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FALL BIOSOFT INTERNATIONAL RESEARCH TEAM MEETING 2025

BOOK OF ABSTRACTS

Fall *BioSoft* International Research Team Meeting 2025
Soft Matter for Bioimaging and Regenerative Medicine, AMU IDUB

29.10.25 – Wednesday

8:55	Welcome, Dr. Grzegorz Nowaczyk
9:00 – 9:30	Prof. Wei Wang (Zhejiang University)
9:30 – 10:00	Prof. Jakub Rybka (NBMC UAM)
10:00 – 10:30	Prof. Paulina Skupin (Poznan University of Medical Sciences)
10:30 – 11:00	Prof. Radosław Mrówczyński (Faculty of Chemistry AMU)
11:00 – 11:30	*Coffee break*
11:30 – 12:00	Prof. Tomasz Kolanowski (IHG PAS)
12:00 – 12:30	Dr. Dorota Flak (NBMC AMU)
12:30 – 13:00	Dr. Rafał Konefał (NBMC UAM)

30.10.25 – Thursday

9:00 – 9:30	Dr. Benoit Loppinet (FORTH Crete)
9:30 – 10:00	Dr. Xiaolin Li (Zhejiang University)
10:00 – 10:30	Dr. Roksana Markiewicz (NBMC AMU)
10:30 – 11:00	*Coffee break*
11:00 – 11:30	Dr. Jacek Jenczyk (NBMC AMU)
11:30 – 12:00	Dr. Tomasz Zalewski (NBMC AMU)
12:00 – 12:30	Dr. Katarzyna Fiedorowicz (NBMC AMU)
12:30 – 13:00	Dr. Jakub Jagielski (NBMC AMU)

Flexible biopatches

Wei Wang

Zhejiang University

Medical patches have garnered significant clinical attention due to their versatile functionalities and ease of application. Advances in materials science, advanced manufacturing technologies, and bioengineering have greatly expanded the capabilities of medical patches, making them a highly versatile platform for drug delivery, tissue regeneration, and implantable/wearable devices. However, their widespread clinical adoption has been notably hindered by several limitations, including a scarcity of suitable flexible materials, inadequate interfacial adhesion, and low interfacial transfer efficiency.

In response to critical clinical needs and the forefront of biomaterials development, this study addresses three key challenges in flexible medical patches: interfacial adhesion, interfacial mass transfer, and positive modulation of the disease microenvironment [1-3]. Guided by a progressive research approach centered on “interfacial adhesion – material transport – microenvironment modulation,” and through a series of investigations rooted in materials science and surface/interface physical chemistry, we have achieved diverse design and precise construction of surface and interface structures in medical patches. The research elucidates the regulatory mechanisms between the bulk properties of flexible patches and their interfacial adhesion, establishes systematic methods for efficient material transport under external field control, and develops novel strategies for modulating pathological microenvironments using flexible patches. This work provides a material foundation, interfacial engineering theories, and technical basis for the development of new high-performance flexible medical patches.

References:

[1] Zhang Lin#, Yifan Wu#, Yuqi Wang, Peipei Su, Xiaolin Li, Yang Zou, Kangbo Chen, Yaping Li, Jinfeng Zhou, Tingting Ye, Yiying Qi, Wei Wang*. Flexible patterned fuel cell patches stimulate nerve and myocardium restoration. Advanced Materials, 2025, 2416410.

[2] Shang Chi#, Yaping Li#, Tingting Ye, Jiawei Kang, Zhihui Xiang, Xiaoqing Kuang, Chenggang Yi, Yiying Qi*, Wei Wang*. Energy reconversion of ultrasound on a piezoelectric hydrogel promotes ROS/CO generation and wound self-closure for infected chronic wound healing. Matter 2025, 8: 101989.

[3] Yuqi Wang, Peipei Su, Zhang Lin, Xiaolin Li, Kangbo Chen, Tingting Ye, Yaping Li, Yang Zou, Wei Wang*. A tribo/piezoelectric nanogenerator based on bio-MOFs for energy harvesting and antibacterial wearable device. Advanced Materials 2025; 2418207.

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Engineering Collagen-Based Biomaterials: dECM Bioinks, Marine Spongin, and Transcriptome-Driven Meniscus Regeneration

Monika Mankowska Wozniak, Adam Mieloch, Filip Porzucek, Tomasz Szymanski, Piotr Cywoniuk, Ewelina Żuk, Marta Tuszyńska, Weronika Giebel, and Jakub D. Rybka

NanoBioMedical Centre, Adam Mickiewicz University, Poznań, Poland

Collagen-based biomaterials are increasingly recognized for their versatility in regenerative medicine and nutraceuticals. This work presents an integrative approach to collagenous biomaterials by exploring (i) marine-derived spongin as a sustainable collagen-like biopolymer, (ii) decellularized extracellular matrix (dECM) from porcine meniscus for bioink development, and (iii) cellular blueprints via single-cell transcriptomics to inform biomaterial design. Comprehensive structural analyses using proteomics, solid-state NMR, and Raman spectroscopy confirmed that spongin shares key features with mammalian collagen, predominantly types I and III. Notably, HPLC-MS revealed halogenated di- and tri-tyrosine crosslinks, offering insights into its intrinsic stability and crosslinking mechanisms. Concurrently, we developed a scalable protocol for producing collagen-rich meniscus dECM bioinks, integrating homogenization, hydrolysis, supercritical CO_2 extraction, and lyophilization. This method preserves native bioactivity, enhances printability, and supports cell viability despite residual DNA levels exceeding typical thresholds—challenging conventional decellularization standards. Complementing the biomaterial development, a single-cell transcriptome atlas of the porcine meniscus delineates key cell populations, including five chondrocyte subtypes with distinct roles in tissue remodeling, matrix synthesis, and microenvironment modulation. The high cellular congruence between porcine and human menisci underscores the translational potential of these biomaterials. Together, this study advances collagen-inspired materials for bioprinting, regenerative medicine, and functional nutraceuticals.

References:

[1] H. Ehrlich*, I. Miksik, M. Tsurkan, P. Simon, F. Porzucek, J. D. Rybka, M. Mankowska, R. Galli, C. Viehweger, E. Brendler, A. Voronkina, M. Pajewska-Szmyt, A. Tabachnik, K. Tabachnick, C. Vogt, M. Wysokowski, T. Jesionowski, T. Buchwald, M. Szybowicz, K. Skieresz-Szewczyk, H. Jackowiak, A. Ereskovsky, A. CS de Alcântara, A. Dos Santos, C. da Costa, S. Arevalo, M. Skaf, M. Buehler* Discovery of mammalian collagens I and III within ancient poriferan biopolymer spongin; Nature Communications (2025).

[2] F. Porzucek, M. Mankowska, J. Semba, P. Cywoniuk, A. Augustyniak, A. Mleczko, A. Teixeira, P. Martins, A. Mieloch, J. D. Rybka* Development of a Porcine Decellularized Extracellular Matrix (dECM) Bioink for 3D Bioprinting of Meniscus Tissue Engineering: Formulation, Characterization and Biological Evaluation, Virtual and Physical Prototyping (2024).

[3] M. Mankowska, M. Stefanska, A. Mleczko, K. Sarad, W. Kot, L. Krych, J. Semba, E. Lindberg, J. D. Rybka* Pig meniscus single-cell sequencing reveals highly active red zone chondrocyte populations involved in stemness maintenance and vascularization development, Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology) (2025).

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Phospholipids as Components of Multifunctional Drug Delivery Platform: from Nanosized Self-Assembling Systems to Supersaturating Oral Dosage Forms

Paulina Skupin-Mrugalska

Poznan University of Medical Sciences, Faculty of Pharmacy
New Experimental Therapies and Drug Delivery Group (NEXT-Group)

Phospholipids are amphiphilic molecules that self-assemble into nanostructures such as liposomes, micelles, and bilayers, making them ideal drug carriers. This presentation briefly explores the function of phospholipid-based systems in drug delivery, highlighting their ability to encapsulate therapeutic agents, enhance stability, and facilitate controlled or targeted release. Furthermore, when administered orally, phospholipids can interact with polymers and other gastrointestinal components to form **mixed polymeric-lipid nanostructures**, which significantly influence **oral bioavailability** by affecting drug solubilization, absorption, and transport across the intestinal barrier. Understanding these self-assembling behaviors in both *in vitro* systems and the **gastrointestinal tract** is essential for designing efficient oral formulations and bridging laboratory research with practical therapeutic applications.

Applications of Polycatecholamine-Based Materials in Biomedical Engineering

Radosław Mrówczyński

Adam Mickiewicz University, Faculty of Chemistry, Poznań, Poland

In this presentation, I will discuss the design and application of polydopamine (PDA)-based nanostructures in nanomedicine, with particular emphasis on their multifunctionality and biological performance.

The first part will focus on the preparation and characterisation of PDA-derived nanoplatforms engineered for targeted drug delivery, imaging, and combined chemo-photothermal therapy. I will present how structural modifications with dendrimers, PEG, folic acid, and iron species enable precise control over drug loading efficiency, photothermal conversion, and cellular targeting. The second part will be devoted to the toxicological profiling of PDA-based nanomaterials, covering both short-term therapeutic exposure and long-term *in vivo* safety studies. Special attention will be given to the relationship between particle size, dose, and exposure duration and the resulting oxidative stress parameters (TBARS, GSH, CAT, SOD, GST, and TEAC) in major organs. Together, these studies establish PDA as a redox-tunable and biocompatible nanomaterial, with dual functions as both a therapeutic agent and a model system for nanosafety assessment.

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Engineering the Human Heart. Subtype-specific macroscopic tissue models with IPS-derived cardiomyocytes for drug testing purposes

Tomasz Kolanowski

Advanced Tissue Models Group. Department of Molecular Pathology, IHG PAS

The development of human-relevant in vitro models is essential for advancing cardiac research, drug discovery, and regulatory safety testing. Current preclinical methods, largely dependent on small-animal models, fail to accurately mimic human cardiac physiology, contributing to costly translational inefficiencies and adverse drug reactions. To address these limitations, human heart tissue models are developed. Our group has contributed to this topic by engineering macroscopic, chamber-specific human Engineered Heart Tissues (chEHTs) derived from induced pluripotent stem cell (iPSC)-based cardiomyocytes and cardiac fibroblasts. These bioengineered constructs replicate the distinct electrophysiological and contractile characteristics of atrial and ventricular myocardium, providing a physiologically relevant platform for pharmacological and mechanistic studies.

We demonstrate that atrial and ventricular EHTs exhibit chamber-specific gene expression and contractile profiles corresponding to their in vivo counterparts. The chEHT platform accurately recapitulated the Frank-Starling mechanism and produced human-like EC_{50} values for calcium response, markedly improving translational fidelity compared with conventional 2D systems.

Application of the selective SK channel inhibitor AP14145, a candidate antiarrhythmic compound, revealed prolongation of contraction duration exclusively in atrial-specific tissues, consistent with its proposed atrial-selective mechanism of action. This result underscores the predictive capacity of chEHTs in modeling subtype-specific pharmacodynamics relevant to atrial fibrillation therapy.

Furthermore, co-culture experiments demonstrated that chamber-matched fibroblasts modulate cardiomyocyte subtype differentiation and functional maturation, indicating their potential role as key biological modulators in human heart development and disease modeling.

Overall, the iPSC-derived, chamber-specific EHT system represents a robust, scalable, and regulatory-aligned human cardiac model. It enables mechanistic insight into myocardial physiology, improves preclinical predictivity, and supports ongoing efforts under the FDA Modernization Act to replace animal testing with advanced human-based methodologies.

Keywords: iPSC-derived cardiomyocytes, Engineered Heart Tissue (EHT), chamber-specific modeling, drug testing, atrial fibrillation, cardiac fibroblasts, FDA Modernization Act.

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Advancing MRI Contrast Agents: Lipid Nanoparticles as Biocompatible Carriers for Paramagnetic Agent

Dorota Flak [1], Karolina Dydak [1,2], Katarzyna Fiedorowicz [1], Jakub Jagielski [1], Tomasz Zalewski [1], Grzegorz Nowaczyk [1]

[1] Adam Mickiewicz University, NanoBioMedical Centre, Poznań, Poland
[2] Adam Mickiewicz University, Faculty of Physics, Poznań, Poland

The potential health risks associated with certain gadolinium (Gd)-based chelates as magnetic resonance imaging contrast agents (MRI CAs), raised by the responsible authorities [1], has intensified the search for safer and more efficient alternatives. A promising direction undertaken in our research involves the development of high-molecular-weight and nanoparticulated contrast systems through various strategies: (1) incorporation of paramagnetic ions into nanostructured inorganic frameworks; (2) creation of hybrid nanoconstructs combining inorganic and organic components, where the paramagnetic functionality resides in either domain; and (3) formation of "nano-co-assemblies" composed of organic constituents with at least one paramagnetic component. Among the emerging systems, nanoparticle-based CAs have attracted significant interest due to their tunable physicochemical and magnetic properties [1]. In particular, lipid-based nanoparticles have shown great potential as carriers for contrast-providing entities, offering enhanced physicochemical stability, improved biocompatibility, increased intracellular uptake, and higher longitudinal relaxivity (r_1) compared to conventional agents [2] due to expected restricted molecular motion and possible improved water exchange rate.

Our studies explore the potential of glyceryl monooleate-based lipid nanoparticles as carriers for magnetic resonance imaging (MRI) contrast agents. The focus was on the design and characterization of hybrid lipid liquid crystalline nanoparticles incorporating paramagnetic oxides with hydrophilic or hydrophobic properties (LLCNPs@Gd_2O_3 and LLCNPs@MnO), as well as nano-co-assemblies formed using Gd-chelating lipids (LLCNPs@Gd-DTPA-BSA). Comprehensive physicochemical and biological assessments were performed to elucidate the relationship between nanoparticle composition and the resulting longitudinal relaxation rates (r_1). Particular attention was given to the efficiency of paramagnetic ion loading, ion release behavior under different conditions, and cellular uptake profiles. The findings demonstrate that these glyceryl monooleate-based systems are promising, biocompatible, and effective T_1-enhancing MRI contrast agents, offering a safe and innovative platform for future *in vivo* imaging applications.

Keywords: glyceryl monooleate, nano-co-assemblies, hybrid nanoparticles, Gd-chelating lipid, gadolinium oxide, manganese oxide

References:

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[2] J. Pellico, C.M. Ellis, J.J. Davis, Contrast Media & Molecular Imaging, 2019, 1845637.
[2] D. Flak, T. Zalewski, K. Fiedorowicz, et al., Journal of Materials Chemistry B, 2023, 11(36), 8732-8753.

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Interactions in stimuli-responsive polymer systems investigated by NMR spectroscopy

Rafał Konefał

Adam Mickiewicz University, NanoBioMedical Centre, Poznań, Poland

Stimuli-responsive (or smart) polymers undergo distinct physical or chemical changes upon small external stimuli, enabling them to adapt to environmental conditions, regulate ion and molecule transport, and convert chemical or biochemical signals into optical, electrical, or mechanical responses. Such materials are increasingly applied in controlled drug delivery, diagnostics, tissue engineering, biosensors, and adaptive coatings. Depending on the stimulus, they can respond to variations in temperature, pH, ionic strength, light, mechanical stress, or magnetic and electric fields.

Among these, temperature is the most widely exploited because of its non-invasive nature and reversible effect on polymer solubility. Thermoresponsive polymers undergo temperature-induced phase separation, transforming from molecularly dissolved coils to compact globules.

In this study, we employed ^{1}H NMR spectroscopy, temperature-dependent spin–spin relaxation, and 2D NOESY to investigate temperature-induced phase separation in aqueous solutions of various thermoresponsive polymer systems based on: poly(N-isopropylacrylamide) (PNIPAM), poly(2-ethyl-2-oxazoline) (PEtOx) and poly(triethylene glycol methyl ether methacrylate) (PTEGMA) homopolymers and copolymers of different compositions.

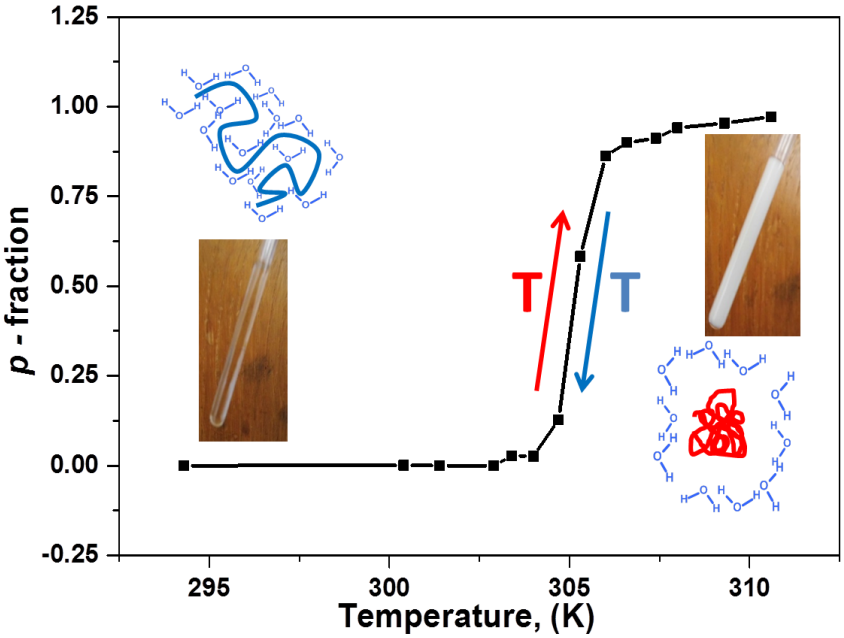

Fig. 1 Schematic representation of temperature-induced phase-transition.

From Bonds to Behavior: Investigating Gel Networks State Transitions *via* Rheological and Scattering Techniques

Benoit Loppinet

Institute of Electronic Structure and Laser, Foundation for Research and Technology – Hellas (IESL-FORTH), Crete, Greece

Gels are defined as non-fluid networks (colloidal or polymeric) expanded throughout their whole volume by a fluid. The network forming bonds can be many and strongly influence the gels properties.

I will present experimental studies joining rheology and scattering of different gel-forming materials (gelatin, supramolecular polymer, colloidal), showing state variation depending on external conditions and especially pressure.

Advanced Functional Biomaterials for Cartilage and Annulus Fibrosus Regeneration

Xiaolin Li

Zhejiang University, China

We outline innovative biomaterial approaches for cartilage and annulus fibrosus regeneration. Our research started from developing injectable hydrogel systems using thiol-ene click chemistry, combining functionalized extracellular matrix materials with hyperbranched PEG polymers. We pioneered introducing mesenchymal stem cells from arthroscopic flushing fluid into the injectable systems and revealed kartogenin's mechanism in stimulating cartilage progenitor cell proliferation via the IL-6/Stat3 pathway. The latest breakthrough introduces a supramolecular hydrogel for annulus fibrosus repair, incorporating tannic acid/Mn^{2+} crosslinked gelatin with kartogenin-loaded nanofibers and SDF-1α mimic peptide. This multifunctional system exhibits exceptional mechanical strength, potent antioxidant activity, and controlled dual-drug release, successfully promoting endogenous stem cell recruitment and functional tissue regeneration in animal models. These advanced biomaterial strategies show translational potential for treating osteoarthritis and intervertebral disc degeneration through minimally invasive approaches.

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From Nanostructure to Functionalization: Ionic Liquids and Their Application in Biopolymer Modification

Roksana Markiewicz [1], Bartosz Fabiszczak [1,2], Jacek Jenczyk [1], Pedro Jose Sebastião [3], Michał Taube [4], Adam Klimaszyk [1,2], Marek Kempka [1,2], Tomasz Zalewski [1]

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[2] Faculty of Chemistry, Adam Mickiewicz University, Poznan, Poland
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[4] Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznan, Poland

Ionic liquids are unique type of materials with variety of properties, which usually comprise low vapor pressure, great thermal stability, ionic conductivity, and tunable polarity, with additional possibility to dissolve organic and inorganic substances including polymers. As we were interested in the molecular behaviour of the ionic liquids in bulk, their organization, and variety of interactions from weak, isotropic ones to strong, anisotropic forces, we decided to focus on ammonium ionic liquids with varied cation structure: aliphatic (alkyltriethylammonium), cyclic (alkylcyclohexyldimethy-lammonium), and aromatic alkyl(benzyldimethylammonium) with varied alkyl chain, with bis(trifluoromethanesulfonyl)imide anion. These systems demonstrate significant nanostructuring behavior, which can be examined for example via small-angle X-ray scattering (SAXS). Moreover, by means of nuclear magnetic resonance (NMR) we were able to determine their molecular dynamics and local mobility. These techniques together give us a better idea of how cation structure affect how ionic liquids create domains and how they change over time.

We decided to go a step further and examine the benefits of ionic liquids functionalized on biopolymers taking into consideration the intriguing interactions which can be observed at the molecular level between ionic liquids and solids. Therefore, the second part of the talk will concern cellulose-based nanostructures with quaternary ammonium groups. To make nanocellulose structures, a combination of mechanical and chemical treatment was used. Afterward, nanocellulose was functionalized with quaternary ammonium groups with varied alkyl chains, mainly to change their surface properties (hydrophilicity or adsorption capacity). These changes allowed us to prepare ionic liquids supported on cellulose with appropriate surface behaviour, for further use in sorption, separation and other environmental applications.

Acknowledgements: RM, BF and JJ would like to acknowledge the National Science Centre, SONATA 18 project no. 2022/47/D/ST8/02389.

Modelling Lamella to Gyroid transition – searching for potentially feasible order-order transition pathway

Jacek Jenczyk

NanoBioMedical Centre, Adam Mickiewicz University, Poznań, Poland

Since the first discoveries made by Hermann Schwarz, triply periodic minimal surfaces (TPMS) have attracted significant attention from scientists and engineers. These unique architectures can spontaneously develop in so-called self-assembling systems. It has been shown that thermodynamically driven structural transitions can lead to the formation of various morphologies, including TPMS, such as double diamond (DD) and double gyroid (DG) structures (see Fig. 1). These bicontinuous, domain-like structures have been experimentally observed in synthetic copolymers and lipids [1, 2]. Notably, the remarkable gyroidal morphology, discovered by Alan Schoen, has also been found in biological systems, where it plays the role of a natural photonic crystal. Recently, with the rapid advancement of 3D printing technology, these fascinating geometries have gained particular interest among engineers working in the fields of metamaterials and novel structural designs. It has been documented that intertwined truss geometries based on TPMS exhibit unique mechanical and optical properties.

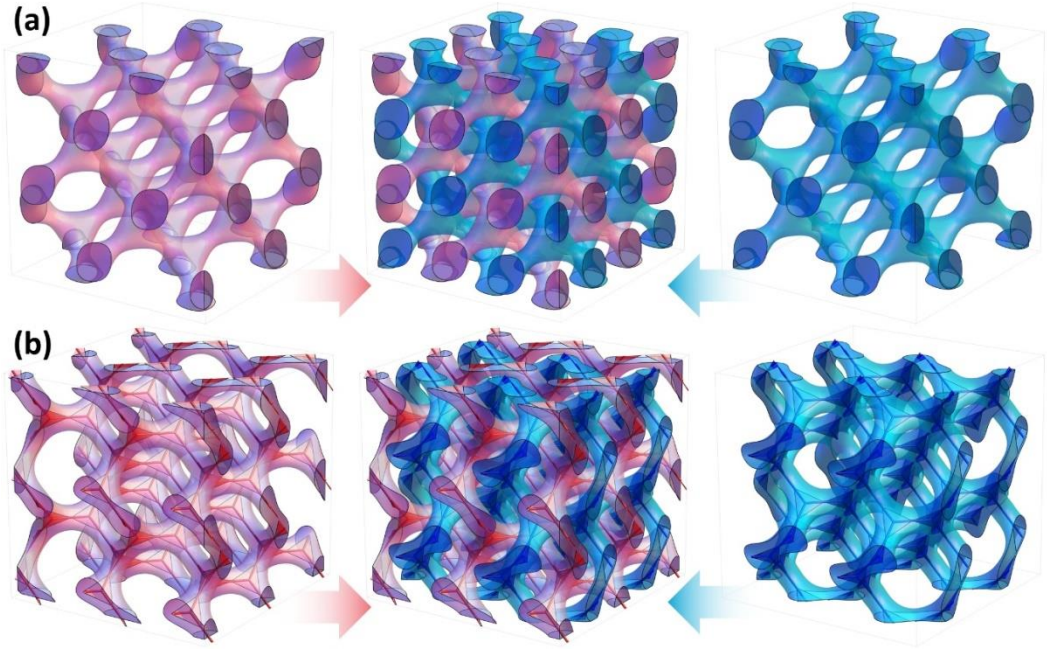

Figure 1: *a) DD and b) DG morphology*

Although TPMS are well-defined and well-documented, it is difficult to find a clear structural transition model in the literature that explains the formation of these exotic architectures. Here, I would like to introduce two geometrical transformation models that propose alternative pathways leading directly from lamellae to either DD or DG domain morphology.

References:

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Multifunctional nanocarriers as an MRI contrast agents

Tomasz Zalewski

Adam Mickiewicz University, NanoBioMedical Centre, Poznań, Poland

Nanoscience is one of the fastest-developing fields of modern science, particularly in biomedical applications. Multifunctional nano-objects created using highly sophisticated methods demonstrate unique physical properties, versatile transport capabilities, and excellent biocompatibility, making them highly desirable for research. The broad range of chemical compositions available for nanocarriers allows their properties to be precisely adjusted to suit specific applications. For example lipid-based nanocarriers can serve as efficient carriers for hydrophobic drugs, while metal ion-based nanoparticles can be used as magnetic markers for high-resolution MRI studies. Moreover, by modifying their structure, composition, or surface, it is possible to fine-tune existing properties or introduce entirely new ones.

Nanocarriers enriched with magnetic, particularly paramagnetic, components are of special interest as potential MRI contrast agents. To evaluate the influence of paramagnetic components, and the effect of their location within the modified nanoparticle structure, on contrast efficiency, NMR relaxation studies must be performed. Additionally, to assess how nanoparticle size affects MRI contrast properties, NMR relaxation experiments should be conducted over a wide range of magnetic field strengths. Finally, to confirm the potential of these nanocarriers as MRI contrast agents, imaging experiments are required.

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Lipid nanocarriers: a new hope for liver cancer therapy

Katarzyna Fiedorowicz [1], Karolina Dydak [1,2], Dorota Flak [1], Jakub Jagielski [1], Radosław Misiak [1,3], Grzegorz Nowaczyk [1]

[1] Adam Mickiewicz University, NanoBioMedical Centre, Poznań, Poland
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Hepatocellular carcinoma (HCC) remains a major global cause of cancer-related mortality. The disease progression often leads to intrahepatic spread, extrahepatic metastasis, and liver failure. Conventional therapies are frequently limited by systemic toxicity and modest curative outcomes. Lipid nanoparticles (LNPs) have recently emerged as promising delivery systems for anticancer drugs, offering high biocompatibility, tunable surface properties, and potential for selective tumor targeting.

This study aimed to develop and characterize LNPs with doxorubicin (LNPs:DOX) and to assess their cytotoxicity against human HCC HepG2 cells. Additionally, their biocompatibility and ability to induce M1 phenotype in murine macrophage RAW 264.7 cells were confirmed.

These findings highlight the potential of doxorubicin-loaded LNPs as a selective and biocompatible therapeutic platform for HCC treatment.

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Resensitization - modern approach to combat antibiotic resistance

Jakub Jagielski

NanoBioMedical Centre, Adam Mickiewicz University, Poznań, Poland

Antimicrobial resistance is reducing the effectiveness of standard treatments across clinical care and is jeopardizing procedures - such as oncology and transplantation - that depend on reliable infection control. Current estimates indicate nearly one million deaths worldwide each year and an annual economic burden of about $66 billion in developed countries due to healthcare costs and productivity losses. Development of entirely new antibiotic classes remains slow and costly, while resistance to existing drugs can emerge within a few clinical seasons. In response, resensitization strategies are being explored - adjunct approaches that disable bacterial defenses (limited permeability, proton-motive-force–dependent efflux, enzymatic degradation, biofilm tolerance) to restore or enhance the activity of available agents.

In this presentation, a membrane-targeted resensitization approach is described in which glyceryl monolaurate (GML), a bioactive lipid, is embedded within structurally defined glyceryl monooleate (GMO) lipid liquid-crystalline nanoparticles (LLCNPs). By increasing the local concentration of GML at the bacterial envelope and inducing curvature stress and partial depolarization, these nanoparticles are designed to weaken efflux and improve antibiotic penetration, thereby increasing intracellular drug exposure without altering the antibiotic's core pharmacophore.

Preliminary formulation and biological data support this concept. A central composite design identified an optimized composition (GMO:GML:F127 = 26.5:3.5:1.5) that forms ~140-nm, low-polydispersity dispersions with $\zeta \approx -27$ mV, week-scale colloidal stability, and bicontinuous cubic (Pn3m) as well as sponge-like internal structures. The dispersion is cytocompatible up to 100 μg mL^{-1}. In vitro, selective activity is observed against Gram-positive bacteria: Staphylococcus aureus growth is suppressed at ≥10 μg mL^{-1} with concurrent $DiOC_2(3)$-detected membrane depolarization, whereas Escherichia coli remains largely unaffected, consistent with an intact outer-membrane barrier. These findings support formal combination studies with frontline antibiotics in resistant Gram-positive strains using checkerboard MIC testing, fractional inhibitory concentration indices, and effect-based synergy analyses.


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