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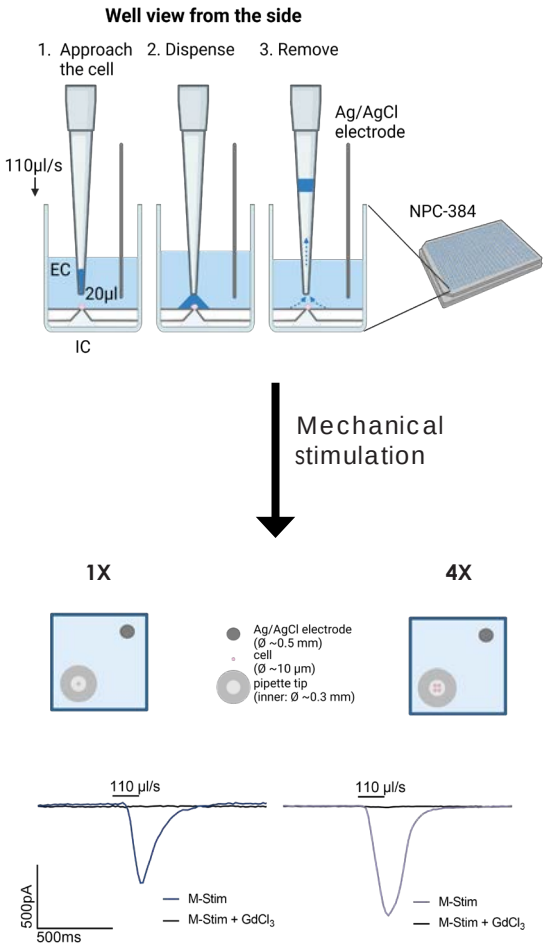

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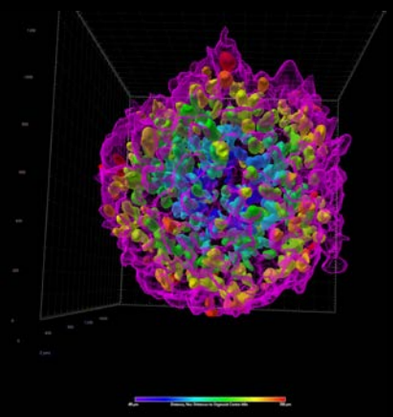

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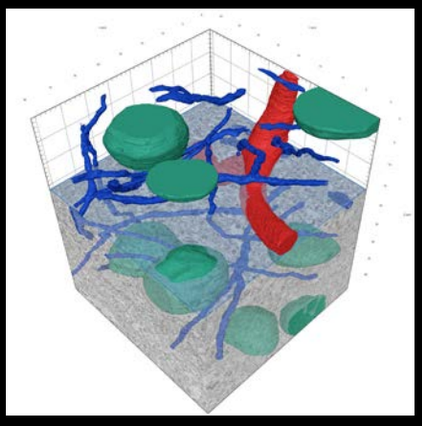

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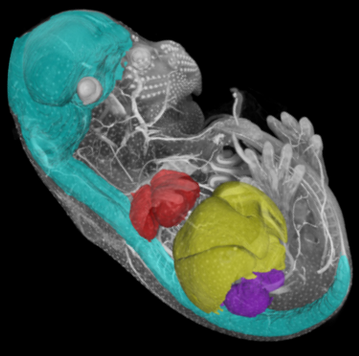

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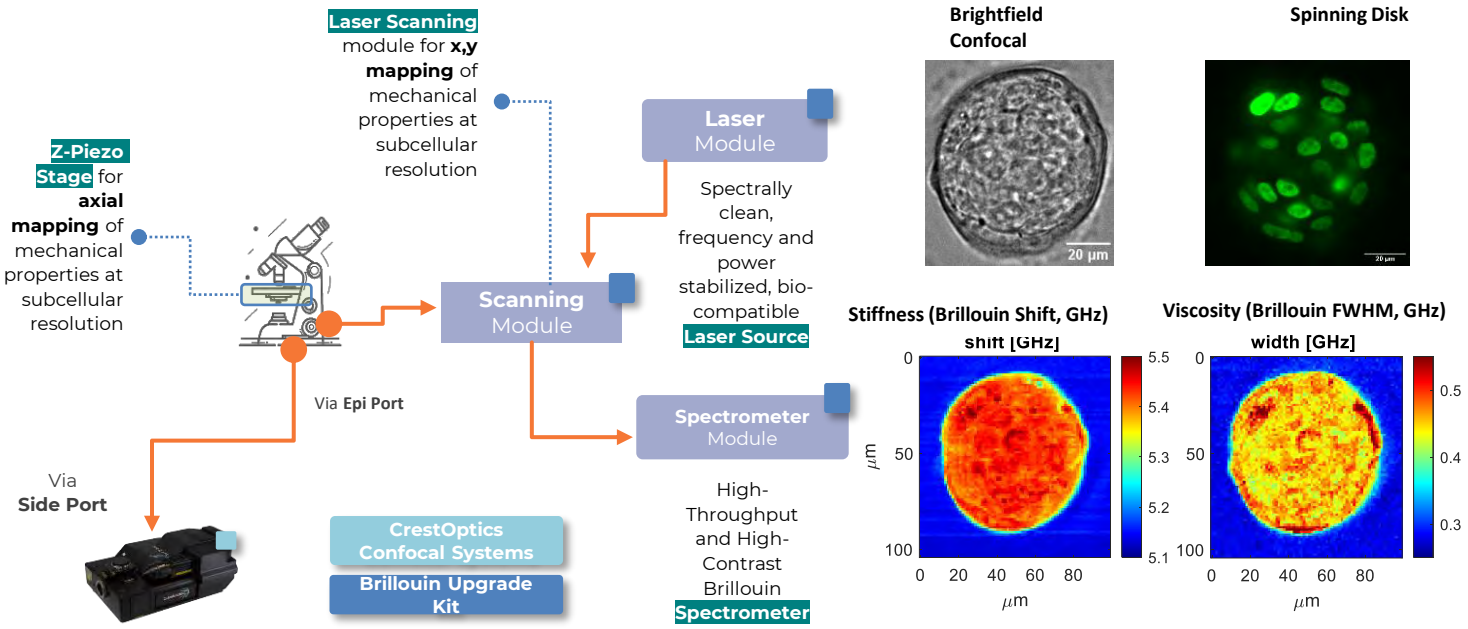

Schematic representation of the system architecture. Representative data acquired on the CrestOptics Brillouin System.

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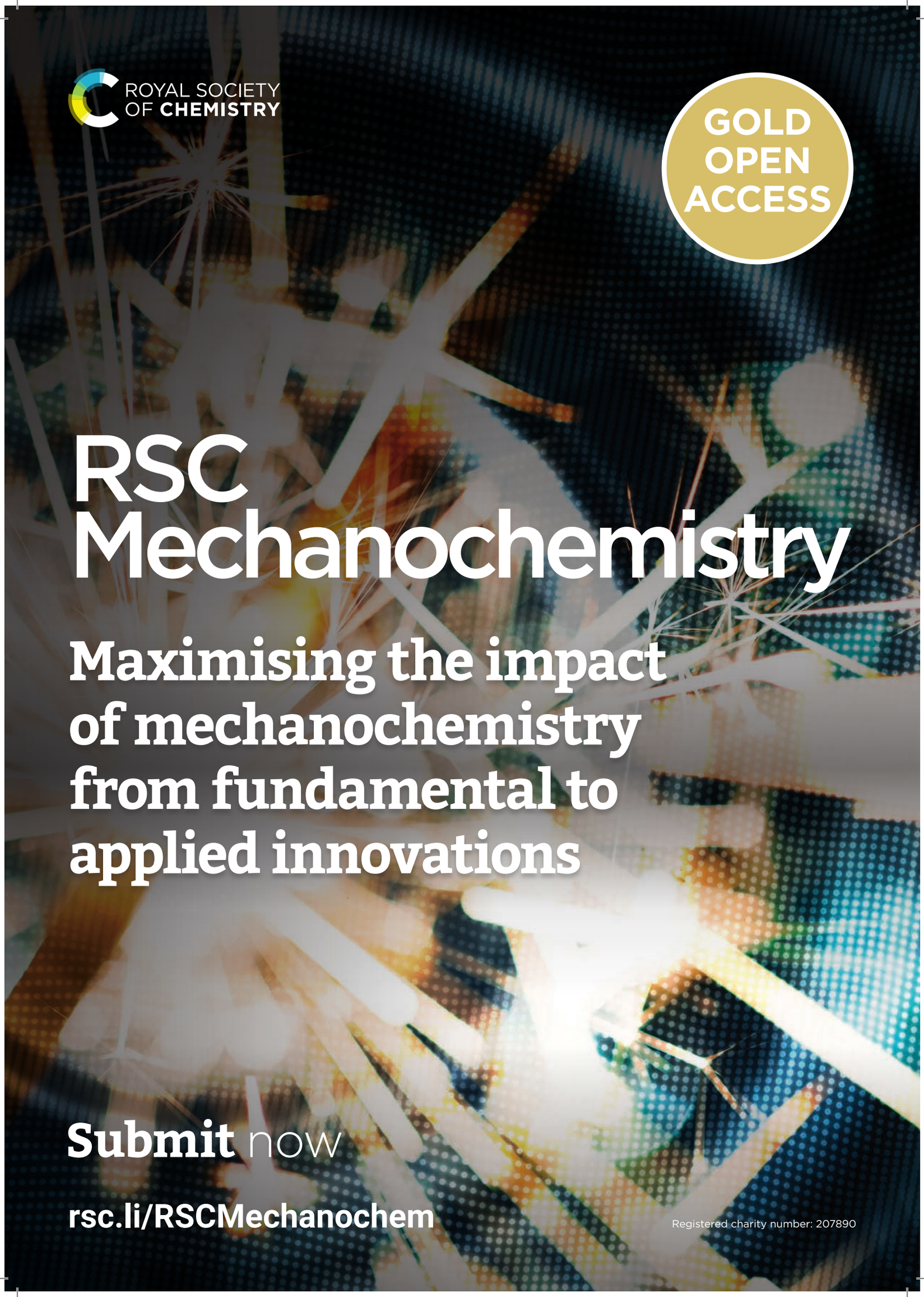
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Plenary Speakers

Innovation for global justice

Patricia Osseweijer[1]
[1]Delft University of Technology, Netherlands

Plenary Session: Patricia Osseweijer, July 13, 2026, 11:00 - 11:45

The transition from a fossil- to a bioeconomy has long been promoted as a way to mitigate climate change by reducing carbon emissions. However, progress has been slow. At the same time, competing uses of biomass - for food, feed, plastics, fuels and chemicals - became the subject of intense public and political debate. The sustainability of biomass production was increasingly questioned, feedstock availability became a major concern, and the renewable products proved often more costly than the fossil products they aimed to replace. These criticisms weakened support for the bioeconomy and shifted attention towards alternative technological pathways. While science and innovation in the bioeconomy domain continued to improve biomass conversion technologies, logistics and market development, transition agendas became increasingly dominated by wind and solar energy and renewed interest in nuclear power with large enthusiasm for hydrogen as novel energy storage system.
This shift risks overlooking the broader societal contributions of research and innovation for the bioeconomy. Sustainable agriculture, including soil and water management and biodiversity conservation, is essential for health, for food and water security, while the responsible use of biomass and waste streams can simultaneously strengthen energy security, rural development and social resilience. Wind, solar and nuclear energy based transitions cannot provide these wider benefits, while hydrogen remains only an energy carrier.
The bioeconomy can therefore be considered to be much more than a substitute for fossil resources. It spans the entire innovation chain, from fundamental research in biological processes and biotechnology to sustainable production systems and circular value chains. Providing valuable insight in life itself and the complex ecological system on our globe. Importantly, biomass utilisation uniquely provides opportunities for improving livelihood and social development for rural communities. However, reaching such objectives requires other design principles and integration with social sciences.
This places an important responsibility on scientists and innovators. Rather than focusing solely on technological performance or carbon reduction, research should be designed from the outset with societal objectives such as human wellbeing, resilience and global justice in mind.
In this lecture, I will examine the assumptions underlying the bioeconomy debate and reflect on lessons from public communication and stakeholder engagement around genetic modification (GM). I argue that scientists have an essential role not only in developing new technologies, but also in considering the societal directions in which they evolve. This requires integrating moral questions ex ante into research and innovation, while engaging more proactively with society, policy and industry. Drawing on several interdisciplinary projects, I will show how scientific research can be organised to maximise technological performance while simultaneously advancing sustainability, social development and global justice.

May the Force be with you! Piezo channels in mechanosensory biology

Ardem Patapoutian[1]
[1]Howard Hughes Medical Institute, Scripps Research, United States

Plenary Session: Ardem Patapoutian, July 13, 2026, 09:00 - 09:45

Mechanotransduction was perhaps the last major sensory modality not understood at the molecular level. Proteins/ion channels that sense mechanical force are postulated to play critical roles in sensing touch/pain (somatosensation), sound (hearing), shear stress (cardiovascular function), etc.; however, the identity of ion channels involved in sensing mechanical force had remained elusive. The Patapoutian lab identified PIEZO1 and PIEZO2, mechanically activated cation channels that are expressed in many mechanosensitive cell types. Genetic studies established that PIEZO2 is the principal mechanical transducer for touch, proprioception, baroreception, bladder, and lung stretch, and that PIEZO1 mediates blood-flow sensing, which impacts vascular development and iron homeostasis. Clinical investigations have confirmed the importance of these channels in human physiology. Current work in Patapoutian continues to explore the role of mechanosensation and interoception in physiology and disease.

The human organ atlas as a resource for open biomedical research

Claire Walsh[1]
[1]University College London, United Kingdom

Plenary Session: Claire Walsh, July 13, 2026, 09:45 - 10:30

Understanding the human body across scales remains one of the central challenges in biomedical research. Clinical imaging can visualise whole organs but lacks microscopic detail, while histology reveals cellular structure but only within small, physically sectioned samples. The Human Organ Atlas was formed to bridge this gap: to create an open, multiscale, three-dimensional reference of intact human organs in health, ageing and disease.
The Atlas grew from the development of Hierarchical Phase-Contrast Tomography, a synchrotron-based imaging approach established through an international collaboration between clinicians, imaging scientists, engineers and data specialists. Initially driven by the urgent need to understand organ-level pathology during the COVID-19 pandemic, the project rapidly evolved into a broader open-science effort. By imaging intact organs non-destructively, while retaining the ability to zoom into selected regions at near-cellular resolution, the Atlas preserves the spatial context that is often lost when organs are reduced to small samples or two-dimensional sections.
This talk will describe the history of how the Human Organ Atlas was formed: from method development and early biological discoveries, to the creation of an open-access data and visualisation platform, and the building of a wider community around this technique. I will discuss how technical work in large-scale data formats, metadata, web-based visualisation and reusable analysis pipelines has made these complex datasets accessible beyond the original imaging teams. I will also highlight how clinical and biological collaborations are turning the Atlas into a resource for health impact, supporting anatomical discovery, disease research, validation of clinical imaging, education, and the development of AI models trained on high-quality, spatially contextualised human data.

Cardiac mechanics to cure cancer

Serena Zacchigna[1]
[1]International Centre for Genetic Engineering and Biotechnology, Italy

Plenary Session: Serena Zacchigna, July 13, 2026, 11:45 - 12:30

The talk will focus on the mechanisms that prevent the spontaneous regeneration of the heart after damage and discuss mechanistic link with the rarity of cardiac cancers, to eventually move to therapeutic solutions to both promote cardiac repair and treat cancer.

ISMB Invited Speakers

Aging Beyond Earth: New Ways to Understand Cellular Decline and Renewal from Immune Senescence to Autophagy

Ghada Alsaleh[1]
[1]University of Oxford, United Kingdom

Immunomechanobiology 1, July 14, 2026, 14:00 - 15:45

Increases in lifespan without extending of healthspan poses a growing socioeconomic challenge for developed countries, as population demographics shift to become disproportionately older. Older populations face a rising prevalence of age-related diseases, including neurodegenerative, musculoskeletal, and cardiovascular conditions, placing an escalating burden on healthcare systems. Strategies that promote optimal ageing and compress morbidity are therefore essential to ameliorate this growing socioeconomic challenge.
However, studying human ageing remains inherently challenging due to confounding lifestyle-related variables in cross-sectional studies, and long timescales required for longitudinal research. Astronauts exposed to microgravity for prolonged periods of time exhibit multi-tissue physiological deteriorations which resemble aspects of ageing-related functional decline. As such, microgravity provides an innovative means to model human ageing on compressed timescales. Despite this, most current spaceflight studies rely on animal models or simplified in vitro systems that fail to capture human tissue complexity.

In a first-of-its-kind study, our Space Innovation Lab has developed physiologically relevant, human-derived in vitro organoid models of joint tissues and skin to study the effects of microgravity on the ageing process. Tissue-matched Earth and space-flown organoids are currently being analysed using complementary multi-modal approaches, including molecular, cellular, and functional phenotyping, to comprehensively characterise space-induced age-related changes and identify pathways relevant to human healthspan.

Regulation of mesenchymal stromal (stem) cell mechanotransduction to support better cells for cell therapies

Matt Dalby[1]
[1]University of Glasgow, United Kingdom

Mechanobiology of Ageing 1, July 15, 2026, 14:00 - 15:45

Mesenchymal stromal cells (MSCs) are recognised for their regenerative (bone, cartilage), support (for e.g. haematopoietic stem cells) and immunomodulatory phenotype that can make them a major target of future cell therapies. Indeed, GMP manufacturers are developing production protocols, regulators are used to considering use of this cell type and clinical trials are underway for products focussing on e.g. bone healing, support of tissue integration and preventing tissue rejection. However, understanding how to control MSC phenotype in vitro, out of their niche, remains a major hurdle to use of these key cells. The bone marrow niche regulates the growth of MSCs to maintain multipotency, stromal behaviour and immunosuppressive phenotype. During large scale culture on e.g. polystyrene, they key features are lost and the clinical usefulness of the cells diminishes – and the cells can enter senescence. In this talk, I will focus on showing, firstly, that materials can be used to retain multipotency and immunomodulatory phenotype. I will then discuss how materials can be used to understand the mechanobiology of MSC phenotype retention during growth. By understanding how cells adhere and how resultant intracellular tension changes can regulate growth, differentiation and senescence, we can design materials that can be used for large scale culture of cell therapies.

More than the sum: how composite interfaces govern function

Alba Diz-Muñoz[1]
[1]EMBL, Germany

Cell Mechanics Across Length Scales 2, July 15, 2026, 11:00 - 12:00

The cell surface of animal cells is a composite interface with several layers, the plasma membrane, the actomyosin cortex and a membrane-to-cortex attachment protein layer that binds them together. Biochemically and mechanically each of these layers differs. My group is taking an engineering-inspired approach, combined with traditional cell biology methods, to quantitatively measure and predict how the various mechanical layers at the surface of animal cells govern function. Together, our work identifies actin crosslinking as a critical mechanotransducer in cells, and the intra-filament distance as a key geometrical parameter that regulates the cell surface.

Mechanochemistry of Protein Hydrogels: Linking Molecular Forces to Macroscopic Function

Lorna Dougan[1]
[1]University of Leeds, United Kingdom

Mechanochemistry 1, July 15, 2026, 14:00 - 15:45

Biological systems rely on hierarchical architecture to achieve the superior mechanical performance and environmental responsiveness essential for life. These assemblies are built from proteins that perform their roles by undergoing precise structural and mechanical rearrangements. However, a major challenge is to understand how the mechanical properties of an individual protein translates to the collective response of a protein network. Without this understanding, we remain limited in our capacity to decode the complexities of living systems and fully exploit the potential of proteins as building blocks in engineered biomaterials. Solving this problem requires an integrated interdisciplinary approach. In this talk I will share our recent progress in understanding how folded protein networks behave across scales, and show how this knowledge allows us to mimic Nature's complexity and engineer novel living matrices for applications in healthcare and sustainability.

The chemo-mechanical regulation of brain development

Kristian Franze[1,2]
[1]Institute of Medical Physics and Max Planck Centre for Physics and Medicine, , Germany,
[2]University of Cambridge, United Kingdom

Mechanobiology in Disease and Mechanomedicine 1, July 13, 2026, 14:00 - 15:45

During development, cells are highly dynamic and respond to a plethora of chemical and mechanical signal in their environment. During brain morphogenesis, for example, neurons extend axons over large distances along well-defined pathways. Axon pathfinding is regulated by both gradients of chemical guidance cues and gradients in tissue stiffness. However, we currently know very little about how these signals interact. Using a combination of ex vivo and in vivo approaches, we identified the mechanosensitive ion channel Piezo1 as a key integrator of chemical and mechanical signals. Downregulation of Piezo1 in the brain parenchyma surrounding healthy growing axons led to aberrant neuronal growth patterns with reduced fasciculation and pathfinding errors. We found a decrease in both the chemical guidance cues Semaphorin3A and Slit1 and brain stiffness. While the stiffness of cells was unaffected, cell-cell adhesion was significantly reduced, leading to a fluidization of the tissue. While a decrease in chemical guidance cues did not lead to tissue softening, tissue softening led to a decrease in guidance cues. Hence, tissue stiffness not only directly impacts neuronal growth but also indirectly by regulating the availability of long-range chemical guidance cues far away from the actual mechanical signal in the surrounding tissue. Our data thus strongly indicate that chemical and mechanical signaling pathways are intimately linked, and that their interaction is crucial for morphogenetic events.

Encoding mechanical memory during confined migration

Sylvain Gabriele[1]
[1]University of Mons, Belgium

Mechanobiology of Development and Tissue Engineering 2, July 15, 2026, 16:15 - 17:15

Cell migration through confined environments is essential for development, tissue repair and cancer invasion. While confinement is generally viewed as a physical obstacle, we propose that it acts as a source of mechanical information that cells can encode and remember.

Using quantitative biomimetic microsystems, we show that spatial confinement regulates cell morphology, force generation and migration efficiency by controlling actin treadmilling and protrusive forces in the lamellipodia. We further demonstrate that collective migration depends primarily on the geometry of cell-cell interactions, allowing epithelial clusters to efficiently navigate complex environments. Finally, we reveal that transient confinement leaves a persistent mechanical imprint through actin cortex remodeling, generating long-lived morphological states that facilitate subsequent passage through narrow constrictions. Together, these findings establish a new framework in which physical confinement is not merely a mechanical constraint but a physical cue that is stored and reused to optimize future migration. This concept of mechanical memory of confinement provides new insights into collective migration during development, tissue regeneration and metastatic dissemination

Targeting FAK Mechanosignaling to Mitigate Extracellular Matrix Overproduction and Inflammatory Cascades in Pulmonary Fibrosis

Andrés Garcia[1,2,3]
[1]Petit Institute for Bioengineering and Bioscience, United States, [2]Regents' Professor at Woodruff School, United States, [3]Georgia Institute of Technology, United States

In vivo Mechanobiology 1, July 16, 2026, 08:45 - 10:30

Idiopathic Pulmonary Fibrosis (IPF) is a progressive, fatal lung disease driven by aberrant fibroblast recruitment, extracellular matrix (ECM) overproduction, and tissue stiffening. Focal Adhesion Kinase (FAK) serves as a central mechanosensing hub that translates tissue tension into pro-fibrotic signaling. This study utilizes a medium-throughput 3D pulmonary human microtissue platform to model the disease burden using healthy and IPF patient-derived fibroblasts exposed to a pro-fibrotic cocktail.
Treatment with the clinical-stage FAK inhibitor VS-6063 effectively halted fibrotic progression in patient microtissues. VS-6063 demonstrated dose-dependent inhibition of key fibrotic metrics, reducing pathogenic collagen I, alpha-smooth muscle actin, and EDA-fibronectin down to baseline levels. Crucially, FAK inhibition substantially reduced pro-inflammatory cytokines implicated in IPF mortality, including MCP-1 and IP-10. Comparative analysis revealed that VS-6063 significantly outperformed currently available FDA-approved therapeutics in lowering ECM accumulation. Ongoing efforts focus on evaluating this therapy in murine bleomycin models using dry-powder porous microparticles formulated for efficient deep-lung inhalation delivery.

Mechanical scaffolding of enzymatic signalling by talin

Ben Goult[1]
[1]University of Liverpool, United Kingdom

ECM Mechanobiology in Physiology and Disease 2, July 16, 2026, 11:00 - 12:00

Talin forms the principal mechanical linkage between integrins and the actin cytoskeleton and acts as a central mechanosensitive signalling hub within integrin adhesion complexes. The talin rod contains 13 force-dependent binary switch domains that unfold under mechanical load, converting mechanical inputs into biochemical signals by controlling the spatial and temporal recruitment of signalling proteins. Through this mechanism, talin integrates mechanical information from the extracellular matrix and cytoskeleton to regulate signalling outputs at adhesion sites.

Our recent work shows that talin also functions as a mechanical scaffold for enzymes, providing a direct route through which force can regulate enzymatic signalling. In this talk I will describe how force-dependent conformational changes within talin control the localisation and activity of enzymes that bind directly to the talin rod. I will discuss established interactions with CDK1 and PKA and present new unpublished data revealing direct binding of CDKL5 and Src to talin. These enzymes exemplify distinct mechanisms by which mechanical signals can regulate enzymatic processes, allowing us to define emerging design principles for mechanically operated enzyme scaffolds.

Talin works in concert with vinculin to form an interconnected network of force-regulated molecular switches within focal adhesions. We refer to this network as the MeshCODE, in which the collective unfolding state of talin switch domains processes and stores force- and time-dependent mechanical information. As talin molecules change conformation in response to mechanical load, the spatial organisation of proteins within adhesion sites is remodelled, providing a mechanism through which mechanical inputs can drive persistent changes in signalling architecture.

These findings suggest that talin-based switch networks operate as a molecular information-processing system within cells. I will outline ongoing work testing the hypothesis that this system provides a physical mechanism through which cells encode and retain mechanical memory.

Spatial mechano-transcriptomics: mapping mechanical forces and gene expression in tissues at single-cell resolution

Adrien Hallou[1]
[1]University of Oxford, United Kingdom

Immunomechanobiology 2, July 14, 2026, 16:15 - 17:15

Advances in spatial profiling technologies are providing insights into how molecular programs are influenced by local signalling and environmental cues. However, cell fate specification and tissue patterning involve the interplay of biochemical and mechanical feedback. Here, we propose a new computational framework that enables the joint statistical analysis of transcriptional and mechanical signals in the context of spatial transcriptomics. To illustrate the application and utility of the approach, we use spatial transcriptomics data from the developing mouse embryo to infer the forces acting on individual cells, and use these results to identify mechanical, morphometric, and gene expression signatures that are predictive of tissue compartment boundaries. In addition, we use geoadditive structural equation modelling to identify gene modules that predict the mechanical behaviour of cells in an unbiased manner. This computational framework is easily generalized to other spatial profiling contexts, providing a generic scheme for exploring the interplay of biomolecular and mechanical cues in tissues [1].

[1] A. Hallou, et al. A computational pipeline for spatial mechano-transcriptomics. Nature Methods 22, 737–750 (2025).

Mechano-Immunoengineering for Cancer Therapy

Song Li[1]
[1]University of California, United States

In vivo Mechanobiology 1, July 16, 2026, 08:45 - 10:30

Immune cells are sensitive to mechanical cues in the microenvironment, but how to harvest this potential for cell engineering and disease therapy remains to be addressed. Here we develop a scalable microfluidic platform to fabricate microspheres as synthetic viscoelastic activating cells (SynVACs) with programmable mechanical and chemical properties. We demonstrate that the viscoelastic nature of SynVACs significantly impacts T cell functionality. Compared to rigid or elastic microspheres, SynVACs induce superior T cell expansion with higher CD8+/CD4+ T cell ratio, enhanced tumor killing capability, high efficiency of chimeric antigen receptor (CAR) introduction into T cells, and significant increase in T memory stem cells. These engineered CAR-T cells are more efficient in eliminating tumor cells, not only in a human lymphoma mouse model but also in an ovarian xenograft mouse model, and persist in vivo for longer time periods to suppress tumor growth and recurrence. These findings underscore the crucial role of mechanical signals in T cell engineering and highlight the potential of SynVACs in CAR-T therapy and immunoengineering applications. In addition, based on this platform, we have developed a biomimetic in vivo “charging station” that incorporates chemotactic and activation signals to facilitate the recruitment, activation, and expansion of CAR-iNKT cells, which significantly enhances tumor infiltration, strengthens long-term immune memory, and demonstrates superior efficacy over conventional CAR-iNKT therapies in solid tumor models.

Engineering mechanical behaviour into single DNA molecules: catch bonds, compliance, and beyond

Isaac Li[1]
[1]The University of British Columbia, Canada

Mechanochemistry 1, July 15, 2026, 14:00 - 15:45

DNA is a programmable mechanical material. In this talk I will show two ways we engineer mechanical behaviour into individual DNA molecules, organised around two complementary concepts: engineering mechanical unfolding pathways, and engineering the mechanical energy landscape. Both are characterised by single-molecule force spectroscopy. First, engineering unfolding pathways. We present the fish-hook, a rationally designed DNA catch bond that strengthens under tension, as biological catch bonds do. A catch bond works by redirecting how a bond yields under load, so designing one is an exercise in programming its force-dependent pathway. Unlike earlier artificial designs, the fish-hook's catch behaviour is finely tunable across a wide range through sequence, opening a large programmable space for reprogramming adhesive interactions and engineering force-strengthening materials. Second, engineering the energy landscape. We found that unzipping the same duplex from opposite ends produces markedly different responses despite identical sequence and identical zero-force free energy: one direction unfolds in a clean two-state manner, the other forms a compliant, force-dependent ensemble of intermediates. This anisotropy traces to asymmetry in how base pair strength is distributed along the molecule, which reshapes the underlying energy landscape. Building on this, I will present new data showing that the molecular compliance of DNA hairpins can be tuned by design, with precise control over force dynamic range and elasticity guided by a simple model. Together these results cast DNA as a substrate for both modulating and detecting molecular forces at cellular interfaces. Lastly, I will show our latest technique for high-throughput single-molecule force spectroscopy that combines force and fluorescence to accelerate the development of mechanically programmable DNA molecules.

Decoding the Mechanoresilience of Circulating Tumor Cells

Chwee Teck Lim[1]
[1]NUS, Mechanobiology Institute, National, University of Singapore, Singapore
Advanced Tools for Multiscale Mechanobiology 1, July 14, 2026, 08:45 - 10:30

Metastasis is responsible for the vast majority of cancer-related deaths, yet only a small fraction of circulating tumor cells (CTCs) survive the intense mechanical stresses encountered during dissemination. As CTCs squeeze through narrow capillary networks, they experience extreme deformation and compression that eliminate most cells while selecting for a rare mechanoresilient subpopulation with enhanced metastatic potential. This keynote will present recent advances in decoding the mechanoresilience of circulating tumor cells and demonstrate how biomechanical selection drives metastatic evolution. Using biomimetic microfluidic platforms that mimic capillary-scale constrictions, we show that repeated mechanical deformation enriches for cancer cells capable of surviving squeezing-induced cell death. Multi-omics analyses reveal that these mechanoresilient cells activate pathways associated with proliferation, DNA damage repair, and cellular stress adaptation, leading to enhanced growth, increased metastatic competence, and greater resistance to chemotherapy. The talk will further highlight how integrating microfluidics, mechanobiology, imaging, and single-cell analyses is uncovering the biomechanical principles governing CTC survival and potentially revealing new therapeutic opportunities to selectively target mechanoresilient cells before they seed secondary tumors. Together, these findings establish biomechanics as a fundamental regulator of metastasis and open new avenues for developing anti-metastatic therapies that exploit the mechanical vulnerabilities of cancer cells.

Encoding mechanochemical information in the plasma membrane of a living cell

Satyajit Mayor[1]
[1]University of Warwick, United Kingdom

Mechanochemistry 2, July 15, 2026, 16:15 - 17:15

A eukaryotic cell interfaces with the external milieu constantly decoding signals in the form of chemical and mechanical inputs. These cues are interpreted by receptors embedded in the plasma membrane. Compelling evidence from numerous studies including our own1, indicate that the plasma membrane is involved in encoding, amplifying and providing feedback for these extracellular signals. How can a fluid lipid bilayer with the kind of compositional heterogeneity exhibited by the plasma membrane, carry out such information processing tasks? By studying the impact of integrin receptor activation on membrane organization, the cell appears to construct localized mesoscale liquid-ordered (lo) membrane domains (termed active emulsions)2 downstream of RhoA-signalling and mechano-transduction. These membrane domains are necessary for sustaining integrin-mediated Rac1 activation, required for cell spreading and migration. This level of regulated organization in an actively maintained asymmetric membrane bilayer is only possible due to its engagement with a medley of myosin proteins at or near the plasma membrane, draped over a dynamic cortical actin meshwork. This ATP-fuelled actin-membrane composite thus behaves as a mechano-responsive medium, integrating chemical and physical cues presented at the cell periphery for the regulation of cell physiology.

Refs: (1) PMID: 31104842. (2) PMID: 35867835
*on lien from National Centre for Biological Science- TIFR, Bangalore, India

Water content in the cell and the nucleus

Matthieu Piel[1]
[1]Institute Curie, France

Cell Mechanics Across Length Scales 1, July 15, 2026, 08:45 - 10:30

The cell and its compartments are delineated by semi-permeable membranes with high permeation, meaning that their water content adjusts rapidly to balance osmotic and hydrostatic pressures. The consequence of these water movements, that can happen at a variety of timescales, from milleseconds to days, is primarily to change the concentration of the macromolecules trapped in the cell and its compartments. This can have multiple effects, from reaction rates, to condensate formation and changes in the mobility of a variety of intracellular objects depending on their size. Although the physical principles remain the same, the precise quantities matter and determine various regimes. In this talk I will first describe recent findings on dry mass density homeostasis in cultured cells and then focus on the case of the nucleus to describe how it differs from the cell, leading to contexts, such as confinement, in which the cytoplasm and the nucleoplasm can display very distinct properties.

Morphogenesis in chaos: Building a beating heart

Rashmi Priya[1]
[1]The Francis Crick Institute, United Kingdom

Mechanobiology of Development and Tissue Engineering 1, July 15, 2026, 14:00 - 15:45

Organogenesis is a remarkably robust process, as it is critical for organismal growth and life. Yet, our understanding of how developing embryos reproducibly build organs with the right shape, size, and function remains limited. By combining the exceptional tractability of zebrafish heart with interdisciplinary approaches, our lab seeks to address several fundamental questions, including 1) geometric control of morphogenesis, 2) how 3-D topological meshworks are shaped, constrained, and canalized, 3) mechano-adaptation of cells and nuclei under extreme mechanical deformation, and 4) mechanics of organ scaling and regeneration. In this seminar, I will discuss some of our recent findings across these themes (PMID: 33208950, bioRxiv 2025.03.07.641942). The long-term goal of my lab is to uncover the design principles that govern the emergence of robust, functional organs during embryogenesis.

Regulation of Osteogenesis and Anti-Osteoclastogenesis by Noninvasive Low-Intensity Ultrasound with Piezo-1 Channel Activation

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Sonomechanobiology 1, July 16, 2026, 08:45 - 10:30

Osteoporosis and osteopenia are major health issues that mainly affect the elderly population, women after menopause, and immobilized patients. Mechanical stimulation has shown promising in bone adaptation, promoting bone formation, and enhancing healing. A review of musculoskeletal tissue and cell responses to dynamic mechanobiological signals will be provided. Among various physical regulations and modalities, such as mechanical strain/stress, electrical and magnetic and thermal fields, and fluid flow, quantitative ultrasound imaging and acoustic radiation force (ARF) provide unique approaches for evaluating both bone strength and density, particularly under the extreme condition like a long-term space mission, and guided treatment in a mode of noninvasive and multiple configurations. Three folds of the studies will be presented, 1) scanning confocal acoustic navigation (SCAN) imaging for bone quality assessment; 2) guided ARF in the acceleration of fracture healing and promote tissue regeneration in disuse and fracture; and 3) cellular mechanism of loading induced proliferation and motility by key gene/proteins, i.e., sclerostin (Scl) and Piezo channels. Recently, Piezo1 is proposed as a mechanotransducer in regulating the cellular response to external loading. As an effective noninvasive method, ARF elevated by the low-intensity pulsed ultrasound (LIPUS), has been evaluated to promote bone regeneration and fracture healing. It is hypothesized that Piezo1, a mechanosensitive ion channel, could transduce ultrasound-induced mechanical signals and activate downstream signaling processes. It has been shown that piezo (acoustics) induced ARF can promote Piezo1 activation and intracellular calcium influx, in which calcium acts as the second messenger in activating ERK1/2 phosphorylation and polymerization of perinuclear F-actin. ARF has the potential to regulate tissue adaptation and membrane channels, i.e., Piezo1, and eventually promote osteogenesis.

Nanovibration as a precise mechanotransductive tool for cell engineering

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Sonomechanobiology 1, July 16, 2026, 08:45 - 10:30

Cells continuously sense and respond to their mechanical environment, and this mechanotransduction can be harnessed to control cell behaviour without chemical or genetic intervention. This talk overviews aspects from more than a decade of work from the Universities of Strathclyde and Glasgow on nanovibrational stimulation ("nanokicking"), in which precisely controlled sinusoidal nanoscale displacements (typically 30 to 90 nm at 1 kHz) are delivered to cells using piezoelectric actuators and interferometrically validated bioreactors.
Applied to bone marrow mesenchymal stromal cells, nanovibration drives osteogenic differentiation and matrix mineralisation in both 2D and 3D culture, without the growth factors or chemicals (for example BMP-2 or dexamethasone) conventionally required. The mechanisms will be discussed, spanning adhesion and cytoskeletal signalling (RhoA/ROCK) and mechanosensitive ion channels (Piezo1, TRPV1), and how the same stimulus enhances osteogenesis while suppressing osteoclastogenesis. The translational pipeline will be discussed: scale-up from single dishes to flasks and microcarrier suspension bioreactors for manufacturing cell therapies and bone-graft substitutes, and wearable devices that deliver nanovibration in vivo, including studies targeting spinal-cord-injury-induced osteoporosis.

The same nanoscale forces (peak forces of order 10 pN per cell) can also significantly reduce Pseudomonas aeruginosa biofilm formation and extracellular-matrix production, pointing to applications in infection control. Together, these results position nanovibration as a versatile, scalable and chemistry-free mechanotransductive platform that connects nanoscale forces to tissue-level outcomes and real clinical needs.

Mechanical regulation of nucleocytoplasmic transport

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Mechanobiology of Development and Tissue Engineering 1, July 15, 2026, 14:00 - 15:45

Cell proliferation and differentiation, as well as key processes in development, tumorigenesis, and wound healing, are strongly determined by mechanical forces, and the mechanical properties of tissues. In this talk, I will discuss how mechanical force is transmitted from the ECM to the nucleus, and how this affects proteins in general, and transcription factors in particular, by controlling their shuttling between the cytoplasm and nucleus. Further, I will discuss how force transmission to the nucleus spatially regulates mechanical tension in the nuclear envelope, and how this affects nuclear pore complexes.

Physico-chemical signals driving metastatic behaviour

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Cell Mechanics Across Length Scales 1, July 15, 2026, 08:45 - 10:30

Amoeboid behaviour represents a distinct and clinically significant cancer cell state within the epithelial-to-mesenchymal transition (EMT) spectrum. Defined by the loss of cell–cell junctions and adoption of a rounded morphology, amoeboid cancer cells exhibit low adhesion and rely heavily on Rho–ROCK–myosin II-mediated cortical contractility. This combination of high contractility and reduced adhesion enables rapid migration through dense, confining environments, using blebs as functional protrusions. This behaviour is commonly observed at tumour invasive fronts, within metastatic deposits and among therapy-resistant cell populations. Amoeboid identity integrates multiple biochemical signalling programmes alongside mechanical cues such as confinement, matrix topography and shear stress. Collectively, these factors drive a highly plastic state characterised by stem-cell-like traits, metabolic adaptability, low oxidative stress and an immunosuppressive secretome. Such features confer strong metastatic potential and broad resistance to therapy, underpinned by core physicochemical dependencies on cortical tension, membrane mechanics and redox balance. I will highlight these defining characteristics, establishing amoeboid behaviour as a crucial driver of cancer progression and an increasingly promising therapeutic target.

Brillouin microscopy for cell and tissue biomechanics

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Advanced Tools for Multiscale Mechanobiology 1, July 14, 2026, 08:45 - 10:30

The ability to measure the mechanical properties of biological tissues, cells and biomaterials in vivo would have a significant impact in many areas of biological research and clinical medicine. However, current instruments to assess material mechanics require contact or are limited to the analysis of few points at set locations. Brillouin light scattering is an intriguing solution to this gap as it allows to read out mechanical information optically via the spectral analysis of the scattered light. In the past years, we have developed Brillouin spectroscopy technology, where label-free contrast is provided by the material elastic modulus, viscosity and density. Our first area of application has been in ophthalmology as the loss of corneal strength leads to ectasia and is a major risk factor for refractive surgery complications. In this space, we have developed an in vivo Brillouin ophthalmoscope and showed Brillouin microscopy outperforms any existing technology in differentiating ectatic corneas. Then, we improved the imaging resolution to analyze cell mechanical properties and we are investigating the metastatic cascade, where several rate-limiting processes are known to be mechanical in nature. Recently, we have been researching novel solutions to dramatically speed up the image acquisition employing nonlinear optical interactions and atomic spectroscopy.

Kanazawa Institute of Technology, Nagoya University

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Mechanobiology in Disease and Mechanomedicine 2, July 13, 2026, 16:15 - 17:15

The "Kibo" module of the International Space Station(ISS), which began operations in 2008, provides a microgravity (μG) environment (10^{-4} g) at 1 atmosphere, offering valuable insights into organisms' responses to μG. While body weight loss in higher animals in μG leads to a significant decrease in bone and muscle mass,μG has also been reported to alter the morphology and function of cultured cells, where the effect of weight loss should be negligible. What exactly is the mechanism behind this?

In higher animals, body weight acts on cells from the outside as pressure, tensile force, and/or shear stress. On the other hand, in cultured cells, organelles with a large mass and specific gravity, such as the nucleus and mitochondria, are thought to exert gravitational effects from inside the cell. However, because their calculated weight is extremely small (sub-pN), it is supposed that individual ordinal cells may not be able to sense gravity.

We have discovered that decreases in the sub-pN tension in actin filaments induce atrophy of the actomyosin bundle stress fiber and less activity of mechanosensitive ion channels linked to it. Based on this, we have proposed that on Earth, the weight of the nucleus and mitochondria increases tension in the actin filaments attached to them, whereas, in μG, this increase would disappear, leading to changes in cell morphology and function. To verify this, we have analyzed the dynamics of intracellular Ca2+, stress fibers, focal adhesions, etc., using live-imaging, through six times-space experiments in Kibo since 2014, and have obtained solid evidence that single cells respond to μG in accordance with our scenario. In other words, the cells that make up our bodies are exposed to dual gravitational stimuli, macro- and micro-scales on Earth. The physiological significance of the latter awaits future research.

Mechanobiology of cellular senescence and ageing

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Mechanobiology of Ageing 2, July 15, 2026, 16:15 - 17:15

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Tissues are maintained by homeostatic feedback mechanisms in which cells respond to and modify the chemical and mechanical properties of the extracellular matrix (ECM). Mechano-sensitive mesenchymal stromal/stem cells (MSCs) in the marrow niche experience a diverse mechanical environment, but ageing affects bone and marrow tissue composition and quality. Senescence protects against uncontrolled proliferation, but senescent cells accumulate in ageing tissues as the immune system fails to remove them. This accumulation reduces tissue regeneration capacity and negatively affects tissue function, for example by secreting inflammatory factors. Previous work showed that proliferating MSCs rapidly and reversibly remodel their proteomes in response to mechanical stress, for example breaking protein linkages between the nucleus and cytoskeleton. However, replicative senescence in MSCs leads to significant loss of chaperone proteins responsible for maintaining the cytoskeleton. Furthermore, senescent MSCs lack the translational capacity to rapidly remodel their proteomes in response to stress, even when transcriptional responses are functional. These mechanisms result in a blunted response to the environment, evidenced by changes in morphology and the ability to remodel the surrounding ECM. As the potential of MSCs to be used in regenerative medicine continues to be explored, this work demonstrates how cell replication, senescence, and ageing affect our ability to direct cell behaviour.

Mechanical Barriers to Immunity: Collagen Fibril Alignment as a Determinant of Immunological Suppression and Exhaustion in the Tumor Microenvironment

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ECM Mechanobiology in Physiology and Disease 1, July 16, 2026, 08:45 - 10:30

The desmoplastic reaction in solid tumors is characterized by the transition of the extracellular matrix (ECM) from a disorganized meshwork to a highly linearized and aligned collagen architecture. While this alignment is a known driver of contact guidance for cancer cell invasion, its role in modulating the immune contexture remains a critical frontier. Drawing on foundational immunomechanobiology research, our lab investigates how collagen fibril alignment serves as a mechanical regulator of immune cell dysfunction.

Using 3D collagen-based scaffolds as the backbone, we engineered tunable gradients of fibril alignment to simulate the peritumoral stroma. We integrated these biomimetic models with human dendritic cells, macrophages, and Tlymphocytes separately and utilized multiparametric flow cytometry, metabolic profiling, and advanced live-cell imaging to quantify the mechanobiological shifts induced by ECM anisotropy. Our findings demonstrate that collagen fibril alignment dictates immune dysfunction through three main mechanisms.
Dendritic cells, intelligence officers of the immunity, are mechanically silenced across DC maturation states. In Immature DCs (iDCs), alignment enhances proinflammatory chemokine secretion without impacting antigen uptake capacity; however, there is downregulation in mitochondrial ATP production. This forces a metabolic shift towards glycolysis that fails to maintain sufficient ATP, which restricts iDC migratory characteristics. Conversely, mature DCs maintain an unaltered matured phenotype independent of matrix alignment, the aligned icroarchitecture does significantly modulate their interactions with T-lymphocytes (T-cells), activation and proliferation of T-cells are also dampened.

Macrophages, traffic controllers of immunity, are immune cells that can traverse between pro- and antiinflammatory roles. Matrix stiffness, act as a deterministic biophysical regulator that drives their polarization towards a pro-tumor, M2-like phenotype. RNA-sequencing reveals conserved transcriptomic profiles and enhanced PI3K signaling in macrophages cultured on these stiffened matrices. Through sequential blocking experiments, enhancement of PI3K signaling was found to be integrin-mediated and in response to matrix tension and possibly supports an IL-4 autocrine positive feedback loop. Ultimately, fibril alignment and matrix crosslinking, the latter also a known phenomenon in peritumoral stroma, work in tandem to suppress macrophage proinflammatory activity, sequestering them into a suppressive state.

The workhorse of the adaptive immune system, T-cells, act as versatile, highly specific, and long-lasting force responsible for identifying, destroying, and remembering pathogens. Essentially, they should prevent tumors from reoccurring. Aligned collagen fibrils compromise T-cell efficacy through structural and molecular reprogramming.

Activated T-cells exhibit increased protrusions and reduce actin content that may lead to their marked reduction in migratory capacity within aligned collagen. Furthermore, increased matrix stiffness and alignment also suppress their activation and proliferation. Critically, this suppression is reversible through the inhibition of YAP signaling, which we show improved T-cell activation within aligned matrices.

In summary, our data establish that physical microarchitecture of the stroma is a primary determinant of the immune excluded phenotype. By identifying the YAP, PI3K and OXPHOS axes as key mechanosensitive nodes, we propose that future immunotherapies must prioritize matrix-normalizing strategies to bypass these barriers and restore immune infiltration and function.

How does nuclear mechanobiology shape neutrophil functions?

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Nuclear Mechanobiology 1, July 14, 2026, 14:00 - 15:45

To help defend the host from pathogens and maintain tissue homeostasis, neutrophils – the most abundant immune cell in our body – need to remodel their nuclei to move and kill their targets. Our lab aims to understand how neutrophil tune and leverage the mechanical properties and functions of the nucleus to achieve their host defense functions. Such knowledge will open the door to biophysics-inspired strategies that harness nuclear mechanobiology for controlling and re-engineering neutrophil functions to improve immune responses. In this talk, I will discuss our lab's current work toward understanding how neutrophils tune the mechanical properties of the nucleus to release chromatin to the extracellular environment during NETosis - an immune response that worsens inflammation. Our work identified novel mechanisms by which chromatin within the nucleus regulates the mechanical properties of cells, independently of gene expression, materially advancing our understanding of the biophysical roles of chromatin and the nucleus in cell physiology.

Programming Shape in Living Tissues

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Mechanobiology in Disease and Mechanomedicine 1, July 13, 2026, 14:00 - 15:45

Living tissues are active materials that continuously generate, transmit, and dissipate mechanical stresses across scales. Yet how these stresses give rise to robust three-dimensional shapes remains incompletely understood. In this talk, I will present recent work exploring two complementary physical mechanisms by which cellular monolayers undergo shape transformations: active viscoelastic buckling and nematic-guided morphogenesis.
In the first part, I will delineate the mechanical rules governing epithelial buckling by combining an experimental system that allows us to sculpt epithelial shells and subject them to controlled deflation with a 3D computational model linking cytoskeletal dynamics to tissue mechanics. We show that epithelial buckling emerges from the interplay between the applied loading rate, the viscoelasticity of the actin cortex, and active contractility. We find that epithelial buckling is a multiscale phenomenon involving long-lived supracellular folds as well as short-lived subcellular wrinkles in the actin cortex. By forming epithelial shells with anisotropic curvature, we explore symmetry breaking and direct buckling into predictable wrinkle patterns.
In the second part, I will present a strategy to program tissue shape transformations through the nematic organization of cellular forces. By controlling nematic order and topological defects, we generate tissues programmed with specific stress fields. Using a theoretical framework coupling contractile nematics with thin-sheet mechanics, we show that nematically guided active stresses can drive morphogenesis through Gaussian morphing. Experimentally, detachment of nematic tissues triggers out-of-plane deformations, generating reproducible three-dimensional shapes.

Together, these studies establish a unifying physical framework in which tissue shape emerges from active stresses, viscoelasticity, nematicity, and geometric frustration. Beyond advancing our understanding of morphogenesis, this framework enables the design of synthetic shape-programmable living surfaces.

Forcing inflammation to drive tumor initiation and progression

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ECM Mechanobiology in Physiology and Disease 1, July 16, 2026, 08:45 - 10:30

The Weaver group uses cultured 3D spheroids and organoids, and in vivo PDX and syngeneic models with tuned ECM stiffness, as well as genetically engineering mouse models in which ECM stiffness and integrin mechanosignaling are manipulated to explore the interplay between inflammation and the ECM in cancer risk, progression and treatment. We showed that infiltrating macrophages induce ECM deposition, remodeling and crosslinking to stiffen the ECM and drive tissue fibrosis. We determined that the stiffened ECM thereafter increases STAT3 activity to elevate cytokine levels that further potentiate inflammation. Macrophages exposed to a stiff stroma undergo a YAP/TAZ-dependent pro-tumorigenic synthetic ECM metabolic switch that alters tissue metabolites to repress T cell dependent anti-tumor activity. Consistently, our studies revealed that a stiff ECM, via integrin-mechanosignaling, enhances signaling to disrupt tissue organization, promote cell growth and survival and drive invasion and motility that foster malignant progression. The stiffened ECM also induces an epithelial to mesenchymal transition, enhances tumor cell dissemination and represses anti-tumor immunity to support metastasis. Intriguingly, the infiltrating macrophages also respond to the stiff ECM by elevating ROS production to increase lipid aldehyde-mediated DNA damage that induces pro-tumorigenic pro-metastatic mutations in the epithelium. Chromatin analysis of organoid models revealed that a stiff ECM renders regions within the chromatin that harbor many frequently mutated tumor suppressors including p53 and BRCA1 more accessible, suggesting that a stiff stroma predisposes the epithelium to tumor-associated mutations that promote malignancy. Consistently, women with high mammographic density and those with germline BRCA1 mutations, who exhibit a heighted risk for breast cancer, have a stiffer stroma that contains a higher frequency of pro tumor ECM synthetic tumor-associated macrophages, and their epithelium shows elevated nuclear lipid aldehyde modifications and DNA damage. Thus, a stiffened stroma, in addition to promoting malignant progression, may increase DNA mutations that initiate malignancy.

Sonoepigenetics: Mechanopriming Stem Cells Toward Early Osteogenic Commitment

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Sonomechanobiology 2, July 16, 2026, 11:00 - 12:00

Cells are known to respond to diverse forms of mechanical cues, yet most dynamic mechanostimulation studies have been conducted at low frequencies—typically several Hz, characteristic of the physiological frequencies experienced by cells in their local environment. Higher frequency mechanostimulation to date has largely been limited to the kHz range, although it has been suggested that there would be no significant advantage in utilising higher frequencies. In contrast, we have nevertheless observed 10 MHz order nanoscale vibrational stimulation to be capable of eliciting unique cellular responses in a similar manner to our prior discoveries of nonlinear high frequency vibrational coupling into fluids and crystalline materials. These include modulation of mechanosensitive ion channels and transient yet reversible permeabilisation of the cell membrane, which have implications for efficient intracellular cytosol delivery, exosome biogenesis, immune cell and sperm activation, stem cell differentiation , cytoskeletal reorganisation and endothelial barrier modulation—all while maintaining very high cell viabilities (>95%). As an example, we demonstrate, in particular, the possibility for early induction of mesenchymal stem cells toward an osteogenic lineage in as little as three days—without requiring osteogenic factors. This is shown to stem from a ‘mechanopriming’ effect as a consequence of epigenetic modifications induced by the high frequency mechanostimulation: chromatin fluctuations driven by the spatiotemporal dynamics associated with the bidirectional crosstalk between two key second messengers, namely calcium and cyclic adenosine monophosphate (cAMP). Altogether, these findings highlight the potential of high-frequency mechanostimulation as a powerful and underexplored paradigm for mechanobiology and cell engineering.

Elucidating distinct roles of extracellular matrix in cardiac aging

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Mechanobiology of Ageing 1, July 15, 2026, 14:00 - 15:45

Age-related remodeling of the cardiac extracellular matrix (ECM) is a major contributor to cardiovascular disease and dysfunction. In aging, specific components of the ECM undergo abnormal secretion, degradation, structural changes, and mechanical alterations, directly affecting organ physiology and cell behavior. Specifically, the stiffness of murine cardiac tissue has been shown to increase from ~10 kPa (young) to ~40 kPa (aged), which has important implications in cellular mechanotransduction and function. While ECM stiffening often compensates for a weakening heart, these altered matrix properties can lead to further complications. It is well known that cardiac cells are mechanosensitive, but most current in vitro systems are incapable of decoupling distinct ECM cues while maintaining native scaffold properties. To do this, we developed a hybrid material approach termed DECIPHER (DECellularized In Situ Polyacrylamide Hydrogel-ECM hybRid) consisting of in situ decellularized ECM from intact cardiac tissue sections linked to a synthetic hydrogel. The ECM 'ligand age' can thus be tuned independently from the ECM 'stiffness age' via the manipulation of the synthetic hydrogel component connected to the tissue proteins, resulting in four scaffold combinations. DECIPHER scaffolds were used to elucidate the specific roles of these interconnected age-specific ECM cues (ligands vs. stiffness) in regulating cardiac fibroblast function. Scaffolds were first assessed using quantitative mass spectrometry, immunohistochemistry, and nanoindentation, and were found to maintain the original composition and organization of young or aged murine cardiac tissue while allowing independent control of the mechanical properties that reflect the stiffness of young (~10 kPa) or aged (~35 kPa) cardiac tissue. We then seeded these scaffolds with primary cardiac fibroblasts (CFs) isolated from young or aged murine hearts and carried out immunofluorescence, RNA-seq, and RT-qPCR. We discovered distinct age-dependent mechanisms of CF activation in which the integration of ligand and mechanical cues drive the phenotypical transition toward a myofibroblast state. Notably, for aged CFs, young ECM ligand presentation was found to outweigh profibrotic stiffness cues, thereby regulating CF quiescence and age phenotype independent of mechanics. Ultimately, these tunable scaffolds enable precise investigations into the specific properties of the ECM that regulate age-related dysfunction and provide insights into potential avenues for rejuvenation strategies.

Force-Gated Mechanosensing in the VWF–Platelet GPIb-IX Axis: From A1 Mechanoactivation to Fc-Independent Immune Thrombocytopenia

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Immunomechanobiology 1, July 14, 2026, 14:00 - 15:45

Mechanical forces in the circulation are not merely physical byproducts of blood flow, but important signals that regulate hemostasis, thrombosis, and platelet clearance. This talk will introduce our work on the von Willebrand factor (VWF)–platelet glycoprotein Ib-IX (GPIb-IX) axis, a force-sensitive molecular system that captures platelets at sites of vascular injury and, when dysregulated, drives bleeding or thrombotic disease. Using single-molecule force spectroscopy, single-molecule fluorescence imaging, microfluidics, and molecular modeling, we have identified multiple hidden mechanosensors within this axis. I will focus on recent discoveries showing that the VWF A1 domain is autoinhibited by a discontinuous autoinhibitory module (AIM) formed by its N- and C-terminal flanking regions. Tensile forces in the 8-20 pN range mechanically unfold this module, rapidly activating A1 for GPIb-IX binding. Disease mutations and antibodies can destabilize the AIM, whereas therapeutic nanobodies can mechanically stabilize it. I will also discuss how force transmitted through VWF-A1 unfolds a juxtamembrane mechanosensory domain in platelet GPIb-IX, triggering platelet signaling, activation, and clearance. This mechanism provides a physical basis for Fc-independent immune thrombocytopenia, in which pathogenic antibodies induce platelet activation and clearance without Fc-mediated phagocytosis. Together, these findings highlight the promise of mechanomedicine: targeting force-gated molecular switches to diagnose and treat vascular disease.