research tools. Besides, he has led a project to accumulate evidence on the safety and effectiveness of neurotechnologies such as neurofeedback and neuromodulation since August 2022. The project team consists of approximately 40 early to mid-carrier researchers and will conduct 12 systematic reviews by the end of 2025.

PGM: Dr Chris MacDonald
University of York, UK

Chris completed his undergraduate degree (Biomedical Science) and PhD (Molecular Cell Biology) at the University of Glasgow before starting an American Heart Association fellowship at the University of Iowa (Molecular Physiology & Biophysics). Chris moved to the University of York in 2017 as a lecturer in Biomedical Science and Sir Henry Dale Fellow, funded by the Royal Society and Wellcome Trust.

The focus of the MacDonald lab is to understand how cell surface membrane proteins are trafficked through the cell, using yeast as a model to discover and define fundamental trafficking mechanisms.

Introductory speaker: Professor Kyoko Miura
Kumamoto University/Kyushu University, Japan

Dr Kyoko Miura is a professor at the Faculty of Medical Sciences, Kyushu University, where she leads the Laboratory of Longevity and Stem Cell Biology. She also holds a concurrent appointment at Kumamoto University as a professor at the Faculty of Life Sciences. Dr Miura is a pioneering researcher in the biology of long-lived mammals, with a particular focus on the naked mole-rat—the longest-lived rodent, renowned for its exceptional resistance to aging, cancer, and other age-related diseases. Her laboratory maintains one of the world’s largest colonies of this species. By integrating molecular biology, stem cell technology, and comparative biology, Dr Miura seeks to uncover the mechanisms underlying extended health span and resistance to age-related diseases, with the ultimate goal of translating these insights into innovative strategies to promote human health and longevity.

Unlocking biological time: insights from the naked mole-rat and the turquoise killifish

With the rapid advances in next-generation sequencing and genome editing technologies, research on non-conventional or 'non-model' organisms has expanded significantly in recent years. These developments are opening new avenues to explore biological phenomena that were previously difficult to study using standard laboratory animals alone. This session highlights two fascinating non-model animals that exhibit unique ways of controlling biological time. The naked mole-rat, the longest-lived rodent, shows little sign of aging and is highly resistant to age-related diseases such as cancer and Alzheimer's disease–maintaining a youthful state for most of its life. Meanwhile, the turquoise killifish is a small fish that can enter a long-term dormant state in response to environmental changes, effectively 'pausing time' during early development. Studying these unusual animals provides valuable insights into how living organisms manage biological time. In this talk, I will introduce recent advances in non-conventional organism research and present our study on the mechanisms of aging and disease resistance in the naked mole-rat.

[1] The Naked Mole-Rat as a Model for Healthy Aging. Oka K, Yamakawa M, Kawamura Y, Kutsukake N and Miura K. Annu. Rev, Anim. Biosci 15:11:207-226. 2023.
[2] Cellular senescence induction leads to progressive cell death via the INK4a-RB pathway in naked mole-rats. Kawamura Y, Oka K, Miura K. et al. EMBO J. 15;42(16):e111133. 2023

Session speaker: Dr Kamil Jaron
Tree of Life Programme, Wellcome Sanger Institute, UK

Kamil did his PhD on the evolution of genomes of parthenogenetic animals at the University of Lausanne, and a postdoc on paternal genome elimination at the University of Edinburgh. Right now, he is a group leader at the Wellcome Sanger Institute focusing on genomics of reproduction as well as development of scalable methods that unlock analyses of complicated genomes.

Genome evolution of Germline restricted DNA in fungus gnats

Germ-line restricted chromosomes are chromosomes that are eliminated from all somatic tissues but retained in the germline. They are found in several taxa often conserved among large number of species. In dark-winged fungus gnats, these chromosomes are found in vast majority of species across the whole family suggesting their origin in their common ancestor more than 50 mya. We have sequenced the germ-line of three species and reconstructed these chromosomes to study their origin and evolutionary trajectory. They happen to be large chromosomes that contain thousands of genes. Phylogenetic reconstruction indicated that most of them originated via an ancient introgression from a distantly related dipteran family of gall midges that also shows germ-line restricted chromosomes which indicates the evolutionary origin of these peculiar genomic features in the family. Furthermore, the germ-line restricted chromosomes show very dynamic evolution and only very little preserved synteny between species creating a perplexing paradox of deeply conserved, but yet very dynamic chromosomal system.

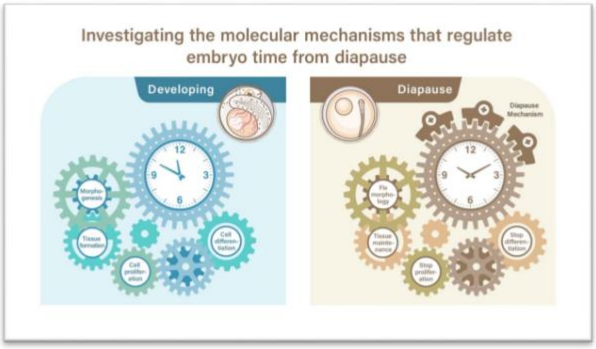
Session speaker: Dr Oginuma Masayuki

RIKEN, Japan

Dr Masayuki Oginuma is a developmental biologist and Team Leader of the Chrono-Developmental Biology Laboratory at the RIKEN Center for Biosystems Dynamics Research. He earned his PhD in Science and has held postdoctoral positions at the National Institute of Genetics and other research institutions. Dr Oginuma's research focuses on the genetic and molecular mechanisms that regulate embryonic timing, particularly the phenomenon of diapause in the turquoise killifish (Nothobranchius furzeri). His work aims to uncover how organisms can pause and resume development, shedding light on the ‘blueprint of time’ encoded in genes. By developing innovative methods to analyse gene dynamics, his lab seeks to apply these findings to broader biological contexts, enhancing our understanding of developmental biology across species.

Chrono-Developmental Biology: Exploring the Blueprint of Time via Killifish Diapause

Organisms possess a remarkable “blueprint of time” that orchestrates embryonic development—from fertilization to body formation—according to a precisely regulated genetic clock. However, the molecular mechanisms underlying this temporal regulation remain largely unknown. The African turquoise killifish Nothobranchius furzeri, which inhabits ephemeral ponds, has evolved the ability to enter diapause—a unique developmental arrest that pauses this embryonic clock for extended periods. Our laboratory is focused on uncovering the molecular basis of diapause, a highly specialized mechanism for suspending embryonic time. We have established a rapid and efficient method for functional analysis of genes in the turquoise killifish, allowing us to investigate the genetic regulation of embryonic timing in unprecedented detail. By analysing the dynamics and functions of candidate genes involved in diapause, we aim to elucidate the full picture of the “blueprint of time.” Ultimately, we seek to extend our findings to understand temporal regulation across diverse species. In this meeting, I will present novel findings on embryonic clock mechanisms revealed through studies of diapause.



[1] Oginuma M, Nishida M, Ohmura-Adachi T, et al. Rapid reverse genetics systems for Nothobranchius furzeri, a suitable model organism to study vertebrate aging.
*Scientific Report*s, 12(1), 11628 (2022)

Meeting day 2
Wednesday 18 June 2025

Session 3
Earth Science/Environment: Resourcing society: metals for the future

PGM: Dr Ross Anderson
University of Oxford, UK

Ross Anderson is a Royal Society University Research Fellow at the University of Oxford's Museum of Natural History, and a Fellow of All Souls College. He received a bachelor’s degree (2012) in Earth and Planetary Sciences from Harvard University, before master’s (2014) and doctoral (2017) degrees in Geology and Geophysics from Yale University. At Yale, his doctoral work was funded by a NASA Earth and Space Science Fellowship. His work uses exceptionally preserved fossils to track the emergence of complex eukaryotic life on our planet. Ross also works to understand the chemical pathways leading to exceptional fossil preservation so that we can more easily target geological successions and begin to recognise the record’s bias. Ross was a recipient of the President’s Prize of the Palaeontological Association in 2017.

PGM: Dr Hideko Takayanagi
Department of Earth Science, Graduate School of Science, Tohoku University, Japan

Dr Hideko Takayanagi is an Associate Professor at Department of Earth Science, Tohoku University, Japan. She is interested in changes in ocean circulation and ventilation dynamics under climate changes on various time scales, such as recent global warming, glacial-interglacial cycles, and greenhouse and icehouse Earth in the Phanerozoic. To understand the roles of the oceans in the Earth’s climate system, she establishes and/or improves a method for paleoenvironmental analyses of sedimentological, crystallographical, and geochemical records in carbonate (CaCO3) sediments, crystals, and fossils and reconstructs water mass structure/conditions and composition of surface to intermediate waters in the past Pacific and Indian oceans. In April 2024, she joined the Advanced Institute for Marine Ecosystem Change (WPI-AIMEC), a joint organisation of Tohoku University and JAMSTEC, and started studying marine biogeochemical cycle dynamics and its response to climate changes based on the geochemical composition of seawater and sediments.

Introductory speaker: Dr Frances Cooper
University College London, UK

Frances Cooper is a geologist whose research seeks to understand the mechanics of large-scale continental deformation, the evolution of mountain belts, and the interplay between tectonics and climate. Her work has spanned active normal faulting in the Gulf of Corinth, Greece, the exhumation of deeply buried rocks in Nevada USA, and the role of crustal extension in building the eastern Himalayas in Bhutan. In recent years, she has worked closely with the mining industry to understand how tectonics, magmatism, volcanism, and landscape evolution combine to control the formation, enrichment, and preservation of porphyry copper deposits, particularly in the Central Andes and the southwest USA.

From Rocks to Renewables: Earth Science and the Future of Metals

The global shift from fossil fuels to a low-carbon, resource-efficient green economy is essential to combat climate change but introduces complex environmental, economic, and societal challenges. Renewable technologies rely on metals such as copper, lithium, cobalt, and rare-earth elements, which are difficult to find and exist in low concentrations. Extracting them requires processing vast volumes of material and generating significant waste. We are thus confronted with the dual challenge of rapidly locating more deposits while prioritising those with the lowest environmental and societal impact. This requires a truly international collaboration between earth and environmental scientists, engineers, policymakers, and industry leaders to maximise new discoveries while minimising negative impacts.

Innovative methods offer potential solutions. Recent UK efforts to extract lithium from deep geothermal waters in Cornwall and new research into extracting copper from magmatic brines beneath volcanoes highlight sustainable alternatives. Seafloor metal deposits near Japan also offer great promise but carry significant environmental risks associated with deep-sea mining. However, realising these alternative resources is hindered by technological, political, and economic obstacles, meaning reliance on traditional mining from crustal rocks will continue for some time.

Exploration for such deposits, especially in poorly studied regions, is challenging and expensive, requiring large-scale efforts over hundreds of kilometres. Porphyry copper deposits serve as a key example, where the interplay between tectonic activity and climate significantly influences their formation and enrichment. Advancing our understanding of these processes will enhance our ability to target the most metal-rich deposits and support efforts to build a greener, more sustainable future.

Session speaker: Dr Kazutaka Yasukawa

The University of Tokyo, Japan

Dr Kazutaka Yasukawa is an Associate Professor at the Frontier Research Center for Energy and Resources, School of Engineering, The University of Tokyo. He earned his PhD in Engineering from The University of Tokyo in 2015. He worked as an assistant professor at the Department of Systems Innovation, School of Engineering, The University of Tokyo from 2015 to 2019, and as a lecturer at the current affiliation from 2019 to 2022. His research interests are in linkages between the genesis of seafloor mineral resources and global environmental changes. The goal of his research is to figure out the spatiotemporal distribution of industrially critical elements on Earth and provide a useful guide for the exploration and development of the resources for the sustainable development. He has specialist skills in geochemical analyses and multivariate statistical techniques.

Critical metal resources on the seafloor as a key to a sustainable future

Achieving a carbon-neutral society is an urgent challenge in addressing the ongoing climate change. Most of low-carbon technologies rely on critical metals such as rare-earth elements (REE) used in powerful magnets for electric vehicles and wind-power generator, or cobalt (Co) and nickel (Ni) for high-capacity lithium-ion batteries. However, these conventional, onshore mineral resources have severe problems, including oligopoly and resource nationalism, human rights violation (e.g., child labour), and environmental pollutions (e.g., radioactive wastes from light REE deposits associated with magmatic activity).

In recent years, seafloor mineral resources have attracted attention as a new source for such industrially critical metals. Especially, deep-sea sediments enriched in REE, called “REE-rich mud” [1], and “ferromanganese (Fe-Mn) nodules” that were precipitated from seawater and contain high concentrations of Co, Ni, or Cu [2] are widely distributed in the world ocean (Fig. 1). They have tremendous resource potential [2,3]. Developing these seafloor mineral resources will be implemented by nations or companies with good compliance, which can avoid severe issues involved with current onshore mines and, thus, can be a foundation of a sustainable future.

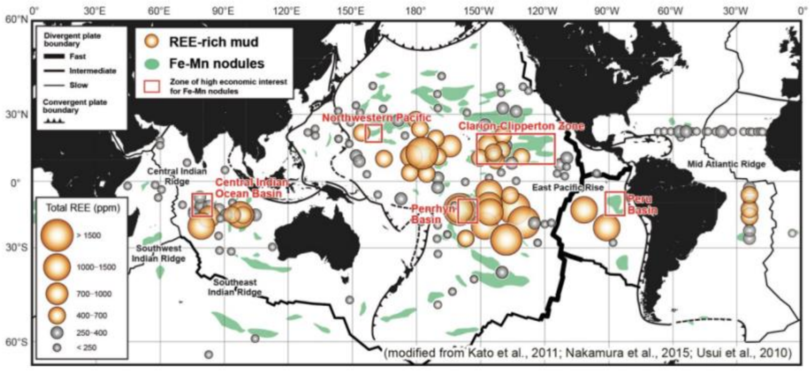


Figure 1. Global distribution of REE-rich mud (less than 2 m below seafloor) and ferromanganese nodules.

[1] Kato et al. (2011) Deep-sea mud in the Pacific Ocean as a potential resource for rare-earth elements. Nature Geoscience 4, 535-539.
[2] Hein et al. (2020) Deep-ocean polymetallic nodules as a resource for critical materials. Nature Reviews Earth & Environment 1, 158-169.
[3] Takaya et al. (2018) The tremendous potential of deep-sea mud as a source of rare-earth elements. Scientific Reports 8, 5763.

Session speaker: Professor Julie Cosmidis

University of Oxford, UK

Professor Julie Cosmidis is a geomicrobiologist whose research focuses on microbe-mineral interactions. She is currently leading the Microbe-Mineral laboratory in the Department of Earth Sciences at the University of Oxford, where she works as an Associate Professor. Before this position, she was a postdoctoral Research Associate at the University of Colorado in Boulder, and an Assistant Professor at Penn State University. Julie Cosmidis' research group focuses on deciphering the mechanisms controlling microbial biomineralization an organomineralization processes, using microscopy and spectroscopy combined with molecular methods. Her group is also working on potential applications of microbial biomineralization processes, such as advanced mineral biomanufacturing and metal biorecovery and bioremediation. Julie Cosmidis is currently leading the European Research Council (ERC) funded project BioFacts, which aims at developing new high-throughput methods to interrogate the genetic controls of microbial mineral formation, and to engineer and improve microbial biominerals for different technological applications.

Microbes as mineral engineers: sustainable pathways for resource recovery and advanced material synthesis

The accelerating global energy transition demands unprecedented quantities of critical metals, creating an urgent need for innovative extraction and recycling technologies. Microbial processes offer significant potential to address the widening gap between metal demand and supply, with important advantages in environmental footprint, energy requirements, and accessibility compared to conventional methods. Established bioleaching applications already deployed at industrial scales exist alongside promising emerging biotechnologies. Microbial biomineralization, the process through which bacteria produce mineral phases from diluted metal sources in diverse environments, represents a sustainable approach not only for metal bio-recovery and recycling, but also for toxic metal bioremediation, particularly in mining-impacted areas, with the potential to significantly reduce the negative environmental footprint of conventional mining industries. Additionally, these biomineralization pathways show considerable promise for processing and manufacturing advanced mineral materials for technological applications. Research efforts in our laboratory focus on elucidating the environmental parameters and genetic pathways governing microbial biomineralization processes. Through advanced analytical techniques, we are looking to develop a mechanistic understanding of microbial biomineralization processes, that will enable the engineering of microbial systems tailored to specific metal extraction and manufacturing contexts. Despite critical challenges including process optimization, scalability, and economic viability, microbial mineral biotechnologies may in the future contribute crucial solutions to both resource recovery and advanced materials fabrication in a more sustainable, circular bioeconomy.

Session 4
Physics/Astrophysics: Quantum information science and technology 2025

PGM: Professor Yoshifumi Nakata

Yukawa Institute for Theoretical Physics, Kyoto University, Japan

Yoshifumi Nakata is a researcher at the Yukawa Institute for Theoretical Physics, Kyoto University, specialising in theoretical quantum information science. His research delves into areas such as mathematical foundation of quantum information, quantum communication, and applications of quantum information techniques to theoretical physics. He has been contributing to the theoretical advancement of quantum technologies, and his work explores the potential of quantum phenomena for information processing and communication.

PGM and Introductory speaker: Dr Youngchan Kim

University of Surrey, UK

Youngchan is a Lecturer in Quantum Biology from the School of Biosciences and Director of the Quantum Biology Doctoral Training Centre at the University of Surrey, UK. He leads an interdisciplinary research group investigating how quantum mechanical effects play a role in biological processes. His group uses time-resolved spectroscopy, molecular biology, and quantum optics techniques to study energy transfer dynamics and develop fluorescent protein based biosensor technologies for biology and medicine research.

Quantum Biology in Photoactive Proteins

Quantum Biology explores the profound role in biological processes, an emerging frontier that complements classical biological frameworks. While classical approaches provide a valuable framework for investigating living systems, they often fail short in explaining phenomena where quantum effects, such as superposition, tunnelling, and entanglement, are thought to be crucial. This includes the remarkable near-unity efficiency of photosynthesis, the sensitivity of magnetoreception in migrating animals, the speed and specificity of enzyme catalysis, and the effects of weak magnetic fields in biological systems. Explicitly incorporating quantum principles offers a powerful avenue to advance our understanding of life at the molecular and quantum levels. This deeper insight into quantum biology holds significant promise for the development of quantum biotechnology, leading to innovative technologies such as quantum-enhanced biosensing and novel room-temperature, protein-based single photon sources. This talk will present the state-of-the-art developments in investigating quantum biology, focusing on photoactive proteins like fluorescent proteins and photosynthetic light harvesting complexes. I will also introduce this fascinating and rapidly evolving field of quantum biology and discuss its potential implications for future advancements in quantum biotechnology.

Session speaker: Dr Kosuke Mitarai

The University of Osaka, Japan

Kosuke Mitarai is an Associate Professor at Osaka University, specialising in quantum computing and quantum algorithm. He received his PhD in Engineering Science from Osaka University in 2020 and has since focused on developing algorithms for near-term quantum devices. His work spans quantum machine learning, quantum simulation, and quantum chemistry. In 2018, he co-founded QunaSys, a startup dedicated to quantum software for practical applications. He has been recognised by several awards including Forbes 30 Under 30 Asia and Innovators Under 35 Japan. With a commitment to interdisciplinary collaboration, he actively engages in both theoretical research and experimental implementation, contributing to the advancement of quantum technologies and their integration into real-world problem-solving.

Simulating Quantum Systems with Quantum Computers: New Approaches for Understanding Materials and Fundamental Physics

How do materials behave at the atomic scale? How do electrons interact to give rise to the properties of matter? These questions are fundamental to physics, chemistry, and materials science, yet solving quantum many-body problems on classical computers becomes exponentially difficult as system size increases. This is because the number of quantum states that must be considered grows exponentially with the number of interacting particles.

Quantum computers, which operate based on quantum mechanics, offer a promising alternative. Unlike classical computers, which use bits (0s and 1s), quantum computers use qubits, which can exist in multiple states simultaneously. This allows them to explore quantum interactions in ways that classical methods cannot.

Despite their potential, today's quantum computers are still in their early stages, facing limitations in qubit count and computational accuracy. To make quantum simulation practical, we are developing new algorithms for both near-term devices and future large-scale quantum computers.

For current and near-term quantum devices, we focus on Quantum-Selected Configuration Interaction (QSCI) [1], a hybrid quantum-classical method that reduces computational cost by selecting only the most relevant electronic configurations in quantum chemistry calculations. For future large-scale quantum computers, we explore Quantum Signal Processing for Perturbation Theory [2], which systematically incorporates higher-order corrections, and Schwinger model simulations [3], which estimate computational resources needed for fundamental physics problems. These studies provide insights into how quantum computers might one day surpass classical methods.

By explaining these challenges and advancements, this talk aims to provide an accessible introduction to the role of quantum computing in materials science, chemistry, and fundamental physics.

[1] K. Kanno, M. Kohda, R. Imai, S. Koh, K. Mitarai, W. Mizukami, Y. O. Nakagawa, "Quantum-Selected Configuration Interaction: Classical Diagonalization of Hamiltonians in Subspaces Selected by Quantum Computers," arXiv:2302.11320 (2023).

[2] K. Mitarai, K. Toyoizumi, W. Mizukami, "Perturbation Theory with Quantum Signal Processing," Quantum, 7, 1000-1000 (2023).
[3] K. Sakamoto, H. Morisaki, J. Haruna, E. Itou, K. Fujii, K. Mitarai, "End-to-End Complexity for Simulating the Schwinger Model on Quantum Computers," Quantum, 8, 1474 (2024).

Session speaker: Dr Anna Kowalczyk
University of Birmingham, UK

Dr Anna Kowalczyk specialises in development of quantum sensors based on the interaction of the resonant light with atomic vapours of alkali atoms and in applications of Optically Pumped Magnetometers for brain imaging and biomedical diagnostics. She has extensive experience in experimental atomic physics and optics, spectroscopy and metrology, signal processing and magnetoencephalography. She has expertise in applying physics concepts, methods and techniques to healthcare.

Development of Quantum Sensors for the detection of human biomagnetism

Recent advances in quantum sensing technologies are enabling the study of previously difficult-to-detect biomagnetic signals in human and animal neurophysiology.

In particular, magnetoencephalography (MEG)—which detects the tiny magnetic fields produced by the human brain—requires extremely sensitive sensors. Optically Pumped Magnetometers (OPMs) are quantum sensors that use thermal atoms and laser light to measure magnetic fields with the sensitivity required by MEG, making it possible to study brain activity in ways that were previously out of reach. Unlike traditional MEG systems, OPMs are small, wearable, and can be placed directly on the scalp. This enables recording of higher-amplitude brain signals, greater comfort, compatibility with a wider range of participants, and more naturalistic brain imaging. Additionally, the flexibility of sensor arrangements allows easier combination with other neuroscience methods.

At the Centre for Human Brain Health, we are developing a novel type of OPM. We have realised an intrinsic optically pumped magnetic gradiometer based on non-linear magneto-optical rotation. Our sensors are sufficiently sensitive and resilient to be employed in biomagnetic applications, even under challenging conditions. One of our key goals is to measure brain responses immediately following transcranial magnetic stimulation (TMS)—a technique used in both neuroscience research and clinical therapies.

In this talk, I'll discuss our progress in sensor development and how innovations in quantum science are not only enhancing how we measure brain activity but also reshaping what's possible in brain research.

Meeting day 3
Thursday 19 June 2025

Session 5
Chemistry/Material Science: Experimental and computational exploration of three-dimensional biological structures

PGM: Professor Keiichi Inoue
The University of Tokyo, Japan

Keiichi Inoue is an Associate Professor at the Institute for Solid State Physics, the University of Tokyo, Japan. He received his PhD in 2007 from Kyoto University in the study of the photoreceptive rhodopsin proteins under the supervision of Professor Masahide Terazima. From 2007 to 2009, he joined Professor Masaaki Fujii and Professor Makoto Sakai's laboratory at Tokyo Institute of Technology as a project assistant professor, developing infrared super-resolution microscopes. He then moved to Professor Hideki Kandori's laboratory at Nagoya Institute of Technology, where he studied the molecular mechanisms of microbial rhodopsins using functional assays and spectroscopic methods, first as an assistant professor (2009–2016), then as an Associate Professor (2016–2018). His current research centres on the exploration of new functional rhodopsins and the physicochemical study of their molecular mechanisms through time-resolved spectroscopy, electrophysiology, and structural analysis. Notably, he identified light-driven outward sodium-pumping and inward proton-pumping rhodopsins. Additionally, he is pioneering machine learning methodologies for designing novel functional proteins.

PGM: Dr Alice Bowen
The University of Manchester, UK

Dr Alice Bowen is a Royal Society/EPSRC Dorothy Hodgkin Research Fellow, she started her fellowship at Oxford University in 2016 and moved to the University of Manchester in 2019, where she is part of the team running the EPSRC funded National Research Facility for Electron Paramagnetic Resonance (EPR). Alice obtained her an MChem (2008) and DPhil (2013) in Chemistry, from Oxford University, followed by a Marie Curie post-doctoral fellowship at Goethe University in Frankfurt. Her research interests lie in the field of pulsed EPR; specifically, applications to structural determination of biological and chemical systems and quantum information processing. Her group both use and develop pulsed EPR methodologies, they have been at the forefront of recent developments in Light-induced EPR and pulsed dipolar spectroscopy techniques for measuring nm length scale distances in proteins and peptides. Alice is a member of the UK Young Academy.

Introductory speaker: Dr Junpei Yamamoto
The University of Osaka, Japan

Junpei Yamamoto has investigated on DNA repair of carcinogenic and mutagenic DNA damage by DNA repair enzymes, on the basis of chemical synthesis of oligonucleotides containing DNA damage at the defined positions. Especially, his major interests are the repair of UV-induced DNA damage by photolyases, flavoproteins responsible for light-driven DNA repair of the UV-damaged DNA. He has gained new insights into the activation process of the photolyase, DNA recognition and binding process, and DNA repair process of (6–4) photolyase. Taking the opportunities of international collaborative works on structural analyses of DNA-protein complexes using X-ray crystallography and cryogenic electron microscopy, his research interest is now centred on cinematography of enzymatic reactions acting on DNA via time-resolved structural analyses.

Cinematography of enzymatic reactions at atomic resolutions

Determination of the actual structures of biomolecules and organelles that consist of a cell, a fundamental unit of organisms, provides indispensable information and deeper insights into the understanding of biological systems in organisms. After the first determination of the three-dimensional structure of myoglobin – a molecule responsible for oxygen storage – via X-ray crystallography by Professor John Kendrew [1], more than 200,000 structures have now been solved and registered in the Protein Data Bank. Using the coordinates of the biomolecules as training data, computational prediction of the unsolved structures of biomolecules has been achieved [2], leading to development of new pharmaceutical drugs.

Recent trends in structural biology can be divided into two major directions: one is toward chemistry, which details how proteins/enzymes move during their function, and the other is toward biology, which seeks to understand the whole biological system, i.e. how these biomolecules and organelles are connected and work together. Computational studies complement the experimental observations and even extend the limitations of experiments.

Over the past decade, a sophisticated experimental technique has been developed for real-time visualization of chemical reactions in biomolecules at near-atomic resolutions. This technique, called time-resolved serial femtosecond X-ray crystallography (TR-SFX), using an X-ray free-electron laser (XFEL) can capture kinetically resolvable intermediates as snapshots, providing a time evolution of the three-dimensional molecular structure during a reaction [3]. By flipping through the snapshots, we can produce a molecular film of the reaction. Experimental and computational cinematography of enzymatic reactions will pave the way for a new era of enzymology.

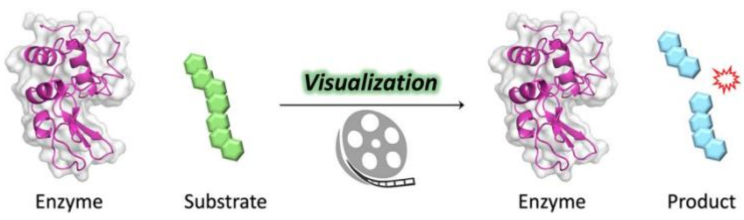


Figure. Graphical abstract of filming enzymatic reactions. Here, the lysozyme (PDB: 2LYS) reaction is shown as an example of enzymatic reactions.

[1] Kendrew et al. Nature 181, 662-666 (1958)
[2] Jumper et al. Nature 596, 583-589 (2021)
[3] Maestre-Reyna et al. Science 382, eadd7795 (2023)

Glossary:
- X-ray crystallography【X 線結晶構造解析】: the experimental science to determine the atomic and molecular structure of a crystal. When X-rays are incident on a crystal, the beam can be diffracted in specific directions. By measuring the angles and intensities of the diffraction patterns, we can reconstruct a three-dimensional map of the density of electrons in the crystal, thus providing the atomic model structures of the molecule in the crystal.
- X-ray free electron laser【X 線自由電子レーザー】: an advanced light source producing extremely brilliant and short pulses of X-ray enough to resolve chemical bonds and reactions. Currently, the TR-SFX experiment can be performed in five facilities, i.e Linac Coherent Light Source in US, European XFEL in Germany, SwissFEL in Switzerland, SPring-8 Angstrom Compact Free Electron Laser in Japan, Pohang Accelerator Laboratory XFEL in South Korea. In addition, Shanghai XFEL in China will be launched soon

Session speaker: Dr Jennifer Tomlinson
School of Molecular and Cellular Biology, University of Leeds, UK

Jennifer started her Dorothy Hodgkin Research Fellowship at the University of Leeds in 2018 and recently received a renewal. She currently supervises two PhD students. She studies protein structure and dynamics and protein-protein interactions and their role in antibiotic resistance, making use of NMR spectroscopy and other biophysical and techniques. Before her fellowship, she completed her PhD at the University of Sheffield with Mike Williamson then moved to Leeds to work as a postdoc studying antibiotic resistance using structural biology techniques.

Inhibition of fusidic acid resistance through restricting conformational flexibility in domain III of EF-G identified using NMR methyl relaxation dispersion

Fusidic acid (FA) is one of few remaining antibiotics active against MRSA but resistance is increasing, predominantly through expression FusB-like proteins. FA stalls bacterial protein synthesis by binding to elongation factor G (EF-G) once it is bound to the ribosome and preventing its release. FusB binds to EF-G and promotes dissociation of the stalled complexes via modulation of the dynamics in EF-G domain III, increasing a more disordered minor state of the domain. With the lack of new antibiotics entering the clinic, inhibiting existing resistance mechanisms could prolonging the usefulness of current antibiotics. We therefore aimed to identify key regions controlling the FA resistance mechanism to identify a potential druggable site to inhibit resistance. Disulphide bonds were introduced throughout domain III of EF-G, restraining different secondary structure elements. The effects of these restraints on FusB-induced changes in dynamics were measured using NMR relaxation dispersion and their effect on FA resistance was measured using a fluorescence assay to measure buildup of stalled complexes. This identified key regions controlling FA resistance, such that restraints in the central β-sheet of the domain prevented FusB-induced dynamics changes and abolished FusB-mediated FA resistance in vitro. Restraint of the second α-helix of the domain promoted increased changes in dynamics in domain III, conferring resistance even in the absence of FusB. This study has therefore identified key regions controlling the dynamics of domain III of EF-G that are crucial in causing FA resistance and identified a potential druggable site to inhibit FA resistance.

Session speaker: Dr Takahiro Kosugi
Institute for Molecular Science, National Institutes of Natural Sciences, Japan

Takahiro Kosugi obtained a doctorate degree in chemistry from Kyoto University. In his doctoral study, he theoretically elucidated the critical role of protein structural dynamics in an enzymatic catalysis by developing a novel method.

Subsequently, as a postdoctoral fellow at University of Washington, to rationally design enzymes, he ventured into the field of computational protein design, in which proteins are computationally designed and experimentally validated.

In his current position, an assistant professor at Institute for Molecular Science, he developed a method based on protein design technologies to regulate the concerted function of naturally occurring protein complexes. For example, he succeeded in creating allosteric sites in a rotary molecular motor and accelerating the rotation rate. Moreover, he applied his technologies to cell biology, to address biological questions through the rational engineering of proteins.

Computational Protein Structure Prediction and Design

Protein structure research has entered a transformative new era. Proteins aremacromolecules composed of 20 different types of amino acids and folded into specific three-dimensional structures determined by their amino acids sequences. Over half a century has passed since the first success of experimental structure determination by using crystal structural analysis, and then a substantial number of protein structures have been elucidated experimentally (experimental structures > 200,000). This extensive repository of experimental structure data has been trained using advanced machine learning, resulting in the development of high-performance protein structural prediction algorithm, AlphaFold [1]. Although the task of predicting folded structures from an astronomical number of possible conformations was considered unattainable at one time, it is now possible to easily obtain a huge number of highly reliable predicted structures (predicted structures > 200 million).

Computational protein design has also advanced significantly by insights derived from extensive experimental structural data [2]. Using the technologies, many kinds of de novo designed proteins and rationally redesigned native proteins have been reported to date. The technologies for creation of proteins with novel structures and functions promise applications to a wide range of research fields or industries. We also have recently reported de novo design of adenosine triphosphate (ATP) hydrolase [3] and design of allosteric sites into a rotary molecular motor by restoring the lost functions [4]. These achievements were realized through the analysis of previously solved structures and the structural determination of our designed proteins.

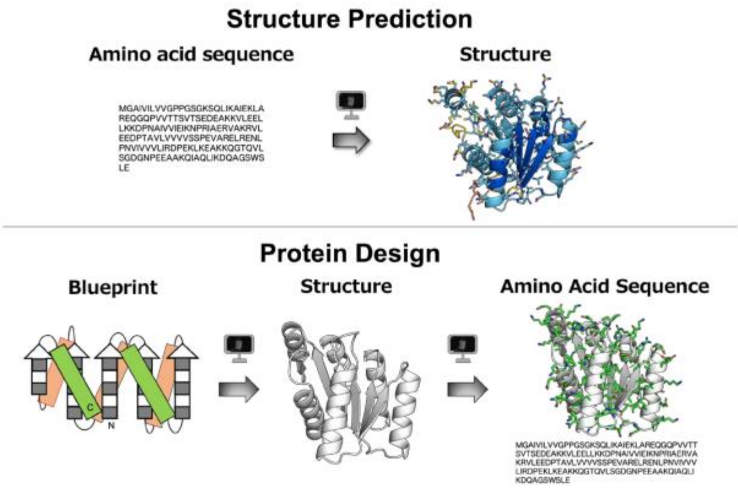
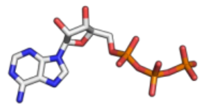


Fig. 1 Protein structure prediction (top) and design (bottom)

Both experimentally determined and computationally predicted structures are opening up a bright future for broad fields.

[1] Jumper, J. et al. Nature 596, 583-589 (2021).
[2] Huang, P.-S.; Boyken, S. E. and Baker D. Nature 537, 320-327 (2016).
[3] Kosugi, T.; Tanabe, M.; Koga, N. Protein Sci. in press.
[4] Kosugi, T.; Iida, T.; Tanabe, M.; Iino, R. and Koga, N. Nat. Chem. 15, 1591-1598 (2023).

- Adenosine Triphosphate (ATP): 【アデノシン三リン酸】
ATP is called energy currency of the cell and provides energy to drive and support many process in living cells.



- Allosteric site: 【アロステリック部位】
A substance binds to this site distant from a functional site, resulting in regulation of the protein function.

- Rotary molecular motor: 【回転型分子モーター】
Rotary molecular motor rotates using chemical energy generated by ATP hydrolysis.

Session 6
Biology/Life Science: Experimental evolution to understand and engineer life

PGM: Professor Thomas Gorochowski
University of Bristol, UK

Professor Gorochowski is a Royal Society University Research Fellow and Co-Director of the Bristol BioDesign Institute at the University of Bristol in the UK. Having originally trained in computer science, he has since transitioned to the area of biological engineering, working across both industry as a Marie Curie Fellow at DSM in the Netherlands, and academia as part of the Synthetic Biology Centre at the Massachusetts Institute of Technology in the USA. In 2016, he established his own group at the University of Bristol with the aim of better understanding the computational architecture of biological systems and to use that knowledge to more rationally engineer synthetic biology across scales. Most recently his group has explored the role of evolution when engineering biology and ways that this creative force can be effectively harnessed for biological design.

PGM: Professor Masato Yamamichi
National Institute of Genetics, Japan

Masato Yamamichi holds a diploma degree in Ecology from the University of Tokyo (2007). He finished his PhD in Evolutionary Biology at SOKENDAI (the Graduate University for Advanced Studies) of Hayama in 2012. Thereafter, he worked as a JSPS Postdoctoral Fellow at Cornell University (USA: 2012-2014), as a Program-Specific Assistant Professor of Hakubi Center for Advanced Research at Kyoto University (2014-2017), as a Lecturer of Department of General Systems Studies at the University of Tokyo (2017-2020), and as a Senior Lecturer of School of Biological Sciences at the University of Queensland (Australia: 2020-2023). Since April 2023, he is an Associate Professor of Center for Frontier Research at the National Institute of Genetics (Mishima).

Introductory speaker: Professor Tiffany Taylor
University of Bath, UK

Work from the Taylor lab broadly focuses on using experimental evolution to address fundamental questions concerning ecological and evolutionary processes. Specifically, microbial experimental evolution is employed in combination with molecular and bioinformatic techniques to determine the evolutionary drivers of gene regulatory networks (GRNs) and the features that influence the predictability of evolutionary outcomes during GRN rewiring. Additionally, there is an interest in exploring the evolutionary and ecological drivers behind the distribution, maintenance, and interactions of bacterial defence systems.

Experimental evolution as a guide to building predictable adaptive paths

What do we need to know to predict evolution? While mutation – the raw material for natural selection – is random, experimental evolution reveals that adaptive outcomes can be strikingly repeatable under certain conditions. This approach offers a powerful framework to identify genomic and regulatory features that bias and constrain evolutionary paths — insights that can inform the design of synthetic organisms capable of predictable adaptation.

In my lab, we use the model bacterium Pseudomonas fluorescens to explore these features. I will present work in which we dissect the molecular features that define a mutational hotspot that is capable of driving near-deterministic evolutionary outcomes. We show that this mutational hotspot can be built and broken with a few synonymous changes to the genetic code, and that its potency can be finely tuned through changes to neighbouring nucleotides. Evolution is the ultimate engineer — and by learning from it, we can design synthetic systems that are both adaptable and controllable, laying the groundwork for more resilient and evolvable biotechnologies.

Session speaker: Dr Ryo Mizuuchi

Waseda University, Japan

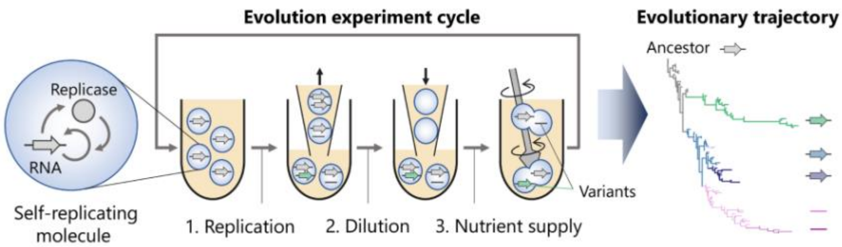
Ryo Mizuuchi is an Associate Professor at Waseda University, where he investigates the origins and early evolution of life. He earned his PhD from Osaka University in 2018 and has conducted research at NASA Ames Research Center, Portland State University, and the University of Tokyo. He has also served as a PRESTO and FOREST researcher at the Japan Science and Technology Agency (JST). His interdisciplinary work combines synthetic biology, evolutionary biology, biophysics, and bioinformatics to explore how life could have emerged from non-living matter. By creating and evolving artificial self-replicating genetic systems, he studies potential evolutionary transitions from simple molecular assemblies to complex biological systems. His achievements have been recognised with a number of honours, including the Young Scientists' Prize (MEXT), the Early Career Award in Biophysics (The Biophysical Society of Japan), and the Young Scientist Initiative Award (Society of Evolutionary Studies, Japan).

Exploring life's origins through experimental evolution

How did life originate from non-living matter about four billion years ago? It is widely believed that simple self-replicating molecules gradually evolved into complex living systems. To study the evolutionary history of life, researchers often rely on fossil records or comparisons of the genomes of living organisms. However, simple molecular systems did not leave behind fossils, and genome comparisons can only reveal evolutionary events that occurred after the emergence of the last universal common ancestor—an already complex cell that gave rise to all known life. To overcome these limitations, we are working to experimentally evolve primitive molecular systems in the laboratory, allowing us to directly "witness" possible evolutionary processes that may have taken place before life began.

We have developed several evolvable molecular systems based on our understanding of the origins of life. One such system contains a self-replicating RNA that encodes a replicase, a protein that copies the RNA and is synthesized by a translation system [1]. When encapsulated in cell-like compartments and subjected to repeated experimental cycles of replication, dilution, and nutrient supply, the RNA can evolve spontaneously toward increased complexity. During these experiments, replication errors introduce mutations, generating RNA variants with different properties. Some variants may replicate more efficiently and increase in frequency by outcompeting others, representing a form of evolution. Using this RNA replication system, we have observed various evolutionary behaviours, including adaptation, diversification, cooperation, and functional integration, all contributing to the development of more complex replicating systems [1–3]. We are currently conducting new evolutionary experiments to further explore potential pathways that could have led to the origins of life.

[1] Mizuuchi, R., Furubayashi, T., Ichihashi N. Evolutionary transition from a single RNA replicator to a multiple replicator network. Nature Communications, 13, 1460 (2022).
[2] Mizuuchi, R., Ichihashi, N. Sustainable replication and coevolution of cooperative RNAs in an artificial cell-like system. Nature Ecology & Evolution, 2, 1654–1660 (2018).
[3] Ueda, K., Mizuuchi, R., Ichihashi, N. Emergence of linkage between cooperative RNA replicators encoding replication and metabolic enzymes through experimental evolution. PLOS Genetics, 19, e1010471 (2023).



An overview of experimental evolution using a molecular system. A self-replicating molecule (RNA, in our case) is subjected to repeated cycles of replication, dilution, and nutrient supply. During these cycles, variant RNAs can arise and may come to dominate the RNA population depending on their replication efficiency. The diagram on the right is called a phylogenetic tree, which depicts evolutionary relationships among detected RNAs; the tip of each line represents a different RNA.

Glossary:
- **RNA**: Ribonucleic acid, a molecule that can encode genetic information (such as proteins). RNA is a polymer composed of four types of monomers (called nucleotides). While DNA is the primary genetic information carrier in most organisms today, some viruses use RNA instead. It is believed that primitive genetic systems were also based on RNA.
- **Translation system**: A set of molecules that synthesize proteins encoded by RNA. This “translation” process is a fundamental biological mechanism shared by all extant life.
- **Mutation**: A change in part of an RNA (or DNA) sequence, such as the replacement, deletion, or insertion of nucleotides. In our experiment, mutations occur due to replication errors.

Background Review Article:
- Szathmáry, E., and Maynard Smith, J., The major evolutionary transitions. Nature, 374,227-232 (1995).
- Yukawa, K., Mizuuchi, R., Ichihashi, N., How prebiotic complexity increases through Darwinian evolution. Current Opinion in Systems Biology, 34, 100456 (2023).

Session speaker: Professor Harrison Steel
University of Oxford, UK

Harrison Steel is an Associate Professor of Engineering at the University of Oxford. His work is at the interface of control engineering, synthetic biology, and robotics. He builds new technologies that combine electronic and biological components and applies these to address new scientific questions as well as industrial and environmental applications. Recently this has included building tools that can mitigate the evolution of antibiotic resistance, control microbial ecosystems (such as the gut microbiome), and perform high-throughput control and measurement of bacteria to better understand complex behaviours. He is the founder of a not-for-profit Bioreactor platform and is science advisor to several start-ups in areas including biomanufacturing, carbon-capture technologies, and development of new biomedical therapeutics.

Predicting bacterial evolution to engineer novel biotechnologies and understand AMR

Methods for the experimental evolution of microbes have broad potential for application in fields ranging from synthetic biology to the fight against antimicrobial resistance. Although the individual mutations that fuel evolution arise randomly, theory shows that, in large populations, it may be possible to predict statistical trends in mutation-selection dynamics, and possibly even their outcomes. Toward this goal, we have developed unique robotic platforms that can automate experimental microbial evolution over tens of thousands of generations while precisely applying adaptive pressures. With this level of control, we show that microbial evolution becomes highly repeatable at the population scale, and that small changes in selective pressures can lead to diverse-yet-predictable genotypic and phenotypic outcomes. We apply this novel technology to antimicrobial resistance, demonstrating that it may be used to explore the space of possible resistance trajectories. By evolving many such populations in parallel, we also simplify the attribution of cause and effect to observed mutations, broadening the method's utility for directed evolution. Taken together, these advances provides an integrated mathematical and robotic framework for the quantitative prediction and control of evolution.

Closing remarks

Professor Kenji Tanaka
JSPS FoS Advisory Board, Japan

Kenji Tanaka graduated from the Keio University School of Medicine in 1997 and completed his doctoral program at the Keio University Graduate School of Medicine in 2003. After serving as a postdoctoral fellow at the National Institute for Physiological Sciences and then as a postdoctoral research scientist at Columbia University, he returned to the National Institute for Physiological Sciences, where he became an assistant professor in 2008. He held positions as a Project Associate Professor and Associate Professor in Neuropsychiatry at the Keio University School of Medicine before taking on his current position in 2021. Professor Tanaka has received numerous awards, including the NARSAD Young Investigator Award, the Sanshikai Young Investigator Award, the Japanese Society for Neurochemistry’s Distinguished Investigator Award, the Tatsuji Nomura Award, and the Kitasato Award.

Mr Ian Wiggins
The Royal Society, UK

Ian is Director of International Affairs for the Royal Society, the UK's National Academy of Science, where he leads on the Society’s global engagement. Before joining the Royal Society in 2022, Ian worked at the University of York in a number of roles including as Director of Operations, and served as the first Director for the York-Maastricht Partnership, the university's strategic relationship with Maastricht University. Ian is also a former British Diplomat where he worked in the Foreign Office HQ in London on counter terrorism, climate change, and energy policy briefs and had diplomatic postings in Moscow and in Washington D.C. where he was Deputy Head of the Embassy’s political section during the 2016 Presidential elections. He is a chemist by training and holds a Master's degree in Chemistry from the University of Nottingham.

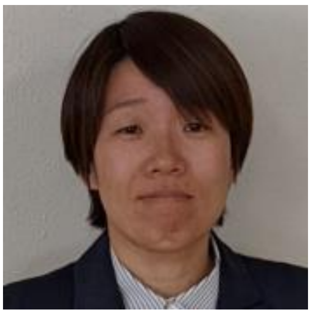
Poster presentations
Maths/Applied Maths/Informatics: Singular learning theory

1. Dr Alexander Kasprzyk
University of Nottingham, UK

Alexander Kasprzyk is an Associate Professor in mathematics at the University of Nottingham. He directs a world-leading research group developing classifications of Fano varieties, the "atomic pieces" of geometry. This involves massively parallel computational algebra and large databases of geometric objects, applying tens of centuries of computing time to make substantial and important mathematical advances. Through this work he has pioneered the use of techniques from data science and machine learning in Pure Mathematics to uncover new mathematical structure.

Towards the landscape of Q-Fano threefolds

Fundamental to the study of geometry is our understanding of geometric spaces called Q-Fano varieties. These can be regarded as the 'atomic pieces' of geometry, from which other spaces are constructed. Although fundamental, very little is known, and the classification of Q-Fano varieties remains an open problem, even in dimension three. Recent theoretical advances coming from mirror symmetry have suggested a new way of viewing these varieties, via the so-called quantum period sequence. This change in view-point has allowed us to rephrase the problem as a combinatorial challenge, which in turn has allowed us to begin hunting for Q-Fano threefolds using massively parallel computer-aided searches. Machine learning on this data has exposed a rich, previously unsuspected mathematical structure. Although the challenge of turning these insights into rigorous mathematics is considerable, the conjectural landscape suggested by machine learning is both compelling and beautiful, and will guide research for years to come.



2. Dr Yoko Uwate
Tokushima University, Japan

Yoko Uwate received the B.E., M.E., and Ph.D. degrees in electrical engineering from Tokushima University, Tokushima Japan, in 2003, 2005 and 2006, respectively.

From April 2008 to March 2010, she was working as Post Doctoral Fellow for Research Abroad of Japan Society for the Promotion Science (JSPS) at STOOP Group, Institute of Neuroinformatics (INI), University and ETH Zurich, Switzerland.

In 2010, she joined the Department of Electrical and Electronic Engineering, Tokushima University, Tokushima Japan, where she is currently working as an Associate Professor at Nonlinear Circuits Laboratory, Tokushima University, Japan.

Dr. Uwate is a member of the IEEE CAS Society Board of Governors (2013 to 2015, and 2021 to present). She was the Chair of the IEEE CAS Society Technical Committee on Neural Systems and Applications (NSA)

(2019 to 2021). Also she was the DEI (Diversity, Equality, and Inclusion) Committee Chair of the IEEE CAS Society (2022-2024).

Developmental Changes in Foetal Brain Neuronal Signals Analysed by Nonlinear Time Series Methods

Understanding how neural circuits in the brain are formed and function is a major goal of many neuroscience projects. In this study, we investigate how neuronal signals in the foetal mouse brain change during development using nonlinear time series analysis. As a first step, we visualize the attractor structure by applying attractor reconstruction. We then quantify temporal instability by calculating the Lyapunov exponent. Finally, we assess spatial self-similarity by estimating the fractal dimension. Our results showed that the attractor structure becomes simpler and the Lyapunov exponent tends to decrease as development progresses. Although the box-counting method indicated an increasing trend in self-similarity, we were unable to obtain accurate values for the fractal dimension due to insufficient parameter tuning. In future work, we aim to refine these parameters and explore alternative methods to more accurately determine the fractal dimension. Additionally, we plan to investigate other dimensional measures to further understand how the spatial characteristics of neuronal signals evolve throughout brain development.

Y. Uwate, M. E. J. Obien, U. Frey and Y. Nishio, "Time Series Analysis of Neurons and Visualization of Network Characteristics," 2019 RISP International Workshop on Nonlinear Circuits, Communications and Signal Processing (NCSP2019) , pp. 450-453, Mar. 2019.

Co-authors:
Martin Schule (Zurich University of Applid Sciences), Thomas Ott (Zurich University of Applid Sciences) and Yoshifumi Nishio (Tokushima University)

3. Dr Anne-Sophie Kaloghiros
Brunel University London, UK

Anne-Sophie Kaloghiros completed her PhD in Algebraic Geometry at the University of Cambridge in 2007. After postdoctoral appointments in Trinity Hall, Cambridge, MSRI, Berkeley, RIMS, Kyoto, and Imperial College London, she joined Brunel University London in 2014.
Her research is concerned with the birational geometry and moduli of Fano varieties.

Explicit K-stability and moduli construction of Fano 3-folds

The Calabi problem asks which compact complex manifolds are Kähler-Einstein (KE)- i.e. can be endowed with a canonical metric that satisfies both an algebraic condition (being Kähler) and the Einstein (partial differential) equation. Such manifolds always have a canonical class of definite sign. The existence of such a metric on manifolds with positive and trivial canonical class (general type and Calabi Yau) was proved in the 70s. In the case of Fano manifolds the situation is more subtle - Fano manifolds may or may not have a KE metric.

We now know that a Fano manifold admits a KE metric precisely when it satisfies a sophisticated algebro-geometric condition called K-polystability. Surprisingly, K-polystability also sheds some light on another important problem: while Fano varieties do not behave well in families, K-polystable Fano varieties do and form K-moduli spaces.

Our explicit understanding of K-polystability is still partial, and few examples of K-moduli spaces are known. In dimension 3, Fano manifolds were classified into 105 deformation families by Mori-Mukai and Iskovskikh. This poster will present an overview of the Calabi problem in dimension 3 and some constructions of explicit K-moduli spaces of Fano 3-folds.

4. Professor Kien Nguyen

Chiba University, Japan

Kien Nguyen is an Associate Professor at Chiba University, affiliated with the Institute for Advanced Academic Research and the Graduate School of Informatics. He received his PhD in Informatics from the Graduate University for Advanced Studies, Japan. Prior to joining Chiba University in 2018, he was a researcher at the National Institute of Information and Communications Technology (NICT), Japan, from 2014 to 2018. His research interests lie in networking and distributed systems, with a focus on Internet architecture, communication protocols, Internet of Things (IoT) technologies, and distributed ledger technologies. He is an Associate Editor of Computer Communications and has served on the steering, organising, or technical program committees of numerous international conferences.

Your Device, Your Networks, Your Payment: User-Centric Solutions for 5G/6G

The transition to 5G and future 6G networks prioritizes user-centric connectivity, replacing outdated, one-size-fits-all systems with adaptable experiences tailored to individual needs. This research introduces two key innovations driving this shift. First, software-defined device architectures empower smartphones to intelligently manage connectivity: using wireless virtualization to decouple network functions from hardware, devices can simultaneously tap into multiple networks (e.g., Wi-Fi and cellular) and automatically select user-defined connections for each app (e.g., ensuring smoother video calls, enhanced privacy for sensitive tasks like emails). Second, the research introduces networks that support on-demand service upgrades: users can request guaranteed speeds or lag-free performance for critical tasks via instant micropayments, enabled by programmable SDN frameworks. Together, these advances create a seamless, user-centric ecosystem where connectivity balances performance, cost, and reliability in real time. Initial testing demonstrates efficient operation, with virtualization incurring minimal overhead and micropayments processing swiftly for real-world use.

5. Dr Sara Veneziale

Imperial College London, UK

Dr Sara Veneziale is a Chapman-Schmidt research fellow at the Imperial-X Centre for AI in Science and the Department of Mathematics at Imperial College London, where she is mentored by Dr Anthea Monod. Her research focuses on using AI to discover and prove new results in pure mathematics, and on studying the high-dimensional geometry that underpins Large Language Models. She completed her PhD at Imperial College London with the thesis 'Fano Varieties and Machine Learning', supervised by Professor Tom Coates and Dr Alexander Kasprzyk. Previously she graduated with an MMath at the University of Warwick in 2020 with a thesis in algebraic topology.

Machine learning detects terminal singularities

In this poster, I will describe recent work in the application of machine learning to explore questions in algebraic geometry, specifically in the context of the study of Q-Fano varieties. These are Q-factorial terminal Fano varieties, and they are the key players in the Minimal Model Program. In this work, we ask and answer if machine learning can determine if a toric Fano variety has terminal singularities. We build a high-accuracy neural network that detects this, which has two consequences. Firstly, it inspires the formulation and proof of a new global, combinatorial criterion to determine if a toric variety of Picard rank two has terminal singularities. Secondly, the machine learning model is used directly to give the first sketch of the landscape of Q-Fano varieties in dimension eight. This is joint work with Tom Coates and Al Kasprzyk.

Medical/Neuroscience: Non-conventional organismal biology

6. Dr Susie McLaren
Gurdon Institute, University of Cambridge, UK

Susie is a developmental biologist with a background in understanding the intersection of biology and physics in generating diverse biological shapes.

She earned a BSc in Natural Sciences from UCL and a PhD at the University of Cambridge investigating early embryo head-to-tail elongation in zebrafish embryos. Her recent postdoctoral work in the Xiong lab at the Gurdon institute has uncovered differences in tissue mechanics that lead to the divergence of embryonic brain and spinal cord shape under fluid pressure.

Susie now leads research seeking to understand how cnidarian corals and their algal symbionts interact at cellular, tissue and organismal levels to develop a symbiotic relationship that sustains coral reef ecosystems.

Building and Breaking an Ecosystem Sustaining Symbiosis

Our research seeks to understand how a cnidarian host and its dinoflagellate algal symbionts build an ecologically critical symbiotic relationship during host morphogenesis. Symbiosis, the close long-term interaction between two distinct species, regulates key biological functions that support diverse ecosystems. The closest symbioses occur when single-celled microorganisms are physically internalised into the cells of their host, a partnership that drives the evolution of novel biological adaptations. This is the case for the symbiotic relationship formed between cnidarian corals and their large algal symbionts - which underpins coral reef ecosystems. Interestingly, this symbiosis is built during the mechanically dynamic process of host morphogenesis and results in an adult cnidarian polyp with algae localised to its tentacles where they perform photosynthesis and transfer nutrients to the host, enabling these benthic animals to thrive in nutrient-poor environments. Whilst the molecular exchanges between host cells and symbionts have been explored, particularly in the context of symbiosis breakdown, the interplay between host and symbionts in building a symbiotic relationship during host morphogenesis is not known. Using a combination of high-resolution imaging, machine learning-based approaches and mechanical perturbation we show that symbionts are dynamically patterned during host morphogenesis and that this may occur through a mechanical mechanism. We are now investigating how symbiont spatial patterning in the host is regulated and its ability to adapt to different environmental conditions. This work aims to reveal fundamental principles of how interacting species dynamically shape each other’s biology to survive in demanding ecological niches and has potential implications for coral reef ecosystem recovery.

7. Dr Mitsuaki Takemi

Hiroshima University, Japan

Mitsuaki Takemi is an Associate Professor in the Biological Systems Engineering Laboratory at Hiroshima University. His research focuses on the neural process of learning and control of physical movement and on the potential of non-invasive neural stimulation to enhance these processes. Neuroimaging, kinematic analysis, and computational modelling are also his main research tools. Besides, he has led a project to accumulate evidence on the safety and effectiveness of neurotechnologies such as neurofeedback and neuromodulation since August 2022. The project team consists of approximately 40 early to mid-carrier researchers and will conduct 12 systematic reviews by the end of 2025.

A Versatile and Fully Automated Robotic TMS System for Human Brain Mapping and Modulation

Transcranial magnetic stimulation (TMS) is a powerful, non-invasive method widely used to assess and modulate human brain activity in both research and clinical settings. However, conventional hand-held TMS often suffers from variability due to operator differences in coil positioning and stimulation protocols, limiting reproducibility and efficiency. Although existing commercial robotic TMS systems address some of these limitations, they typically depend on structural MRI scans for accurate coil placement, restricting their applicability in facilities without MRI access.

To overcome these limitations, we developed a novel robotic TMS system (shown in the figure) that offers significant practical advantages beyond existing commercial solutions. Our system employs an RGBD depth camera to rapidly construct accurate individual 3D head models, thereby eliminating dependency on MRI imaging. Integrated software automates complex stimulation procedures, including motor hotspot localization and motor threshold estimation, standardizing measurement conditions and minimizing human error. Additionally, our robotic platform features versatile communication protocols, making it compatible with various commercially available TMS stimulators and thus highly adaptable to diverse research environments.

Since April 2022, our robotic TMS has been successfully deployed at three institutions across Japan and one in Canada, with additional installations ongoing both domestically and internationally. Results from over 400 stimulation sessions confirm its safety, reliability, and reproducibility, underscoring its broad applicability in neuroscience and clinical research. Such flexibility and automation open promising avenues for interdisciplinary scientific collaborations.

8. Dr Adam Bentham

Centre for Programmable Biological Matter, Durham University, UK

Dr Adam Bentham is an Assistant Professor and Co-Director of the Centre for Programmable Biological Matter at Durham University. The Bentham Lab specialises in host-pathogen interactions across kingdoms of life, through the lens of structural biology and AI-based protein design.

AI-guided protein design for engineering plant immunity

Bioengineering the plant immune system has emerged as an increasingly viable solution to the problem of waning disease resistance. However, the development of bespoke resistance has proven challenging. Current efforts to tailor resistance to specific pathogen signatures require extensive characterisation and have proven difficult to translate between different pathosystems. Here, we harness recent advances in protein design technologies to develop protein binders against secreted virulence proteins (effectors), which can be readily integrated into existing nucleotide-binding leucine-rich repeat (NLR) immune receptors. These de novo immune sensors expand NLR effector recognition profiles, with potential for translation into transgenic crops for enhanced disease resistance. As these protein binders can be rapidly generated, screened, and tailored to a variety of secreted pathogen effectors, this work represents a significant advance toward bespoke resistance bioengineering.

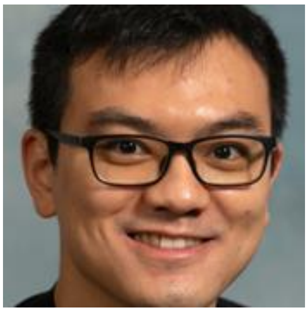
9. Dr Sayako Kanamori

The University of Osaka, Japan

Dr Kanamori is currently a Professor at Center for Education in Liberal Arts and Sciences at The University of Osaka. Before joining, she was a Director of Research at the Japan Institute for Global Health, a health specialist at Japan's Ministry of Foreign Affairs, and a business consultant specializing in finance and accounting management. She has overseen technical support to promote greater awareness of and commitment to global health by leading research, advocacy, and policy recommendations. She is also managing and providing consultancy to various organizations. Her main research focuses on global health policy and diplomacy, global health human resource development and healthcare business, whereas her most recent interest is how each country can maximise national and international interests by promoting planetary well-being. She also serves a board member of Girls Unlimited Program (GUP), a non-profit organization that provides empowerment programs for junior high and high school girls in Japan.

From global health to Planetary Well-Being: Conceptual arrangement and future exploration

The recent climate change and the COVID-19 pandemic have trig- gered the importance of the concept of "Planetary Well-Being", which aims to create a future in which people can enjoy a state of physical, mental, and social well-being and not merely the absence of disease or infirmity, but also considers the impact on future generations and the global environment. In this study, the researcher will organize the concept and definition of Planetary Well-Being, issues to be included, and comparative advantages of Japan and other countries, which will ultimately identify what kind of initiatives Japan could lead in the era of post-SDGs.



10. Dr Yin-Wei (Kris) Kuo

MRC-Laboratory of Molecular Biology, UK

Yin-Wei (Kris) Kuo obtained his bachelor's in chemistry from National Taiwan University in 2014 and studied biophysical chemistry at Yale University until 2022. He is currently a postdoctoral fellow at MRC-Laboratory of Molecular Biology in Cambridge. His current research focuses on understanding the biophysical and molecular principles underlying cell division cycle in archaea with emphasis on the cytoskeletal polymers and the cell cycle transcriptional program.

Principles of cell division cycle in a hyperthermophilic archaeon

The cell division cycle requires precise temporal regulation. This is most critical during the process of cell division, when it is essential to coordinate DNA segregation, cytokinesis, and the re-replication of DNA. In eukaryotic cells, these events are orchestrated by the Cdk-cyclin clock, which works in concert with a series of checkpoint control systems that monitor the execution of critical processes to ensure that the next event in the cycle is not initiated until the previous event has been completed. While orderly progression through the cell cycle is usually thought of as being unique to eukaryotes, archaea, which share common ancestry with eukaryotes, possess a precisely ordered cell cycle with discrete G1, S, G2 and Division phases, despite lacking CDKs and cyclins. These data suggest that an ordered cell cycle predates the evolution of a CDK-cyclin clock. While it is not known how cell cycle control is achieved in archaea, cell cycle progression in Sulfolobus, a close archaeal relative of eukaryotes, is known to be accompanied by a series of transcriptional waves, just as it is in eukaryotes. Here we demonstrate that the expression of the ESCRT-III genes (which constitute the Sulfolobus division apparatus) is rapidly switched off upon the completion of cytokinesis. Furthermore, we discovered a checkpoint-like feedback control mechanism that monitors the completion of physical changes in the ESCRT-III ring structure. As a result, the ability of cells to switch off this pre-division wave of transcription depends on the completion of ring assembly. We speculate that by enabling cells to keep track of the execution of key events in the cell cycle, a similar type of feedback regulation could underlie the orderly progression.

Earth Science/Environment: Resourcing society: metals for the future

11. Dr Atsushi Okazaki
Chiba University, Japan

Atsushi Okazaki is a hydrometeorologist specialising in the modelling of stable water isotopes (e.g. HDO) and data assimilation, with broad applications in fields such as numerical weather prediction and paleoclimate reconstruction. He earned his bachelor's degree at Tohoku University and both his master's and PhD degrees at The University of Tokyo. After completing his PhD, he worked as a postdoctoral researcher at RIKEN and Penn State and later served as an assistant professor at Hirosaki University. As of April 2025, he is Associate Professor at the Institute of Advanced Academic Research/Center for Environmental Remote Sensing at Chiba University.

Ground-breaking Spatiotemporal Resolution Reconstruction of the Climate around Japan with Old Documents

Many of the old documents in Japan, whether it be private or public, contain the records of weather types (e.g., sunny, cloudy, rainy) on a daily basis. Previous studies have used such records to reconstruct monthly to seasonal mean climate at the point where the document was written. Only a few studies reconstructed point-wise climate on a daily scale due to the difficulty of using such qualitative data. Climate field reconstructions with old documents are also limited.

This study uses an emerging reconstruction technique known as "data assimilation (DA)" to reconstruct daily weather fields with 20 km resolution. The data assimilation merges model simulations and observations based on the dynamic theory and the statistics. This study uses a dataset of large ensemble climate simulations known as d4PDF (database for Policy Decision making for Future Climate Change) as model simulations. The d4PDF provides simulations that are longer than 3000 years, which serves as rich prior information in the context of DA.

In the presentation, we first show the feasibility of the approach, where it is applied to the present climate, and AMeDAS data is used as observations. Then, we show the reconstruction and the evaluation result for the Edo era assimilating old documents data, especially focusing on hydroclimate variables.

12. Dr Tobermory Mackay-Champion
University of Oxford, UK

Tobermory read for a 1st-class MEarthSci degree in Earth Sciences at the University of Oxford from 2016 to 2020, winning an undergraduate scholarship at University College. He completed his masters research with Professor Mike Searle on the tectonic history of the Variscan Lizard ophiolite in Cornwall, UK. Tobermory held the Oxford-Radcliffe Graduate Scholarship at University College (University of Oxford) from 2020 to 2024, completing his DPhil (PhD) research on the use of geological and passive seismic methods for examining the tectonic context of sedimentary copper deposits. He was supervised by Professor Michael Daly, Professor Mike Kendall, and Associate Professor Richard Palin.

Tobermory is currently a Postdoctoral Research Assistant in Seismology at the University of Oxford, working with Professor Mike Kendall. Tobermory's research focuses on the application of passive seismology to resource exploration. His other interests include field geology and applying petrological modelling to better understand the formation of mineral deposits.

An Integrated Geophysical and Geological Analysis of the Kansanshi CopperGold Mine and Its Implications for the Mineral System of the Central African Copperbelt

Tobermory Mackay-Champion[1], Nicholas Harmon[2], Sekelo Mutelekesha[3], Martin Purkiss[4], Mulenga Chanda[5], Thomas Hudson[6], Richard Palin[1], Munshya Zimba[3], John-Michael Kendall[1], Michael C. Daly[1]

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[2] Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, USA, Woods Hole Oceanographic Institute, USA,
[3] First Quantum Minerals Ltd
[4] Ivanhoe Mines
[5] Geological Survey Department, Ministry of Mines, Zambia
[6] Institute of Geophysics, ETH Zürich, Switzerland

As global demand for metals intensifies amid the energy transition, innovative exploration techniques are urgently required to counter declining discovery rates [1]. This must be paired with an improved understanding of the geological controls on the formation of significant deposits. The Central African Copperbelt (CACB), of Zambia and the Democratic Republic of the Congo, is the world's largest sediment-hosted copper and cobalt province [2]. It contributes ~14 % and ~60 % of the world's supply of these two metals, respectively. However, there remain significant unknowns surrounding the structural and tectonic evolution of the CACB, which significantly hamper the exploration for further deposits[3]. This problem is exemplified by the Kansanshi Copper-Gold Mine, which for many years was Africa's largest active copper mine [4]. This study combines passive seismic imaging, new geological mapping, structural analysis, metamorphic thermobarometry, and existing geochronology to examine Kansanshi's tectonic evolution and mineral system, with implications for the broader CACB.

Ambient Noise Seismic Tomography (ANT) was performed using a 50 km NE–SW network of 30 Sercel WiNG MEMS accelerometers deployed throughout Kansanshi and the surrounding area, with the aim of constraining sub-surface structure. The tomography reveals a multi-kilometre-thick package of sediments and evidence of focused fluid flow pathways beneath Kansanshi, indicative of a potential mineralizing system[5]. Complementary geological mapping, structural analysis, and metamorphic thermobarometry are integrated with the geophysics to create a coherent tectonic model for north-western Zambia and the Kansanshi Mine. The deposit lies above a Tonian-age subbasin filled with Lower Roan Group syn-rift sediments [6], which were overthrust by allochthonous Lufilian-age metamorphic rocks around 510 Ma. These allochthonous rocks, characterized by garnetand biotite-grade metamorphism, reached peak metamorphic conditions of approximately 550–620 °C and 7.5–9.5 kbar—equivalent to burial depths of ~26–33 km.

Copper and gold mineralization occurred during or shortly after this overthrusting event.

The integrated geophysical–geological approach taken in this study significantly improves our understanding of the Kansanshi deposit and the broader evolution of the CACB. We demonstrate the effectiveness of ANT using MEMS accelerometers as a cost-efficient tool for greenfield mineral exploration. The study also raises the possibility that Lufilian-age granitic magmatism played a pivotal role in driving the Central African Copperbelt mineral system.

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[3] M. J. Hoggard et al., Nat. Geosci. 13, 504–510 (2020).
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[6] M. Purkiss, Journal of African Earth Sciences. 227, 105617 (2025).

13. Dr Yuki Takai

Kyushu University, Japan

Yuki Takai (PhD, Agriculture) is an assistant professor at Kyushu University, specialising in environmental toxicology with a focus on aquatic environments. His research centres on developing behavioural testing methods that efficiently assess the effects of pollutants on ecologically important behaviours, such as social interaction and predator response. He is also involved in elucidating Adverse Outcome Pathways (AOPs) to better understand the mechanisms underlying pollutant-induced effects and to contribute to environmental risk assessment and the conservation of aquatic ecosystems. In addition, he is developing innovative, non-invasive environmental monitoring techniques for coastal areas using wharf roach faeces as a bioindicator. His interdisciplinary approach integrates behavioural science, toxicology, and environmental monitoring to address pressing ecological challenges.

For Sustainable Aquatic Environments: Insights from Medaka Fish Behaviour and Wharf Roach

My expertise is in environmental toxicology, a specialized field within environmental science that aims to balance human health and ecosystem conservation. In this context, I take two main approaches to address pollution in aquatic environments: (1) developing standardized behavioural toxicity tests using medaka fish (Oryzias latipes), and (2) establishing non-invasive environmental monitoring methods for coastal areas. (1) Fish behaviour has been recognized as a valuable endpoint in toxicity assessments since the early 2000s. However, many existing behavioural testing methods require complex equipment, limiting their accessibility and broader application. To address this issue, I am developing simplified behavioural testing methods to quantify behavioural changes in fish, particularly using medaka fish (Peek-A-Boo test, Takai et al., 2023). (2) For environmental monitoring, I am working to establish non-invasive approaches suitable for coastal environments. Currently, I am investigating the use of wharf roach (Ligia spp., commonly known as Funamushi in Japanese) faeces as a non-invasive sample for detecting pollutant accumulation, offering a promising alternative to lethal sampling techniques. By integrating behavioural effect assessment with non-invasive monitoring, I aim to develop practical and broadly applicable tools for evaluating ecological risks and supporting the sustainable management of aquatic ecosystems.

14. Dr Rich Crane

Camborne School of Mines, University of Exeter, UK

Rich Crane is a Senior Lecturer in Sustainable Mining at the Camborne School of Mines, Department of Earth and Environmental Sciences, University of Exeter, UK. His research focuses on understanding how we can apply novel methods in extractive metallurgy and applied geochemistry for a range of applications including primary ore mining, mine site reclamation, waste treatment and water treatment. He has particular interest in the development of new electrochemical “key-hole” metal extraction approaches which enable critical metal (Cu, Co, Ni, REE, PGMs) recovery from ores and wastes using dramatically less environmental disturbance and energy requirement.

Novel approaches for the selective extraction of metals from geological materials and water

Humankind is in the midst of an unprecedented effort to upscale green technology metal production to decarbonise society and tackle the Climate Emergency. Whilst a prosperous net zero society must be achieved, we face a currently intractable environmental challenge: conventional metal mining (where rocks are blasted and hauled to the surface to retrieve the target metal, often <1% of the total mass) results in global scale environmental impacts. We therefore face a paradox where we must increase metal production dramatically, yet their extraction, haulage and primary processing is one of our most energy intensive and carbon emitting processes. Mining also produces our largest solid wasteform by mass, several hundred billion tonnes produced annually, resulting in global-scale environmental impacts including water pollution, dust emission and tailings dam failures.

To address this challenge, my research focuses on developing next-generation ""keyhole surgery"" mining techniques. These approaches enable the selective extraction of metals from geological materials (including ores, mine waste, and contaminated land) and mine water. This work reimagines how we access critical metals – lowering environmental impacts and unlocking previously stranded resources.

15. Dr Yasuto Watanabe

National Institute for Environmental Studies, Japan

Yasuto Watanabe (YW) is specialised in doing simulations of surface environments of the Earth system. YW has been working on the evolution of the atmospheric oxygen levels in the history of the Earth and associated changes in the climate and marine biogeochemical cycles. YW has also been working on the estimation of the early Earth atmosphere, which is critical for understanding the origin of life and in understanding the planetary habitability. YW has also been working on the simulation of the global carbon cycle and activity of land vegetation under the Earth’s paleoclimate and under the global warming to further reduce the uncertainty of the future climate change.

Evolution of the atmosphere, climate, and biogeochemistry on Earth

The surface environment of the Earth has experienced dramatic evolution. On early Earth at around four billion years ago, the atmospheric oxygen level was very small while the atmospheric CO2 level was much higher than the present level. In such atmospheres, the atmospheric CO level, which is useful for the primitive marine microbial ecosystem as a source of carbon and electron, can become very high, which may have been important for the origin of life (Watanabe and Ozaki, 2024). After the emergence of primitive marine ecosystem, the atmospheric CO level decreases while atmospheric CH4 level would have increased, which would have also increased the temperature of the surface (Akahori et al., 2024). When the oxygenic photosynthesis emerged, the productivity of the marine ecosystem would have increased until the supply rate of nutrient to the ocean limits their activities. As the expansion of the activity of oxygenic photosynthesis, the atmospheric CH4 level would have decreased, which may have caused the global-scale glaciation known as the snowball Earth event at around 2.4 billion years ago (Watanabe et al., 2023a). At a similar age, a first major increase of the atmospheric O2 level occurred, reflecting the increase of the activity of oxygenic photoautotrophs and/or decreased volcanic supply of reducing gases (Watanabe et al., 2023a; 2023b; Watanabe and Tajika, 2021). The atmospheric O2 level increased to a level comparable to modern level at around 0.4 billion years ago, which would have been associated with the emergence of land plants (Lenton et al., 2016). As can be seen in the history of the Earth, the life and surface environment have co-evolved while dramatically affecting the atmospheric composition and climatic conditions. The evolution of the surface environment of the Earth would further provide important information for detecting sign of life in the future observation of Earth-like terrestrial exoplanets. In this presentation, I will outline my investigations so far regarding the evolution of the surface environment of Earth based on numerical simulations.

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16. Dr Hideko Takayanagi

Department of Earth Science, Graduate School of Science, Tohoku University, Japan

Dr Hideko Takayanagi is an Associate Professor at Department of Earth Science, Tohoku University, Japan. She is interested in changes in ocean circulation and ventilation dynamics under climate changes on various time scales, such as recent global warming, glacial-interglacial cycles, and greenhouse and icehouse Earth in the Phanerozoic. To understand the roles of the oceans in the Earth's climate system, she establishes and/or improves a method for paleoenvironmental analyses of sedimentological, crystallographical, and geochemical records in carbonate (CaCO3) sediments, crystals, and fossils and reconstructs water mass structure/conditions and composition of surface to intermediate waters in the past Pacific and Indian oceans. In April 2024, she joined the Advanced Institute for Marine Ecosystem Change (WPI-AIMEC), a joint organisation of Tohoku University and JAMSTEC, and started studying marine biogeochemical cycle dynamics and its response to climate changes based on the geochemical composition of seawater and sediments.

Changes in Pacific Ocean ventilation under glacial/interglacial states

Water masses at the surface to intermediate water depths play a crucial role in controlling heat transport, biogeochemical cycles, and ocean-atmosphere CO2 exchange through ocean circulations and ventilations in the North Pacific Ocean. Recently, the subsurface and intermediate water masses in the northwestern Pacific Ocean, such as the North Pacific Mode Water, North Pacific Central Water, and North Pacific Intermediate Water, have gained considerable interest due to large amounts of heat and CO2 absorption under recent global warming. However, variations in dynamics and physical/chemical composition of the subsurface and intermediate layers under different climatic conditions, e.g., glacial periods, still need to be better understood. Here, we analysed the oxygen isotope composition (δ18O values) of four surface-to-subsurface species of planktic foraminifers (Globigerinoides ruber, Trilobatus sacculifer, Neogloboquadrina dutertrei, and Pulleniatina obliquiloculata) and neodymium isotope composition (εNd values) of bulk benthic foraminifers to elucidate paleoceanographic conditions and water mass exchanges in surface to subsurface water depths around the Ryukyu Islands, southwestern Japan, for the last 70,000 years. The sediment core (YK12–15 PC02) used in this study was recovered from a water depth of ~400 m off Ie Island, west of Okinawa Jima.

Our results indicate that δ18O profiles of the four surface-to-subsurface planktic foraminifers varied synchronously throughout 70,000 years, except for the upper thermocline species of T. sacculifer. The extent of δ18O differences between G. ruber and T. sacculifer and between T. sacculifer and N. dutertrei/P. obliquiloculata changed significantly in centennial to millennial timescales, suggesting large fluctuations in the thickness of the mixed layer and the degree of surface water stratification around the Ryukyu Islands. In contrast, εNd values of bulk benthic foraminifers showed a significant fluctuation between –7.8 and –5.3, displaying centennial to millennial variations with an abrupt change at ca. 8 ka. Such changes in εNd of subsurface water are considered the balance of the North Pacific Mode Water and the North Pacific Intermediate Water contributions, suggesting the larger contribution of the latter during the last glacial period. Our results indicate that the intermediate circulation in the Pacific was stronger during the last glacial period compared to that of the Holocene (interglacial period), and the ocean ventilation through meridional overturning circulation in the Pacific changed significantly under glacial and interglacial climate states.

Co-authors: Kosuke Tachi1, Yoshimi Kubota2, Shigeyuki Wakaki3, Azumi Kuroyanagi1, Tsuyoshi Ishikawa4, Yasufumi Iryu1

1 Tohoku University, 2 National Museum of Nature and Science, 3 National Museum of Japan History, 4 JAMSTEC

17. Dr Kazutaka Yasukawa

The University of Tokyo, Japan

Dr Kazutaka Yasukawa is an Associate Professor at the Frontier Research Center for Energy and Resources, School of Engineering, The University of Tokyo. He earned his PhD in Engineering from The University of Tokyo in 2015. He worked as an assistant professor at the Department of Systems Innovation, School of Engineering, The University of Tokyo from 2015 to 2019, and as a lecturer at the current affiliation from 2019 to 2022. His research interests are in linkages between the genesis of seafloor mineral resources and global environmental changes. The goal of his research is to figure out the spatiotemporal distribution of industrially critical elements on Earth and provide a useful guide for the exploration and development of the resources for the sustainable development. He has specialist skills in geochemical analyses and multivariate statistical techniques.

Genesis of REE-rich mud: A perspective from multivariate statistical analyses on geochemical datasets

Rare-earth elements (REE) are essential materials for a variety of state-of-the-art and low-carbon technologies including electric vehicles, wind power generators, and light-emitting diodes. Securing resources for the industrially critical metals has been one of the most crucial issues for every nation.

In recent years, deep-sea mud has attracted much attention as a promising resource for REE [1]. Understanding the formation mechanism(s) of the “REE-rich mud” is a key to find areas of high resource potential worthy of detailed exploration. Moreover, from a scientific viewpoint, this also reveals latent relationships between the Earth system and the genesis of marine mineral resources.

In this poster presentation, I will introduce two data-driven approaches to reveal the genesis of REE-rich mud [2, 3]. One is based on a huge dataset of bulk chemical composition of deep-sea sediments, whereas the other focuses on in situ chemical composition of biogenic apatite grains (fish teeth and bone debris) that concentrate REE in the sediments. In both approaches, Independent Component Analysis (ICA), a kind of multivariate statistical, signal processing technique [4], worked effectively to deduce key information on the REE-enrichment processes that contributed to form REE-rich mud.

In the analysis of bulk sediment composition, three key components involving REE-enrichment were extracted as different independent components (ICs): hydrogenous Mn-oxides, biogenic apatite, and hydrothermal Fe-oxyhydroxides [2]. Among them, the most important mineral phase as a REE host is biogenic apatite. Thus, in situ analysis of biogenic apatite was implemented using a laser-ablation inductively coupled plasma mass spectrometer [3]. By analysing the apatite data with ICA, two signatures suggesting REE-enrichment processes (IC1: substitution and IC2: adsorption) were extracted [3]. It is notable that the IC2 score showed higher values in the extremely REE-rich layers than other sediment layers around Minamitorishima Island, Japan, in the western North Pacific Ocean. This suggests that, during the formation of the extremely REE-rich mud, surface ocean productivity and, thus, the sinking organic matter as a REE carrier in the water column increased, which facilitated REE release at seafloor and adsorption of the REE onto the apatite mineral surface. These studies indicate an intrinsic relationship between an oceanographic environmental change and deep-sea REE-enrichment.

[1] Kato, Y., Fujinaga, K., Nakamura, K., Takaya, Y., Kitamura, K., Ohta, J., Toda, R., Nakashima, T., Iwamori, H. (2011) Deep-sea mud in the Pacific Ocean as a potential resource for rare-earth elements. Nature Geoscience 4, 535-539.
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[3] Yasukawa, K., Ohta, J., Hamada, M., Chang, Q., Nakamura, H., Ashida, K., Takaya, Y., Nakamura, K., Iwamori, H., Kato, Y. (2022) Essential processes involving REE-enrichment in biogenic apatite in deep-sea sediments decoded via multivariate statistical analyses. Chemical Geology 614, 121184.
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Physics/Astrophysics: Quantum information science and technology 2025

18. Dr Dousatsu Sakata
National Institute of Advanced Industrial Science and Technology, Japan

Dousatsu Sakata is a researcher specialising in radiation science and Monte Carlo simulations. He currently serves as a Senior Researcher at the National Institute of Advanced Industrial Science and Technology (AIST) in Japan. Sakata earned his PhD from the University of Tsukuba, where he focused on experimental high energy nuclear physics. His current research interests include radiation biology, radiation chemistry, and computational physics, with significant contributions to the Geant4-DNA project. Over his career, he has held positions at prestigious institutions such as University of Osaka. He has received several awards, including the Galileo Galilei Award for his work on DNA damage prediction. His extensive publication record and active participation in international collaborations underscore his impact on the field.

Frontier of Computational Radiation Biology: Evaluation of radiation effects with radiation transport simulations

Radiation is basically everywhere, and its risk could be negligible in normal human life. However, in some specific conditions, radiation risk needs to be assessed, such as in radiation treatments, space missions, chronic exposure around the Fukushima nuclear power plant, etc. The most important phenomenon of radiation risk is radiation-induced cell death, which is one of the most typical biological endpoints after high-dose irradiation. The endpoint is usually triggered by critical DNA damage (such as double strand break: DSB) caused by physical and chemical interaction processes between radiation and DNA. This fact has long been understood qualitatively. It is however difficult to understand a whole biological system quantitatively because the system involves multi-layered complex probabilistic processes. Therefore, it was necessary to develop a simulation platform that allows the simulation of physical/chemical DNA damage processes and the prediction of radiobiological endpoints. As part of the international collaboration for the development of radiation transport simulations: Geant4-DNA [1], we have developed a simulation platform called “moleculardna” [2-4] to investigate a whole radiobiological system, combining simulations for DNA damage and mathematical modelling for radiobiological endpoint predictions. The integration of DNA damage simulations and model calculations of the repair kinetics facilitates a comprehensive description of the biological effects on a single normal human fibroblast cell following irradiation. The advancements in this field have led to the emergence of a new research domain, "computational radiobiology", which has the potential to contribute to the investigation of radiation effects in the domains of radiation treatment and protection from environmental and space radiations.

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[2] D. Sakata et al., Physica Medica 62, 152-157 (2019)
[3] D. Sakata et al., Scientific Reports 10 20788 (2020)
[4] D. Sakata et al., Physica Medica 105 102508 (2023) - Galileo Galileo Award (Elsevier, 2024)
Co-authors: K. Chatzipapas, M. Dordevic, N. Lampe, W.G. Shin, H. Tran, and S. Incerti

19. Dr Mingee Chung

School of Physics and Astronomy, University of Birmingham, UK

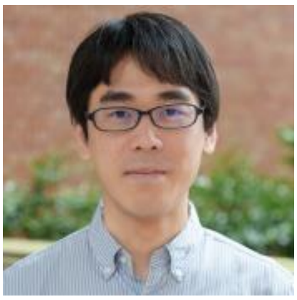
Dr Mingee Chung (Minki Jeong) is an experimental physicist and a member of the academic staff in the Condensed Matter Group, originally established by Professor W (Joe). F. Vinen, FRS, in 1962. His research group applies Nuclear Magnetic Resonance (NMR) spectroscopy to explore and understand novel phenomena in solid quantum matter. He is currently Project Lead of the Strategic Infrastructure 'Ulta-Low-Temperature NMR Facility' funded by the Engineering and Physical Sciences Research Council.

Born and educated in South Korea, Dr Chung embarked on an academic career in Europe following the completion of his PhD at KAIST. His journey began in France, with appointments in Orsay and Grenoble, before continuing in Switzerland at Lausanne. Since 2017, he has been based in Birmingham UK.

Quantum Materials probed at Atomic Scale

Quantum magnets offer a rich platform for exploring quantum many-body physics, hosting a rich variety of quantum phases including Tomonaga–Luttinger liquids, quantum spin liquids, spin super-solids, and magnon Bose–Einstein condensates. They also serve as analogue simulators for other quantum systems—such as cold atomic gases—and provide experimental grounds for validating theoretical constructs like spin–fermion mappings in one dimension. I will present experimental results demonstrating Nuclear Magnetic Resonance as a powerful atomic-scale probe of the quantum magnets.

We have recently launched an Ultra-Low-Temperature NMR facility as part of a Strategic Infrastructure investment by the UK Engineering and Physical Sciences Research Council. This capability enables atomic-scale investigation of quantum materials under extreme conditions: temperatures down to 20 mK, magnetic fields up to 16 T, and high pressures. While tailored for advancing research in quantum magnetism, this infrastructure is designed to address broader challenges across materials chemistry, including energy harvesting and molecular machines.



20. Dr Takafumi Tomita

Institute for Molecular Science, Japan

Dr Takafumi is an experimental physicist specialising in quantum computing with ultracold neutral atoms. He received his PhD in Physics from Kyoto University under the supervision of Professor Yoshiro Takahashi, where his research focused on quantum simulation for many-body quantum physics.

Currently, Takafumi is an Assistant Professor at the Institute for Molecular Science, where I lead experimental efforts to develop scalable quantum computing platforms. His research interests span quantum information, quantum technology, and quantum many-body physics. Takafumi’s passion for quantum science lies in exploring how precisely humans can control the quantum world, pushing the boundaries of our understanding and manipulation of nature's fundamental laws.

Development of a neutral-atom quantum computer

Quantum computers are a new type of computing device that harnesses the principles of quantum mechanics to solve certain problems much faster than today's conventional computers. They have the potential to impact a wide range of fields, including cryptography, materials science, optimization, and drug discovery. Various physical systems are being developed as platforms for realizing quantum computers, such as superconducting circuits, trapped ions, and neutral atoms. Among these, neutral-atom systems—which use individual atoms trapped and controlled by lasers — have been attracting growing interest due to their long coherence times, high scalability, and the availability of advanced techniques such as laser cooling and optical trapping. [1-3].

We are developing a quantum computer based on neutral atoms. Our approach uses arrays of individual atoms trapped by optical tweezers as quantum bits (qubits). By selectively illuminating atoms with laser light, we manipulate their quantum states and perform computational operations. In this poster, I will present the architecture of a neutral-atom quantum computer, provide an overview of the machine we are currently building, and share our roadmap for future development.

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[2] A. G. Radnaev et al., "A universal neutral-atom quantum computer with individual optical addressing and nondestructive readout", arXiv:2408.08288 (2024).
[3] B. W. Reichardt et al., "Logical computation demonstrated with a neutral atom quantum processor", arXiv:2411.11822 (2024).

Co-authors: Kritsana Srakaew, Omar Kecir, Jorge Mauricio, Genki Watanabe, Seiya Shinkawa, Harumu Odagawa, Valentine Anthoine-Milhomme, Titouan Jaunet-Lahary, Sylvain de Leséleuc, Kenji Ohmori.

21. Dr Ophelia Crawford
Riverlane, UK

Ophelia Crawford is a Staff Quantum Scientist at Riverlane, a quantum computing company based in Cambridge. While there, she has undertaken research in a variety of areas across quantum algorithms and quantum error correction (QEC). She has also collaborated with external partners such as quantum hardware developers and potential end-users of quantum computers. She currently leads the team responsible for exploring and developing QEC protocols and logical operations for Riverlane's QEC Stack, Deltaflow. Ophelia joined Riverlane in 2018 after completing a PhD in theoretical and computational geophysics at the University of Cambridge, where she developed PDE-constrained optimisation methods for the glacial isostatic adjustment inverse problem.

To reset, or not to reset — that is the question

Quantum computers are not, and never will be, perfect. To ensure errors occurring during quantum calculations do not render results useless, the process of quantum error correction will be required. In quantum error correction, multiple physical qubits are used to represent a single logical qubit, introducing redundancy and providing some protection against errors. In order to understand and correct the errors that occur, measurements are made.

Whether to reset measured qubits, or not, during quantum error correction experiments is a question of both foundational and practical importance for quantum computing. Text-book quantum error correction demands that qubits are reset after measurement. However, fast qubit reset has proven challenging to execute at high fidelity. Consequently, many cutting-edge quantum error correction experiments are opting for the no-reset approach, where physical reset is not performed. It has recently been postulated that no-reset is functionally equivalent to reset procedures, as well as being faster and easier. For memory experiments, we confirm numerically that resetting provides no benefit. On the other hand, we identify a remarkable difference during logical operations. We find that unconditionally resetting qubits can reduce the duration of fault-tolerant logical operation by up to a factor of two as the number of measurement errors that can be tolerated is doubled. We support this with numerical simulations. However, our simulations also reveal that the no-reset performance is superior if the reset duration and infidelity exceed given thresholds. For example, with the noise model we considered, we find the no-reset performance to be superior when the reset duration is greater than approximately 100 ns and the physical error probability is greater than approximately 10-2.5 ~ 0.003. Lastly, we introduce two novel syndrome extraction circuits that can reduce the time overhead of no-reset approaches. Our findings provide guidance on how experimentalists should design future experiments.

22. Dr Eriko Kaminishi

Keio University, Japan

Dr Eriko Kaminishi received her Undergraduate, MS, and PhD degrees in physics from Ochanomizu University, Tokyo, Japan, in 2009, 2011, and 2013, respectively. During her student years, she studied mathematical physics, focusing on exactly solvable models such as the Bethe ansatz. In 2012, she held a JSPS Postdoctoral Fellowship at Ochanomizu University, followed by another fellowship at the University of Tokyo in 2013. From 2014, she continued her postdoctoral research at the University of Tokyo, where she worked on thermalization in isolated quantum systems. Since 2018, she has been a researcher at the Quantum Computing Center, Keio University, Yokohama, Japan. Her current research interests include quantum dynamics and variational quantum algorithms for noisy intermediate-scale quantum (NISQ) devices, with a focus on understanding how noise can be exploited in optimization processes.

Stochastic Dynamics of Saddle Point Escape in Noisy Variational Quantum Algorithms

In recent years, quantum computing has gained increasing attention as a promising technology for solving complex computational problems. One such application is the Variational Quantum Eigensolver (VQE), a hybrid algorithm that combines quantum and classical computing to find the lowest energy states of quantum systems. This approach is particularly relevant in fields like quantum chemistry and condensed matter physics.

To optimize the parameters in VQE, Stochastic Gradient Descent (SGD)—a widely used technique in machine learning—is often employed. When running VQE on actual quantum hardware, however, the limited number of measurements introduces measurement noise, which naturally adds randomness to the optimization process.

In this study, we focus on how such measurement noise affects the efficiency of optimization, especially in escaping from so-called saddle points—regions in the parameter space where progress can be slow or stagnant. Our analysis reveals that increasing the level of measurement noise can actually help escape saddle points more quickly, with the escape time following a power-law scaling relative to the ratio between the learning rate and the number of measurements.

Furthermore, we show that this behaviour is well captured by a stochastic differential equation (SDE), which provides a continuous-time approximation of the SGD dynamics. These findings suggest that, despite being a source of uncertainty, measurement noise can play a constructive role in optimization, and that studying simplified SDE models can provide valuable insight into the behaviour of noisy quantum algorithms like VQE.

E. Kaminishi, T. Mori, M. Sugawara, and N. Yamamoto, Impact of Measurement Noise on Escaping Saddles in Variational Quantum Algorithms, arXiv:2406.09780 (2024).

Co-authors: Takashi Mori, Michihiko Sugawara, and Naoki Yamamoto.

23. Dr Laura Blackburn

University of Sussex, UK

Dr Laura Blackburn is a Postdoctoral Research Fellow in the Department of Physics and Astronomy at the University of Sussex. She is a member of the Sussex Centre for Quantum Technologies and the Ion-Trap Cavity-QED and Molecular Physics (ITCM) group, where she completed her PhD in 2022 under the supervision of Prof Matthias Keller. Her research focuses on the development of a quantum clock based on a trapped molecular nitrogen ion to search for new physics beyond the Standard Model. Outside the laboratory, she enjoys sharing her work with the public and has presented at events including Soapbox Science and Café Scientifique.

Building a molecular clock to test fundamental physics

At the University of Sussex, we are building a clock based on a trapped molecular nitrogen ion to search for physics beyond the standard models of particle physics and cosmology.

Nitrogen ions are very good candidates for measuring potential changes in the fundamental constants because they have vibrational and rotational transitions that are sensitive to changes in the proton-to-electron mass ratio, but insensitive to changes in their environment. Precision spectroscopy of these vibrational transitions has the potential to achieve a fractional frequency uncertainty below 10-20, which is better than what has been achieved with the best atomic clocks to-date.

In this experiment, we will probe a vibrational transition in the molecular ion. A single nitrogen ion will be trapped in an ion trap alongside a calcium ion, which is necessary to cool and detect the nitrogen ion. I will present our recent progress on the experiment, including the development of techniques and laser systems for producing molecular nitrogen ions in the desired state and progress towards the spectroscopy of nitrogen.

Chemistry/Material Science: Experimental and computational exploration of three-dimensional biological structure

24. Dr Andrew Holding
University of York, UK

Dr Andrew Holding is a researcher, educator, and science communicator with a focus on breast cancer biology. Holding earned a degree in chemistry and a PhD in chemical biology and has since dedicated his career to developing and applying innovative technologies to answer critical questions in biomedical research. His work includes designing isotopically labelled probes, cross-linking mass spectrometry pipelines, and machine learning tools for molecular analysis. Recently, he has contributed to advancing our understanding of tissue-specific glucocorticoid responses in healthy and cancerous tissue and novel factors regulating breast cancer progression. Andrew also holds awards for his public science engagement, currently, he shares insights into new research and scientific news on his Twitch channel and on local Radio.

Elucidating Steroid Hormone Receptor Complexes

Steroid Hormones Receptors (SHRs) are ligand-activated transcription factors that mediate cellular responses to steroid hormones (SHs) through regulating gene expression. Understanding how these receptors function is vital for elucidating SH-driven physiology and pathology, including the roles of SHs in normal development, metabolism, and reproduction, alongside their aberrant function in cancer, endocrine disorders, and inflammatory diseases. Investigating the mechanisms by which SHRs signal and are regulated is therefore essential for advancing our understanding of both normal physiology and disease processes, and will inevitably lead to the development of novel therapeutic strategies.

Here, we present novel methodologies for the investigation of large-scale protein complexes and SHR interactions with chromatin and co-regulatory proteins. Our approaches include UV-induced and chemical cross-linking coupled with mass spectrometry-based proteomics, and machine learning algorithms for expanding our opportunities from current data. This combination enables detailed exploration of SHR signalling in increasingly physiologically relevant settings.

25. Dr Yuzu Kobayashi
RIKEN/JST, Japan

Dr Yuzu Kobayashi received her master’s degree in chemistry from Kyoto University in 2019, where she studied molecular spectroscopy. She then worked on battery development at Nippon Telegraph and Telephone Corporation (NTT) before earning her PhD in Materials Science from the University of Tokyo in 2023. During her doctoral studies, she conducted research at RIKEN as a Junior Research Associate, focusing on electrochemical reactions at the single-molecule level using a combined approach of electrochemistry and scanning tunnelling microscopy (EC-STM). Currently, she is a JST PRESTO researcher at RIKEN, where she integrates spectroscopy into EC-STM to perform electrochemical tip-enhanced Raman spectroscopy (EC-TERS). Her research aims to elucidate the mechanisms of chemical reactions at the molecular and atomic scales, contributing to a deeper understanding of fundamental electrochemical processes.

Unveiling Reaction Mechanisms with Molecular-Level Measurements

Electrochemical reactions, discovered over 200 years ago, are now at the core of a wide range of technologies—from batteries and catalysts to sensors—that support our modern society. However, we still do not fully understand what occurs at the electrochemical interface where electrodes meet solution, at the level of atoms and molecules—the fundamental units of chemical reactions. To tackle global challenges with more advanced and efficient electrochemical technologies, we must uncover and control these hidden interfacial processes.

To address this, I am developing a technique called electrochemical scanning tunnelling microscopy (EC-STM), which enables nanoscale measurement of interfacial molecules [1]. In this method, a needle-like probe—sharpened to the atomic scale—is brought close to the electrochemical interface and scanned across the surface while detecting tunnelling current, allowing us to visualize the molecules at the interface. However, fabricating such probes has remained a persistent challenge for more than 30 years due to the technical difficulty of achieving the required precision.

To overcome this, I introduced a novel idea: using ultrafine glass pipettes, originally developed for biological applications, as probes for EC-STM. This breakthrough addresses the longstanding bottleneck in probe fabrication [2]. Moreover, I am integrating spectroscopic techniques with this platform to gain chemical information at the nanoscale. By capturing complex, invisible phenomena with a single tiny probe, this research paves the way toward a molecular-level understanding of electrochemical reactions.

[1] Y. Kobayashi et al., J. Phys. Chem. C, 127, 746 (2023).
[2] Y. Kobayashi et al., J. Phys. Chem. C, 127, 13929 (2023).

26. Dr Lauren Hatcher
Cardiff University, UK

Lauren completed her PhD in Chemistry at the University of Bath in 2014, under the supervision of Professor Paul Raithby. After postdoctoral positions in the Metastable Materials group at Bath, and the EPSRC's Continuous Manufacturing and Advanced Crystallisation Future Manufacturing Research Hub (CMAC), Lauren moved to Cardiff University in 2020 where she holds a Royal Society University Research Fellowship. Lauren's research is centred around photo- and electrically-switchable materials and their study using dynamic X-ray diffraction techniques. She also conducts extensive equipment and method development work for in-situ photocrystallography and serial crystallography, using state-of-the-art set-ups in both in the home X-ray lab at Cardiff and at National Facilities.

Exploring Multifunctional Switching in Lead Free Hybrid Organic-Inorganic Crystals by In-situ X-ray Diffraction

Hybrid organic-inorganic pervoskites (HOIPs), e.g. methyl ammonium lead iodide, have received particular attention in recent years and are successfully applied in a variety of areas including as next-generation solar photovoltaics.[1] However, concerns over the stability and toxicity of lead-containing systems have led to a considerable effort to discover novel hybrid organic-inorganics containing less toxic alternatives.[2-5] In addition, in-depth understanding of the key structure-property relationships responsible for the useful switching behaviours in these hybrid materials remains limited,[1] and would benefit significantly from in-situ studies using advanced diffraction techniques.

We present our recent investigation into iron-based hybrid organic-inorganic crystals of the general formula (A)[$NaFe(CN)_5(NO)$].xH_2O, where A = an organic ammonium cation. The nitroprusside anion [$Fe(CN)_5(NO)$]$_2$- is a well-known photoswitch[6] and, by incorporating this fragment, we can aim to rationally design-in photoswitching behaviour with the potential to couple to other useful properties common in HOIP-like materials, such as pyroelectric or ferroelectric switching.

This talk will focus on the novel crystalline system (FA)[$NaFe(CN)_5(NO)$].H_2O (FA = formamidinium), which concomitantly displays photo- and pyroelectric switching, as well as second and third harmonic generation.[7] We present in-situ 3D structure determination of these switching processes using in-situ single-crystal X-ray diffraction, both in our home X-ray lab and at Diamond Light Source, exploring the combined effects of temperature, light irradiation and applied electric field. The latter experiments uncover unusual phase transitions induced by the combination of temperature and electric field, and provide 3D information at the atomic scale that will guide the development of improved crystals which are rationally engineered for enhanced functionality in the future.

[1] Tsai, H. et al. Light-induced lattice expansion leads to high-efficiency perovskite solar cells. Science 360, 67 (2018).
[2] Gao, Y., Pan, Y., Zhou, F., Niu, G. & Yan, C. Lead-free halide perovskites: a review of the structure–property relationship and applications in light emitting devices and radiation detectors. Journal of Materials Chemistry A 9, 11931-11943, doi:10.1039/D1TA01737C (2021).
[3] Zhang, S., Malič, B., Li, J.-F. & Rödel, J. Lead-free ferroelectric materials: Prospective applications. Journal of Materials Research 36, 985-995, doi:10.1557/s43578-021-00180-y (2021).
[4] De Angelis, F. The Prospect of Lead-Free Perovskite Photovoltaics. ACS Energy Letters 6, 1586-1587, doi:10.1021/acsenergylett.1c00636 (2021).
[5] Zhang, F. et al. Recent Advances and Opportunities of Lead-Free Perovskite Nanocrystal for Optoelectronic Application. Energy Material Advances 2021, 5198145, doi:10.34133/2021/5198145 (2021).
[6] Carducci, M. D., Pressprich, M. R. & Coppens, P. Diffraction studies of photoexcited crystals: Metastable nitrosyl-linkage isomers of sodium nitroprusside. Journal of the American Chemical Society 119, 2669-2678 (1997).
[7] Morris, J. J. et al. Exploring Pyroelectricity, Thermal and Photochemical Switching in a Hybrid Organic-Inorganic Crystal by In Situ X-Ray Diffraction. Angewandte Chemie International Edition 63, e202401552 (2024).

27. Dr Masazumi Fujiwara

Okayama University, Japan

Masazumi's research applies quantum sensor technology to biological systems, requiring collaboration across quantum physics, spectroscopy, cellular biology, and analytical chemistry. Since launching this work in 2016, he has collaborated with biologists to successfully demonstrate quantum biosensing techniques, resulting in publications such as Science Advances (2020), Physical Review Research (2020), and Nanotechnology (2021). These partnerships have also enabled Masazumi to expand into environmental chemistry, as shown by a recent publication in Chemosphere (2024). He believes that interdisciplinary collaboration is essential for advancing quantum sensing in real-world applications. This belief strongly motivates Masazumi's desire to participate in the FoS symposium and connect with researchers from diverse scientific backgrounds.

Quantum Sensing in Biology Using Fluorescent Nanodiamonds

Fluorescent nanodiamonds (FNDs) with nitrogen-vacancy (NV) centres are promising tools for chemical and biological sensing. They are non-toxic, photostable, and capable of detecting temperature and magnetic fields at the nanoscale via quantum spin properties.

We recently demonstrated real-time temperature sensing in Caenorhabditis elegans using FNDs and developed a chip-based platform compatible with standard biological assays. To enhance sensitivity, we engineered quantum-grade FNDs with improved spin coherence, enabling precise measurements with low microwave power. These advances make FNDs a versatile platform for probing cellular environments, with potential applications in neuroscience, developmental biology, and regenerative medicine.

28. Dr Glenn Masson

University of Dundee, UK

Dr Glenn Masson is a specialist in protein structure determination, using two complementary techniques: cryo-electron microscopy and hydrogen deuterium exchange mass spectrometry (HDX-MS). He primarily studies a class of protein kinases which activate the Integrated Stress Response (ISR), a pro-survival pathway which is often misregulated in cancer and neurodegenerative diseases.

Using Hydrogen Deuterium Exchange Mass Spectrometry (HDX-MS) to resuscitate lifeless protein structures

Protein structures, whether determined by cryo-EM, X-ray crystallography, or AI-based methods, are typically presented as static models. However, this contrasts with the reality of proteins in biological systems, where they are dynamic entities in constant motion—a feature that is critical to their function within the cell. Hydrogen-deuterium exchange mass spectrometry (HDX-MS) is a structural mass spectrometry technique that reveals which regions of a protein are most mobile and how different domains interact, enabling us to animate protein structures. In addition to providing insight into protein dynamics, HDX-MS can be used to screen for drug candidates and to assess how these compounds affect protein flexibility. Notably, it allows for the investigation of intrinsically disordered proteins and supports the discovery of novel therapeutics that may be inaccessible through conventional drug discovery approaches. Here I present several examples of how HDX-MS has guided our understanding of cancer-causing mutations in critical cell growth proteins, and how we have created drugs to combat these mutations.

29. Professor Keiichi Inoue

The University of Tokyo, Japan

Keiichi Inoue is an Associate Professor at the Institute for Solid State Physics, the University of Tokyo, Japan. He received his PhD in 2007 from Kyoto University in the study of the photoreceptive rhodopsin proteins under the supervision of Professor Masahide Terazima. From 2007 to 2009, he joined Professor Masaaki Fujii and Professor Makoto Sakai’s laboratory at Tokyo Institute of Technology as a project assistant professor, developing infrared super-resolution microscopes. He then moved to Professor Hideki Kandori’s laboratory at Nagoya Institute of Technology, where he studied the molecular mechanisms of microbial rhodopsins using functional assays and spectroscopic methods, first as an assistant professor (2009–2016), then as an Associate Professor (2016–2018). His current research centres on the exploration of new functional rhodopsins and the physicochemical study of their molecular mechanisms through time-resolved spectroscopy, electrophysiology, and structural analysis. Notably, he identified light-driven outward sodium-pumping and inward proton-pumping rhodopsins. Additionally, he is pioneering machine learning methodologies for designing novel functional proteins.

Rhodopsin: Photoreceptive Membrane Proteins with Diverse Functions

Rhodopsins are photoreceptive membrane proteins that utilise a retinal pigment embedded within a seven-transmembrane helix structure to capture sunlight energy. They are broadly classified into two distinct classes: animal and microbial rhodopsins. Traditionally, animal rhodopsins have been known to mediate visual signalling, whereas microbial rhodopsins convert solar energy into chemical energy. Through genomic and metagenomic analyses, we have identified novel rhodopsins exhibiting a wide range of functions [1-16]. By employing state-of-the-art spectroscopic techniques and structural analyses, we have also elucidated the molecular mechanisms by which these functions are realised, all based on their shared, compact seven-transmembrane architecture.

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Biology/Life Science: Experimental evolution to understand and engineer life

30. Dr Nao Nakagawa-Tamagawa
Kagoshima University, Japan

A neuroscientist investigating how the neuronal network of the neocortex develops correctly. During his postdoctoral period, he discovered that neocortical neurons of neonatal mice selectively connect with neurons of the same type by gap junctions (Maruoka*, Nakagawa* et al., Science, 2017). He is currently working on the hypothesis that this gap junction network contributes to the formation of cell type-specific precise synaptic network. In another project, he recently discovered that ion channel mutations associated with neurodevelopmental disorders alter neuronal migration, axonal projection, and neuronal morphology in a disease-specific manner (Nakagawa-Tamagawa et al., Front Neurosci, 2021; and unpublished data). As the next step, he aims to elucidate the molecular mechanisms and responsive genes that link between channel mutations and cortical abnormalities. His goal is to contribute to the establishment of protective and therapeutic approaches against the diseases.

Ion channels and gap junctions in neocortical circuit formation and malformation

Ion channels permeate specific ions through the cell membrane of neurons. Sodium channels (Nav) permeate Na+ and generate action potentials, whereas calcium channels (Cav) permeate Ca2+ and trigger various cellular responses. Gain-of-function mutations in Nav and Cav have been identified in patients with infantile epilepsy and autism spectrum disorder, respectively, suggesting that these mutations exert distinct effects on neocortical development in different manners. I introduced mutant channels into neurons in the mouse neocortex and investigated their effects on the circuit formation. Cav mutants disrupted neuronal migration and altered neuronal distribution [1]. In contrast, Nav mutants affected neuronal morphology and axonal projection in the corpus callosum (unpublished). Both mutants reduced interhemispheric connections. I am working to elucidate the mechanisms underlying these phenotypes and clarify their relevance to pathophysiology.

Gap junctions permeate ions between cells. They mediate electrical coupling between neurons to form coordinated activity in the nervous system. Gap junctions also regulate circuit formation through adhesive function [2] and channel function [3]. Though excitatory neurons in the mouse neocortex do not possess gap junctions in the mature stage, I previously found that gap junctions are densely formed between neurons of the same cell type during neonatal stage [4] and mediate synchronous firing [5]. Gap junction networks may regulate cell type-specific circuit formation during development, and the mechanisms are under investigation.

In summary, ion channels and gap junctions regulate activities and other aspects of neurons in the developing neocortex. These functions are likely responsible for the proper construction and function of circuits throughout the brain. I am dedicated to elucidating these mechanisms systematically.

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31. Professor Masato Yamamichi

National Institute of Genetics, Japan

Masato Yamamichi holds a diploma degree in Ecology from the University of Tokyo (2007). He finished his PhD in Evolutionary Biology at SOKENDAI (the Graduate University for Advanced Studies) of Hayama in 2012. Thereafter, he worked as a JSPS Postdoctoral Fellow at Cornell University (USA: 2012-2014), as a Program-Specific Assistant Professor of Hakubi Center for Advanced Research at Kyoto University (2014-2017), as a Lecturer of Department of General Systems Studies at the University of Tokyo (2017-2020), and as a Senior Lecturer of School of Biological Sciences at the University of Queensland (Australia: 2020-2023). Since April 2023, he is an Associate Professor of Center for Frontier Research at the National Institute of Genetics (Mishima).

How does rapid evolution prevent population extinction?

One of the most fundamental questions in biology is how populations avoid extinction in stressful environments. Classical studies in ecology and evolutionary biology assumed that adaptive evolution to changing environments is too slow to prevent extinction. Recent studies, on the other hand, revealed that evolution can be rapid enough to affect contemporary ecological processes and impede population extinction (i.e., evolutionary rescue). To understand how evolutionary rescue occurs, we analysed mathematical models and conducted laboratory experiments using green algae. We found that evolutionary rescue is affected by various factors including sexual reproduction, environmental fluctuations, and species interactions (predation and competition). We propose future integrative approaches for understanding the potential importance of rapid evolution in population persistence in nature.

32. Dr Zheren Zhang

Imperial College London, UK

Zheren Zhang is a research associate working at the interface of evolutionary and synthetic microbiology. He received his PhD from Leiden University in the Netherlands, where he studied the evolutionary role of genomic instability in antibiotic-producing Streptomyces, uncovering mechanisms of division of labour. He then moved to the University of Oxford to investigate labour-divided degradation of toluene in Pseudomonas putida. At Imperial College London, his work has focused on plastic valorisation using P. putida. Later this year, he will start his own group at Queen Mary University of London, applying evolutionary and synthetic approaches in biotechnology to tackle environmental challenges.

The evolution of division of labour

The division of labour is a foundational principle across all biological systems. Gaining insight into how and why division of labour evolved offers a deeper understanding of many fundamental aspects of life. In this study, we use *Pseudomonas putida* as a model organism to investigate division of labour in the toluene biodegradation pathway, a system for breaking down hydrocarbon pollutants. This two-step pathway involves an upper operon that converts toluene into benzoate, a diffusible intermediate, and a lower operon that enables cells to use benzoate as their sole carbon source.

Interestingly, we observed a division of labour phenotype in the wild-type strain, suggesting the potential for functional specialisation in natural populations. Through synthetic engineering of specialist strains expressing either the upper or lower operon, alongside a generalist strain expressing both, we explore how varying environments favour the evolution of division of labour versus generalisation.

33. Professor Yosuke Tashiro

Shizuoka University, Japan

Yosuke Tashiro is focused on the dynamics, functions, and applications of microbial-derived nanoparticles. His interest began during his PhD at University of Tsukuba, where he studied extracellular vesicles surrounding bacteria in Nobuhiko Nomura’s lab. Since then, he has used molecular biology techniques to understand bacterial cell-to-cell communication via nanoparticles and their formation. In 2012, he was a postdoctoral researcher at University of Cambridge. In 2013, he began his academic career at the Department of Engineering at Shizuoka University, where his research on nanobioparticles has extended to medical and bioengineering applications. Additionally, in 2024, he was a visiting researcher at University of Oxford. His ultimate goal is to advance the science of synthetic nanobioparticles by utilising bacteria to produce functional nanoparticles that contribute to human health, particularly in medical treatments and disease prevention.

Cracking the code of bacterial membrane vesicles: Integrating molecular insights, engineering, and biomedical innovation

Bacterial membrane vesicles (MVs) are a universal feature of prokaryotic life, enabling the transfer of proteins, nucleic acids, and small molecules beyond the cell envelope. Despite their ubiquity, the precise mechanisms underlying MV biogenesis remain only partially understood. This poster summarizes recent findings that elucidate the genetic and physicochemical processes driving vesicle formation, including alterations in lipid composition, cell envelope dynamics, and cellular signalling pathways [1, 2, 3].

The formation of MVs with diverse sizes and morphologies has been shown to be modulated by environmental and genetic factors [4, 5]. This controllability opens new avenues for vesicle engineering, enabling the design of tailored MVs for specific biomedical applications.

Conditions have also been identified in which pathogenic bacteria release MVs that potently elicit inflammatory responses in host immune cells, underscoring their role as immunostimulatory agents [6]. To address these diverse roles, advanced detection and isolation techniques have been employed, including membrane curvature-selective probes and nano/microfluidic devices.

Altogether, this integrated perspective not only deepens the understanding of MV biology but also expands their potential as natural nanocarriers in drug delivery, diagnostics, and vaccine development. These insights provide a roadmap for leveraging MVs in both fundamental research and clinical innovation.

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Additional participants

Dr Yume Imada
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Imada studies evolutionary ecology, focusing on insect ecology and plant-animal interactions.

Professor Niko Kimura
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- Doctor of Philosophy in Engineering, (Mar. 25, 2021): Graduate School of Chemical Sciences and Engineering, Hokkaido University, Japan
- JSPS Research Fellowship for Young Scientists (DC1), (Apr. 1, 2019–Mar. 31, 2021): Graduate School of Chemical Sciences and Engineering, Hokkaido University, Japan
- Assistant Professor, (Apr. 1, 2021–Aug. 31, 2023): Department of Applied Chemistry, Faculty of Engineering, Kyushu University, Japan
- Senior Assistant Professor, (Sep. 1, 2023–): Division of Advanced Mechanical Systems Engineering, Institute of Engineering, Tokyo University of Agriculture and Technology, Japan