FACULTY OF PHYSICS

Warsaw Symposium
"Patterns: On Growth and Form"
Tuesday, May 26, 2026

UNIVERSITY OF WARSAW

Program

08:45 – 08:55	**Registrations**
08:55 – 09:00	**Opening Remarks**
09:00 – 10:30	**Presentations**

09:00 – 09:30 | (1) **Jaap A. Kaandorp** | Modelling gastrulation in jelly fish and sea anemones

09:30 – 09:45 | (2) **Laureline Julien** | Morphogenesis establishes directional transport in the gastrovascular network of the jellyfish Aurelia aurita during development

09:45 – 10:00 | (3) **Thibault Chassereau** | Estimation of flow inside the gastrovascular network of the jellyfish Aurelia aurita induced by the swimming motion

10:00 – 10:15 | (4) **Jarosław Stolarski** | Who draws the pattern? Physiology behind coral fine-scale skeletal structures

10:15 – 10:30 | (5) **Łucja Kowalewska** | Gyrobodies: gyroid-type cubic membranes emerging from the plant thylakoid network

10:30 – 11:00	**Coffee Break**
11:00 – 12:30	**Presentations**

11:00 – 11:30 | (6) **Alina Ciach** | Self-assembly in mixtures with competing interactions

11:30 – 11:45 | (7) **Joanna Materska** | System of motile and growing particles

11:45 – 12:00 | (8) **Marta A. Chabowska** | Morphological diversity induced by surface potential energy

12:00 – 12:15 | (9) **Magdalena Załuska-Kotur** | Pattern formation mechanisms in recrystallization processes

12:15 – 12:30 | (10) **Anna Niedźwiecka** | How proteins shape mineral patterns: spherulitic growth of calcium carbonate controlled by acid-rich proteins

12:30 – 13:15	**Lunch**
13:15 – 15:00	**Poster session**
15:00 – 16:15	**Presentations**

15:00 – 15:30 | (11) **Michael Berhanu** | Erosion patterns by dissolution

15:30 – 15:45 | (12) **Michał Bogdan** | Quantifying the openness of porous materials using topological parameters

15:45 – 16:00 | (13) **Martin Chaigne** | Sediment transport instability in a radial experiment

16:00 – 16:15 | (14) **King Lun NG** | Patterns of oscillating droplets on vibrating substrates: A molecular model study

Presentation Abstracts

(1) **Jaap A. Kaandorp** (Computational Science Lab, University van Amsterdam)
‘‘Modelling gastrulation in jelly fish and sea anemones’’
A three-dimensional cell-based model of gastrulation in the sea anemone Nematostella vectensis is presented. The model is a three-dimensional version of a deformable cell boundary model. The basic idea of the model is that the cell boundary is tessellated with triangles, every edge of the triangles and the simulated cytoplasm are loaded with with visco elastic elements. The whole system is updated with a method borrowed from molecular dynamics (the Velocity Verlet method). In earlier work we used a similar approach to study gastrulation in two dimensions in the sea anemone Nematostella vectensis and the jelly fish Clytia hemisphaerica. In the three-dimensional simulations cells are represented as separate deformable entities with a conserved cell volume. A blastula is formed by adhering the cells together as a sphere. The simulation results show that changing individual mechanical properties, like cell stiffness, cell-cell adhesion, and the apical constriction factor, have a direct effect on the cell's behavior and future shape. These properties influence the ability of a cell sheet to bend and eventually change the global shape of the embryo. The observed shape transitions of the endodermal region during the inward bending of the cell sheet in the simulation can give an insight into the mechanisms involved, and timing of events in gastrulation. Changing geometrical properties (endodermal plate shape, endodermal cell number and the start position of constriction) is not possible in 2D models. The 3D model shows that the inwards bending is more dependent on the number of cells involved than on the shape of the endodermal region. The result is that the invagination process is very robust to irregularities.

(2) **Laureline Julien** (University of Oulu)
‘‘Morphogenesis establishes directional transport in the gastrovascular network of the jellyfish Aurelia aurita during development’’
Jellyfish Aurelia aurita possesses a gastrovascular system composed of stomachs connected to a canal network that evolves during development. At the juvenile stage, this network consists of separate canals in which fluid motion shows back-and-forth flow. During development, canals connect, and directional circulation emerges. We investigate the development of transport mechanisms that give rise to flow directionality in this system.
We identify two candidate drivers: 1) peristaltic pumping generated by muscle contractions used for swimming, and 2) beating cilia lining the canal walls. To separate the contributions of cilia and peristalsis, we track food particles in canals. Under anesthesia, contractions cease, and flow is driven solely by cilia. Cilia beat in coordinated waves and are oriented in the direction of the adult flow in all canals, already from the juvenile stage, highlighting a form of collective coordination at the tissue scale.

Comparing velocities in anesthetized animals shows that cilia maintain a baseline flow, while muscular contractions accelerate transport at all phases of the swimming cycle. In addition, canal fluid contains mucus with a shear-thinning behavior facilitating transport by lowering resistance under pumping.
In growing canals, we observe planar cell polarization aligned in the direction of the growth. Our results suggest that cilia do not require net flow to get orientation, and that directionality of flow is set by tissue growth.
This study links growth of a network with mechanics of transport that induces circulation and distribution inside the gastrovascular system. It shows how collective coordination at the cellular scale can organize transport at the system level without centralized control.

(3) **Thibault Chassereau** (Matière et Systèmes Complexes, Université Paris Cité, CNRS)
''Estimation of flow inside the gastrovascular network of the jellyfish Aurelia aurita induced by the swimming motion.''
While many models can explain the formation of branched physical networks, few can explain reticulated networks. Some theoretical studies suggest that reversing flows through these networks encourages the formation of loops. The question here is whether pulsatility affects morphogenesis and promotes the formation of loops in the vascular networks of biological systems.
We use the scyphozoan jellyfish Aurelia aurita as an experimental model. This species has a gastrovascular network that connects the mouth and four stomachs in the centre to a circular canal at the periphery via a series of unbranched adradial or branched interradial canals.
There are two potential mechanisms responsible for flow within the jellyfish's network. The first is the beating of the cilia that line the inside of the canals. The second, which we focus on here, involves contractions of the canals by the swimming muscle.
One experimental setup enables us to observe the flow through the canals and the deformations induced by the muscle contractions across the entire jellyfish. However, this setup requires the jellyfish to be constrained in two dimensions. Therefore, it cannot be guaranteed that the muscle contractions are representative of the deformations induced by the jellyfish's free swimming movement. In addition, we use a second experimental system with stereovision to observe the three-dimensional deformations of the jellyfish's gastrovascular network during swimming. Combining the results of these two setups with theoretical models enables us to estimate the flow and pulsatility within the different canals induced by swimming, as well as the impact of different networks depending on the jellyfish's age and condition.

(4) **Jarosław Stolarski** (Institute of Paleobiology, Polish Academy of Sciences)
''Who draws the pattern? Physiology behind coral fine-scale skeletal structures''
An important question in biology is to what extent organismal functions and skeletal pattern formation are driven by external physicochemical factors versus internal physiological regulation. Although mathematical models explain large-scale coral skeletal patterns, the mechanisms initiating these processes at the microscale remain poorly understood. Recent findings indicate that coral calcification is a highly biologically controlled process, the main components of which will be briefly discussed.

(5) **Łucja Kowalewska** (Faculty of Biology, University of Warsaw)
''Gyrobodies: gyroid-type cubic membranes emerging from the plant thylakoid network''
Biological membranes adopt a remarkable diversity of three-dimensional architectures, from flat bilayers to intricate bicontinuous cubic geometries. In plant chloroplasts, the thylakoid membrane network - responsible for the light reactions of photosynthesis — has long been considered to exist exclusively in a lamellar configuration of stacked grana connected by helical stroma lamellae. Here we report the discovery of gyroid-type cubic membrane structures, which we term gyrobodies, forming within mature chloroplasts of Arabidopsis thaliana. Using cryo-electron tomography and SPIRE analysis, we demonstrate that gyrobodies are genuine three-dimensional gyroid minimal surfaces, directly connected to the surrounding thylakoid network, with unit cell sizes of around 500 nm. Gyrobodies form reversibly during day-night cycles in the stn7-1 kinase mutant and constitutively in aba1-6, and can be induced in wild-type plants by extended darkness. We show that reduced thylakoid membrane surface charge density - resulting from decreased protein phosphorylation - triggers the lamellar-to-gyroid transition, which is further facilitated by elevated levels of the curvature-inducing lipid MGDG. Despite the massive topological transformation of the membrane network, gyrobody-containing chloroplasts maintain photosynthetic competence. Fluorescence correlation spectroscopy reveals that gyrobodies increase the mobility of stromal proteins in their vicinity, suggesting a potential role in regulating molecular diffusion within the chloroplast. These findings reveal an unexpected capacity for topological transformation in mature plant membranes, connecting the geometry of biological minimal surfaces to photosynthetic regulation.

(6) **Alina Ciach** (Institute of Physical Chemistry, Polish Academy of Sciences)
''Self-assembly in mixtures with competing interactions''
In the lecture, examples of mixtures with competing interactions leading to spontaneous pattern formation as well as generic 3D and 2D or quasi-2D models inspired by soft- and living matter will be presented. The latter models represent monolayers of charged nanoparticles or macromolecules adsorbed at interfaces or embedded in lipid bilayers. We focused on binary mixtures with like particles interacting with short-range attraction long-range repulsion (SALR), and cross-

interaction of opposite sign. The distribution of the particles and the phase diagrams were obtained for several versions of the above potentials in mean-field approximation and with the effect of fluctuations taken into account. The results were verified by MC and MD simulations. We obtained self-assembly into alternating layers of the first and the second component, and hexagonal arrangement of clusters of the minority component in the liquid of the majority component. Different shapes of the above interactions lead mainly to different size of the aggregates, and to some differences in fine details of the ordered patterns. Nontrivial structure of the disordered phase with mobile aggregates of various sizes will be illustrated. Finally, regular patterns assembled on a surface of a large colloidal particle from a mixture of oppositely charged nanoparticles will be shown and discussed.

(7) **Joanna Materska** (Institute of Physical Chemistry, Polish Academy of Sciences)
''System of motile and growing particles''
Groups of simple motile particles display phenomena absent in equilibrium systems, most notably motility induced phase separation (MIPS) [Cates, 2015] and flocking [Vicsek, 1995]. Assemblies of growing particles seem to lack spectacular emergent behaviours, yet they too yield significant results: for example, some relatively simple models of growing spherocylinders provide satisfactory visual approximation of growing bacterial colonies [Farrell et al., 2013]. Many basic models of either motile, or growing matter are well understood, but, so far, the mixtures of the two types receive little attention. In particular, not much is known about the behaviour of motile matter in the presence of growing matter, despite recent progress [Hupe et al.,2026]. I have conducted simulations of noisy mixtures of 2D motile spherocylinders (movers) and their counterparts (growers), that grow divide and die. Notably, for low motilies, movers cluster together. As the movers innate velocity increase, the two types of the particles mix, which is the reverse of what happens in MIPS. The clustering-mixing shift resembles thermodynamic continuous phase transition, with transition velocity modulated, among others, by growers density and movers length. The sizable clusters of movers continuously change shape, but retain some structural order on the short time scales: at most times microdomains of the particles facing similar directions take up significant part of the biggest clusters. The formation of the microdomains cannot be explained simply by the alignment of the elongated particles, as the almost round spherocylinders often form bigger (almost) unidirectional groups. Investigation into other properties of the model, such as distribution of the sizes of the clusters or velocity correlations of the movers also reveal some non-obvious characteristics.

(8) **Marta A. Chabowska** (Institute of Physics, Polish Academy of Sciences)
''Morphological diversity induced by surface potential energy''
The surface morphology and its evolution are of critical importance in the production of electronic and optoelectronic devices. The phenomenon is intriguing in its own right, particularly with respect to the mechanisms that give rise to it.
Using (2+1)D Vicinal Cellular Automaton (VicCA), we investigate the role of surface potential energy in the formation of various patterns on the crystal surface. By

distinguishing between surface diffusion and adatom incorporation in our model, we have identified the key factors that influence the dynamics of surface patterns. A detailed analysis of the diffusion process shows that the mere presence of a potential well at the bottom of a step is sufficient to trigger the formation of meanders. The addition of an Ehrlich - Schwoebel barrier at the top of the step significantly affects meandering and can lead to the formation of three-dimensional mounds. Further changes to the shape of the surface potential energy can lead to the formation of nanopilars or the step bunching. Nanopillars can be obtained by introducing an effective "Ehrlich-Schwoebel barrier" that induces an upward flux of particles due to the temperature gradient present during growth. In contrast, introducing a second potential well at the top of the step instead of a barrier results in the formation of a cluster of steps. The relative depth of the two wells (below and above the step) significantly alters the final surface morphology.

(9) **Magdalena Załuska-Kotur** (Institute of Physics, Polish Academy of Sciences)
''Pattern Formation Mechanisms in Recrystallization Processes''
Crystal surfaces serve as the primary interface for growth and sublimation, where evolving morphologies give rise to diverse patterns ranging from atomic steps to complex nanowires. This study investigates the emergence of these patterns as a function of the surface potential energy landscape.
To simulate these dynamics, we employ a modified Vicinal Cellular Automata (VicCA) model, which effectively decouples the processes of particle diffusion, attachment, and detachment. Unlike traditional Monte Carlo simulations, the VicCA framework enables systematic control over the potential energy profile dictated by particle-particle interactions. This approach proves particularly effective for the precise modeling of recrystallization processes.
Furthermore, we extend this framework to explore pattern evolution under Ion Beam Sputtering, a high-throughput technique for producing large-scale surface nanopatterns. By varying key parameters—such as diffusion length, temperature, and initial conditions—we demonstrate transitions between distinct morphologies, including ripples and checkerboard patterns. Our results indicate that the vicCA model is an efficient and versatile computational tool for predicting the self-organization of crystal surfaces under far-from-equilibrium conditions.

(10) **Anna Niedźwiecka** (Institute of Physics, Polish Academy of Sciences)
''How proteins shape mineral patterns: spherulitic growth of calcium carbonate controlled by acid-rich proteins''
Spherulites are striking examples of pattern formation in nature. These radially organized mesocrystals occur in systems ranging from polymers to minerals and produce the characteristic Maltese cross pattern under polarized light. In the context of in vitro biomineralization studies, calcium carbonate spherulites form under control of acid-rich proteins, yet the molecular mechanisms that govern their emergence remain unclear.
Here, we investigate how coral acid-rich proteins regulate the formation of calcium carbonate spherulites. We focus on AGARP and SAP1 A, highly polyanionic

intrinsically disordered proteins from the reef-building coral Acropora millepora. Under mild in vitro conditions at seawater Ca^{2+} concentration, the proteins induce the formation of tens-of-micrometer $CaCO_3$ spherulites displaying the characteristic Maltese cross pattern. Raman spectroscopy shows that these structures correspond to vaterite, whereas accompanying polycrystals are calcite. Fluorescence imaging further reveals that the proteins become incorporated into the mineral and accumulate both at nucleation centers and at the edges of growing structures, indicating that they act simultaneously as a nucleator and a regulator of crystal growth.

By systematically varying protein concentration we observe a transition from rhombohedral calcite crystals to polycrystals and finally to nearly perfectly spherical vaterite spherulites. Moreover, the range of protein concentration determines the tiny geometrical features of the spherulites. Higher protein concentrations increase the number of nucleation centers and produce smaller spherulites, illustrating how the balance between nucleation and growth shapes the emerging pattern.

Comparative experiments with synthetic polymers show that negative charge triggers the emergence of spherulites, whereas aromatic amino acids strongly influence their growth and final size. Together, these results reveal how molecular features of an unstructured protein at a sequence level can control the appearance and geometry of complex mineral patterns, offering new insight into coral biomineralization and suggesting design principles for controlling spherulitic structures in synthetic materials.

(11) **Michael Berhanu** (Matière et Systèmes Complexes, Université Paris Cité, CNRS)

''Erosion patterns by dissolution''

Landscapes are shaped by water and wind flows. Understanding their formation and evolution requires identifying the physical processes at work. While the processes of erosion involving sediment composed of macroscopic grains have been extensively studied, this is not the case for chemical erosion and dissolution. Hydrodynamics often controls the dynamics of erosion and modifies the shape of the dissolving interface, creating characteristic patterns.

In our group at MSC (Université Paris Cité), using fast-soluble materials, we study the role of hydrodynamics and geometry in the dynamics of erosion by dissolution and we investigate formation of dissolution patterns. One of the most common dissolution patterns is known as 'scallops' and consists of a cellular pattern of cup-like concavities surrounded by very sharp crests. These can typically be found on the walls of limestone caves that have been carved by underground rivers. By comparing field measurements, numerical models and experiments, we propose a geometric approach to explain the generic emergence of scallops. In the laboratory, we then investigate the competition between gravity- and current-driven solute transport, and the consequences of this competition on dissolution patterns.

(12) **Michał Bogdan** (Institute of Mathematics, Polish Academy of Sciences)
''Quantifying the openness of porous materials using topological parameters''
Gas pycnometry is commonly used to quantify to what extent a porous material is composed of open vs. closed pores when the true material density is known. The output of a gas pycnometry experiment, which measures the fraction of the pores penetrable to an externally delivered gas, is summarised by a single parameter, called the "fraction of open pores" or "open porosity".
However, its informative value may be limited when otherwise open pores are not connected to the surface of the sample, when sample size is not much larger than the pore size, when gas choice affects accessibility (for example, if the material features micropores accessible to helium but not to oxygen), and when some of the pores are blocked by impurities such as condensating water microdroplets.
We suggest a complementary method of estimating the proportion of open and closed pores of a porous material based on measuring Betti numbers and Betti curves on structures recorded by 3D scanning. We define a cell-openness index which can be used instead of or complementary to the proportion of open-celled volume reported by gas pycnometry. We discuss in what types of structures mismatches between the two indices can occur and how such mismatches convey addidional information about the structure. We also demonstrate the first examples of correlations between our new index and measurable physical quantities in numerically generated structures. We also discuss how Betti curves can be used to estimate characteristic feature sizes in 2D and 3D porous structures.

(13) **Martin Chaigne** (Institut de Physique du Globe de Paris)
''Sediment transport instability in a radial experiment''
Alluvial rivers shape their channels by exchanging sediment with their bed. Increasing sediment discharge typically widens the channel. Yet, above a critical threshold, laboratory rivers destabilise into several intertwined channels — the experimental analogue of a braided river. The physical mechanism controlling the number of channels and their dynamics, however, remains poorly understood.
To investigate this transition, we design a radial experimental setup consisting of a vertical cylinder filled with grains. A mixture of water, glycerol, and sediment injected at the centre forms a thin laminar film that spreads outward while exchanging grains with the underlying granular bed. Although initially axisymmetric, the flow rapidly destabilises into one or several channels where sediment transport concentrates. The number of channels increases with sediment discharge.
To rationalise these observations, we model the evolution of two channels sharing fixed fluid flow rate and sediment discharge. Mass balance leads to a two-dimensional dynamical system with a subcritical pitchfork bifurcation. The model predicts that a stable two-channel state exists only above a critical sediment discharge, in quantitative agreement with experiments.
Despite the simplicity of our laminar experiment, we believe that these results represent a first step toward a better understanding of natural braided rivers.

(14) **King Lun NG** (Institute of Physics, Polish Academy of Sciences)

''Patterns of oscillating droplets on vibrating substrates: A molecular model study''

Oscillating droplets on a horizontally vibrating substrate can exhibit various patterns. In this study, we use Many-body Dissipative Particle Dynamics (MDPD) to investigate the evolution of droplet shape during oscillation. Our results reveal three distinct oscillation modes: a stable oscillating droplet (Mode I), a rotational oscillating droplet (Mode II), and a shear-dominated oscillating droplet (Mode III). This work contributes to the understanding and optimization of systems involving droplet transport on vibrating substrates.

Poster Abstracts

[1] **Akash Unnikrishnan** (Faculty of Physics, University of Warsaw)

''Mapping Deformation Fields: Mechanical Drivers of Directional Angiogenic Growth''

We investigate the mechanical interplay between a growing vascular network and the extracellular matrix (ECM) during in vitro angiogenesis. By embedding endothelial cell-coated beads in a fibrin hydrogel and tracking fluorescent tracer particles, we utilize Particle Image Velocimetry (PIV) to reconstruct high-resolution displacement fields. These fields allow for the computation of local strain tensors, which we compare against image-based densitometry to identify spatial variations in ECM densification.

Our results demonstrate a strong correlation between sprout growth and compressive strain in the ECM. We find that while the first principal strain (aligned with the growth direction) shows negligible correlation with densification, the second principal strain (compressive) is predominantly oriented tangentially to the sprout. This anisotropic response reveals a lateral, drawstring-like compression that accompanies radial sprout extension. This mechanism provides a physical basis for contact guidance, linking local fiber alignment directly to vascular network dynamics. Finally, a comparison with in-silico models suggests that capturing the full complexity of these network-matrix interactions requires moving beyond purely elastic descriptions to incorporate viscoelastic effects.

[2] **Binyam Zigta Teferi** (Institute of Physics, Polish Academy of Sciences)

''Effect of external magnetic and electric fields on blood flow and drug transport in a cardiovascular tube''

Cardiovascular diseases (CVDs) remain the leading cause of death worldwide, and efficient drug delivery (DD) is critical for treatment success. The use of external electric (EF) and magnetic fields (MF) offers a promising approach to enhance targeted drug transport in vascular systems. This study investigates the effect of combined electric and magnetic fields (EMF) on blood flow and drug delivery (DD) in a cardiovascular tube model. The governing equations for momentum, energy, and concentration were formulated using magneto-hydrodynamics (MHD) theory with slip boundary conditions and external electromagnetic forces (EEF). Similarity transformations reduced the equations to ordinary differential form (ODEs), which were solved numerically using MATLAB code. Increasing magnetic field strength reduced flow resistance while improving drug penetration, whereas the electric field (EF) enhanced solute dispersion via electro-osmotic effects (EOE). The combined effect significantly improved concentration profiles along the tube. Conclusion: The findings suggest that external electromagnetic fields (EEF) can optimize drug delivery (DD) efficiency, providing a theoretical framework for advanced cardiovascular therapies.

[3] **Maciej Pawlus** (Faculty of Physics, University of Warsaw)

''The growth of a transport network with a coevolving boundary''

The work presents a simplified physical model of leaf vein network growth with its co-evolving boundary. It is assumed that the vein network grows in a field of growth hormone (auxin) described by the Laplace equation. A thin-finger model was used for the evolution of the branches of the network. Additionally, the model was extended to include the co-evolving boundary. The finite element method was used to solve the Laplace equation. An initial geometry of circular boundary and a varying number of branches in the center was considered. It was observed that the speed of the veins increases as it approaches the boundary, but tends towards a finite value. The rate of relaxation to the asymptotic state decreases with an increasing number of branches. Competition between the veins was observed depending on their number. The distance from the tip of the branch to the moving boundary asymptotically approaches a constant value independent of the number of branches. The work concludes with a presentation of the network geometries with bifurcations.

[4] **Jolanta Wolowicz** (Institute of Fundamental Technological Research, Polish Academy of Sciences)

''Phyllotaxis and 2d crystallization patterns''

The formation of primordia occurs by an algorithm guided by the Fibonacci sequence and the golden ratio [1]. This provides primordial the best position [2]. The patterns of the resulting structure consist of rings separated by circles of penta- and heptagonal dislocations. Similarly, 5|7 dislocations appear in 2d polycrystals at grain boundaries. Thus, the grains' counterparts in the phyllotaxial arrangement are the rings of shoots in the hexagonal arrangement. One newly formed primordium induces one change in each grain boundary. the contacts in the primordium arrangement [3]. The final patterns in phyllotaxis and 2d crystallization are similar.
Patterns of primordia growth in phyllotaxis will be shown as simulation in computer films.

[1] N. Rivier, A. Lissowski, On the correlation between sizes and shapes of cells in epithelial mosaics, Journal of Physics A: Mathematical and General, 15, 3, L143, 1982.
[2] N. Rivier, R. Occelli, J. Pantaloni and A. Lissowski, Structure of Bénard convection cells, phyllotaxis and crystallography in cylindrical symmetry, Journal de Physique 45 (1984) 49-63.
[3] J.M. Wołowicz, R.Wojnar, A. Lissowski,. Matematyczne aspekty filotaksji. Ciąg Fibonacciego i złota proporcja (Mathematical aspects of phyllotaxy. Fibonacci sequence and the golden ratio), in Polish. Perspektywy rozwoju w naukach inżynieryjno-technicznych, trendy, innowacje i wyzwania Tom 3, Redakcja: Maciej Świtalski, Monika Maciąg, Wydawnictwo Naukowe TYGIEL, Lublin 2024, ISBN 978-83-67881-75-3, pp 89-134.

[5] **Ryszard Wojnar** (Institute of Fundamental Technological Research, Polish Academy of Sciences)

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[6] **Paulina Kaczyńska** (Institute of Fundamental Technological Research, Polish Academy of Sciences)

''Spatial patterns of cell deaths in viral infection''

In multicellular organisms, programmed cell death is not merely a cell-autonomous event but a coordinated tissue-level response. We investigated the collective dynamics of cell death within A549 lung epithelial monolayers during infection with Influenza A Virus (IAV) and Respiratory Syncytial Virus (RSV). We utilize live-cell imaging from fluorescent microscopy to characterize the distinct spatial and temporal patterns emerging from two cell death modalities: apoptosis and pyroptosis. To quantify these events, we employed a convolutional neural network trained on a human-annotated dataset of four-channel imagery (brightfield, nuclear staining, propidium iodide associated with cell death, and CellEvent for caspase activation).
Our observations reveal that pyroptotic deaths exhibit greater spatial and temporal clustering compared to the apoptotic deaths. We find that membrane rupture, a hallmark of pyroptosis, frequently occurs synchronously among small groups of neighboring cells. We hypothesize that, due to the timescale of minutes rather than hours, this clustering is driven by mechanical feedback rather than the release of

intracellular content triggering neighbours' death or transplantation of gasdermin pores by extracellular vesicles. Rapid osmotic swelling and subsequent membrane rupture of a primary pyroptotic cell exerts significant mechanical strain on the plasma membranes of adjacent cells.
Furthermore, we examine how the addition of Natural Killer (NK) cells modulates kinetics of these death patterns.

[7] **Luís H. Carnevale** (Institute of Physics, Polish Academy of Sciences & Kyushu University)
''Anionic Surfactant Model based on the MDPD-Martini Force-Field''
Understanding the behaviour of anionic surfactants is important for many applications, such as detergency and drug delivery. This study evaluates the phase behaviour and interfacial properties of sodium dodecyl sulfate (SDS) solutions by comparing two simulation approaches: traditional molecular dynamics (MD) and many-body dissipative particle dynamics (MDPD), both parameterised within the Martini coarse-grainning framework. Long-range electrostatic interactions were modeld by a particle-mesh Ewald method. Our results demonstrate that MD and MDPD exhibit equivalent bulk phase behaviour across various surfactant concentrations. However, MDPD shows better agreement with experimental surface tension isotherms at the air-water interface. Furthermore, MDPD allows for a time step 20 times larger than MD, making it more computationally efficient. These findings highlight the MDPD-Martini force-field as a powerful and efficient tool for simulating complex surfactant systems.

[8] **Laureline Julien** (University of Oulu)
''Drivers of perivascular flow in the brain: a microfluidic approach''
In the brain, two fluid circulation systems coexist: vascular blood flow and cerebrospinal fluid (CSF) circulation. More recent research has highlighted that CSF plays a key role in a brain-wide clearance pathway known as the glymphatic system. In the subarachnoid space and along with penetrating arterioles, cerebrospinal fluid (CSF) circulates around blood vessels within concentric annular structures known as perivascular spaces (PVS).
However, the physical mechanisms driving flow in perivascular spaces remain unclear. Some authors hypothesize that arterial pulsations, through peristaltic motion, could generate a net flow within PVS. Yet, numerical studies suggest that this mechanism alone is not sufficient to account for the magnitude of flow observed in vivo. Alternative hypotheses include contributions from low-frequency vasomotion and indirect respiratory-driven pressure variations. Moreover, experimental investigations remain scarce.
In this work, we develop microfluidic chips to mimic fluid–structure interactions between blood flow, perivascular spaces, and the arterial wall modelled as a compliant thin membrane. By imposing controlled oscillatory flow conditions within the vascular channel, and changing the geometry of the compartments, we identify regimes in which net flow is generated in the adjacent perivascular compartment. Furthermore, using a system of air chambers, we try to replicate the effects of

vasomotion and respiration-induced transmural pressure variations on perivascular dynamics.
Our aim is to provide experimental insight into the relative contributions of different physiological drivers of perivascular flow, and how such flows are shaped by the underlying geometry.

[9] **Maciej Matyka** (Faculty of Physics and Astronomy, University of Wrocław)
''Computational modelling with single prompts''
Regardless of how we look at AI large language models (LLMs) - as a massive collection of data from which we can cleverly extract information, as an assistant who can perform simple tasks for us and write simple codes, or perhaps as a machine that randomly selects words, in a sense guided by what it have had has seen in the past - we are undoubtedly witnessing a revolution.
In the poster, I will present the concept of a single prompt and its use to generate computer code for dozens of models across computational physics, statistical physics, computational fluid dynamics, and more. I will illustrate the presentation with practical example of how language models generate code for research in computational physics with a focus and specific example in porous media flows and computation of tortuosity.