

EUROMECH COLLOQUIUM 638
CELLULAR MECHANOBIOLOGY AND MORPHOGENESIS
21– 24 August 2023, Sirmione, Lake of Garda, Italy

Final report

Overview:

An important international congress took place in Sirmione from August 21st to 24th, sponsored by the European Mechanics Society and coordinated by the University of Brescia. Thirty-four internationally renowned scientists and 10 young researchers were invited to present their latest research on the theme "Cellular Mechanobiology and Morphogenesis". Mechanobiology is more than just a recently formed discipline. It is a scientific arena where different areas of research - computer science, mechanics, biology, biochemistry, imaging - come together to address problems of enormous complexity and tremendous social impact, such as tumor development or cellular differentiation. It is now clear to the scientific community that problems of such magnitude cannot be addressed without an interdisciplinary approach. The congress was a unique opportunity to gather and connect the brightest minds in traditionally separate disciplines, with an intellectually interconnected path. The event was so successful among participants that it will be hopefully repeated in the years to come, a prospect that was hoped for by all, even though initially not planned.

The Euromech colloquium brought together distinguished scientists from around the world, from prestigious Asian and overseas institutions to European ERC grant winners. By illustrating substantially new scientific themes (cellular motility and contractility, single or collective motion during metastasis, the role of the extracellular matrix, and the reproduction of cellular dynamics with organs on a chip, super-resolution microscopy) or the most recent results in slightly more consolidated areas (the response of the nucleus and mitochondria to mechanical stresses, embryonic morphogenesis, and the vascular system), the congress has drawn new scientific paths and allowed for the creation of new collaborations and projects that will play an important role in future medicine.

For example, the control of cellular motility can be a determining factor in anti-cancer therapies, limiting or delaying the onset of metastatic processes. However, some dynamics associated with cell motion, both collective and single, are not yet fully understood. In what circumstances and for what reasons does collective motion prevail over single motion? What signals reach the nucleus during cellular motion, and what alterations occur, guided for example by chromatin? What cytoskeletal differences emerge in 3D motion compared to 2D, and how is homeostatic tension maintained during the process? What is the role of the extracellular matrix in cell-cell interaction and mechanosensing regulation? What biological factors alter its rigidity? What is the energetic cost of motility? What quantitative indicators describe the mechanobiological processes underlying cell division and its fundamental applications in embryogenesis, angiogenesis, metastasis? What physico-chemical interactions govern the formation of blood clots, and what cellular remodeling follows the implantation of heart valves, conditioning their behavior? New models and new tools (such as super-resolution microscopy, with the ability to discern at distances less than 10 nm, thus at intermolecular distances; organoids and organs on chips; bio-printing; indirect systems for measuring inter-cellular and intra-cellular forces) have been discussed and will be developed to address these and other questions.

A window into the personalized medicine of the future has been opened. Visionary companies (Copan, MDE, BiomimiX, Theras) found fertile ground at the congress, and we hope that their participation in the conference can pave the way for new successful entrepreneurial initiatives.



Sponsors:

University of Brescia; Copan, MDE, BiomimiX, Theras;

Conference fees:

Early registration speakers: 250 euros ; Late registration speakers: 300 euros ;

Poster registration speakers: 250 euros .

Euromech provided 2000 euros support.

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- Three days of scientific presentations and round-table discussion, in presence format (34 speakers, 11 posters) at the Congress Center in Sirmione, Lake of Garda.

- Four coffee breaks with pastries and cookies. Wine and cheese welcome reception on Sunday night.

- 1 colloquium dinner at the winery " *Podere Selva Capuzza*", Desenzano del Garda. The dinner included bus transport, a performance by a duet (Daniela Fusha arpa and violin ensemble); cocktail.

- Welcome address from the Rector of the University of Brescia, from the Major of Sirmione.



- Service of remote connectivity, safety, cleaning.
- 11 Posters printing.

Focus of this colloquium

The purpose of the Euromech Colloquium "CELLULAR MECHANOBIOLOGY AND MORPHOGENESIS" was to bring together the most active international research and industrial groups (with a special focus on Europe) to discuss fundamental issues for the development of mechanobiology, from research to clinics.

All living cells and tissues exert and experience physical forces that guide their function. Those mechanical processes are pivotal in the biophysics of embryonic formation, tumor angiogenesis, cancer growth and metastasis, wound healing, and developmental diseases. A fundamental understanding of these mechanisms can contribute to the advancement of medical intervention, from reducing bone fracture risk in osteoporosis to device-based treatment of aortic aneurysm.

Tissue development and remodeling are mediated by cell-generated stresses and strains, which emerge at the nanoscale in response to complex biochemical interactions among cells and with their microenvironment. Cells can sense and mechanically respond to their surroundings by attaching to extracellular matrix (ECM) fibers through the formation of focal adhesions, developing actin networks, and actively generating tension via myosin motor contractility. This physical system is one of the most complex known to mankind and continues to be the subject of intense multidisciplinary research.

Theoretical and experimental characterization of living matter requires the collective effort of scientists across a wide range of disciplines, including solid mechanics and bio-fluid dynamics at different length and time scales. The role of mechanics in biology is therefore particularly relevant to the activities and expertise of the EuroMech community. We proposed this Colloquium to encourage worldwide cooperation in advancing scientific understanding of *cellular mechanobiology and morphogenesis*.

Objectives of this colloquium

While computational and experimental methodologies in mechanobiology have been applied to understand tumor progression and cardiovascular diseases, there is significant opportunity to explore their applicability in many other areas of medicine, spanning microbial resistance, device-driven tissue remodeling, and reprogramming of cells in immunotherapy. This colloquium aims to bring together biologists and mechanicians tackling biophysical problems of major social impact. To restrict the scope, the colloquium will focus on biological processes that are underpinned by active remodeling of cells at different length scales. This colloquium is particularly concerned with the mechanics of cytoskeletal contractility and protrusion, migration, adhesion, ECM remodeling, morphogenesis, and nuclear mechano-transduction. The colloquium will therefore explore important biological phenomena in cells that may be explained by mechanical principles, including topics related to:

Cytoskeletal contractility and remodeling; Cellular protrusion and migration; Cellular adhesion and matrix interaction; Mechano-transduction through the cytoskeleton and nucleus; Protein active mechanics; Mechanical Homeostasis; In-vitro cytoskeletal gels; Bioinspired active materials; Cell Fate Transition; Cell Proliferation and Mitosis; Embryogenesis; Metastasis; Angiogenesis.

Multi-disciplinarity and the organization of this colloquium

A key aspiration is to bring together the most authoritative experts in the field exploring frontier problems, with a view to bridging theoretical and experimental methodologies. We aim to achieve a balance between leading perspectives in theoretical and computational mechanics, fluid modelling, experimental cell biomechanics, and mechanobiology. Moreover, the colloquium will foster the use of novel integrative methodologies to bridge experiments and theory with the use of data-driven approaches for the estimation of model parameters.

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Final programme.

Monday Aug. 21		
<i>Opening</i>	<i>Institutional welcoming by Alberto and Eoin</i>	
19:00		Carrozza, M. – Municipality of Sirmione
		Castelli, F. – Rector of the University of Brescia
		Wine and cheese welcoming

Tuesday Aug. 22		
<i>Session 1</i>	<i>Nuclear Mechanobiology</i>	<i>Char: M. Bacca</i>
9:00	9:30	Shenoy, V., How do Forces From the Cell's Environment Affect DNA Organization?
9:30	10:00	Roca-Cusachs, P., Controlling nuclear mechanics from the extracellular matrix
		Coffee break
<i>Session 2</i>	<i>Morphogenesis</i>	<i>Chair: A. Gizzi</i>
10:30	11:00	Garcia-Aznar, JM., Unraveling the morphogenetic pattern of cystic spheroids: an AI-guided physics-based approach
11:00	11:30	Deshpande, V., The role of geometry and boundary conditions in cell organisation in tissue morphogenesis
11:30	12:00	Rangamani, P., Multiscale modeling of lipid bilayers for mitochondrial membrane mechanics.
12:00	12:30	Saif, T., Disorder to order transition in multicellular systems through dynamic nonlinear elastic interactions
		Lunch break

<i>Session 3</i>	<i>Mechanobiology of vascular systems</i>	<i>Chair: V. Vogel</i>
14:00	14:30	Loerakker, S., Computational approaches to analyze and predict cell-mediated cardiovascular growth and remodeling
14:30	15:00	Conte, V., The border zone in myocardial infarction: the mechanobiological perspective of cells
15:00	15:30	Schön, I., Mechanobiology of platelet-extracellular matrix interactions during thrombus formation
15:30	16:00	Ristori, T., Multiscale modelling of the spatiotemporal dynamics of angiogenesis in regenerative medicine
		Coffee break
<i>Session 4</i>	<i>Active contractility</i>	<i>Chair: V. Deshpande</i>
16:30	17:00	McGarry, P., Modelling active contractility in cells and tissue
17:00	17:30	Nardinocchi, P., Self-contractile biopolymer gels: a continuum mechanics perspective
17:30	18:00	Smith, M., Tensional homeostasis: role of signaling and contractile machinery in suppression of mechanical extremes

Wednesday Aug. 23		
<i>Session 5</i>	<i>Mechanobiology of cancer</i>	<i>Chair: V. Shenoy</i>
9:00	9:30	Gräter, F., Protein mechanoradicals: how tissues turn mechanical into oxidative stress
9:30	10:00	McNamara, L., Osteocyte mechanobiology and bone disease: multicellular models to study bone loss during estrogen deficiency and bone metastases
10:00	10:30	McEvoy, E., Mechanobiology of stress-dependent cell and tumour growth
		Coffee break
<i>Session 6</i>	<i>Cellular Motility</i>	<i>Chair: P. McGarry</i>
11:00	11:30	Doyle, A., Cell mechanics and motility in 3D microenvironments
11:30	12:00	Madzvamuse, A., Unravelling mechano-biochemical models for 2- and 3-D single cell migration
12:00	12:30	Salvadori, A., Actin-based motility unveiled: from bacteria to cells
		Lunch break
<i>Session 7a</i>	<i>Fluidics and Organs on a chip</i>	<i>Chair: A. Gizzi</i>
14:00	14:30	Occhetta, P., <i>BiomimX</i> , Beating organs-on-chip as innovative tools for diseases modelling and advanced therapies evaluation
14:30	15:00	Vassalli, M., Fluidic Force Microscopy to study Cellular Mechanosensing
<i>Session 7b</i>	<i>Extracellular Matrix</i>	<i>Chair: P. Roca-Cusachs</i>
15:00	15:30	Genin, G., Cell-matrix feedback and the development of polarity
15:30	16:00	Vogel, V., Bridging Length Scales: Mechano-Chemical Switching of Extracellular Matrix Fibers
16:00	16:30	Gizzi, A., Growth and remodeling in distributed fiber-reinforced materials
16:30	17:00	Pathak, A., Environmental memory and cell invasion through fibrous microenvironments
18:30	23:00	<i>Poster session and social dinner Podere Selva Capuzza, Desenzano del Garda</i>

Thursday August 24		
<i>Session 8</i>	<i>Experimental and Theoretical Mechanobiology, 1.</i>	<i>Chair: E. McEvoy</i>
9:00	9:30	Bacca, M., Energetics of Diffusion-mediated Processes in Biological Systems: Virus Replication & Cytoskeletal Contraction
9:30	10:00	Kaul, H., Synergy between mechanics and biochemical signalling hinges on cellular energetics
10:00	10:30	Klotzsch, E., Lymphocyte mechano-stimulation for adoptive immunotherapies
		Coffee break
<i>Session 9</i>	<i>Experimental and Theoretical Mechanobiology, 2</i>	<i>Chair: A. Doyle</i>
11:00	11:30	Jungmann, R., Localizomics: towards spatial omics using DNA-based super-resolution microscopy
11:30	12:00	Alvarado, J., Connecting active “hardware” to biological “software”
12:00	12:30	Cheng, L., Experimental and modelling techniques for quantifying the electro-mechanical activity in the gut
		Lunch break
<i>Session 11</i>	<i>Multicellular systems</i>	<i>Chair: A. Salvadori</i>
14:00	14:30	Marino, M., Phase-field modeling of cell motility in biodegradable hydrogel scaffolds
14:30	15:00	Scita, G., Tissue fluidification in pathophysiology
15:00	15:30	Arroyo, M., A mechano-biological feedback between cancer organoids and the ECM initiates and sustains collective invasion
	<i>Closing by Alessio and Mattia</i>	