Field:
Biology / Life Sciences

Session Topic:
Uncovering Plant Biology with Cutting-edge Imaging Technology

Introductory Speaker:
NAKAJIMA Kohdai, Keio University

Title: Frontiers in Plant Science with Advanced Microscopy

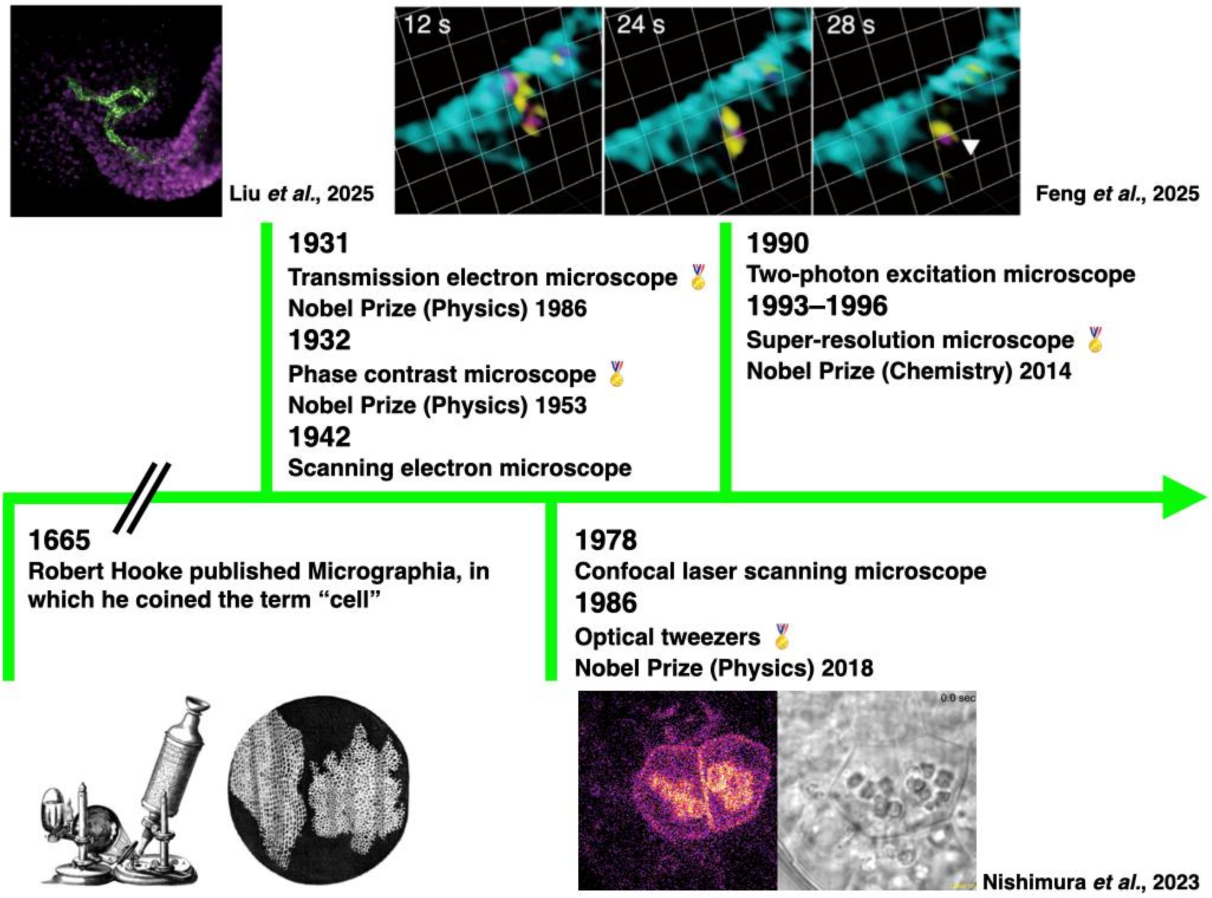
The history of plant research began almost in parallel with the dawn of microscopic observation. Robert Hooke, well known for formulating Hooke's law, constructed his own microscope and discovered “cells” while observing cork tissue [1]. The structures that Hooke described were in fact the rigid cell walls of dead plant cells. Later, Robert Brown, famous for the discovery of Brownian motion, identified the cell nucleus through careful observation of epidermal cells of orchids [2]. These pioneering studies illustrate that several fundamental discoveries in cell biology were originally made using plant materials.

Notably, these breakthroughs were achieved before the theoretical foundation of microscopy was formally established by Ernst Karl Abbe. Abbe’s work later clarified the optical principles that determine the resolving power of microscopes and laid the groundwork for modern optical design [3]. Thus, advances in microscopy and progress in plant science have historically developed in close parallel, each driving the other forward.

In recent decades, the development of microscopy technologies has accelerated dramatically. New optical methods have emerged that surpass the classical diffraction limit, such as super-resolution microscopy [4], while deep-tissue imaging has become possible with two-photon excitation microscopy [5]. In addition, live-cell imaging techniques now enable researchers to observe dynamic cellular processes in living cells in real time [6], and tools such as optical tweezers allow precise physical manipulation of cells and intracellular structures under the microscope [7]. Together with sophisticated image analysis approaches that extract quantitative information from imaging data, these advances are transforming our ability to investigate complex biological phenomena that were once inaccessible.

In this symposium, Dr. Sasaki and Dr. Landrein will present how advanced imaging approaches have contributed to our understanding of intracellular dynamics and developmental processes in plants, and discuss future perspectives for the field. Dr. Sasaki has investigated the dynamics of microtubules—one of the major cytoskeletal components—revealing new insights into plant cell division and the differentiation of xylem vessels that serve as conduits for water transport. Dr. Landrein has developed mechanical models of seed growth, providing a framework for understanding how the final size and shape of seeds are determined through the interplay of growth dynamics and physical forces.

References:
[1] Hooke, R. Micrographia or some physiological descriptions of minutes bodies made by magnifying glasses. (J. Martyn and J. Allestry, 1665).
[2] Brown R. 1829–1832 Observations on the organs and mode of fecundation in Orchideae and Asclepiadeae. Trans Linn Soc Lond 16: 685–746
[3] AbbeE. (1873). Beiträge zur Theorie des Mikroskops und der mikroskopischen Wahrnehmung.Arch. Mikrosk. Anat.9413–468.
[4] Feng, Y. et al. Retrieval from vacuolar and endosomal compartments underpinning the neofunctionalization of SNARE in plants. Nat. Plants 11, 2168–2180 (2025)
[5] Liu, X et al., (2025). Fertilization-dependent phloem end gate regulates seed size. Current Biology, 35(9), 2049-2063.e3.
[6] Toyota et al., Glutamate triggers long-distance, calcium-based plant defense signaling. Science 361,1112-1115 (2018)
[7] Nishimura et al., Cell polarity linked to gravity sensing is generated by LZY translocation from statoliths to the plasma membrane. Science 381,1006-1010 (2023)



Field:
Biology / Life sciences

Session Topic:
Uncovering Plant Biology with Cutting-edge Imaging Technology

Speaker:
Benoit LANDREIN, CNRS, ENS de Lyon

Title: Mechanical Control of Plant Organ Growth

In plants, as in animals, *morphogenesis* primarily depends on the ability of cells to communicate with each other using biochemical signals. This communication allows cells to organize and acquire an identity based on their position within developing organs. However, morphogenesis also relies on growth, a biophysical process through which cells and tissues deform and extend, enabling organs to reach their final size and shape.

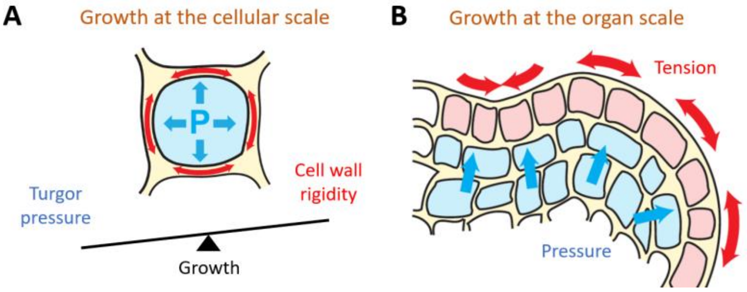


Fig.1 Plant growth control at cell and organ scale

In single plant cells, growth is governed by the mechanical properties of the cell: it is driven by internal *turgor pressure* but constrained by the rigidity of the surrounding *cell wall* (**Fig.1A**). In multicellular organs, growth depends not only on the mechanical properties of individual cells but also on mechanical interactions between adjacent cells and tissues[1,2] (**Fig.1B**). These interactions generate forces that cells can sense, triggering specific responses through a process known as *mechanosensing*. Nevertheless, the extent to which mechanical signals influence the growth of plant organs, and the molecular mechanisms underlying this process, remain to be fully characterized[1].

In my group, we investigate the mechanical control of plant organ growth, using the seed of *Arabidopsis thaliana* as a model (**Fig. 2**). By combining experimental approaches from molecular biology, imaging, biophysics, and computational modeling, our work demonstrates that developing seeds behave like balloons: the inner tissue of the seed, the endosperm, promotes growth through turgor pressure. However, this process generates tension in the surrounding seed coat, which is perceived by the cells, triggering specific mechanosensitive responses that ultimately restrict growth, thereby determining the final seed size and shape[3,4].

Presentation Abstracts

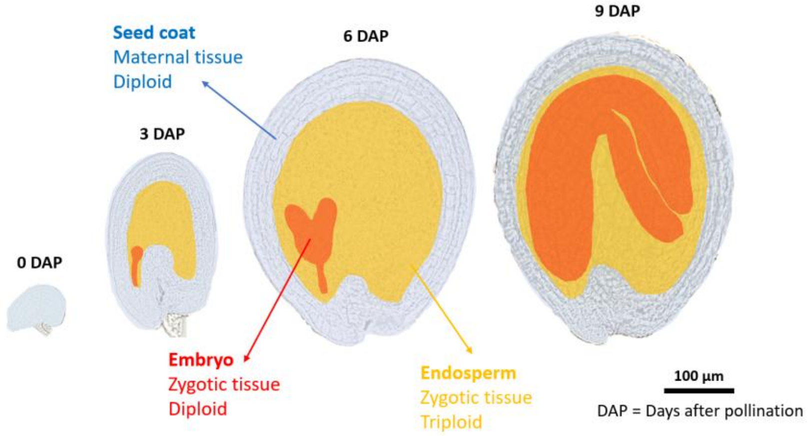


Fig.2 Development of the seed in *Arabidopsis thaliana*
Product of the double fecundation of the ovule by the pollen, the seed is composed of three tissues that are genetically and physically distinct: the embryo, the endosperm and the seed coat

References:

1.Landrein, B., and Ingram, G. (2019). Connected through the force: Mechanical signals in plant development. J. Exp. Bot. https://doi.org/10.1093/jxb/erz103.
2.Braat, J., and Landrein, B. (2025). Mechanical control of plant organ growth: Lessons from the seed. Current Opinion in Plant Biology *85*, 102737. https://doi.org/10.1016/j.pbi.2025.102737.
3.Bauer, A., Ali, O., Bied, C., Bœuf, S., Bovio, S., Delattre, A., Ingram, G., Golz, J.F., and Landrein, B. (2024). Spatiotemporally distinct responses to mechanical forces shape the developing seed of Arabidopsis. EMBO J *43*, 2733–2758. https://doi.org/10.1038/s44318-024-00138-w.
4.Creff, A., Ali, O., Bied, C., Bayle, V., Ingram, G., and Landrein, B. (2023). Evidence that endosperm turgor pressure both promotes and restricts seed growth and size. Nat Commun *14*, 67. https://doi.org/10.1038/s41467-022-35542-5

Glossary:

- *Morphogenesis*: The collective processes by which organs acquire their specific size and shape during development.
- *Turgor Pressure*: The hydrostatic pressure generated by osmosis, which pushes the plasma membrane against the cell wall, placing it under tension. Turgor pressure is a primary driver of plant cell expansion and growth.
- *Cell Wall*: The rigid extracellular matrix that surrounds plant cells, connecting them and providing structural support. It is composed of cellulose fibers cross-linked by hemicellulose and embedded in a pectin-rich gel. Growth occurs when the cell wall undergoes irreversible (plastic) deformation.
- *Mechanical Interactions*: Plant cells are physically interconnected via their cell walls, allowing neighboring cells to exert forces on one another, such as stretching or compressing each other, during growth and development.
- *Mechanosensing*: The ability of plant cells to detect mechanical stimuli, such as compression or stretching, and respond by activating specific signaling pathways.

Background Review Article:

1.Landrein, B., and Ingram, G. (2019). Connected through the force: Mechanical signals in plant development. J. Exp. Bot. https://doi.org/10.1093/jxb/erz103.
2.Braat, J., and Landrein, B. (2025). Mechanical control of plant organ growth: Lessons from the seed. Current Opinion in Plant Biology *85*, 102737. https://doi.org/10.1016/j.pbi.2025.102737.

Field:
Biology / Life Sciences

Session Topic:
Uncovering Plant Biology with Cutting-edge Imaging Technology

Speaker:
SASAKI Takema, Nagoya University

Title: Intracellular dynamics shape plant cell form

Plant cells appear static from the outside, but internally they are highly dynamic. These intracellular dynamics drive plant-specific processes such as cell division and cell differentiation, allowing plants to generate a wide variety of specialized cell types. My central question is how plants create diverse cell shapes to build functional tissues. In this talk, I will present imaging-based approaches to understanding how intracellular dynamics shape plant cell architecture. We focus on microtubules—dynamic filamentous structures that act as internal scaffolds guiding cell shape. Using advanced live cell imaging, we analyzed how microtubule dynamics contribute to both cell division (*Sasaki et al., Current Biology,* 2025) and xylem cell differentiation (*Sasaki et al., Nature Communications,* 2023).

In our study of xylem cells, we revealed that spatially confined microtubule dynamics shape three-dimensional cell wall structures. By visualizing microtubule behavior in living cells, we found that restricting microtubule growth to specific cellular regions promoted self-organized curved and bundled assemblies. These assemblies guided the formation of arched cell wall patterns, demonstrating how physical constraints and dynamic self-organization can generate complex cellular architecture. To uncover the physical mechanisms underlying this process, we complemented live-cell imaging with in vitro reconstitution experiments, allowing us to examine microtubule dynamics under simplified and controlled conditions.

Together, these findings show that plants use intracellular dynamics and simple physical rules to shape specialized cell types. By integrating live imaging in cells with imaging-based in vitro reconstitution, our work seeks to uncover general principles by which cytoskeletal dynamics generate biological form.

References:

[1] **T Sasaki**, K Ishizaki, H Motose, Y Oda, The conserved machinery of bipolar prospindle formation controls acentrosomal spindle orientation in land plants, Current Biology 35 (20), 5060-5070. e2

[2] **T Sasaki**, K Saito, D Inoue, H Serk, Y Sugiyama, E Pesquet, Y Shimamoto, Y Oda, Confined-microtubule assembly shapes three-dimensional cell wall structures in xylem vessels, Nature communications 14 (1), 6987

Glossary:

Microtubules: Dynamic filaments that organize cell shape in eukaryotic cells.
Live-cell imaging: Microscopy for observing processes in living cells.

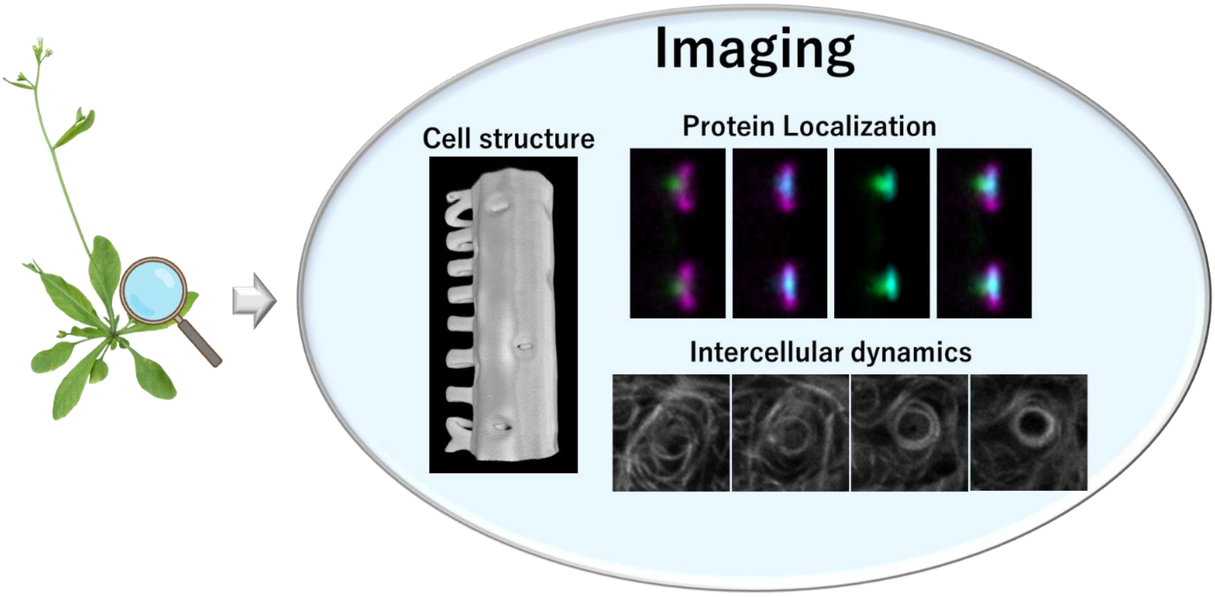


Figure Visualizing intracellular organization in plant cells

Field:
Chemistry / Materials Science

Session Topic:
Circular Materials: The Chemistry of Making and Unmaking / The Chemistry of Reuse

Introductory Speaker:
Damien MONTARNAL, University of Lyon 1

Title: Introducing circularity in modern materials: from a historical perspective and societal challenges to new research perspectives.

Polymers, have become commodity materials in modern society due to their light weight, versatility, high chemical stability and ease of processing. Although natural polymers such as natural rubber, polysaccharides, and proteins have long been known, the twentieth century marked the rapid rise of synthetic polymer science and mass industrialization. The consequences of such a massive production of highly durable materials are becoming a stringent societal concern, they include persistent pollution and questionable use of resources. The large economic inertia of polymer production and their societal necessity is unlikely to enable a complete and immediate technological shift; most beneficial developments of polymers are thus rather focused on industrial recycling or reusing of end of life products. In this perspective, the chemical stability of polymers also becomes a weakness: and compromises are to be found between durability, easy making and easy unmaking the materials.

In this context, increasingly large parts of academic research on polymers is now focusing on modifying or designing new materials with built-in unstable bonds of physical interactions. Such unstable bonds can typically vary from dynamic exchanges to irreversibly cleavable bonds. While the former are often exploited to give properties such as controlled, autonomous reorganization of the materials for self-healing, directed self-assembly or reprocessing, the later are rather oriented to degradable materials, including upcycling into functional building blocks that can be reincorporated in various processes.

This introductory talk will present the various tools and concepts that have been proposed in the last 20 years and introduce the work of the different speakers of this session.

Field:
Chemistry / Materials Science

Session Topic:
Circular Materials: The Chemistry of Making and Unmaking / The Chemistry of Reuse

Speaker:
HSU Yu-I, The University of Osaka

Title: Salt-Responsive Biopolymer Composites for Controlled Disintegration and Sustainable Materials Design

Plastic pollution in oceans has become a serious global challenge. Although biodegradable plastics are often proposed as solutions, many do not break down in seawater because they were designed for microbes found on land, not in marine environments. This gap highlights the need for materials that function well during use but reliably disintegrate once they reach the ocean.

Here, we present a design concept for seawater-responsive bioplastics made from plant-derived polymers. Instead of relying on microbial degradation, our materials physically disintegrate or dissolve in seawater due to changes in salt concentration. The approach uses ionic interactions: the films remain stable in fresh water but lose integrity in seawater, where salt ions weaken the ionic bonds. We examined two film systems. A starch–cellulose film with ionic interactions rapidly disintegrated in seawater, whereas films without such interactions remained intact (Figure 1(a)). A second system combined ionic and permanent chemical bonds, enabling stability in fresh water while still allowing controlled disassembly in salty environments (Figure 1(b)).

Importantly, all components used in this work are renewable, plant-derived, and biodegradable, making them attractive for sustainable packaging and disposable applications. While these materials are not intended to replace high-performance plastics directly, they provide a new conceptual framework for designing plastics that respond intelligently to their environment.

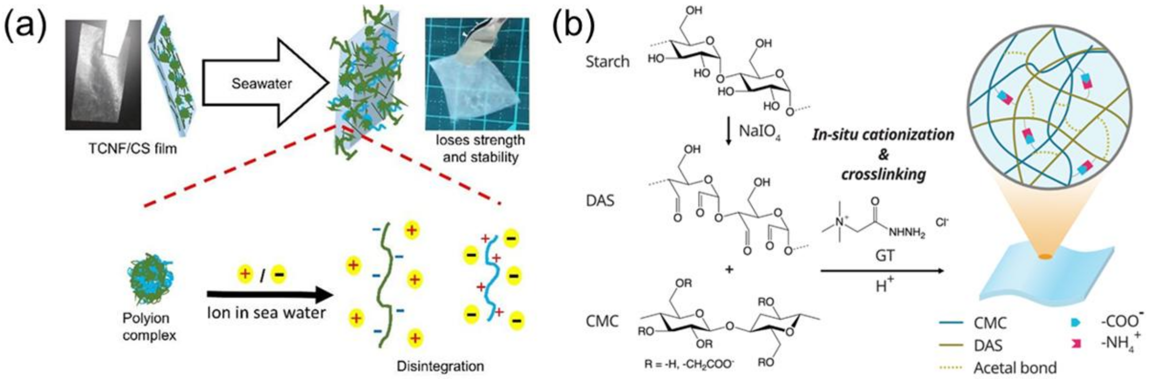


Fig. 1. Schematic illustration of (a) TCNF/CS polyion complex, and (b) DAS/ CMC blend film.

References:

[1] R. Soni, Y.-I Hsu*, T.-A. Asoh and H. Uyama*, J. Appl. Polym., 2022, 139 (32)
[2] Y. Jia, Y.-I Hsu*, H. Uyama*, Polym. Degrad. Stab., 2023, 215, 110453 (1-8)

Glossary:

- Bioplastic:【バイオプラスチック】
  A plastic made partly or entirely from renewable biological resources such as plants, rather than from petroleum.
- Biodegradable:【生分解性】
  Capable of being broken down into natural substances (such as water, carbon dioxide, and biomass) by microorganisms over time.
- Marine degradable: 【海洋生分解性】
  Able to break down in seawater conditions. This does not always mean full biodegradation, but may include physical disintegration or dissolution.
- Microplastics: 【マイクロプラスチック】
  Very small plastic fragments that persist in the environment and can be harmful to marine life.
- Circular resource system: 【循環型資源システム】
  A sustainable system where materials are reused, recycled, or safely returned to nature instead of becoming waste.
- Seawater responsiveness: 【海水応答性】
  The ability of a material to change its structure or properties, specifically when exposed to seawater.
- Disintegration: 【物理的崩壊】
  Physical breakup of a material into smaller pieces due to environmental effects (such as water or salt), without necessarily involving microorganisms.
- Dissolution: 【溶解】
  The process by which a solid material dissolves into water at the molecular level.
- TEMPO-mediated cellulose nanofibers (TCNFs): 【TEMPO 酸化セルロースナノフ
- Polyion complex (PIC): 【ポリイオンコンプレックス】
  A material formed when positively and negatively charged polymers attract each other and assemble through ionic interactions.
- Ionic crosslink: 【イオン架橋】
  A reversible connection between polymer chains formed by ionic interactions. Unlike chemical bonds, these links can be disrupted by changes in salt concentration.
- Chemical (covalent) crosslink: 【化学架橋・共有結合架橋】
  A permanent bond between polymer chains that provides structural stability and does not break easily in water.

Presentation Abstracts

Field:
Chemistry / Materials Science

Session Topic:
Circular Materials: The Chemistry of Making and Unmaking / The Chemistry of Reuse

Speaker:
Gaëlle LE FER, CNRS, University of Lille

Title: Reversible Covalent Chemistry, toward a new generation of adaptive materials.

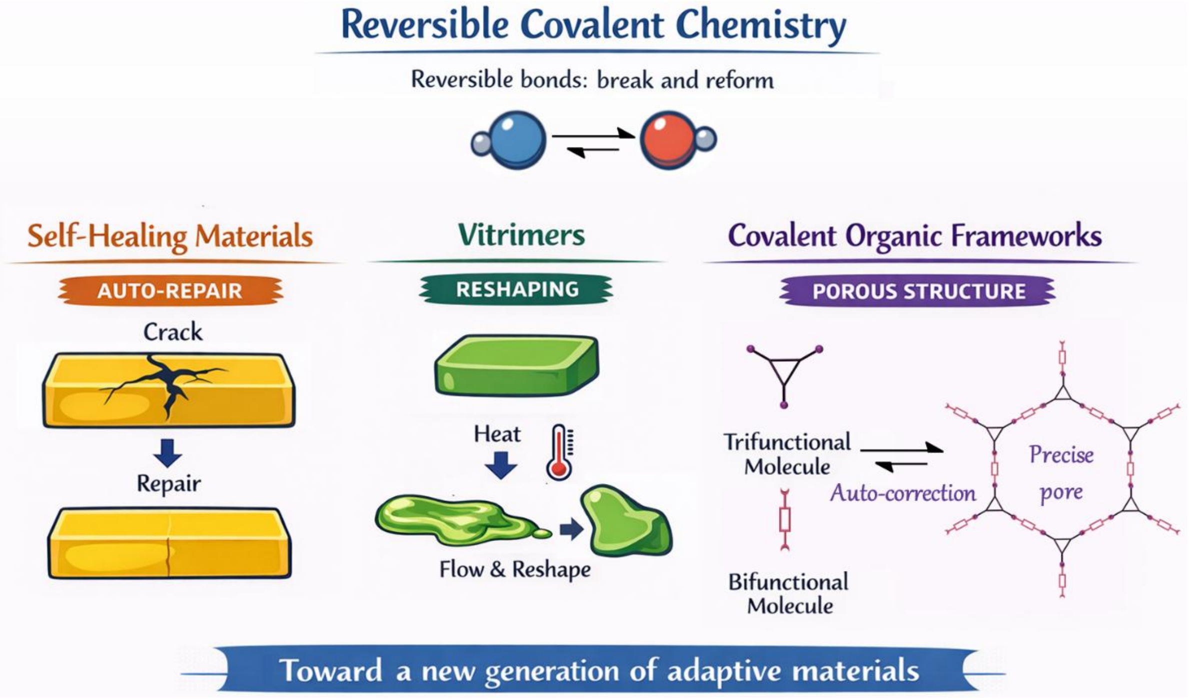
Modern society relies heavily on synthetic advanced materials. However, many are designed for single use and become difficult to recycle once damaged or discarded. To address this challenge, scientists are exploring the concept of **circular materials** designed to be reused, repaired, or reshaped. One key scientific concept behind this idea can be described as the **"Chemistry of Making and Unmaking."**

Traditionally, chemistry focuses on creating strong and stable covalent bonds that give materials durability but limit recyclability or repair. In contrast, **reversible covalent chemistry** (also called dynamic covalent chemistry) relies on bonds that can form, break, and reform under certain conditions. These reactions occur under equilibrium, allowing molecules to reorganize and correct structural defects, combining the strength of covalent bonds with adaptability.[1]

One application is **self-healing polymer materials**, which can repair scratches or cracks. Reversible bonds break when damaged and reform, reconnecting the polymer network. This ability to "heal" damage can extends the lifetime of coatings, electronics, and structural components, reducing waste and improving sustainability.[2]

Another remarkable example is **vitrimers**, polymer networks that combine thermoset strength with thermoplastic recyclability. Their reversible bonds can exchange under heat, letting the material remain solid in use but flow, reshape, or repair at higher temperatures without breaking the overall network. This property makes vitrimers promising candidates for more sustainable plastic technologies.[3]

Reversible covalent chemistry also plays a crucial role in the synthesis of **Covalent Organic Frameworks (COFs)**, crystalline porous materials constructed from organic molecules connected by covalent bonds. Their ordered pores enable gas storage, molecule separation, or hosting reactions. During synthesis, reversible bonds allow **error correction**, breaking and reforming until the most stable, crystalline structure is obtained. This dynamic self-assembly is essential for high crystallinity and functionality in applications like catalysis and energy technologies.[4]



Together, these examples illustrate how reversible covalent chemistry enables a new generation of **adaptive and circular materials**. By allowing bonds to be made and unmade, chemists can design materials that repair themselves, can be reshaped or recycled, and can assemble into highly ordered structures. In the context of sustainability and resource management, this “chemistry of reuse” provides powerful tools for designing smarter materials that last longer and generate less waste.

References

[1] Rowan, S. J.; Cantrill, S. J.; Cousins, G. R. L.; Sanders, J. K. M.; Stoddart, J. F. Dynamic Covalent Chemistry. *Angew. Chem. Int. Ed.* 2002, *41(6)*, 898-952.
[2] Qiu, K., Li, X., Li, Y., Yue, Y., Guo, L. Self-healing behavior of superhard covalent bond materials. *Chemical Society Reviews* 2025, 54(9), 4391-4418.
[3] Montarnal, D., Capelot, M., Tournilhac, F., Leibler, L. Silica-like malleable materials from permanent organic networks. *Science* 2011, 334(6058), 965-968.
[4] Waller, P. J., Gándara, F., & Yaghi, O. M. Chemistry of covalent organic frameworks. *Accounts of chemical research* 2015, *48*(12), 3053-3063.

Field:
Earth Science / Geosciences / Environment

Session Topic:
Human Impact and Disasters

Introductory Speaker:
Floriane PROVOST, University of Strasbourg

Title: How can human societies better prepare for gravitational risk in a changing world?

The frequency of climate-driven hazards — storms, floods, wildfire — has risen in recent decades, posing a growing threat to population worldwide. Human activities such as deforestation and unplanned urban expansion accelerate these phenomena, while broader anthropogenic impacts on the climate (e.g., more intense precipitation, drought, permafrost thaw, sea-level rise) are predicted to increase their occurrences. Recent events such as the ice-rock avalanches in Blatten, Switzerland, 2025; Chamoli, Uttarakhand, India, 2021; the rock avalanche in Aosta Valley, Italy, 2024; and the debris flows Tinée/Vésubie, France, 2020, have contributed to rise awareness on gravitational risk and on the need for improved forecasting systems to protect populations and infrastructures in mountainous regions. It also illustrates the complexity of modelling landslide occurrence and evolution as landslides present varying responses to meteorological forcings (i.e. rainfall, snow cover/snow melt, temperature) depending on the internal structures (fractures, heterogeneities), of the material properties (porosity, strength) and on the hydrological state of the slope (saturated, unsaturated, drained). Therefore, landslide physics span several paradigms—hydrology, rheology, fracture mechanics — that have yet to be integrated within a unified predictive framework. Over the past decade, one has seen the rapid expansion of monitoring networks (e.g. seismic) and the growth of Earth Observation remote-sensing technologies, providing continuous, high-resolution observations at regional and global scales. This opens new avenues for data-driven monitoring and modelling, real-time early-warning, and adaptive risk-management strategies, especially for monitoring sparse, local and episodic phenomenon such as landslides. This session will introduce the current and predicted impact of human activities on the occurrences of catastrophic events including landslides, coastal erosion, and wildfires. Through the example of landslides, we will introduce the complexity and the recent advances for modelling the current evolution of such phenomenon.

Field:
Earth Sciences / Geosciences / Environment

Session Topic:
Human Impact and Disasters

Speaker:
TOUGE Yoshiya, Chiba University

Title: Assessment of future extreme soil dryness for wildfires in Japan

More than 1,000 wildfires occur annually in Japan [1], and large-scale events exceeding 100 ha were observed in 2025 and 2026 under extremely dry condition. Therefore, this study evaluates the impact of climate change on soil moisture in Kamaishi City located in the northeast Japan, where a large wildfire occurred in 2017. Soil moisture was hydrologically simulated using the Simple Biosphere including Urban Canopy (SiBUC) model and the 20-km resolution d4PDF large-ensemble climate dataset [2]. The analysis focused on January–June, when wildfires are frequent, and compared the distributions of annual minimum soil moisture between the present climate and a +4°C warming scenario.

Since d4PDF provides thousands of years of simulated climate conditions for both present and future climates, it allows the frequency distributions of annual maximum and minimum values to be evaluated for each climate. Figure 1 shows the calculated results for soil moisture. Under the future climate, the overall distribution shifts toward drier conditions, indicating that the frequency of extremely dry years increases and the intensity of extreme dryness becomes stronger.

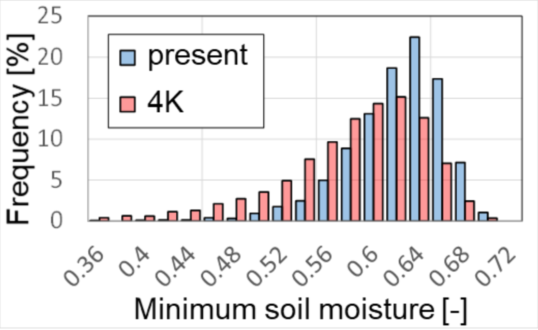


Figure 1: Histogram of minimum soil moisture in the spring in the Kamaishi city (Northeast Japan)

References:

[1] Touge Y. et al.: Spatial-temporal characteristics of more than 50,000 wildfires in Japan from 1995 to 2020. Fire Safety Journal, 142, 104025, 2024.

[2] Mizuta, R. et al.: Over 5,000 years of ensemble future climate simulations by 60-km global and 20-km regional atmospheric models. Bulletin of the American Meteorological Society, 98(7), 1383-1398, 2017

Glossary:

- Large-ensemble: A hypothetical climate simulation using many perturbations to represent the range of possible climate variability and extremes.
- d4PDF (Database for Policy Decision making for Future climate change): A large-ensemble climate dataset used for assessing the impact of climate change, providing long-term simulations for present and future climates.

Presentation Abstracts

__Field:__
Earth Sciences / Geosciences / Environment

__Session Topic:__
Human Impact and Disasters

__Speaker:__
Imen TURKI, University of Rouen Normandie

Title: Research Advances in Coastal Hazards and Climate Resilience: Integrative Approaches from AI-Driven Earth Observation and Modelling to Nature-Based Solutions

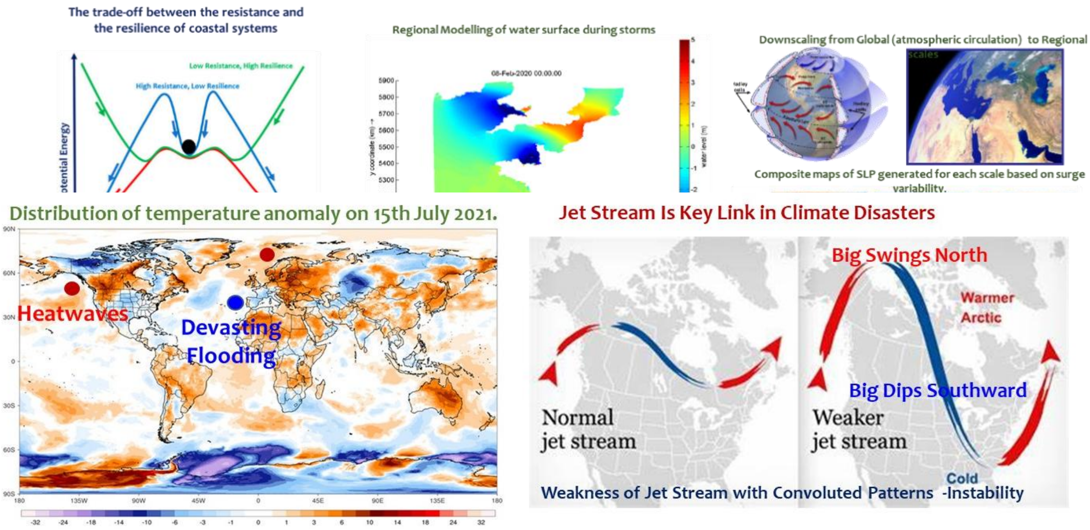
Coastal regions are increasingly exposed to climate-driven hazards arising from interacting drivers operating across multiple temporal scales, ranging from extreme events such as waves and storm surges to longer-term processes including shoreline erosion, compound flooding, and accelerating sea-level rise (SLR). Addressing these risks requires integrative scientific approaches that combine advanced observation systems, numerical modelling, artificial intelligence, and sustainable adaptation strategies. Satellite Earth observation plays a central role in this context by providing synoptic and multi-temporal monitoring of shoreline and nearshore dynamics, enabling the assessment of hazard intensity and coastal resilience across spatial -temporal scales.

I am leading several international actions, including CRESTE (Coastal Resilience Using Satellites), IRN-EONES (Contribution of EO Satellite Missions to the Assessment of Nearshore and Estuarine Hydrodynamics in Response to Environmental Multi-Drivers), and MARS-C (Advancing Integrated Research in Coastal Climate Resilience), to investigate the multi-timescale dynamics of coastal systems, their response to hazardous events and their resilience across diverse wave- and tide-dominated environments worldwide. In the framework of the different actions, we highlight the potential of integrating satellite Earth observation, from conventional missions to the transformative Surface Water and Ocean Topography (SWOT) mission, with in situ measurements, numerical modelling, and artificial intelligence within emerging digital coastal twin frameworks (Figure 1). These systems assimilate multi-source observations to improve process understanding, reduce uncertainties and enhance predictive capabilities for coastal evolution under changing Climate and SLR (Turki et al., 2025a).

Figure 1. Schematic overview of the approaches used across the research activities.

Digital twins support the transition from traditional monitoring to predictive, scenario-based coastal hazard management. They enable the exploration of future coastal trajectories under different climate scenarios, sea-level-rise projections, and human interventions, improving anticipation of hazards such as coastal flooding, compound flooding, and shoreline erosion. They also provide a powerful platform for assessing coastal resilience by evaluating nature-based solutions that enhance the capacity of coastal systems to resist and recover from climate-driven hazards (Turki et al., 2025b). Figure 2 summarizes key highlights of my work, reflecting integrative research activities supported by national and international partnerships and doctoral supervision. This work develops an integrated approach combining satellite observations, numerical modelling, and multi-scale analyses to characterize wave–storm surge–river interactions and their links with large-scale atmospheric circulation, contributing to improved coastal risk assessment and resilience pathways under climate change

Figure 2. Overview of the main research activities, spanning climate downscaling to coastal resilience.



My work has highlighted the key role of atmospheric circulation in driving physical teleconnections between large-scale climate oscillations and local environmental dynamics. A notable example is the cascading interaction between heatwaves and coastal flooding observed in July 2021, controlled by Gulf Stream instability (Figure 3).

Figure 3. Western Europe flooding, July 2021, linking large-scale climate drivers - local impacts.

References:

[1] Turki et al., 2025; Monitoring Resilience in Coastal Systems, https://doi.org/10.3390/jmse13112113
[2] Turki et al., 2025; Multisource Satellite Altimeters for monitoring storms https://doi.org/10.3390/rs17183262

Presentation Abstracts

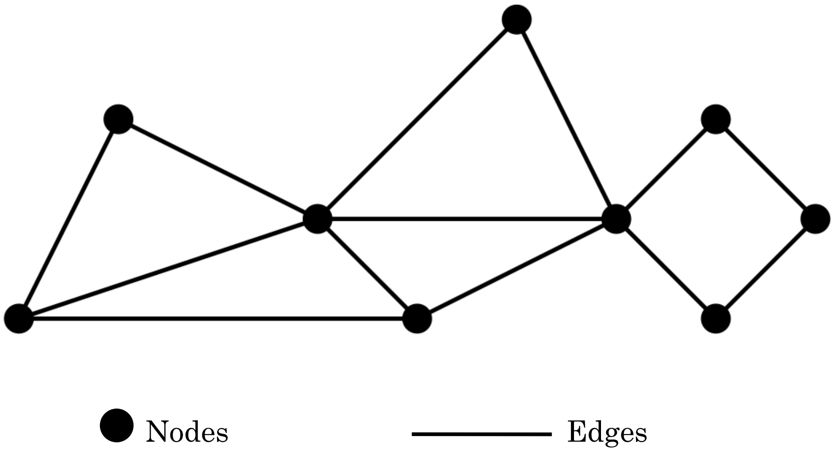
Field:
Mathematics / Informatics / Engineering

Session Topic:
Random Dynamics on Networks

Introductory Speaker:
Laure MARÊCHÉ, University of Strasbourg

Title: Random Dynamics on Networks Introductory Talk

Random dynamics on networks are a type of mathematical model allowing to represent many real-world situations. In this talk, we will first explain how they work with the example of the voter model, which describes how the opinion of a population evolves when each individual's opinion is influenced by their friends'. The individuals are represented by "points" called *nodes* (see the picture below), and when two of them are friends we draw a "line" called *edge* between them. These nodes and edges form what is called the *network*, which describes the friendship relationships. Each node is then given a *state*, which is the opinion of the corresponding individual. Each of these opinions will then evolve with time according to certain rules, partly randomly and partly depending of the opinions of the friends; this evolution is what we call the *dynamics*, and it can describe accurately real-world opinion evolution. More generally, a network is any collection of nodes and edges, and a dynamics on this network is the evolution of states on this nodes according to certain rules. But the nodes, edges and states can be given many other significations than individuals, friendships and opinions; this kind of model is very versatile and is used in many other contexts. Besides the voter model, we will explain how random dynamics on networks can describe the spread of forest fires, how ants find the most effective path to gather food, and the shape of molecules in plastics. Finally, towards the end of the talk, we will introduce the models presented by the two other speakers, for the formation of glass and the propagation of an infection in a population.



Representation of a network

References:
[1] *Interacting particle systems*, T. M. Liggett, 1985, Springer-Verlag.
[2] *Probabilities on trees and networks*, R. Lyons, Y. Peres, 2016, Cambridge University Press.

Glossary:

- Dynamics: A mathematical object is said to follow a dynamics when it evolves with time.
- Edge: In a network, an edge is drawn between two nodes to indicate a relationship between these nodes, whose nature depends on the model chosen; it may be friendship, physical proximity, etc.
- Network: An abstract representation of relationships between a set of elements; the elements are represented by nodes and the relationships by edges.
- Node: The base element of a network. Depending on the model chosen, it can represent anything from an atom to an individual to a city district.
- State: Each node in a network is given one, which depends on the type of model and evolves with time.

Presentation Abstracts

Field:
Mathematics / Informatics / Engineering

Session Topic:
Random Dynamics on Networks

Speaker:
NAKAJIMA Shuta, Keio University

Title: Universality in frog model and infection processes

Universality is a fundamental phenomenon in mathematics and physics: the same law or behavior appears regardless of the details of a system. A classic example is the central limit theorem, which says that the sum of many small independent effects (e.g., measurement errors) is approximately described by the bell curve, known as the normal distribution.

Another type of universality appears in random growth. Consider the boundaries of a spreading wetting region, a burning sheet of paper, or a bacterial colony. Because the growth is affected by random local events, these boundaries do not remain perfectly smooth but instead become rough. The size of this roughness, known as interface fluctuations, describes how far the growing boundary deviates from its average position. Remarkably, various mathematical models show that the typical size of these fluctuations grows exactly as the cube root of time, $t^{1/3}$. In 1986, Kardar, Parisi, and Zhang proposed a theoretical framework for this behavior [1]. Systems sharing this specific growth law are said to belong to the KPZ universality class.

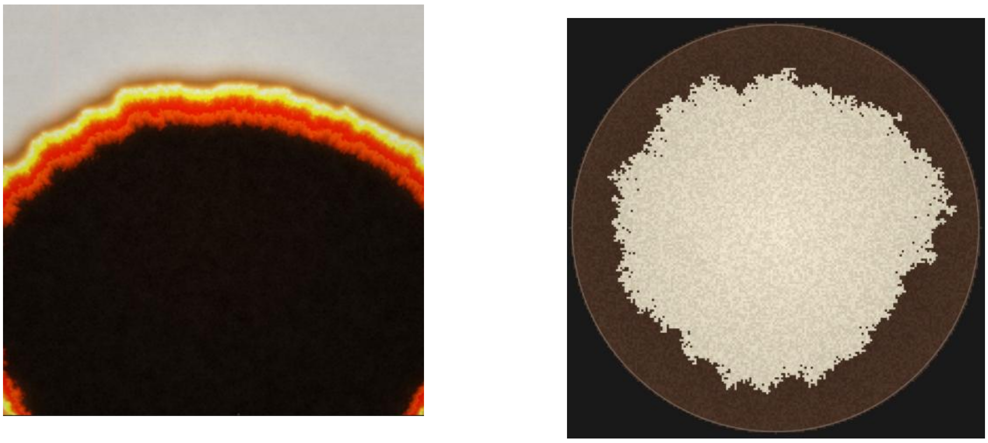


Figure 1: Simulations of paper burning and bacterial colony growth. Although the underlying growth rules are different, the resulting patterns look similar.

An interesting class of examples comes from infection processes. We consider a population consisting of healthy and infected individuals. When an infected individual meets a healthy one, the healthy individual becomes infected. The boundary of the infected region then evolves as a randomly growing interface. Numerical simulations suggest that these infection processes also belong to the KPZ universality class, although the theoretical understanding is still limited.

In this talk, we consider two infection models: the frog model [2], in which only infected individuals move while healthy ones remain in place, and the KS infection model of Kesten and Sidoravicius [3], in which both types move. We present numerical results for fluctuation behaviors, and we discuss related mathematical results and possible real-world applications.

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[2] S. Yu. Popov, "Frogs and some other interacting random walks models," Discrete Mathematics and Theoretical Computer Science, AC, 277-288, 2003.
[3] H. Kesten and V. Sidoravicius, "A shape theorem for the spread of an infection," Annals of Mathematics, 167(3): 701-766, 2008.

Glossary:

- Interface (界面)
  In growth and infection models, an interface is the boundary separating two regions (e.g., infected and healthy individuals). It evolves randomly over time.
- Fluctuation (揺らぎ)
  Definition: The fluctuation of an interface is the typical size of its deviation from its average position.

Field:
Mathematics / Informatics / Engineering

Session Topic:
Random Dynamics on Networks

Speaker:
Assaf SHAPIRA, University Paris Cité

Title: Kinetically Constrained Models and Bootstrap Percolation

Kinetically constrained models are a family of random dynamics on networks, treating situations where, depending on the system's state, some individuals get stuck, unable to change location or state. These models were originally introduced in the context of physics of glasses, in order to model the *cage effect*. This effect is an attempt to explain the seemingly contradictory behavior of glasses, which are on one hand rigid, like solids, but on the other hand have amorphous microscopic structure, resembling a liquid. It was then suggested that, while in equilibrium molecules are placed more or less independently, when a glass is very dense their motion is blocked by neighboring molecules.

In order to model this effect mathematically, it is common to divide the material into many small regions of space, each representing a *node* of a network. Each node will then have a state describing the density of molecules in the corresponding region, and for simplicity we take state 0 for (relatively) dilute regions, and 1 when the density is high. The dynamics then consists in nodes changing their states, but only when there are not "too many molecules nearby", which we model by requiring the number of dense nodes we are connected to not to exceed some fixed threshold.

We will try to understand qualitative properties of such models, and in particular the possibility of *phase transition*. We will discuss how the behavior changes when considering models on different networks.

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[1] Michael Aizenman and Joel L. Lebowitz. "Metastability effects in bootstrap percolation", Journal of Physics A: Mathematical and General 21.19 (1988).
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Glossary:

- Constrained dynamics: Dynamics where, depending on the current configuration of the system, some individuals are blocked and unable to change their state.
- Phase transition: Phase transition describes a situation where a very small variation in the parameters changes drastically the qualitative behavior. For example, changing temperature from $0.001°C$ to $-0.001°C$ turns water into ice. In our context, a tiny variation of density could turn infinitely many nodes from blocked to unblocked.

Background Review Article:

- Ivailo Hartarsky and Cristina Toninelli. "Kinetically Constrained Models", SpringerBriefs in Mathematical Physics, 2025.
- Robert Morris. "Monotone Cellular Automata", Surveys in combinatorics, 2017.

Presentation Abstracts

Field:
Physics / Astrophysics

Session Topic:
Collective Behaviours and Their Simulations

Introductory Speaker:
NISHIGUCHI Daiki, Institute of Science Tokyo

Title: Active matter physics: searching for universal laws in flocking systems

From schools of fish and flocks of birds down to migrating cells and swarming bacteria, collective motion prevails in nature across scales. Such phenomena have long fascinated human beings including physicists. These active entities can spontaneously organize into large-scale coherent patterns even though each individual follows only simple local rules and no leader controls the whole group. Understanding how such coordinated behavior emerges from many interacting units is a fundamental challenge in modern science, relevant not only to physics but also to biology, robotics and artificial intelligence.

In recent years, physicists have started to regard these collective systems as a singular matter, calling them active matter, and to search for universal laws in active matter systems from the viewpoint of thermodynamics and statistical physics [1]. Active matter can be regarded as a novel class of matter composed of nonequilibrium "molecules", where each constituent continuously converts free energy into motion. As such, active matter is intrinsically nonequilibrium with broken time-reversal symmetry at the level of each particle's motion, making it realize novel properties that are impossible in equilibrium systems such as negative viscosity.

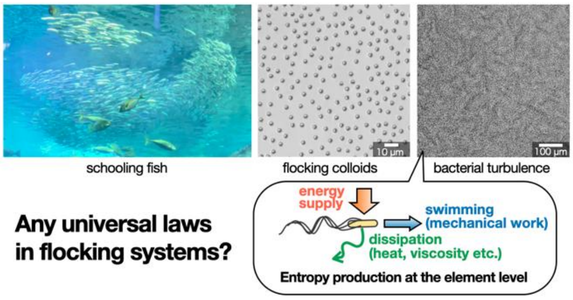

Figure 1 Examples of active mater systems

In this introductory talk, I will first provide an overview of the significance of active matter in nonequilibrium science and present representative experimental/theoretical systems of active matter. I'd like to discuss recent trends, future directions and challenges in active matter physics, namely:

1) Quantum-classical analogy in active matter: How can active matter contribute to quantum science and vice versa? [2]

2) How can active matter contribute to other disciplines such as developmental biology, medical science, crowd dynamics, and (soft) robotics?

References:
[1] T. Vicsek and A. Zafeiris, Collective motion, *Physics Reports* **517**, 71 (2012)
[2] Y. Uchida, D. Nishiguchi and K.A. Takeuchi, Designing topological edge states in bacterial active matter, arXiv: 2601.08243 (2026); K. Sone et al. Hermitian and non-Hermitian topology in active matter, *Rep. Prog. Phys.* **89**, 016501 (2026); L. Yamauchi, et al. Chirality-driven edge flow and non-Hermitian topology in active nematic cells, arXiv: 2008.10852 (2020)

Glossary:

- **Active matter**: Collections of entities that continuously convert energy into motion at the level of each constituent particle. Examples include bacteria, cells, and artificial self-propelled particles.
- **Nonequilibrium systems**: Systems in which energy or particles are continuously supplied and/or dissipated, preventing the system from reaching thermodynamic equilibrium. In such states, net flows of energy or mass exist.
- **Self-propelled particles**: Elements of active matter systems. Entities that generate motion by converting internal or environmental energy into directed movement.
- **Collective motion**: Large-scale coordinated motion or pattern formation emerging from interactions among many individuals, even though each individual follows only simple local rules.
- **Time-reversal symmetry**: A property of physical laws that remain unchanged when time is reversed. For example, both the Schrödinger equation and Newton's equations of motion possess time-reversal symmetry. In contrast, active matter systems break this symmetry because their motion is driven by continuous energy consumption accompanied by entropy production.

Background Review Article:

- D. Nishiguchi, Deciphering long-range order in active matter: insights from swimming bacteria in quasi-2D and electrokinetic Janus particles, *J. Phys. Soc. Jpn.* **12**, 121007 (2023).
- S. Shankar et al., Topological active matter, Nat. Rev. Phys. **4**, 380 (2022)
- I. Aranson, Bacterial active matter, Rep. Prog. Phys. 85, 076601 (2022)

Presentation Abstracts

Field:
Physics / Astrophysics

Session Topic:
Collective Behaviours and Their Simulations

Speaker:
Alexis PONCET - CNRS, ENS de Lyon

Title: Collective motion and order in assemblies of interacting agents

For a physicist studying the behavior of complex matter, there is a fundamental distinction between equilibrium systems, in which the individual constituents are subjected to thermal agitation only, and non-equilibrium systems in which energy (of electrical, chemical… origin) is constantly injected. In the later case, a zoology of behaviors can be observed, such as spontaneous collective motion and unusual transitions between ordered and disordered states.

In a first part, I will focus on self-propelled particles. Experimentally, they consist of beads of micron size that exhibit spontaneous motion in a given direction due to a physical instability caused by an energy injection. I will introduce the basic models that can be simulated on the computer. Then, I will show which ingredients can transform individual motion into a coherent collective motion, and how these interactions can be learnt from experimental trajectories [2]. At a scale much larger that the particles, the collective motion can be described as an unusual liquid that follows very peculiar rules when it flows in a complex network of channels [1], see Fig. a.

In a second part, I will describe another type of non-equilibrium system: rather than injecting energy directly, the individual constituents are now immersed in a liquid medium that couples them indirectly. First, this can lead to the propagation of waves [4]. But most notably, in an experimental system made of repulsive droplets [3] we observe and rationalize that the coupling with the liquid gives rises to a transition between an a disordered state (at weak repulsion) and an ordered crystalline state (at large repulsion), see Fig. b.

Both examples are meant to illustrate the complexity of assemblies of interacting agents and serve as an insight into the modern developments of non-equilibrium physics.

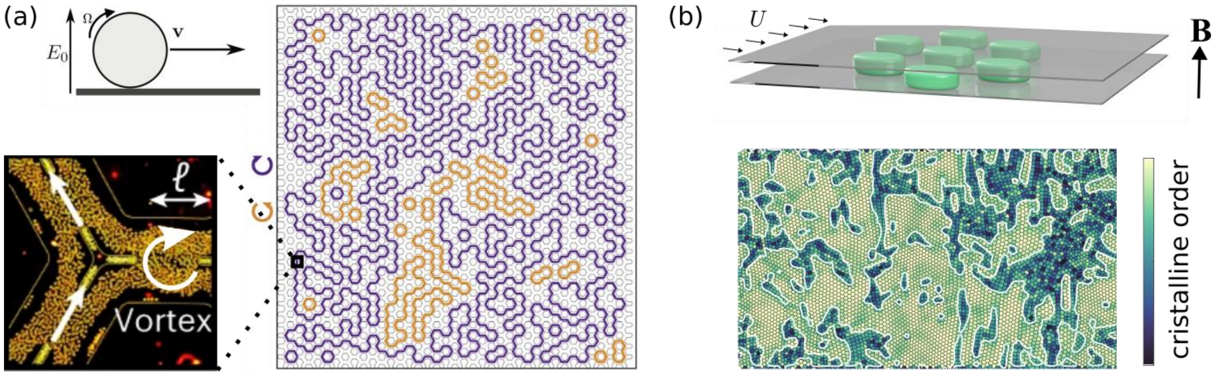

Figure. (a) In an external electric field E_0, a bead can start to rotate and roll on a surface (velocity v). An assembly of such beads moves in a coherent direction (white arrows). In a network of channels, recirculations (vortices) can form. This creates a complex flow pattern made of closed loops. See Ref. [1]. (b) Assembly of repulsive droplets (due to a magnetic field B) that are coupled by an external flow (velocity U). At large scale, we observe a coexistence of disordered zones (dark colors) and ordered crystalline domains (light colors). See Ref. [3].

References:

[1] C. Jorge, A. Chardac, A. Poncet & D. Bartolo, "Active hydraulics laws from frustration principles", Nat. Phys. 20 (2), 303-309 (2024), https://doi.org/10.1038/s41567-023-02301-2

[2] J. Hem, A. Poncet, P. Ronceray, D. Nishiguchi, & V. Démery, "Learning general pair interactions between self-propelled particles", Soft Matter 21 (37), 7257-7269 (2025), https://doi.org/10.1039/D5SM00655D

[3] S. Guillet, A. Poncet, M. Le Blay, W. Irvine, V. Vitelli & D. Bartolo, "Melting of non-reciprocal solids : how dislocations propel and fission in flowing crystals", PNAS 122 (15), e2412993122 (2025), https://doi.org/10.1073/pnas.2412993122

[4] J. Colen, A. Poncet, D. Bartolo & V. Vitelli, "Interpreting neural operators : how nonlinear waves propagate in non-reciprocal solids", Phys. Rev. Lett. 133 (10), 107301 (2024), https://doi.org/10.1103/PhysRevLett.133.107301

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- M. te Vrugt, B. Liebchen & M. Cates, "What exactly is 'active matter'?", arXiv:2507.21621 [cond-mat.soft] (2025), https://arxiv.org/abs/2507.21621

Field:
Physics / Astrophysics

Session Topic:
Collective Behaviours and Their Simulations

Speaker:
KAWAGUCHI Kyogo, RIKEN Pioneering Research Institute

Title: Local Rules and Symmetry as Organising Principles of Collective Behaviour in Living Matter

How do large numbers of cells, with no central coordinator, produce reliable collective behaviour? This question fascinates biologists studying development and tissue-level phenomena, as well as physicists interested in many-body systems, whose concepts have proven increasingly powerful in addressing it.

There has been growing interest in understanding multicellular phenomena through the framework of active matter physics. Cells can establish orientational order whilst remaining motile, and the interplay between these two properties gives rise to anomalous macroscopic behaviour. In dense cultures of neural progenitor cells, we have shown that the elongated shape of individual cells imposes liquid-crystal-like order on the tissue [1]. The inevitable breakdown points of this order, topological defects, dictate where cells accumulate or disperse, sculpting three-dimensional tissue structure without any global biochemical signal. This principle has since proven broadly relevant: topological defects are now implicated in body axis formation in whole organisms such as hydra.

Maintaining tissue integrity during homeostasis requires cells to coordinate division and differentiation with their neighbours, yet the rules governing this remain difficult to identify experimentally. Taking the mammalian skin as an example, we have shown that stem cell self-renewal is precisely triggered by a nearest-neighbour rule: a cell divides only when its direct neighbour differentiates [2]. This interaction rule maps onto the voter model, a nonequilibrium interacting particle system well studied in statistical physics. Applying interpretable machine learning to spatiotemporal cell tracking data, we further recover how these rules differ by body region [3].

At the organ scale, we find that the mammalian heart is an interesting example of three-dimensional liquid crystal, whose pumping efficiency in the heart is encoded not in specific fibre orientations but in the global coherence of a chiral twist.

These cases suggest that quantitative structural and dynamical analysis of cell interactions represents a rich and largely unexplored frontier at the interface of biology and physics.

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[1] Kawaguchi, K. et al. Topological defects control collective dynamics in neural progenitor cell cultures. Nature 545, 327–331 (2017). https://doi.org/10.1038/nature22321

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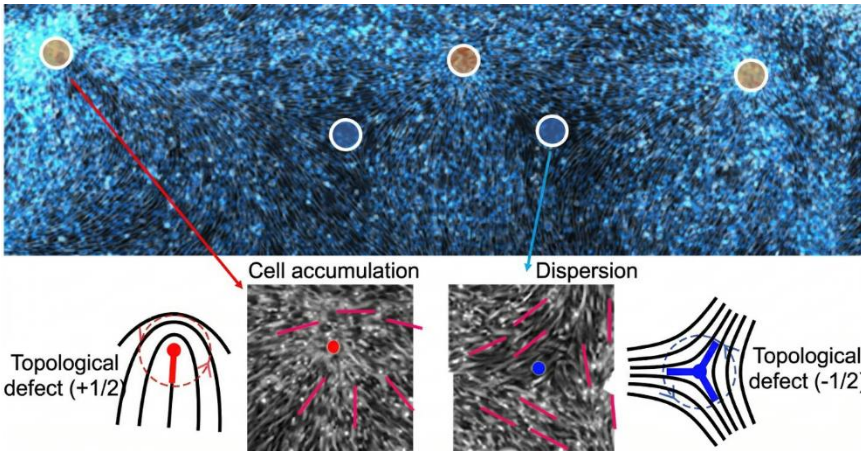
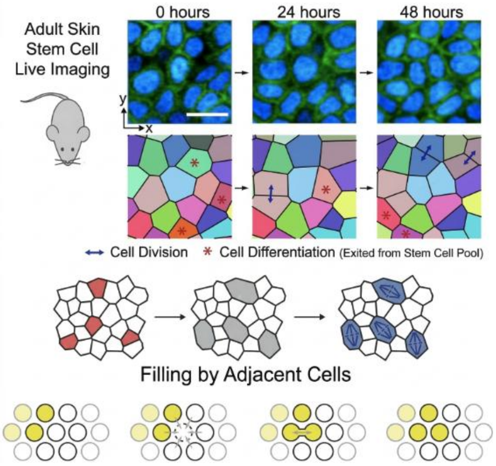
[3] Yamamoto, T., Cockburn, K., Greco, V. & Kawaguchi, K. Probing the rules of cell coordination in live tissues by interpretable machine learning based on graph neural networks. PLOS Computational Biology 18, e1010477 (2022). https://doi.org/10.1371/journal.pcbi.1010477





Field:
Social Sciences / Humanities

Session Topic:
Human Values and Ethics in a Technological World

Introductory Speaker:
KATIRAI Amelia, University of Tsukuba

Title: ELSI/RRI as a Framework for Research on the Implications of Emerging Technologies

We are increasingly living in a technologically-mediated world, with lives shaped by emerging technologies. However, there is simultaneously a growing recognition of both potential and actual harms which arise from emerging technologies. The concepts of Ethical, Legal, and Social Issues (ELSI) and Responsible Research and Innovation (RRI), together often framed as ELSI/RRI, provide a framework through which to investigate and seek to prevent or counteract the harms of emerging technologies [1,2].

This presentation traces the history and evolution of these concepts over the previous decades, including recent cases from the Japanese context of research in these fields. It examines the takeaways from this evolution that continue to shape the focus of ELSI/RRI research today, including the prioritization of stakeholder involvement, interdisciplinary research, and industry-academia collaboration. The presentation then introduces perspectives from the humanities and social sciences broadly that are shaping the field at its cutting-edge, including perspectives on social inequality [3,4,5], disability [6], and the environment [7]. Although ELSI/RRI provides a framework for research across a range of emerging technologies [1,8], the second part of the presentation takes artificial intelligence (AI) as a case study to explore how ELSI/RRI research in action can uncover potential harms, given that AI is increasingly at the frontier of discussions and debates about the role of technology in society [9,10].

Throughout, the aim of the presentation is to show that consideration of the issues which fall under the framework of ELSI/RRI research is not a matter separate to technological research and development, but rather an essential component of it, if we are to ensure that technology is advanced while minimizing its harms.

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[3] Noble, S.U. (2018) *Algorithms of Oppression: How Search Engines Reinforce Racism*. New York University Press.
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[5] Ogawa, M., Tsuruta, S., Yuge, N., (eds.), 2024. ジェンダードイノベーションの可能性［The Potential of Gendered Innovations]. Akashi BookStore.
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Background Review Article:

Braun, M., and Ruth, M., 2025. "Missed opportunities for AI governance: lessons from ELS programs in genomics, nanotechnology, and RRI." *AI & SOCIETY* 40, 3: 1347-1360. (https://link.springer.com/article/10.1007/s00146-024-01986-0)

Field:
Social Sciences / Humanities

Session Topic:
Human Values and Ethics in a Technological World

Speaker:
Francesca MUSIANI, CNRS

Title: Power in and by Digital Infrastructures

The Internet and digital communication tools are rife with controversies and issues surrounding the reconfiguration and redistribution of power. These issues are often embedded in the Internet's technologies and infrastructures themselves, whose design, development, and technical implementation choices become strategic tools for appropriating or maintaining power. The governance of this network of networks we call the Internet — with its multiplicity of components, from physical infrastructures to the interfaces that provide user access — is a matter of alliances and confrontations between multiple actors, from institutions to civil society and the private sector. Internet governance is most often a question of normative systems that intersect, overlap, confront, and clash — from legal instruments protecting fundamental rights, to technological innovation and the laws of the market.

This presentation, based on more than a decade of research across several sites, will aim to shed light on this set of increasingly important phenomena and provide an overview of the analytical tools provided by the social sciences, and more particularly by the sociology of technology and innovation, which we can use to understand these phenomena.

My work, of which this presentation will give an overview, is based on an understanding of Internet governance as a normative "system of systems". I focus particularly on technical architectures and infrastructures, and how these have gradually evolved from *targets* of governance to *instruments* of governance, serving highly varied and often unexpected objectives at the time of their creation.

Information flow intermediaries, critical Internet resources, Internet exchange points, and surveillance and security devices play a crucial governance role alongside national and supranational political institutions and civil society organizations. Internet governance takes shape through a myriad of infrastructures, devices, data flows, and technical architectures that are often discreet and invisible, yet crucial for co-constructing an increasingly public, complex, and interconnected network of networks. I will show how these entities are infrastructural "control points" around which questions of technical and economic efficiency intertwine with negotiations and controversies over human and societal values such as intellectual property rights, privacy, security, and transparency.

References and further reading

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Van Eeten, M. J., & Mueller, M. (2013). Where is the governance in Internet governance?. *New media & society*, *15*(5), 720-736.

Presentation Abstracts

Field:
Social Sciences / Humanities

Session Topic:
Human Values and Ethics in a Technological World

Speaker:
SHIKANO Yusuke, The University of Osaka

Title: Responsible Deployment of Animal Emotion Recognition Technologies

Emerging science and technologies have repeatedly raised ethical, legal, and social questions. In response, actors involved in scientific and technological development are increasingly expected to pursue Responsible Research and Innovation (RRI), understood as an approach that seeks to "take care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013). In this presentation, such challenges are framed as ELSI (Ethical, Legal, and Social Issues) and positioned as issues that should be examined prior to the societal implementation of emerging technologies.

Recent advances in artificial intelligence, particularly large-scale data analysis and deep learning, have enabled the development of technologies that apply human emotion recognition methods to animals, here referred to as animal emotion recognition technologies (AERT). These technologies aim to recognize and visualize animals' emotional or affective states (Kaehrle et al., 2025; Koyasu et al., 2024; Kakani et al., 2024; Waller et al., 2013). By enabling a better understanding of animals' conditions, AERT is expected to contribute to improvements in animal welfare and to applications in livestock farming, veterinary medicine, and animal care.

This presentation examines the ELSI associated with AERT through a literature review and expert interviews. The analysis identifies ethical issues concerning animal manipulation and exploitation, epistemic and methodological biases introduced through AI-mediated interpretation, regulatory and evidential challenges surrounding animal experimentation, and legal concerns such as the potential surveillance of animal owners. Broader societal issues include impacts on animal-related industries and the reinforcement of particular conceptions of animals.

In addition, recent discussions highlight emerging questions regarding data governance and the notion of "animal privacy" in the age of AI (Barton et al., 2025; Bossert & Hagendorff, 2021; Coghlan & Cardilini, 2025; Eke et al., 2023; Rubel et al., 2025a, 2025b). By examining these issues, this presentation reflects on the broader implications of implementing AERT in society.

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Glossary:

Background Review Article: