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# ENVIRONMENTAL SCIENCES

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## Water – A strategic Resource in The Climate Crisis. How to Talk About the Water Crisis to Motivate Action?

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Around the world, water demand exceeds available resources. Global water demand has more than doubled since the 1960s. This increased demand is often associated with population growth and industrial development, particularly agriculture, livestock farming, and energy production. At the same time, lack of investment in water infrastructure, unsustainable water policies, and the intensification of climate change can impact water quality and quantity in the region. Data from the World Resources Institute shows that 25 countries currently face extremely high water stress each year. Bahrain, Cyprus, Kuwait, Lebanon, Oman, and Qatar are among the most affected. By 2050, the situation could worsen; an additional billion people are estimated to live with extreme water stress, even if the world drastically reduces greenhouse gas emissions and increases in global temperatures. Global water demand will increase by 20% to 25%, while the number of river basins characterized by significant year-to-year variability or less predictable water supplies will increase by 19%. At the same time, analyses show that solving global water problems is less expensive than one might think. How can we encourage, rather than discourage, action to reduce the water crisis? Tools include effective information not only on the costs but also the opportunities for developing blue and green-blue infrastructure. As well as environmental and climate education, reaching residents who often lack access to the latest scientific knowledge or lack the ability to understand the results of complex models and analyses.

## Circular Economy – A Business Approach to Implementing Environmental Technologies in Municipal Wastewater Treatment Plants

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The transition towards a circular economy (CE) presents new opportunities for the implementation of environmental technologies in municipal wastewater treatment plants (WWTPs). This approach emphasizes resource efficiency, waste minimisation, and the recovery of valuable materials, including treated water, energy, and nutrients. It is important to change the approach to the WWTPs management process to include a closed-loop approach in standard business models, through the development and implementation of circular business models (CBMs). In this way WWTPs could evolve from traditional end-of-pipe systems into resource recovery facilities, contributing to environmental sustainability and regulatory compliance. As part of the ReNutriWater project, assumptions for CBMs were developed for case studies – pilots dealing with water recovery from treated municipal wastewater. This paper presents assumptions for CBMs in the context of water recovery, grounded in the structure of the Business Model Canvas (BMC). The developed BMC highlights key elements such as value proposition, customer segments, revenue streams, and key partnerships, tailored to the specific needs of municipal wastewater treatment plants implementing water reuse technologies. Particular emphasis is placed on the added value of water recovery in agriculture, regulatory compliance, and cost optimisation. The model also addresses potential barriers and drivers for CBM adoption, offering a practical framework for integrating circular principles into

operational strategies. By aligning technical solutions with business viability, the proposed BMC supports the broader goal of sustainable water management.

**Keywords:** circular economy; circular business models, wastewater; wastewater treatment plant

### Acknowledgements

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## Preserving the Irreplaceable: Nature-Based Solutions for Phosphorus Capture and Reuse

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Phosphorus (P) is an irreplaceable element essential for agriculture, food production, and other key industries. Due to its strategic importance and limited natural reserves, it has been classified by the European Union (EU) as a Critical Raw Material. At the same time, excessive P discharges remain one of the main drivers of eutrophication in aquatic ecosystems, especially in regions lacking advanced wastewater treatment. The EU's circular economy strategies highlight P recovery and reuse as priorities to reduce import dependence and mitigate nutrient pollution. Despite existing conventional wastewater treatment technologies (e.g., enhanced biological P removal, struvite crystallization), there is still a lack of cost-effective, low-maintenance, and nature-based solutions that enable efficient P capture and reuse in decentralized and small-scale wastewater treatment systems as well as surface waters.

This study presents the development and evaluation of integrated prototypes for *in situ* phosphorus capture and reuse in surface water bodies and wastewater treatment systems. The prototypes were designed for three eutrophic lakes in Latvia and Estonia, as well as a pilot-scale installation at the Ādaži municipal wastewater treatment plant (WWTP) in Latvia. Each system combines natural sorbent-based materials with a commercially available material Polonite®, a calcium-rich sorbent derived from thermally treated opoka rock, incorporated into modular units adapted to site-specific hydrological and ecological conditions.

At the Ādaži WWTP, the Polonite®-based prototype achieved an overall 93.9% reduction in total P concentration in the treated effluent (final  $P_{\text{tot}}$  0.23 mg L<sup>-1</sup>). For surface water applications, three prototype concepts were developed using mineral sorbent filters: (1) a floating birdhouse equipped with submerged filter, providing additional habitat and educational functions; (2) a submersible aerator with a P-absorbing filter to improve oxygen levels in the water body and (3) a modular control well with replaceable sorbent cartridges designed to capture nutrient-rich inflows to the lake. All designs employ calcium-rich sorbents including Polonite®, capable of binding and immobilizing soluble P through adsorption and precipitation.

These prototype systems mitigate both diffuse and point-source P pollution while enabling circular nutrient recovery, as P-saturated sorbents can be reused as soil amendments in agriculture or municipal green areas. The results demonstrate that natural sorbent-based solutions can provide an effective, affordable, easy-to-operate and sustainable approach to reducing eutrophication, restoring ecological balance in aquatic environments and closing the phosphorus loop.

#### **Acknowledgements**

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## Big Data and Social Media Platforms as Enablers of the Circular Economy Investigation

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The increasing demand for energy, materials, and natural resources reflects the significant threats posed by the linear economic models. For this reason, the Circular Economy (CE) concept has been proposed as an effective countermeasure to achieve more sustainable production and consumption patterns. Suggesting the circulation of resources in a closed loop implies the existence of several strategies, also mentioned as CE principles. Starting with the fundamental *reduce*, *reuse*, and *recycle*, researchers expanded this basic framework to include more advanced and focused strategies that tackle the production and consumption linearity much more effectively. Further, alternative frameworks included strategies like *recover*, *refurbish*, *rethink*, *repair*, *remanufacture*, *repurpose*, and *refuse*. Considering these additions, the United Nations Economic Commission for Europe (UNECE) and the European Commission proposed additional action plans across different sectors.

This work aims to explore and demonstrate the data availability and importance from diverse online and social media platforms in the context of the CE. LinkedIn, YouTube, Scopus, and many others offer multiple perspectives on sustainability and environmental management. More precisely, the business, academic, and public discourse streams are cross-investigated to deliver insightful

hidden aspects and mismatches that can delay CE adoption. This work employs eigenvector centralities to produce networks of R strategies from online media big data. The developed framework takes text input and calculates how central every keyword is in a selected set. The 9R (+1) framework has been utilized for testing and validation. Different scenarios were tested, and the additional metrics demonstrated the differentiation among industries, years, platforms, and concepts.

Across the four scenarios analyzed, distinct yet converging patterns of CE R-strategies emerge. In the Dutch company networks (Scenarios 1), *reduce*, *recycle*, and *recover* consistently form the structural core, with other strategies such as *repair* and *reuse* present but peripheral, and higher-order interventions like remanufacture and refurbish largely absent. Comparing the construction and water sectors (Scenario 2) revealed a strong alignment around *reduce* and *recycle*, but differences in emphasis on *recover* and *reuse*, reflecting sector-specific sustainability pressures. The cross-platform analysis of microplastics (Scenario 3) showed that academic (Scopus) and public (YouTube) discourses are broadly consistent (cosine similarity 0.80), with *recycle* and *reduce* dominating both. However, YouTube debates integrate repair and refuse more strongly. Finally, the tri-domain YouTube comparison of Green Hydrogen, Microplastics, and Nuclear Energy (Scenario 4) highlighted the universal centrality of the “3Rs” but also domain-specific nuances: hydrogen emphasized *recover*, plastics gave more weight to *repair* and *refuse*, and nuclear discussions uniquely incorporated *refuse* as a central element. Overall, the findings demonstrate that while core R-strategies anchor CE debates across contexts, sectoral and platform-specific dynamics shape the prominence of peripheral strategies, underscoring the need for flexible and context-sensitive frameworks.

## Assessment of Sustainable Regeneration Strategies for Pfas Adsorbents

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Per- and polyfluoroalkyl substances (PFAS) are among the most persistent and mobile pollutants currently regulated in the European Union and globally. Their extreme resistance to degradation, bioaccumulation potential, and tightening legislative limits (0.1 µg/L for any single PFAS in drinking water from 2026 under Directive (EU) 2020/2184) create an urgent need for effective and sustainable treatment technologies. Adsorption has emerged as the most widely deployed removal method, but the long-term viability of adsorption-based systems depends critically on how PFAS-saturated adsorbents are regenerated, managed at end-of-life, and evaluated for environmental and economic sustainability.

This study systematically reviewed regeneration and management strategies for PFAS-loaded adsorbents across five principal categories: thermal, solvent-based, chemical, hybrid and emerging electrochemical methods. Evidence from more than 150 studies was assessed for regeneration efficiency, multi-cycle capacity retention, adsorbent stability, secondary waste generation and compatibility with different PFAS chemistries. Thermal regeneration (typically 400–900°C) remains the most established option for carbonaceous materials such as granular activated carbon and biochar, achieving 75–99% recovery after the first cycle and partial PFAS destruction at  $\geq 1000^\circ\text{C}$ , but at high energy cost and with a risk of pore collapse or surface oxidation. Solvent- and chemically based methods, using alcohols, salts or alkaline/oxidative reagents, often deliver >90% first-cycle recoveries, show good stability over several cycles and are particularly suitable for polymeric and bio-based adsorbents, yet generate PFAS-containing liquids that require downstream treatment or solvent recovery. Hybrid approaches combine moderate-temperature thermal steps with chemical polishing or integrate oxidative treatments, enhancing desorption and partially degrading PFAS in the regenerant.

Life-cycle assessments (LCA) show a persistent trade-off between removal efficiency, long-term reusability and downstream waste costs, yet remain rarely

applied to PFAS adsorbents. Existing evidence indicates regenerable resins can outperform single-use systems in cost and environmental impact if regeneration and brine management are optimized, while high-temperature regeneration of granular activated carbon incurs a substantial greenhouse-gas penalty. Lack of consistent LCA data hampers meaningful comparison and technology selection. Integrated frameworks combining technical performance with environmental and economic indicators, along with standardized testing protocols, are urgently needed. The study confirms that regeneration can extend the life of PFAS adsorbents, but no single method is universally applicable; sustainable treatment requires balancing regeneration efficiency with energy and waste burdens and developing low-cost adsorbents, such as chitosan-modified waste materials, aligned with EU regulatory goals.

Building on these findings, a new project financed under the Polish National Science Centre MINIATURA call investigates innovative natural and waste-derived sorbents modified with chitosan for PFAS removal from water. This research will focus on five materials (biochar, natural zeolite, bentonite and iron/aluminum-rich waterworks sludges), which will be modified, comprehensively characterized, and tested for PFAS adsorption in both model solutions and municipal wastewater. The project will elucidate sorption mechanisms and structure–performance relationships for low-cost sorbents, directly supporting EU water-quality objectives and future large-scale applications in the circular economy.

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## The Concentration of Metals as an Indicator of the Potential for Further Utilization of Plant Biomass

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Currently, sustainable development is of great importance in both the economy and scientific research. An important issue related to this aspect is proper waste management, including plant waste from agriculture and forestry. Therefore, numerous studies are being conducted on the potential utilization of plant biomass as a source of energy or as a raw material for industrial and agricultural applications, eg. production of artificial humic acids. Nevertheless, the proper quality of mentioned organic matter is a necessary requirement for its further processing.

The aim of this study was to evaluate the total content of selected metals in plant biomass samples including oak, pine, spruce and willow wood as well as straw from miscanthus, rye, wheat, and maize. The research material was initially crushed and mineralized. Then, after preparing the appropriate solutions, the content of metals such as Cu, Cd, Pb, Mg, Ca, K, Zn, Ni, Cr, and Na was measured using flame atomic absorption spectrometry (FAAS).

The results of the analysis showed the presence of metals in varying amounts. The straw of maize had the highest magnesium, calcium, and potassium content. In contrast, miscanthus contained the highest amount of sodium. The findings confirm the natural functions of such elements in biomass.

Due to the lack of clear standards specifying the permissible metal content in plant biomass, the results of the analyses were compared with the permissible metal content in agricultural soils applicable in Poland. It was assumed that the metal content in biomass may reflect their availability in the soil environment from which the plants obtained nutrients. In accordance with this, no content is alarming and does not exceed significant values. In contrast, metals such as Cd, Pb, Ni, and Cr were present at levels below those specified in soil standards, suggesting that the biomass was not excessively contaminated. Commission Decision (EU) 2022/1244 for products such as growing media and soil improvers may also be helpful in assessing the condition of plant waste. Taking

these criteria into account, no exceedances of the permissible limits are observed either. Nevertheless, even low concentrations of heavy metals can be significant in the context of further biomass use, especially in combustion or fermentation processes, where the presence of these elements can lead to the emission of toxic substances or inhibit the activity of microorganisms.

Summarizing, the analysis of the metal content in the tested biomass allows for the assessment of its quality and environmental safety in terms of further use. Despite the presence of metals, their concentrations did not exceed the permissible standards for soils, which indicates the possibility of safe management of such biomass – provided that regular monitoring and control are carried out.

Proper use of this type of raw material contributes to waste reduction, greenhouse gas emission reduction, and supports the development of a circular economy. However, particular attention should be paid to agricultural, forestry, and municipal waste biomass, which may have an increased content of hazardous elements. Their presence can negatively affect the efficiency of technological processes and pose a threat to the environment and human health, therefore it is necessary to thoroughly assess the chemical composition before using it for energy or fertilizer purposes.

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## Comparative Life Cycle Assessment (LCA) Assumptions for Evaluating Wastewater Treatment Technologies

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The selection of appropriate life cycle assessment (LCA) assumptions is critical for accurate environmental impact evaluation of advanced wastewater treatment technologies. This research presents a comparative LCA assumptions for two pilot studies conducted at Savonia University of Applied Sciences Ltd. (SAS), Finland, and Schwander Polska (SP), Poland, under the project “Closing local water circuits by recirculation nutrients and water and using them in nature” (acronym: ReNutriWater). This project focuses on developing safe, nutrient-rich reclaimed water for non-potable uses aiming to combat eutrophication and promote circular economy business model. For this case, SAS studied the ozonation, activated carbon (AC) filtration, ultraviolet (UV), and chlorination technologies for reclamation of water. The primary LCA assumptions for these technologies are materials used for chemical dosing and operational energy required for collection of 1 m<sup>3</sup> of reclaimed water. Also, materials and energy used for AC and ozone generation, and ancillary equipment are also calculated, which are significant for impact evaluation. The transportation and final usage of reclaimed water in a greenhouse are also assumed for LCA evaluation. Moreover, SP has a different approach to treat the wastewater. It employed membrane bioreactor (MBR) and UV technologies for reclamation of water. Primary LCA assumptions for MBR and UV include operational energy for 1 m<sup>3</sup> of reclaimed water. MBR is an energy-intensive unit where membrane substitution cycle and sludge management through landfilling or composting are assumed for accurate evaluation of the environmental impact. Here, transportation is assumed to transfer reclaimed water for municipal usage like street cleaning and gardening purposes. Both case studies demonstrate significant sensitivity to operational energy consumption and transportation. The findings of the study provide essential guidance for optimising processes and selecting energy sources and materials for sustainable water infrastructure development.

**Keywords:** Life cycle assessment, wastewater, membrane bioreactor, tertiary treatment, water reclamation

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## Molecular Mechanisms of Tree Microbe Interfaces in Forest Ecosystems

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Plant terpenes, serving as organic compounds and secondary metabolites, exert a significant influence on both plant development and plant-microbe interactions. Among these,  $\mu$ -amyrin, a pentacyclic triterpene, is acknowledged as part of the terpenes involved in plant defence mechanisms. However, the precise role of  $\beta$ -amyrin in reconciling defence mechanisms with symbiotic interactions is still unclear. Our study focuses on unravelling the role of  $\beta$ -amyrin in the context of ectomycorrhiza and endophytic symbiosis. Transgenic poplars were produced with enhanced (OE) or suppressed (KO) expression levels of a gene encoding  $\beta$ -amyrin synthase. Root growth and development, as well as root colonisation by the ectomycorrhiza fungus *Laccaria bicolor* and the endophytic fungus *Hyaloscypha* (synonymous: *Cadophora*) *finlandica*, were evaluated in the study. Our results indicate that overproduction of  $\beta$ -amyrin does not impact root development. No significant differences were observed among the tested poplar lines regarding the rate of ectomycorrhiza (EcM) formation with *L. bicolor* and for the presence of the endophyte *H. finlandica* into roots. Nevertheless, we showed that high-level of  $\beta$ -amyrin inhibits *H. finlandica* coil formation. This suggests that  $\beta$ -amyrin could potentially hinder endophyte fungus penetration and limit its colonization to root cell apoplast. Our results will provide valuable data to understand the function of  $\beta$ -amyrin's in plant immunity and its participation in symbiotic relationships.

Our findings will deepen our understanding on the role of tree terpenes in the regulation of ectomycorrhizal and endophytic interactions.

## Correlation between the surface of nanoparticles and their functionality

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Global water pollution is one of the major problems facing the world today. Water can be contaminated with a wide variety of chemicals, including heavy metal ions, dyes, and pharmaceutical compounds. As an adsorbent, various materials can be used, such as membranes, polymers, carbons, and nanostructures. However, depending on the type of material and structure, it has different effectiveness in pollution removal. Current research seeks to demonstrate the correlation between the surface of nanoparticles and their functionality. Among the many methods used in water purification, adsorption is particularly attractive due to its low operating costs and the ease of maintaining adsorbent materials. However, the effectiveness of the materials proposed for adsorption studies depends on experimental conditions, including pH, ionic strength, the presence of additional molecules, as well as contact time and adsorbent dose. Therefore, it has an impact on the maximal adsorption capacity. Due to the interaction between the adsorbent and the pollution. The maximal adsorption capacity is estimated by using different adsorption models, such as Langmuir, which describes the single layer of adsorbed pollutant; Freundlich, which focuses on heterogeneous surface adsorption, and if, during the adsorption process, a new band (chemisorption) is created or not (physisorption). The combination of these two models is the Redlich-Peterson model. Other models are also applied, but in many studies, adsorption is characterized primarily using linear models and kinetics. Nonetheless, it is often necessary to apply non-linear equations to accurately establish equilibrium.

Depending on the active groups on the surface of the material and conditions, the adsorption process can occur twofold. For instance, for biochars, the Redlich-Peterson adsorption model predominates. It is attributed to fairly large pores. On the other hand, for biochars that include magnetic nanoparticles, the adsorption model can be varied. The presence of a negative charge on the surface of the material indicates the possibility of adsorbing the cathodic dye with high efficiency, based

on electrostatic interaction. However, these interactions are relatively weak, allowing pollutants to be easily desorbed from the surface by organic solvents. This raises environmental concerns, since pollutants may be reintroduced into the environment during adsorbent regeneration.

## Reuse of PVC Waste for Aqueous Dyes Removal from Aqueous Solutions

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Synthetic dyes that are released from the textiles, leather, plastics, and paper industries are one of the major sources of water pollution globally. The scale of this issue has accelerated research on the novel materials to be used in effective and reusable membranes, adsorbents and advanced photodegradation, which offer more sustainable and efficient solutions than classical methods. This work addresses the need of delivering innovative materials in environmental applications by reuse of spent polymer into the functional porous textile that can be used as both adsorbent and membrane. The textile based on the poly(vinyl chloride) (PVC) was electrospun at different experimental conditions to obtain the material with the most uniform and aligned fibers. The optimized material was then used to remove model dye-based pollutants from aqueous solutions – crystal violet (CV) and methyl violet (MV). To determine the most efficient dye removal conditions, adsorption experiments were conducted across different pH values. The pH-dependent study revealed the highest efficiency at pH 7.0 for CV and pH 10.0 for MV. Adsorption studies confirmed superior dye removal efficiency for presented material, achieving up to 80% CV and 55% MV removal. Therefore, the study could serve as an innovative dual-application approach, combining recycling of spent PVC-based materials with wastewater treatment.

### Acknowledgements

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## Sustainable and Circular Management of Terrestrial and Space Raw Materials

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The dynamic development of modern technologies, as well as the energy and climate transition, are driving an unprecedented increase in the demand for critical raw materials such as rare earth elements, cobalt, lithium, and platinum group metals. At the same time, traditional methods of resource extraction carry serious environmental, social, and economic consequences. In this context, the idea of sustainable and circular resource management is gaining importance, aiming to reduce the exploitation of primary deposits, minimize material losses, and maximize the recovery and reuse of resources.

As a result, circular economy models are being continuously developed across entire industrial sectors. These include designing products for easier disassembly, reuse, and recycling, as well as the development of so-called urban mining, which involves recovering valuable materials from resources already in economic circulation. One of the most promising directions is the use of biological methods for metal recovery. Through the application of microorganisms, it is possible to extract metals from industrial waste, electronic waste, or low-grade ores, with significantly lower energy and water consumption compared to traditional mining. These technologies align with the principles of the circular economy and sustainable development, enabling not only resource recovery but also reducing negative impacts on ecosystems.

However, in the long-term perspective even the most efficient recycling may not be sufficient to meet the growing needs of civilization. Consequently, the prospect of extraterrestrial resource extraction is being regarded with growing seriousness as a potential solution to future material demands. The resources of other planets and the Moon may in the future form the basis for the functioning of permanent space stations and potential colonies. The acquisition of extraterrestrial resources would enable the construction of space infrastructure without the need for costly transport of materials from Earth, while also supporting the

expansion of research activities in outer space and potentially even permanent human presence on other planets.

The presentation aims to provide a comprehensive perspective on sustainable and circular resource management – both terrestrial and extraterrestrial. It will discuss modern methods of biological metal recovery, the importance of the circular economy for resource security, as well as the prospects of space exploration in the context of acquiring materials essential for building bases and potentially colonizing other celestial bodies. The correlation of these two areas – resource management on Earth and in outer space – will outline a vision of the future in which humanity learns to use materials in an efficient, responsible, and long-term way, both on our planet and beyond.

**CIVIL,  
MECHANICAL  
& MATERIALS  
ENGINEERING**

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## Closing the Loop: The Mechanics of Circular Materials in Civil Engineering

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The transition to a circular economy in the construction sector requires innovative approaches to material reuse, particularly for complex composite structures such as decommissioned wind turbine blades. These blades, typically composed of glass fibre-reinforced polymer laminates with polymer foam cores, present significant challenges in terms of mechanical characterization, structural integrity, and recycling feasibility. The present study investigates the mechanical behaviour of wind turbine blade materials and their potential reuse in architectural and structural applications, as well as in concrete composites.

## Climate Tipping Points and Extreme Events: On their Formation and Forecasting

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The Earth system is a very complex and dynamical one basing on various feedbacks. This makes predictions and risk analysis even of very strong (sometime extreme) events as floods, landslides, heatwaves, and earthquakes etc. a challenging task. After introducing physical models for weather forecast already in 1922 by L.F. Richardson, a fundamental open problem has been the understanding of basic physical mechanisms and exploring anthropogenic influences on climate. A highlight was the pioneering studies by Hasselmann and Manabe who got the Physics Nobel Price in 2021. I will shortly review their main seminal contributions and discuss most recent challenges concerning climate change.

Next, I will introduce a recently developed approach via complex networks mainly to analyze long-range interactions in the climate system. This leads to an inverse problem: Is there a backbone-like structure underlying the climate system? To treat this problem, we have proposed a method to reconstruct and analyze a complex network from spatio-temporal data. This approach enables us to uncover teleconnections among tipping elements, in particular between Amazon Rainforest and the Tibetan Plateau, but also between the Arctic and Southwest China and California. Implications of these findings in particular for forecasting extreme events are discussed.

## Methods for Enhancing Vibrational Reliability and Damage Diagnostics of Composite Structural Elements in Turbomachinery

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The application of new materials, particularly carbon fiber-reinforced polymer composites, is a priority in the development of aircraft and in improving the performance of gas turbine engines. Investigating the vibrational strength of composite materials and critical structural components under dynamic loading is essential to ensure safe operation. Moreover, early diagnosis of damage is crucial for improving the reliability of structures and advancing manufacturing technologies. The primary goal of the present study is to improve the vibrational reliability of structural elements through enhanced damping capabilities, the development of advanced vibration damage diagnostics, and analysis of blade disk dynamics in turbomachinery under fluid or gas flow.

Experimental studies focused on the dissipative properties of modern composite materials were carried out using upgraded setups that minimize external energy losses and employ non-contact vibration measurement. Based on amplitude-dependent energy dissipation, the damping capacity of woven carbon fiber composites was determined across a broad temperature range, providing valuable reference data for design purposes.

Mathematical models have been developed to predict the elastic and damping properties of smart piezoelectric composites used in active vibration control systems. A mixed variational formulation and semi-analytical finite element

models were used to study the interaction between passive/active layers and feedback parameters. Experimental validation demonstrated a two-fold reduction in vibration amplitudes compared to passive methods.

Advanced vibration diagnostics methods were proposed to detect local damage such as delamination and impact-induced flaws in layered composites. Finite element models showed that changes in modal frequencies due to defects depend on material anisotropy and damage location. A novel technique based on the analysis of harmonic spectra under subharmonic and superharmonic resonances was validated for detecting low-energy impact damage in carbon fiber rods, with the ratio of dominant harmonic amplitudes serving as a quantitative indicator.

Studies on bladed disks in turbomachinery revealed that manufacturing tolerances and service damage lead to local modal mistuning, increasing vibrational stress in disk tenons. Analytical and experimental investigations identified stiffness-related parameters for design optimization. The research outcomes were adopted by leading Ukrainian engine design bureaus.

Additionally, a database of critical flutter parameters was compiled for turbomachinery blade rows. An express method for predicting subsonic flutter stability limits was proposed, offering practical value in gas turbine compressor design.

In conclusion, the Institute has developed a comprehensive suite of computational and experimental methodologies to analyze dynamic behavior and damage sensitivity in composite structures. These tools provide a solid foundation for assessing operational limits and residual life of high-performance mechanical systems and enable broader use of composite materials in safety-critical components.

## Sample-based methods used in an analysis of multistable dynamical systems

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Sample-based methods have become increasingly important in the analysis of dynamical systems, supported by the growing availability of high-performance computing resources. These approaches enable comprehensive exploration of system behavior across a wide range of initial conditions and parameter values, offering deep insights into phase space structure and facilitating the detection of stable solutions, including rare and hidden attractors.

One of the foundational techniques is *basin stability*, which involves multiple numerical simulations with randomized initial conditions and classification based on the final attractor reached. This method is particularly effective for systems with many degrees of freedom, where classical stability measures may fail. Extensions include parameter sensitivity analysis and *survivability*, which tracks transient dynamics before reaching an attractor. Another valuable tool is *basin entropy*, which quantifies the unpredictability and complexity of the system's basins of attraction.

The presentation compares these sample-based techniques with classical methods, highlighting their strengths, limitations, and practical applications. Examples are demonstrated using a representative nonlinear system, making the results broadly applicable to various scientific fields dealing with multidimensional and complex dynamical behavior.

## Cafd-Net: A Real-Time Traffic Congestion Detection Model with Cross-Scale Feature Aggregation and Diffusion

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College of Transportation, Tongji University

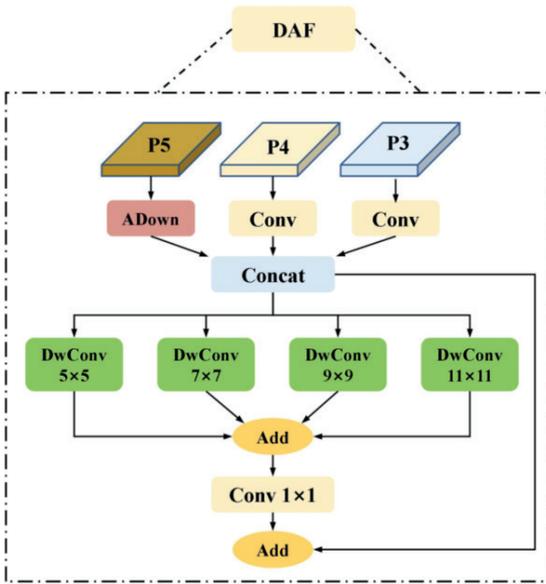
**Background:** Efficient and accurate traffic congestion detection is critical for modern intelligent transportation systems but remains challenging in complex scenarios due to difficulties in capturing global context and multi-scale features, particularly for small vehicles.

**Problem:** Existing methods often struggle with the trade-off between detection accuracy, especially for small targets, and inference speed for real-time applications.

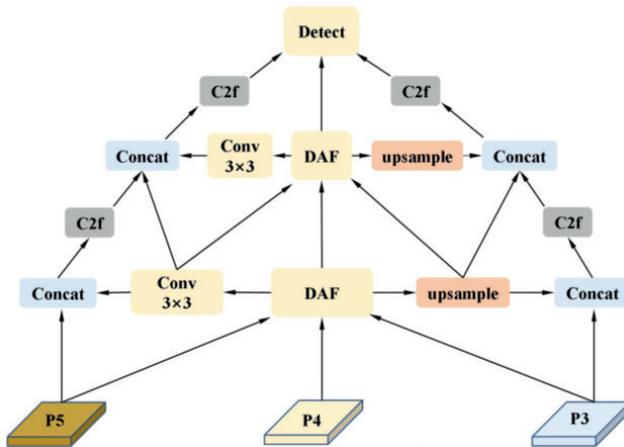
**Method:** To address this, we propose a Cross-scale Aggregation Feature Diffusion model (CAFD). Its core is a novel Dynamic Feature Aggregation module (DAF) that integrates spatial dependencies from different receptive fields via parallel large-kernel depth wise convolutions and multi-level feature reorganization. A three-way propagation path enhances small target detection by diffusing high-level semantics to low-level features. Based on this improved RT-DETR architecture, we construct a real-time system that utilizes a dual-threshold logic (vehicle density and average speed) to accurately calculate congestion duration and length.

**Results:** Experimental results on the COCO dataset show that CAFD achieves an average precision (AP) of 46.9% at 99 FPS, outperforming YOLOv10-S and RT-DETR-r18 by 0.8% and 0.5%, respectively. Real-world validation confirmed the model's accuracy, with threshold-triggering errors consistently below 5%.

**Conclusion:** This demonstrates that the proposed CAFD model is robust and efficient enough for effective deployment in real-world traffic flow monitoring, offering significant potential for improving traffic management and safety.



**Figure 1.** Architecture of the proposed Dynamic Feature Aggregation (DAF) module. The module takes multi-scale feature maps (P3, P4, P5) as inputs. It employs a set of parallel depthwise convolutions with large kernels ( $5 \times 5$  to  $11 \times 11$ ) to capture multi-scale spatial context. The features are then integrated through additive operations and a  $1 \times 1$  convolution, effectively fusing information across different receptive fields



**Figure 2.** Overall architecture of the Cross-scale Aggregation Feature Diffusion (CAFD) model. The model takes multi-scale feature maps P5, P4, and P3 from the backbone network. It employs a top-down path with up sampling and concatenation (Concat) to diffuse high-level semantic features into lower-level, higher-resolution feature maps. The proposed Dynamic Feature Aggregation (DAF) modules are integrated at key points to enhance multi-scale context fusion before the final detection head.

## Short-Term Traffic Flow Prediction Methods for Expressways Considering Stochastic Congestion Scenario

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**Background:** Accurate short-term traffic flow prediction is essential for intelligent transportation systems (ITS), yet it remains challenging under random congestion scenarios on urban expressways.

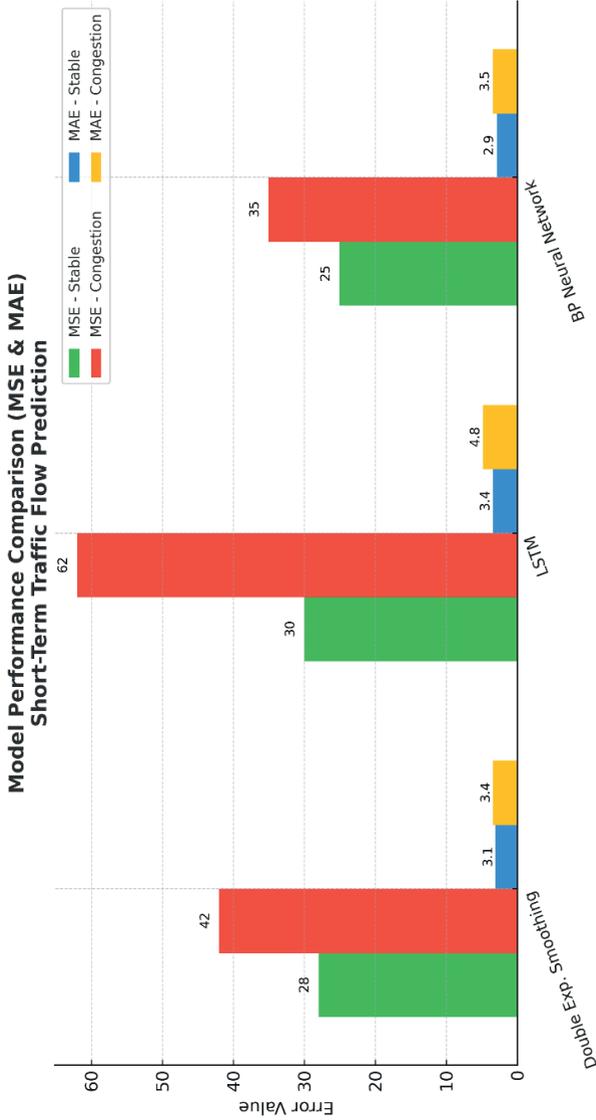
**Problem:** While various models exist, their comparative performance in predicting traffic flow dynamics—particularly using speed as a key indicator—during unpredictable congestion events is not well-studied.

**Method:** This study employs traffic speed data from multiple sections of Suzhou Expressway to conduct a comparative analysis of three prediction models: Double Exponential Smoothing, LSTM neural network, and BP neural network. Mean Squared Error (MSE) and Mean Absolute Error (MAE) were used as evaluation metrics, supplemented by data visualization, to assess model performance under both stable and congested conditions.

**Results:** Results indicate that all models performed satisfactorily under stable traffic conditions ( $MSE \approx 30$ ). However, during random short-term congestion, the LSTM and Double Exponential Smoothing models exhibited significant performance degradation. In contrast, the BP neural network demonstrated superior robustness, achieving a lower MSE ( $\approx 20$  during training,  $< 40$  during congestion events) and better handling of nonlinear, uncertain fluctuations in speed patterns.

**Conclusion:** The BP neural network model proves more effective for short-term traffic flow prediction under random congestion conditions, offering greater reliability and accuracy for real-time traffic management applications compared to LSTM and exponential smoothing approaches.

**Keywords:** Traffic flow prediction, Expressway, Random congestion, Neural networks, Double exponential smoothing, Model comparison, Short-term forecasting



**Figure 1.** Performance comparison of Double Exponential Smoothing, LSTM, and BP neural network models for short-term traffic speed prediction on Suzhou Expressway, evaluated by Mean Squared Error (MSE) and Mean Absolute Error (MAE). BP consistently outperforms other models, especially under random congestion conditions.

## A Hybrid AI-Physics Computational Framework for Accelerated PDE-Constrained Topology Optimization

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Topology optimization has become an indispensable method for designing lightweight, high-performance structures and materials. However, its practical application is often limited by significant computational demands, primarily due to the repeated solution of large-scale finite element problems governed by partial differential equations (PDEs). While purely data-driven machine learning approaches have shown potential in speeding up these processes, they frequently suffer from limited generalizability and may produce designs that lack physical consistency.

In this work, we introduce an integrated computational strategy that effectively merges deep learning with traditional physics-based optimization. Our approach consists of three interconnected elements: first, a convolutional neural network provides optimized initial design guesses based on specified loading and boundary conditions; second, a highly efficient GPU-accelerated optimizer built on the Solid Isotropic Material with Penalization (SIMP) method performs rapid design iterations on a coarse discretization; and third, an adaptive multi-fidelity validation mechanism ensures that design updates are periodically verified on a refined mesh, preserving accuracy and preventing convergence to suboptimal solutions.

The proposed framework is validated on classical two-dimensional problems, including structural compliance minimization. Our results demonstrate that the intelligent initialization provided by the neural network results in significant reduction of iteration counts, while the multi-resolution safeguard maintains solution quality on high-fidelity meshes. This hybrid paradigm offers a balanced and computationally efficient alternative to conventional methods, successfully combining the pattern-recognition strength of machine learning with the rigorous guarantees of physics-based simulation.

## Overview on Inflight Icing Challenges and Research Directions Addressing Them

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Inflight icing is known in the aeronautical industry for more than a century now. In fact the very first ice protection system has been patented 95 years ago. Nevertheless with improved performance of the aircrafts, architectures that utilize complex sensing technologies even on its externals as well as due to the climate changes, the problem of icing itself is continuously evolving. The most basic concept of small, suspended supercooled droplets that were characterized in 1940's is the most common type of icing conditions encountered. This type is particularly dangerous to the aircraft external surfaces. In late 1990's another category of icing conditions addressing newly discovered supercooled large droplets was introduced. Other categories of icing are also known these days i.e. ice crystals, snow and mixed phase conditions. These fundamentally different icing conditions are important for i.e. turbine engines design and some sensors.

In recent decades many aviation companies, universities and institutes were conducting research addressing various icing aspects. Most common focus areas include experimental methods, numerical tools, passive and active ice protection systems with improved performance and atmospheric characterization.

The first category relates to the development of robust testing methods and most commonly improved capabilities of testing in so called Icing Wind Tunnels.

The second category is targeting accurate spatial and temporal modeling of heat and mass balance corresponding to ice accretion. Also shape of ice layer and its impact to performance parameters i.e. aerodynamic degradation are of particular interest. These simulation methods still suffer with not robust enough submodels, i.e., for porous ice density or ice roughness development.

Third category is aiming for ice protection systems that utilize modern materials and smart control to minimize peak power and energy consumption. Also a completely new category of passive ice-phobic materials is of great interest but suffers from durability aspects. The last category relates to atmospheric

characterization for better understanding how climate changes and outdated testing methods would perform against current capabilities and data collected.

The presented topic is an overview of basic concepts explaining fundamental research and engineering problems of icing with a focus on the weak points and areas to improve. Also an attempt of expected outcomes from current research programs is summarized.

## FRP Composites in Construction

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Fiber-reinforced polymer (FRP) composites have been used in structural strengthening and rehabilitation applications to increase flexural, shear, axial and seismic resistance performance of existing reinforced concrete (RC) structures. Investigating the FRP failure modes of FRP-strengthened concrete structures is essential for understanding the FRP failure mechanisms through experimental tests for improving the reliability and efficiency of FRP-based structural strengthening systems. For structural strengthening applications with FRP sheets, the most common externally bonded techniques include side bonding (applied to the beam sides), U-shaped jacketing (bonding the sides and soffit), and wrapping (adhering to four sides). FRP side bonding enhances the shear capacity, whereas U-shaped jacketing improves both shear and flexural performance. And FRP wrapping provides confinement, thereby improving the ductility, as well as enhancing the shear and flexural capacities of the structure. The failure modes of FRP-strengthened reinforced concrete (RC) beams under static loading include shear failure, flexural failure (concrete crushing and FRP rupture), and FRP debonding. The goal of investigating FRP failure modes is to improve the reliability, safety, and design efficiency of FRP-strengthened concrete structures.



Molds



Casting RC beams



Structural Testing



Failure Modes



FRP debonding



Flexural Cracks

## Hot corrosion analysis for the dual phase system $\text{Gd}_2\text{Zr}_2\text{O}_7 + \text{ZrO}_2 \cdot \text{Y}_2\text{O}_3$

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Thermal barrier coatings (TBCs) are advanced ceramic coatings emerged as vital solution for enhancing the durability, efficiency and operational lifespan for all high temperature industrial components, which are randomly and regularly exposed to elevated temperatures, corrosive media, and neutron irradiation. The long-term performance of TBCs is significantly influenced by various degradation mechanisms that occur during service. Dual-phase coatings enhance thermal barrier performance by combining complementary properties of two phases, improving thermal stability, corrosion resistance, and mechanical durability in extreme environments which was proved recently in the dual phase system of samarium zirconate ( $\text{Sm}_2\text{Zr}_2\text{O}_7$ ), neodymium zirconate ( $\text{Nd}_2\text{Zr}_2\text{O}_7$ ) with yttria stabilized zirconia (YSZ). However, there are several degradation routes that are not yet investigated. The authors investigate three types of composite APS-sprayed coatings with varying weight ratios of gadolinium zirconate and YSZ (25–75, 50–50, and 75–25 wt%) and subject them to high-temperature oxidation at 1100°C for up to 2000 hours in air, with phase composition changes analyzed using XRD and SEM techniques. Dual-phase TBCs systems, composed of gadolinium zirconate ( $\text{Gd}_2\text{Zr}_2\text{O}_7$ ) and 8 mol% yttria-stabilized zirconia (8YSZ), exhibit poor thermal stability when subjected to prolonged oxidation at 1100 °C. This instability primarily stems from a mutuals interactions between the  $\text{Gd}_2\text{Zr}_2\text{O}_7$  phase and the 8YSZ.

**Keywords:** high temperature oxidation, Thermal barrier coatings,  $\text{Gd}_2\text{Zr}_2\text{O}_7$ , YSZ, Synergistic dissolution

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## The Advanced Ceramic Materials for Transport Applications -Especially Zirconate based ceramic for the Hot Corrosion

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This topic presents an integrated study on advanced dual-phase zirconate-based thermal barrier coatings (TBCs) designed for harsh high-temperature and corrosive environments. The focus lies on pyrochlore-structured materials in  $\text{La}_2\text{O}_3\text{--Gd}_2\text{O}_3\text{--Nd}_2\text{O}_3\text{--ZrO}_2$  and  $\text{Yb}_2\text{O}_3\text{--ZrO}_2$  systems, where tailored cation substitutions and non-stoichiometric compositions enhance phonon scattering and reduce thermal conductivity to ultra-low, temperature-stable levels.

Dual-phase composites combining 8YSZ with rare earth zirconates ( $\text{Ln}_2\text{Zr}_2\text{O}_7$ ) show improved thermal insulation, mechanical durability, and extended service life compared to traditional single-phase coatings. High-temperature oxidation and hot corrosion tests reveal specific degradation behaviors depending on composition and corrosive agents, yet these coatings maintain structural integrity and resist spallation over long exposures.

Synthesis methods like solid-state reactions and thermal spraying were optimized to control powder homogeneity and microstructure. Experimental thermal conductivity and diffusivity data, supported by theoretical modeling, demonstrate the strong influence of cation size and microstructural features on thermal conductivity. Detailed microstructural and chemical analyses before and after thermal exposure clarify degradation mechanisms and phase transformations affecting coating performance. These findings provide valuable insights for developing durable, efficient TBCs for applications such as gas turbines, aero engines, and nuclear reactors.

**Keywords:** Zirconate, thermal conductivity, degradation routes, corrosion

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## A unified microstructure-sensitive model across low and high cycle fatigue for additively manufactured IN718

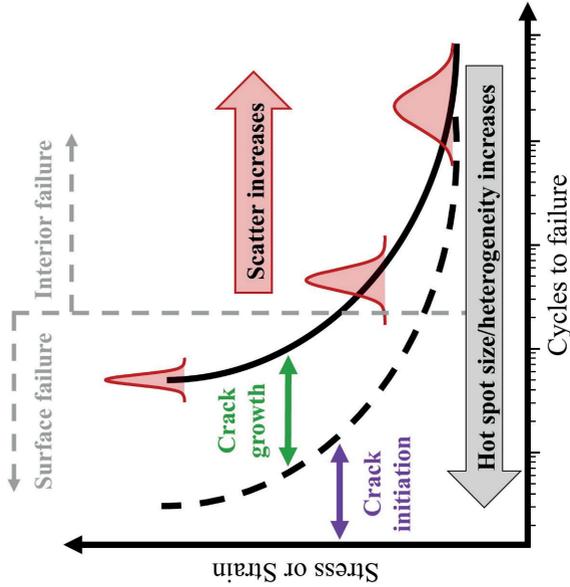
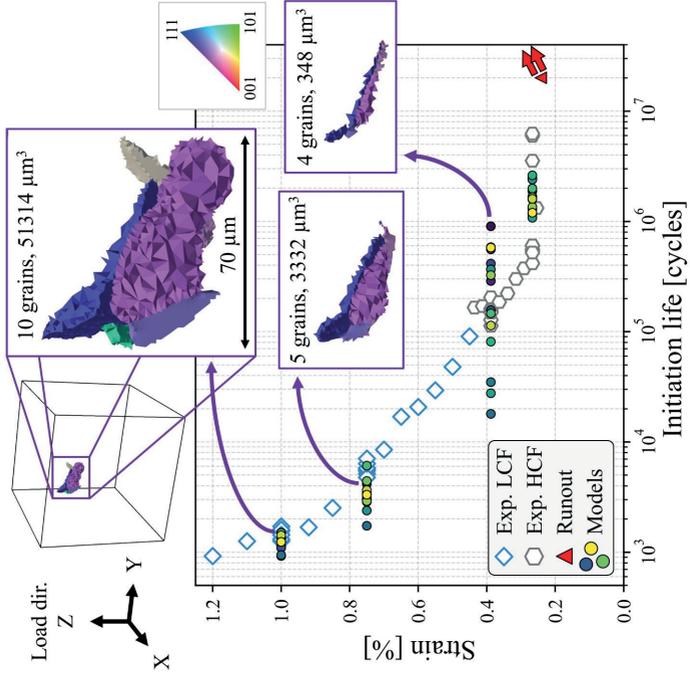
Krzysztof S. Stopka, Michael D. Sangid

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Microstructure-sensitive modeling has shown promise to reduce the central reliance on experimental test campaigns to determine fatigue performance. However, most existing fatigue life models use metrics focused solely on fatigue crack initiation (FCI), but which are calibrated against and validated with total fatigue life of test coupons, leading to large errors, especially in the low cycle fatigue regime. This work unifies coupon-level experiments and microstructure-sensitive crystal plasticity simulations for additively manufactured IN718, explicitly delineating between three stages of life: initiation, small crack growth, and long crack growth. We introduce a load-dependent non-local averaging (NLA) regularization strategy that reveals microplasticity/hot spot confinement prevalent in high cycle fatigue and slip transmission across grain boundaries in the case of low cycle fatigue. The results demonstrate that a single parameter, the critical value of the accumulated plastic strain energy density,  $\gamma_c$ , governs both low cycle and high cycle fatigue. The model reproduces experimental FCI lives and scatter across five orders of magnitude. Statistics of fatigue hot spots extracted from the digital microstructures are used to explain experimental trends of larger hot spot volumes encompassing more grains as load increases, and variability in microstructure features and resulting micromechanical fields directly tied to variability in the resulting fatigue life. The unification of low and high cycle behavior with a single microstructure-sensitive fatigue modeling framework is an important step to adopting model-based strategies for predictions of fatigue performance.

Graphical abstract (p. 48)

Graphical abstract



## A Comparative Analysis of Conventional and Machine Learning Models for Imbalanced Travel Mode Choice Data with an Adjustable Kernel SVM Approach

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Understanding travel mode choice (TMC), particularly in the context of work-related trips, is fundamental for forecasting travel demand and advancing sustainable transport policies. A persistent challenge in TMC research lies in the imbalance of observed data, which often limits the effectiveness of traditional modeling approaches. Conventional statistical models, typically constrained by assumptions, are primarily applied to binary classification tasks. While many machine learning (ML) algorithms are also designed for binary problems, the application of kernel scaling adjustments enables their extension to multi-class regression scenarios. This study introduces a Support Vector Machine with Adjustable Kernel (SVMAK), which leverages kernel scaling theory to address the imbalance issue in TMC datasets. To benchmark its performance, several ML algorithms—including standard SVM, Naïve Bayes (NB), Gradient Boosting (GB), Random Forest (RF), and Neural Networks (NN)—were implemented. The empirical analysis used data from the 2022 National Household Travel Survey (NHTS) for California. The findings demonstrate that ML methods significantly outperform conventional models, with SVMAK showing superior performance relative to other ML techniques. Specifically, the NN achieved 92% accuracy, while the SVMAK improved standard SVM accuracy from 90.2% to 99.8%, highlighting its strong capability for imbalanced TMC prediction. These results suggest that the proposed approach holds promise for supporting transportation planning applications where data imbalance is a critical concern.

## Role of hysteresis in the mechanical response of granular materials to dynamic loading

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**Background:** It is widely acknowledged that the mechanical behavior of granular materials is unusual when compared with other common materials encountered in civil, mechanical and materials engineering. The mechanical response of granular materials to external loading is known to be highly nonlinear, in terms of the recorded stress-strain response (starting from the small strain range) as well as in terms of the volumetric changes experiencing contraction and/or dilation. This complex behavior is still challenging when interpreting experimental results (e.g. from a microscopic point of view) or when formulating soil constitutive models at continuum level (e.g. with respect to the purely elastic strain range, often assumed to be linear and fully reversible). This presentation will show the most recent findings on the role of hysteresis in the mechanical response of the granular materials to dynamic (seismic) loading.

**Formulation of the problem:** High frequency motion oscillations often occur in the dynamic response of granular materials in physical models subjected to simplified sinusoidal seismic excitation. So far, these oscillations have been attributed to various sources of experimental noises, such as interaction with boundaries of the model or imperfect input motions applied at the model base. A new perspective on the occurrence of high frequency oscillations was cast recently following the findings from the PhD thesis and the subsequent works of the author.

Firstly, complementary methodology of numerical studies and benchmark experimental data from the physical models carried out in the past at University of Bristol was used to show that accounting solely for soil hysteresis (at small strain levels less than  $1 \cdot 10^{-3}$ ) results in the occurrence of high frequency oscillations of two types: i) representing soil natural frequencies, ii) representing strain discontinuity and ‘spikes’ in the computed/measured accelerations. This

work suggested that soil response at very small strain range is hysteretic and, therefore, should not be modelled as linear elastic when dealing with seismic wave propagation studies.

Secondly, dedicated soil laboratory tests aimed at replicating soil behavior in the benchmark physical models (i.e. at representative stress and strain levels) were carried out in a state-of-the-art direct simple shear apparatus. The results revealed that two types of soil hysteresis were measured, i.e. a hysteresis without volumetric contraction (up to intermediate seismic excitation levels), and hysteresis with volumetric contraction (for large seismic excitation levels). This observation strengthens the findings that the behavior of granular materials contains a range of nonlinear hysteretic elasticity which should be accounted for in the dynamic analysis of granular materials.

**Main conclusion:** Accounting for hysteresis in the mechanical response of soil is shown in this presentation as essential when replicating the dynamic behavior of granular materials subjected to seismic loading.

## Development of Composite Electrospun PVDF Fibres for Improved Piezoelectric, Mechanical and Thermal Properties

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Polyvinylidene fluoride (PVDF) and its copolymers (PVDF-TrFE) have attracted huge interests from researchers for their potential applications in self-powered flexible electronics. This is mainly attributed to piezoelectric nature of these polymers. Additionally, they can be produced in the form of fibres and meshes that have several favourable properties such as flexibility, mechanical strength, thermal stability and resistance to corrosion from acids and halogens. The piezoelectric performance of the PVDF fibres are linked to the presence and content of the  $\beta$  phase [1, 2].

To improve the piezoelectric performance of these fibres, researchers usually employ a nanocomposite approach incorporating nanoparticles such as piezoelectric ceramics, semiconductors, and conductive carbon-based materials in PVDF fibres matrix. Among these, carbon based fillers such as carbon nano-fibres (CNFs), carbon nanotubes (CNTs), Graphene, reduced Graphene oxide (rGO), and barium titanate ( $\text{BaTiO}_3$ ) particles have attracted recent attention due to the low cost and favourable electrical and mechanical properties [3].

In this work, we fabricate electrospun PVDF fibres using rGO and  $\text{BaTiO}_3$  as a filler materials. Additionally, PVDF fibres without any filler were also fabricated to serve as a reference. We present detailed analysis of the properties of the different fibres using Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) and compare the piezoelectric energy harvesting performance. The Young's modulus of the fibres was estimated using a 20N load cell.

The PVDF fibres with  $\text{BaTiO}_3$  resulted in thinner and more uniform fibres. Uniformity in the fibres are linked to improved mechanical and thermal properties. PVDF composite fibres with 1% wt.  $\text{BaTiO}_3$  resulted to maximum  $\beta$  phase  $\approx 72\%$ . Increased  $\beta$  phase has been linked to superior piezoelectric performance [5]. Consequently, the PVDF- $\text{BaTiO}_3$  fibres were found to generate higher

piezoelectric response. Furthermore, PVDF-BaTiO<sub>3</sub> were found to be almost 3 times stronger than the rGo-PVDF or standard PVDF fibres. The PVDF-BaTiO<sub>3</sub> fibres were also found to retain their properties at higher temperatures than the rGo-PVDF or standard PVDF fibres.

The results will help us understand the properties and behaviour of different filler materials used for preparing composite electrospun fibres for advanced applications.

### Acknowledgments

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## Copper Doped Semitransparent Titania Nanotube Electrodes as a Versatile Platform for Photoactivity, Oxygen Evolution, and Energy Storage

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Semitransparent  $\text{TiO}_2$  nanotube (TiNT) arrays fabricated by anodizing thin Ti films on transparent conducting substrates have emerged as attractive functional nanomaterials due to their straightforward, low-cost synthesis and tunable nanoscale architecture. Compared with conventional opaque TiNTs on Ti foil, these transparent systems allow better light penetration and more efficient electron–hole generation, making them well-suited for photoelectrochemical and optoelectronic devices such as solar cells and electrochromic coatings. Their main drawback, however, is the limited absorption of visible light resulting from titania's wide band gap ( $\sim 3.2$  eV). Incorporation of secondary metals (e.g., Cu) within the nanotube structure has been shown to extend the absorption edge into the visible region while also enhancing charge separation.

In this work, semitransparent electrodes were fabricated by anodizing co-sputtered Ti–Cu thin films deposited onto ITO-coated glass substrates with varying copper contents, resulting in well-aligned oxide nanotube arrays as observed in the SEM images. Post-anodization annealing in air or hydrogen, combined with different Cu loadings during Ti–Cu film deposition, produced distinct electrochemical responses. SEM and TEM images for the  $\text{H}_2$ -annealed samples revealed a random distribution of Cu nanoparticles with varying sizes, while TEM images further confirmed the presence of copper oxide species within the nanotube matrices for air-annealed samples. Raman analysis confirmed anatase formation, while UV–vis spectroscopy revealed a red-shift of absorption edge and reduced band gap for hydrogen-treated samples. The best performing air-annealed electrode exhibited markedly enhanced capacitive behavior, showing up to 15-fold higher current than the corresponding reference bare titania electrode. In contrast, hydrogen-annealed electrode delivered the highest photoresponse, with photocurrent densities of  $7 \mu\text{A cm}^{-2}$  (UV–vis) and  $3.5 \mu\text{A cm}^{-2}$  (visible),

exceeding the corresponding reference bare titania electrode by factors of five and seven, respectively. Hydrogenated sample containing the highest amount of Cu achieved superior oxygen evolution activity, reaching  $2.18 \text{ mA cm}^{-2}$  at +1.3 V vs. Ag/AgCl/0.1 M KCl. Our findings demonstrate the versatility of Cu-modified titania nanotubes for advanced energy-related applications.

#### **Acknowledgements**

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## Pre-Strain Effects on Yield Surface and Texture Evolution in Ti-Cu Bimetal

Ved Prakash Dubey\*, Mateusz Kopeć, Zbigniew L. Kowalewski

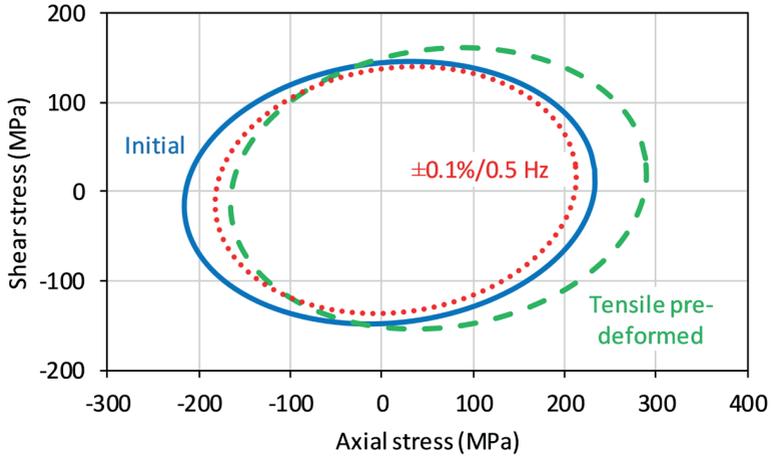
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Bimetallic structures are widely employed in advanced engineering applications due to their ability to combine dissimilar material properties while maintaining cost efficiency. Understanding their deformation mechanisms under complex multiaxial loading is essential for designing reliable structural components. In particular, the characterization of the initial yield surface and its subsequent evolution under different pre-deformation paths is critical to capture the anisotropy, hardening, and softening effects that occur during service conditions [1].

This study investigates the yield surface and texture evolution of Ti–Cu bimetal subjected to controlled monotonic tension and combined tension–cyclic torsion pre-deformation. Yield points were determined using the offset strain method at 0.01% plastic strain, and subsequent yield surfaces were measured following up to 1% permanent axial strain. The initial yield surface was found to closely approximate the isotropic Huber–von Mises–Hencky criterion, confirming the nearly isotropic behavior of the as-received state. However, upon pre-deformation, distinct changes were observed as shown in Figure 1: monotonic tension enhanced the tensile yield strength, while combined tension–torsion loading led to softening. In the axial compression direction, subsequent yield surfaces contracted in size, indicating directional degradation of strength.

Microstructural analyses revealed that shear strain magnitude strongly influenced the activation of slip systems and texture development, particularly in copper, while titanium exhibited more stable grain orientations. These findings highlight that even small pre-deformations can substantially alter yield loci, microstructure, and crystallographic texture in bimetallic systems. Such knowledge supports the development of more accurate constitutive models for functionally graded multi-material systems and guides their application in aerospace, automotive, and structural engineering.



**Figure 1.** Evolution of the initial yield surface of Ti-Cu bimetal due to pre-deformation caused by monotonic tension and monotonic tension assisted by cyclic torsion with strain amplitude of  $\pm 0.1\%$  and at frequency value equal to 0.5 Hz, respectively

### Acknowledgements

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**INTERDISCIPLINARY  
RESEARCH  
IN BIOLOGICAL  
AND MEDICAL  
SCIENCES**

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## Feeding the world – the importance of farm animals for human health and a sustainable food system

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Farm animals have been criticized for being unsustainable, unethical and for not contributing positively to human health. Such claims have mostly come from outside the discipline of agriculture, but they have been able to cement such views despite the fallacy of the claims, not the least due to lack of substantial engagement from scientists in agriculture. A lack of confidence and belief in the value of one's own knowledge has been partly to blame. In Norway, I have been one of the few academics who has argued publicly against such claims. I have learnt from this experience that the knowledge I have is unique and of great value to the society, worthy of being conveyed to the public in various ways such as through books, podcasts and opinion articles.

Farm animals have an important role in providing proteins and essential micronutrients in the diet, and will also potentially prevent obesity through the large satiating effect of lean meats. Thus, a food system without animals will be a less healthy food system. It is often claimed that farm animals eat materials which we can eat directly, thus decreasing the sustainability of the food system. It is true that human-edible food is more sustainable when eaten directly than when passing through an animal. However, close to 90% of the global feed used for farm animals does not have a food value as defined currently. This is due to technical quality considerations such as wheat with too poor baking quality, a low culinary quality such as for barley, or that the residues from the human food production system is used, such as soybean meal or wheat bran. In

addition, feed raw materials such as straw from cereal production and grass are not digestible for humans, and can only become human food through being fed to grazing animals such as sheep or cattle. Thus, a food system without animals would mean a less sustainable food system where more potential food is wasted.

In parallel with a higher focus on animal welfare, a view has become dominant that animals and humans are more similar than earlier thought, and therefore that we have a moral responsibility to treat animals more similar to how we treat our fellow humans. This view fails to take into consideration that animals do not possess the theory of mind-level of thinking required to obtain rights such as ours. Due to lack of ability to reflect upon their own life, they do not necessarily suffer even when confined to closed spaces without windows, as long as their primary requirements for food, water, a comfortable temperature, as well as shelter from danger, fear, and pain due to diseases or painful external events. Viewed in this way, it becomes clear that modern farm animal production systems are mostly well designed – although not perfect – to provide a life to the farm animals that is worth living.

## Adropin and its Role in Controlling Adipose Tissue and Pancreatic Beta Cells – Lessons from *in Vitro* and *in Vivo* Studies

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Adropin is a peptide hormone encoded by the energy homeostasis-associated gene (ENHO). Its biological effects are mediated by activating the G protein-coupled receptor GPR19. Animal and human studies have shown that adropin controls energy homeostasis and metabolism. Growing evidence indicates that circulating adropin levels are inversely correlated with the body mass index in humans. Furthermore, in mice, adropin deficiency is accompanied by impaired insulin sensitivity, while adropin administration or overproduction improves insulin sensitivity and glucose and lipid metabolism. Recently, our group studied the effects of adropin on adipose tissue and pancreatic beta cell functions *in vitro* and *in vivo*. It was found that adropin stimulates proliferation of white and brown rodent preadipocytes and suppresses their differentiation into mature adipocytes.

Furthermore, in differentiated rodent adipocytes, adropin stimulates lipolysis but suppresses lipogenesis. Additionally, in white rodent adipocytes, adropin modulates the expression of the main adipokines: adiponectin, resistin, and visfatin. Studies on rodent pancreatic beta cells and islets indicated that adropin suppresses insulin mRNA expression and secretion. Finally, it was found that in mice with experimentally induced type 2 diabetes mellitus, adropin treatment improves glucose control, attenuates body weight gain, and has beneficial effects on liver functions. In conclusion, these results showed that adropin modulates the functions of adipose tissue and pancreatic beta cells. Thus, it can be considered a promising target in treating obesity and diabetes.

## Somatostatin

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Somatostatin is a key inhibitory peptide hormone that modulates endocrine and exocrine functions throughout the gastrointestinal tract and pancreas. Within the pancreatic islets, it exerts fine-tuned paracrine control over insulin-secreting  $\beta$ -cells and glucagon-producing  $\alpha$ -cells via five G-protein-coupled somatostatin receptor subtypes (SSTR1–5). By suppressing both insulin and glucagon secretion, somatostatin serves as a critical regulator of metabolic homeostasis and glucose dynamics. In physiological states, nutrient ingestion stimulates somatostatin release from  $\delta$ -cells, thereby contributing to the temporal coordination of postprandial hormone release. In type 1 and type 2 diabetes, this regulatory network is disrupted: loss of insulin in type 1 diabetes and impaired somatostatin receptor signaling—particularly SSTR2 internalization—in  $\alpha$ -cells in type 2 diabetes lead to paradoxical hyperglucagonemia and loss of glucose-dependent inhibition. Experimental data in rodents and humans demonstrate that selective modulation of SSTR subtypes can restore intra-islet hormonal balance and improve glycemic control. Somatostatin also interacts with incretin hormones such as GLP-1, linking pancreatic regulation to gastrointestinal feedback loops. Overall, somatostatin represents a central integrative signal maintaining metabolic homeostasis, and its receptor-specific targeting offers potential therapeutic avenues for diabetes and other metabolic disorders.

## Microbiome Beyond Borders – Towards Robust Microbiome Diagnostics and Therapies

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The human gut microbiome is a large and diverse ecosystem of bacteria, archaea and microbial eukaryotes which co-evolved with humans and is important for human health. The importance of the human gut microbiome is well-established and became possible thanks to DNA sequencing. First, by the use of 16S rRNA marker gene sequencing and, at present, thanks to metagenomics sequencing. However, the progress in our understanding of the role of the microbiome, does not go hand in hand with the development of microbiome-derived biomarkers or microbiome-centric therapies.

This is largely due to technical factors which impede drawing robust conclusions from metagenomics data: (1) batch effects coming from experiments on different populations (i.e. the microbiome is population or regio-specific); (2) the structure of taxonomy-based metagenomics data.

To alleviate these problems, we are developing a functional metagenomics approach which goes away from a taxonomy-based analyses of today. The functional potential, describing the possible molecular functions and biochemical pathways which are population independent, unlike taxonomy.

The functional approach is used further to develop machine learning-based microbiome digital twin. The twin learns taxonomic-functional relationships to capture individual's microbiome signatures while maintaining the ability to

predict major phenotypic traits. Our digital twin is able to achieve a state-of-the-art performance in disease prediction on the basis of microbiome sample and basic phenotype information, e.g. age, BMI. In future, we plan on expanding the model to have generative capabilities and test it in clinical settings, so that real microbiome diagnostics and therapies may become more tractable.

## Bio-Enhanced Rock Weathering: Study of the Bio-Chemo-Physical Mechanisms in Fungal-Citric Acid System

Abhijeet Singh

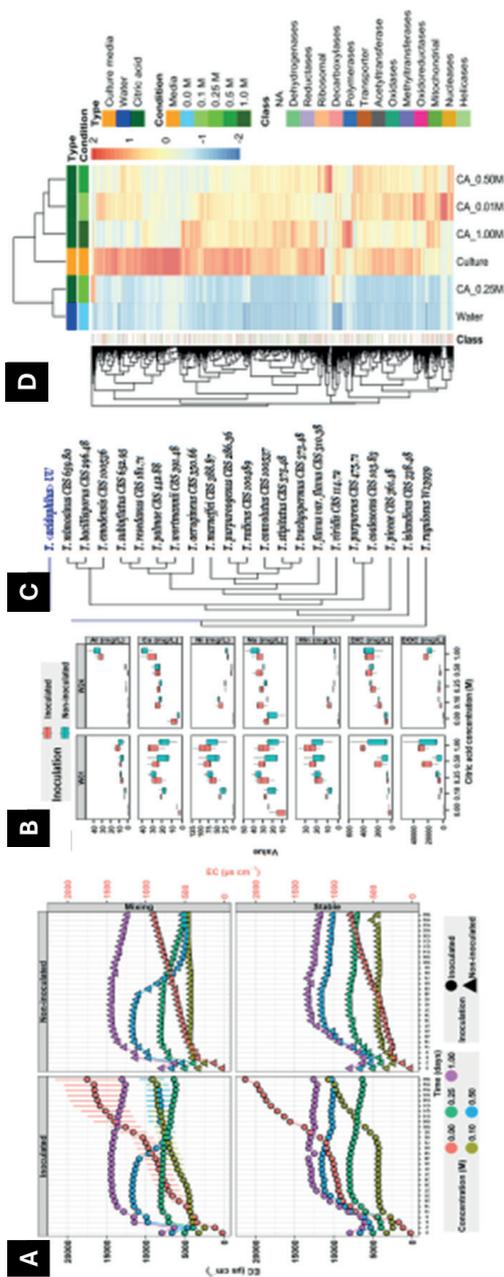
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Enhanced rock weathering (ERW) is getting increased attention as a novel technology for climate change mitigation via carbon dioxide sequestration. The biotic enhancement is of particular importance to increase the rate of rock weathering in natural and artificial processes. In this study, a novel fungal species was isolated and genome sequencing was performed indicating the species belongs to genus *Talaromyces*. In a 24 week long study, the fungi-citric acid system (20 combinations) was used to study the effects of fungal inoculation, different concentrations of citric acid (CA; 0.0, 0.1, 0.25, 0.50, 1.0 M) and mechanical force (shaked, stable) in enhancing the weathering rates of dunite. Molar strength or citric acid has limited impact on the ionic release over 24 weeks / 168 days. Around 93% and 98% enhancement in EC was observed for the deionized water (DI) and 0.1 M CA with inoculation as compared to non-inoculated reactors. More than 130% enhanced EC for DI and 0.1 M CA reactors, respectively, was observed in inoculated stable reactors as compared to non-inoculated mixed reactors. Transcriptomics analysis revealed concentration dependent transcriptome profiles and the expression of Carbonic anhydrase, Urease and other enzymes which are directly connected to the carbon capture pathway. This study provides a crucial insights into the complex mechanism of bio-chemo-physical mechanisms of ERW.

**Figure 1:** Bio-chemical characteristics of ERW system (str. 66)

- A) Electrical conductivity for the dunite-citric acid batch reactor system with fungal inoculation and mixing as experimental treatments over the period of 24 weeks / 168 days.
- B) ICP-MS metal cation and dissolved carbon concentrations,
- C) A 18S rRNA based phylogenetic tree representing the isolated fungi as novel species in genus *Talaromyces*.
- D) Transcriptome expression profile of *Ca. Talaromyces acidophilus* UU in dunite-citric acid batch reactors at different citric acid concentrations along with expression in culture medium.

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## Electrochemical-Lossy Mode Resonance sensing of Dopamine with HaCaT cells

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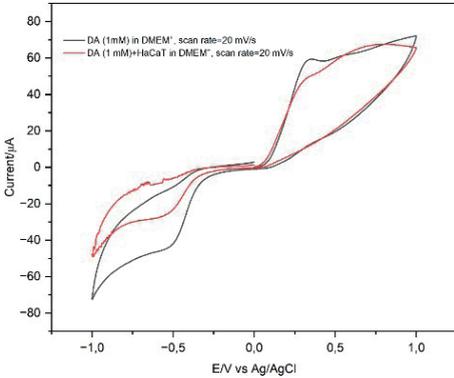
**Introduction:** Manufacturing highly sensitive biosensors is getting crucially important in carcinogenic and neurodegenerative diseases diagnostics. Hopefully, dual-domain sensing devices can provide such an ability. We prepared an Electrochemical-lossy mode resonance (EC-LMR) sensing system to determine Dopamine (DA) as an effective neurotransmitter for high-risk diseases monitoring.

**Materials and Methods:** An ITO covered glass with 265.7 nm thickness as a work electrode, an Ag/AgCl filled in KCl (3 M) solution as a reference electrode and a platinum mesh as a counter electrode were applied in an EC cell connected to an Emstat 4 potentiostat setup. DMEM<sup>+</sup> solution was used as an electrolyte. An Ocean Optics AQ4305 white light source ( $\lambda = 200 - 900$  nm) and an Ocean Optics USB4000 spectrometer collected the LMR data. HaCaT cells with  $1.25 \times 10^5$ /mL concentration are applied. DA was purchased from Sigma-Aldrich.

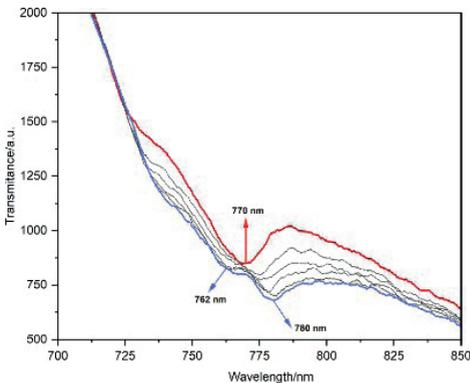
**Results and Discussion:** Simultaneous EC-LMR measurements were performed in 3 consecutive steps:

- In DMEM<sup>+</sup>
- In DMEM<sup>+</sup> + DA (1 mM)
- In DMEM<sup>+</sup> + DA (1 mM) in the presence of HaCaT cells attached to ITO film

Our prepared EC-LMR system showed diverse sensing in these three electrolytes. On Figure 1, cyclic voltammograms (CVs) are consist of two oxidation bands. The band at about 0.5 V for DA (1 mM) has been more pronounced and anodically shifted when DA contacts with HaCaT cells. The interaction between DA and HaCaT cells is strong enough to split out the LMR dip after only 1 hour experiment as it is shown on Figure 2. Scanning CVs in DA solution on the surface of HaCaT covered ITO film was accompanied with anodic shifts



**Figure 1:**  
DA CVs before and after contacting with HaCaT cells



**Figure 2:**  
LMR dip splitting after 1 hour experiment in DA+HaCaT cell

of DA reduction peaks. However, EC-LMR system did not sense any significant changes in pure HaCaT cell. DA sensing itself resulted in 10 nm shift in LMR dip and more intensive dips. Even scanning EC potentials in the pure solvent of DMEM<sup>+</sup> exhibited a more intensive LMR dip after 1 hour experiment. Observed optical changes are the result of variations in refractive index (RI) of ITO film environment. Interestingly, RI changes affected differently on LMR results in three examined electrolytes. Position and visibility changes in CVs of (DA + HaCaT) cell confirms the EC sensitivity of our setting.

**Conclusion:** These initial results are encouraging to obtain a sensitive EC-LMR biosensor to determine DA interactions with the biological cells. This could help to develop dual-domain sensing devices to apply more reliably in diseases diagnostics.

## Decoy EVs: Hype or Hope?

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Extracellular vesicles (EVs) are nanosized membranous particles, including exosomes, ectosomes and apoptotic bodies, released by most cell types. Among them, exosomes (exos, with diameters of 50–150 nm) are particularly attractive as therapeutic carriers due to their biocompatibility, intrinsic stability, low toxicity and minimal immunogenicity. Exosomal surfaces can be engineered by modifying membrane composition, enabling specialized functions, such as acting as decoy receptors. In this study, I proposed an innovative strategy utilizing exosomes derived from CHO-Lec2 cells, which were modified with Functional-Spacer-Lipid (FSL) conjugates, bearing the Gb3 carbohydrate epitope (Gal $\alpha$ 1  $\rightarrow$  4Gal $\beta$ 1  $\rightarrow$  4Glc $\beta$ -R). These engineered vesicles, termed exo-Gb3-FSL, can mimic the natural receptor of Shiga toxins type 1 (Stx1) and 2 (Stx2). Stxs, produced by Shiga toxin-producing *Escherichia coli* (STEC) and *Shigella dysenteriae*, are the key virulence factors responsible for severe food-borne diseases, such as hemorrhagic colitis and hemolytic uremic syndrome (HUS). Their cytotoxic effects are mediated through binding to Gb3, a glycosphingolipid, synthesized by human  $\alpha$ 1,4-galactosyltransferase (A4galt). Given the limited efficacy of antibiotics against Stx-associated infections, there is an urgent need for novel therapeutic approaches. Our findings demonstrate that exo-Gb3-FSL functions as an efficient decoy receptor capable of neutralizing Stx1, highlighting the potential of exosome-based therapeutics as an alternative to conventional treatment. This strategy provides a promising platform for the development of next-generation anti-Stx agents and may open new avenues for combating Stx-related diseases.

### Acknowledgements

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## LEAP2 Modulates Insulin Expression in $\beta$ -Cells and Pancreatic Islets of rat

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Obesity is recognized by the World Health Organization (WHO) as a global epidemic, and hundreds of millions of people suffer from type II diabetes. For this reason, researchers worldwide aim to better understand the mechanisms of obesity development and to produce effective drugs to support its treatment. One promising therapeutic candidate that may support weight loss is hormone LEAP2 (Liver Expressed Antimicrobial Peptide 2), a protein hormone discovered in 2003 and produced mainly by the liver.

In 2018, it was established that LEAP2 acts as an antagonist of the GHSR (Growth Hormone Secretagogue Receptor), blocking its interaction with ghrelin, known as the “hunger hormone”. Current studies suggest that LEAP2 can reduce appetite and stimulate insulin secretion, making it a potential aid in the treatment of obesity and diabetes.

This presentation demonstrates effects of different doses of LEAP2 on the expression of genes associated with energy metabolism. The purpose of these experiments is to better understand properties of LEAP2 by exposing it to cell culture and pancreatic islets in vitro. In addition, a brief overview will be provided of the current knowledge about LEAP2.

To obtain our results we treated various concentrations of LEAP2 (0, 1, 10 and 100nM) under various glucose concentrations to INS1e cell line (rat  $\beta$  cells) and to isolated rat pancreatic islets. After experiments, RNA, protein and medium were collected for further analysis. Changes in mRNA expression were analysed by real time PCR analysis while protein expression changes were measured by western blotting and ELISA. We also evaluated changes in metabolic activity, proliferation and cell survivability with MTT, BrDu and cell death spectrophotometric tests. We used immunofluorescence staining to show location of LEAP2 and related proteins in INS1e cells, islets and pancreas of rat.

Our work discovered, that LEAP2 modulates secretion and expression of insulin on mRNA and protein level depending on concentration of glucose in medium. It also affected genes related to LEAP2 such as GHSR. Spectrophotometric analysis showed no changes for metabolic activity, proliferation and cell survivability after exposing  $\beta$  cells to LEAP2. Immunofluorescence staining confirmed presence of LEAP2 and its receptor – GHSR – in  $\beta$  cells and pancreas.

In summary, LEAP2 may influence insulin secretion, making it a promising candidate as a future therapeutic supporting the treatment of obesity and diabetes. These results provide a base for further in vivo studies in animal models of induced type II diabetes to gain a better understanding of the effects of LEAP2 on the metabolic parameters of this disease.

#### **Acknowledgements**

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## Structure-function characteristics of CemR regulators in *Campylobacter jejuni* and *Arcobacter butzleri*

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**Background and formulation of the problem:** Pathogens of the class *Campylobacter*, including *Helicobacter pylori*, *Campylobacter jejuni*, and *Arcobacter butzleri*, inhabit environments where they are constantly challenged by host-derived reactive oxygen species (ROS). To persist, they rely on redox-sensitive regulatory proteins, also known as a molecular switches, which sense thiol modifications to control stress responses. In *H. pylori*, such regulation is mediated by HpCemR, a protein already established as a thiol-based redox switch. However, the molecular mechanism controlling the activity of their homologous proteins in *C. jejuni* (CjCemR, encoded by Cj1608) and *A. butzleri* (AbCemR, encoded by Abu0127) remain largely unexplored. Deciphering their actual role in oxidative stress response is critical, as redox regulation appears to connect oxidative stress resistance with bacterial survival and possibly virulence, which could have major implications for identifying potential targets to combat these pathogens.

**Main conclusions achieved in a research study:** Our findings reveal that both CjCemR and AbCemR potentially employ cysteine-dependent mechanisms, yet in distinct ways. Results indicated that *in vitro*, cysteine residues in CjCemR were reactive, as demonstrated by significant mass shifts following mPEG (methoxypolyethylene glycol maleimide) thiol trapping. Differences in reactivity between individual mutants suggested different roles of each cysteine in the protein structure-function relationship. CjCemR $\Delta$ 233 mutein (cysteine 233 substituted with alanine) showed an effect on protein-DNA binding similar to that of the CjCemR $\Delta$ Cys mutant, which lacks all cysteines. That indicates that the mutated cysteine residues play a more important role in redox regulation than the CjCemR $\Delta$ 27 and CjCemR $\Delta$ 165 muteins. Experiments confirmed that *in vivo*, diamide (oxidative reagent) partially oxidised cysteine residues in the CjCemR protein. Thiol trapping using mPEG also indicated a probable role of

cysteine 233 in the redox regulation of the CjCemR protein. *In vivo* experiments on *A. butzleri* showed that the cysteine-less AbCemR mutant increased sensitivity to paraquat (oxidant reagent) even more than complete protein deletion, hinting at a dominant-negative effect that blocks alternative defence pathways. *In vitro* analysis of the AbCemR protein revealed that DNA binding by the wild-type AbCemR protein is dependent on the redox state of the protein. The same analyses were performed on the AbCemR $\Delta$ Cys mutant demonstrated that neither reduction nor oxidation had a significant effect on DNA binding when all cysteine residues were absent. This suggests that cysteine residues are likely for the redox regulation of AbCemR. Additionally, structural and biochemical analyses further suggest that specific cysteine residues, such as AbCemR Cys230, may stabilise protein conformation through Zn<sup>2+</sup> coordination, while in *C. jejuni*, redox control does not appear to rely on divalent cations.

The combination of *in vitro* and *in vivo* approaches is essential to fully understand the mechanism by which bacteria defend themselves against oxidative stress. Together, these results position CemR-like proteins as important – yet mechanistically diverse – redox switches across *Campylobacteria*. Whether these thiol-based regulators act merely as guardians of redox balance or integrate oxidative cues into broader cellular decision-making remains an open question that we are now pursuing.

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## Graphene-Oxide–Erlotinib Nanoconjugates Suppress Growth and Angiogenesis in Pancreatic Cancer 2D and 3D Models

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**Background:** Graphene oxide (GO) is a 2D carbon nanomaterial with a large specific surface area, abundant oxygen-containing groups, and  $\pi$ - $\pi$ /hydrogen-bond interactions that enable high drug-loading, aqueous dispersibility, and tunable surface chemistry. These properties make GO a promising carrier to enhance delivery of small-molecule inhibitors. Pancreatic ductal adenocarcinoma (PDAC) shows limited response to EGFR inhibition in the clinic, in part due to poor intratumoral delivery and stromal/vascular barriers. We hypothesized that nano-GO–erlotinib (nGO-Erlo) would enhance intracellular drug delivery, inhibit tumor-cell growth, and concurrently attenuate pro-angiogenic phenotypes that drive PDAC progression.

**Methods:** GO was prepared (modified Hummers), downsized to nano-GO, and surface-activated for covalent conjugation with erlotinib, yielding nGO-Erlo. Two solvent-defined formulations were synthesized (EtOH-based and DMSO-based) and advanced to testing. Hydrodynamic size and dispersity were measured by NanoSight and DLS, while microstructure and elemental maps were obtained by STEM–EDX (HAADF mode). Degree of substitution and dispersion concentration were estimated by UV calibration. Cytotoxicity in PDAC cell lines (MIA PaCa-2, PANC-1, AsPC-1) was quantified by CCK-8 assays. Viability of patient-derived PDAC organoids was assessed separately using the CellTiter 3D assay. To model vascular crosstalk, patient-derived organoids were co-cultured with HUVECs and analyzed by tube-formation metrics (total length, meshes, junctions). Cellular uptake/localization of nGO-Erlo in 3D tissue contexts was

examined by TEM. Appropriate controls (vehicle, GO alone, free erlotinib) and dose–response designs were included.

**Results:** nGO-Erlo produced robust, dose-dependent reductions in viability in all three PDAC cell lines and in patient-derived organoids, outperforming GO alone and matching or exceeding the activity of free erlotinib at equivalent nominal drug doses. In organoid–HUVEC co-cultures, nGO-Erlo significantly decreased tube-formation parameters, indicating anti-angiogenic effects in a tumor-relevant microenvironment. TEM demonstrated intracellular nGO-Erlo within organoid cells, supporting efficient uptake and retention in 3D architectures. Larger apparent sheet sizes reflect superposed nanosheets, with localized hexagonal GO motifs. Formulation effects: DMSO enabled higher substitution and more globular particles, whereas EtOH improved aqueous dispersibility; excessive loading impaired dispersion stability.

**Conclusions:** By coupling erlotinib to nano-GO, we achieve coordinated tumor-cell inhibition and suppression of angiogenic phenotypes in PDAC cell lines and patient-derived organoids, with direct ultrastructural evidence of uptake. These data support nGO-Erlo as a translationally promising EGFR-targeted nanotherapeutic and motivate next steps in in-vivo pharmacology, biodistribution, and safety profiling.

#### Acknowledgements

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## Microstructurization of poly(3,4-ethylenedioxythiophene) films for biosensing applications

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Biosensors are one of the fastest growing branches of biomedicine with market size valued at 27.4 billion USD in 2024 [1]. Among many, detection of cancer biomarkers is specially attractive application of such devices, as it allows a quick and early diagnosis. Moreover, biosensors are affordable and easy to handle, which is another advantage compared with traditional methods of cancer diagnosis. Efforts toward a better understanding and developing of biosensors are needed as cancer is the second main cause of death worldwide and according to WHO estimation the number of cases will continuously increase in the near future.

Microstructurization of biosensors' surface has recently gained a lot of attention as a method to increase their sensitivity and selectivity [2], [3], [4]. Many approaches are used to create favourable patterns on the surface with the aim to increase the electroactive area, immobilize specific compounds or achieve better stability. In this work, a simple method was used for the creation of microcavities in poly(3,4-ethylenedioxythiophene) [PEDOT] films deposited on indium tin oxide (ITO) electrode by the use of polystyrene beads as templates. Microscopic analysis, including Scanning Electrochemical Microscopy and Atomic Force Microscopy, was performed to prove the presence of microcavities and estimate their size. Later, electrochemical response of selected redox mediators was studied, including ferrocene, potassium ferrocyanide, methylene blue and 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic) acid. The results showed that the formation of cavities allows to selectively expose ITO surface and increase the oxidation and reduction currents for most of the redox compounds. Great advantage of the proposed method is a possibility to modulate the size of cavities to induce selectivity of biosensing. Moreover, microcavities in PEDOT films may find other applications, not only in field of biosensing, e.g. in batteries and supercapacitors fabrication, drug delivery or microscopic monitoring of electrochemical reactions.

### Acknowledgements

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## Connecting Wearables, Caregivers and Clinics with Explainable AI

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Cardiovascular disease (CVD) is the leading cause of death among older adults in Poland. In 2023, almost 40% of all deaths in seniors were due to CVD, and the Łódzkie Voivodeship recorded the highest mortality rate among older adults in the country (*GUS, Sytuacja osób starszych w Polsce w 2023 roku*). Local epidemiology, environmental conditions, lifestyle patterns and resource constraints create region-specific risk signs that limit the effectiveness of one-size-fits-all automated solutions. Solving this problem needs more than good AI prediction models, as we also need systems that consider the local population, the way doctors and nurses actually work, and the network of family and paid caregivers who look after patients.

This abstract presents the motivation, local data foundation and anticipated impact of an explainable, patient-centered AI system we aim to develop for older adults in Łódź. Through a partnership with HRP Care Sp. z o.o., anonymized telemonitoring data for 2,000+ local seniors (continuous heart-rate/ECG segments, activity and sleep traces, and socio-demographic information) will provide the empirical basis for a solution tailored to the city's needs. Figure 1 shows the System Interaction Diagram. The AI is envisioned as a bridge: it would connect the wearable band, telecarers, on-site acquaintances/caregivers and clinicians. The system is designed to send prioritized, filtered alerts and give short, patient-level explanations so carers and doctors can quickly understand what the AI has detected.

Our main idea is a system designed to be explainable, clinically useful and practical for triage. Expected benefits include earlier detection of unusual changes from a person's own baseline, clearer explanations that help clinicians understand the problem faster, and fewer false alarms for caregivers. This approach could help clinicians focus on the most urgent patients and improve triage where medical staff are limited. In summary, we believe that an interpretable

AI system trained on local data and connected to existing care networks has the potential to help detect problems earlier and make care coordination for Łódź's seniors more effective.

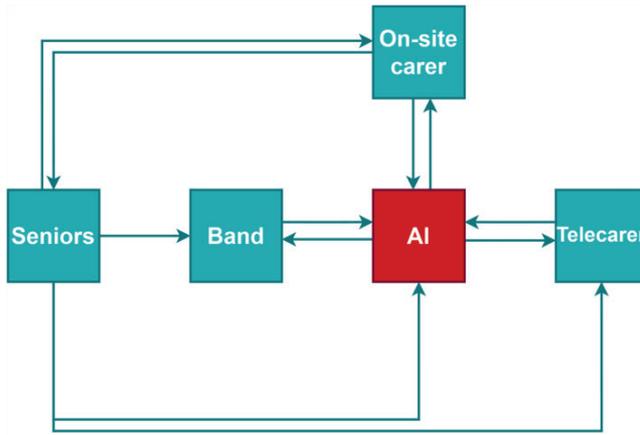
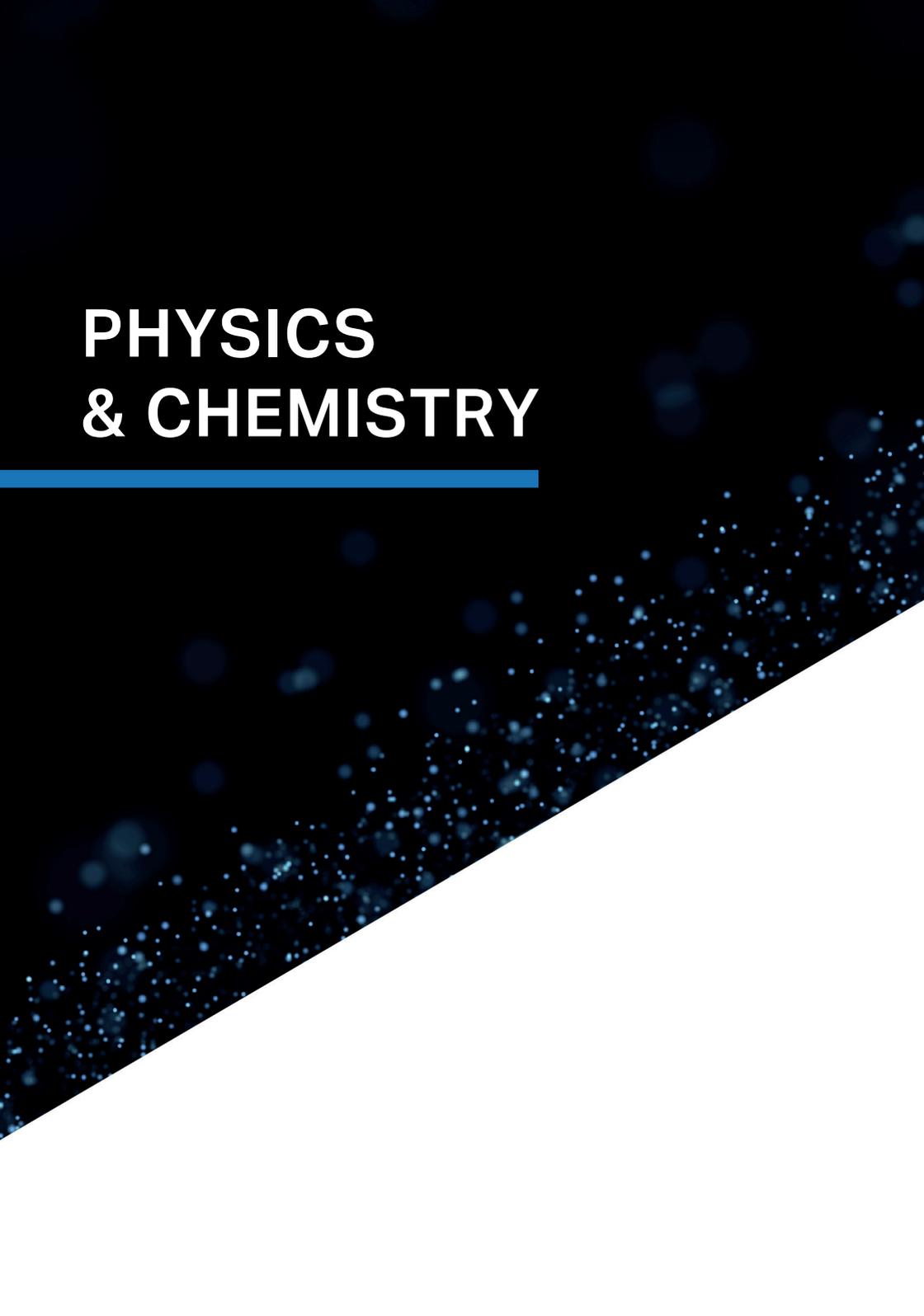


Figure 1: System Interaction Diagram

# PHYSICS & CHEMISTRY

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## Block Copolymers: Promising Materials for Biomedical Applications

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Block copolymers composed of two different segments have become increasingly important in biomedical research. Using the reversible addition–fragmentation chain-transfer (RAFT) method, these polymers can be synthesized with high precision. Double hydrophilic block copolymers (DHBCs) and amphiphilic block copolymers will be presented. DHBCs can be combined with inorganic materials to create hybrid systems, offering a promising alternative to conventional contrast agents used in magnetic resonance imaging (MRI). Amphiphilic block copolymers, on the other hand, can be designed with lipid-like components that interact with cell membranes, making them useful for advanced drug delivery applications.

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## Nanotechnology at the interface of medicine and environment: functional applications of SPIONs

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Nanotechnology plays an important role in modern science. It enables designing of nanoparticles and nanocomposites with tunable physicochemical properties to make them valuable in various fields including medicine and environmental applications. In nanomedicine, their small size, large surface area, and ease of functionalization make them functional as effective theranostic agents, integrating diagnostic and therapeutic functions on a molecular level. Among many different nanomaterials the superparamagnetic iron oxide nanoparticles (SPIONs) exemplify this potential to be used in theranostics. Their unique magnetic properties enable facile and precise drug delivery, real-time imaging with magnetic resonance imaging, and localized mild hyperthermia under alternating magnetic fields. Additionally, SPIONs can be coated with various biologically active compounds like cytostatic drugs, photoactive molecules for photodynamic therapy, or biocompatible polymers that enhance colloidal stability and enable controlled drug release. Depending on the compounds to be used as the shell that coats SPIONs, the SPION-based hybrid offers multifunctionality that can improve the treatment efficacy with reduction of the side effects.

Beyond healthcare, the physicochemical characteristics of SPION-based nanomaterials extends to environmental applications. These nanoparticles occur high reactivity and depending on the outer shell they can bind various chemicals making them attractive for water pollution treatment including emerging

contaminants removal through adsorption and degradation of organic compounds through photocatalysis, as well as sensing of hazardous substances. Incorporation of SPIONs into composite can enhance the effectiveness of the water pollution removal and facilitate the adsorbent/photocatalyst with magnetic separation.

By combining tunable functionality with responsiveness to external stimuli, nanoparticles—especially SPIONs – provide sustainable solutions for different applications to deal with medicine and environmental challenges.

## Anomalous Transport Phenomena Driven by Active Fluctuations

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Transport processes in complex systems are often driven by fluctuations that deviate from thermal noise. In biological environments and soft matter systems active fluctuations originating from energy-consuming processes are inherently nonequilibrium, which implies that they are not constrained by fundamental laws of physics, like the fluctuation-dissipation theorem or detailed balance symmetry. As a consequence they keep the system permanently out of equilibrium even in the absence of external perturbations. Solely this feature opens a new landscape of phenomena that, to a large extent, still remains a *terra incognita*. Understanding the role of active fluctuations in living matter is emerging as a hot topic and a major challenge for physics. In this talk I will briefly discuss recent progress in comprehension of anomalous transport phenomena driven by active fluctuations.

## Modeling of Hard Magnetic Materials Using DFT

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The best permanent magnets in use today contain neodymium or samarium. These elements belong to the group of rare earth metals, whose availability is limited and prices are variable and relatively high. Therefore, for many years, new promising hard magnetic materials that do not contain rare earth metals have been sought. The experimental work carried out in this area is supported by density functional theory (DFT) calculations. This presentation will focus on a theoretical approach to the problem.

The DFT calculations we carry out in our group allow us to both interpret experimental results and point out paths of exploration for new materials. Magnetization, Curie temperature, and magnetocrystalline anisotropy energy – the three characteristic intrinsic properties of magnetically hard materials – are available from density functional theory (DFT) calculations. In this presentation I will discuss the possibilities and limitations of determining the above parameters with DFT. In addition, I will present the most interesting results of my calculations for magnetically hard materials obtained over the past few years.

I will start with the determination of structural parameters (lattice parameters, atomic positions, symmetry groups), formation energies and modeling of chemical disorder using the supercell method and the virtual crystal approximation. I will discuss the possibility of modeling tetragonal, hexagonal and orthorhombic systems. I will present the possibility of modeling the full ranges of pseudo-binary systems and other example calculation results.

I will show what effect the choice of exchange-correlation potential has on the MAE, and how the MAE is related to the magnetic moment, which can be determined by fully relativistic fixed spin moment calculations. The above method also makes it possible to translate changes in magnetic moment values into changes in temperature, and thus obtain the often unintuitive temperature dependence of MAE. I will also present the results of systematic calculations of the change in Curie temperature as a function of concentration and dopant element.

In summary, a number of structural and magnetic properties of magnetically hard materials are available through first-principles calculations. Recognizing the potential and limitations of DFT methods will allow for better collaboration between theoretical and experimental groups searching for new permanent magnets.

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## Metal-Organic-Framework Integrated Electrodes as Electrochemical Biosensors for Early Sepsis Detection

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Metal–organic frameworks (MOFs) are three-dimensional porous structures composed of metal clusters and organic linkers, distinguished by high conductivity, large surface area, and tunable functionality. Owing to these features, MOFs have gained increasing attention in the design of electrochemical biosensors, which provide rapid, sensitive, and cost-effective detection of disease biomarkers, including those relevant to sepsis. Sepsis is a dysregulated and rapidly progressing immune response to infection. Its early symptoms are often nonspecific, making timely diagnosis challenging. Furthermore, conventional diagnostic methods are time-consuming, which may delay clinical intervention and worsen patient outcomes. Therefore, the development of new sensing strategies enabling fast and sensitive quantification of sepsis biomarkers in patient blood remains of critical importance.

In this study, we report the fabrication of a layered electrochemical biosensor based on the UiO-68 MOF for early detection of C-reactive protein (CRP), a well-established biomarker of sepsis. The electrode was modified with conductive MXene ( $\text{Ti}_3\text{C}_2\text{T}_x$ ), followed by immobilization of an anti-CRP antibody ( $\text{Ab}_1$ ). A secondary antibody ( $\text{Ab}_2$ ) was conjugated to a functionalized UiO-68 ligand, enabling the formation of an MOF– $\text{Ab}_2$  complex. In the presence of CRP, sequential binding to  $\text{Ab}_1$  and attachment of the MOF– $\text{Ab}_2$  complex occurred, significantly enhancing detection sensitivity and specificity.

The applied materials were subjected to structural and crystallographic characterization, confirming the successful integration of MOF and MXene components. Electrochemical studies demonstrated high electrode stability and enabled optimization of incubation parameters. Kinetic analysis using the Laviron method provided further insight into the electron transfer processes. Differential pulse voltammetry revealed a wide linear detection range for CRP

( $0.586\text{--}46.88\text{ ng}\cdot\text{mL}^{-1}$ ). These findings demonstrate the potential of MOF-based layered biosensors as a robust and highly sensitive platform for the rapid diagnosis of sepsis.

### Acknowledgments

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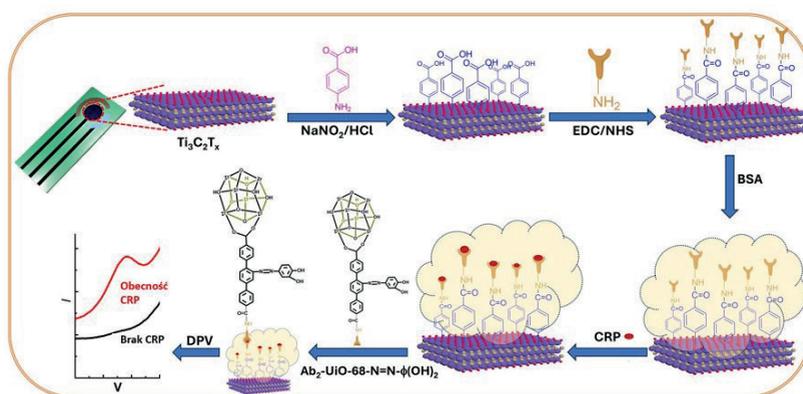


Figure1. Schematic presentation of sensor preparation

## Poly(Vinyl Alcohol)/Poly(L-Lysine)-Functionalised Urinary Catheters with Potential Antibacterial and Antifungal Effects

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Catheter-associated urinary tract infections (CAUTI) have placed tremendous stress on the healthcare sector, which has threatened public health and the economy considerably. Approximately 1 million CAUTIs annually contribute 80% of nosocomial UTIs. In our study, we decided to modify the catheter surface with coatings of poly(vinyl alcohol) and poly-L-lysine (PVA/PLL). Urinary catheter's surface was coated with PVA/PLL using the ultrasonic coating technique, which provides durable, uniform films on both flat and tubular surfaces of catheters. The surface characterization of the PVA/PLL-modified catheter was performed using scanning electron microscopy, energy-dispersive X-ray spectroscopy, and Fourier-transform infrared spectroscopy. The modified catheter showed biocompatibility towards normal human dermal fibroblast cells. The antimicrobial tests showed that the catheter significantly reduced the growth of *Escherichia coli*, *Staphylococcus epidermidis*, and *Candida albicans*. Membrane docking results showed that PLL binds with two membrane adhesins of *E coli* such as FimH and PapG which helps in colonization and biofilm formation. These results provide a solid framework and lay the foundation for future research for the development of advanced anti-microbial catheter coatings including controlled release that could significantly curb catheter-related microbial infections.

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## Anion Transport in Biologically Relevant Lipid Mixtures

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Targeted anion transporters, designed to localize to specific organelle membranes within the cell, can interfere with autophagy or trigger controlled apoptotic pathways by perturbing cellular proton or chloride concentrations, offering a novel approach to cancer therapies [1]. However, each type of organelle membrane is comprised of a unique lipid makeup, which may interact differently with anionophores. It is crucial, therefore, to investigate whether the lipid composition of various organelles has an influence on anion transport activity. The activity of a squaramide-based anion transporter was used to evaluate biomimetic vesicles that resemble organelle membranes with tailored lipid compositions [2]. HPTS and ISE-based assays revealed a dynamic relationship between 3-*sn*-phosphatidyl-ethanolamine (POPE) concentration and anion transport efficiency, where POPE appears to act as a “fatty base” proton transporter while also modulating membrane crystallinity. Our studies provide insights into the role of lipid composition on anion transport and establish a foundation for a suite of biomimetic vesicles (Figure 1) that can be used to more accurately mimic cellular and sub-cellular membrane environments.

### Acknowledgments

This work was supported by the Polish National Agency for Academic Exchange within the Bekker fellowship (BPN/BEK/2023/1/00203) for K.M.-J.

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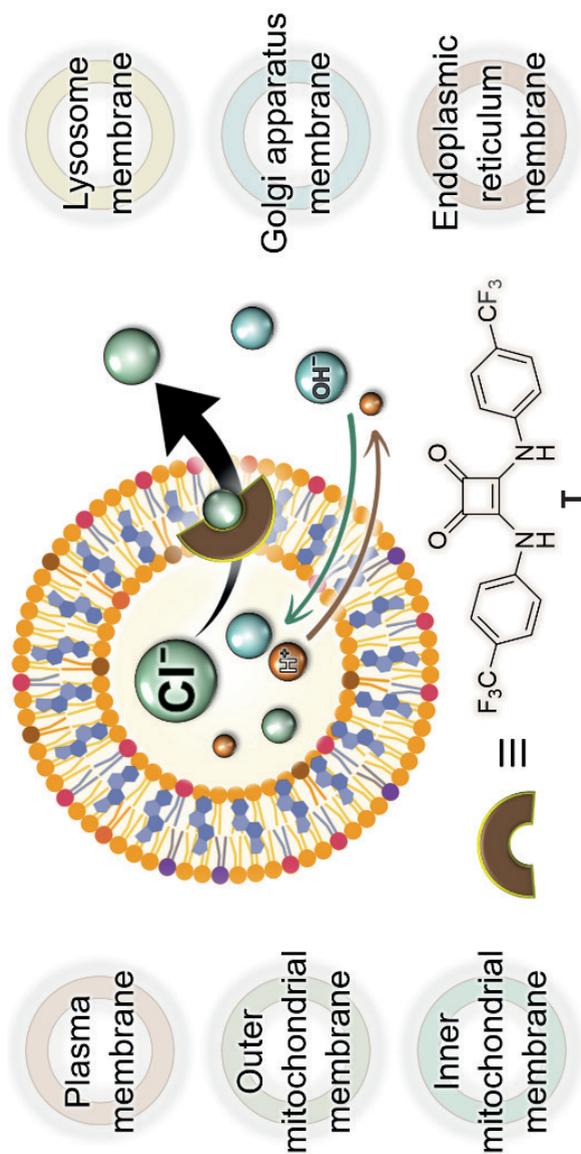


Figure 1. Transmembrane transport of chloride anions by squaramide-based transporter **T** depends on the lipid composition of biomimetic subcellular vesicles

## Nanographene in Hydrogels: Impact on Matrix Properties

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Hydrogels represent a class of biomaterials capable of absorbing significant amounts of water or biological fluids in reversible manner. Their three-dimensional network structure resembles natural tissue, which makes them highly relevant for biomedical applications. Hydrogel matrices can be chemically or physically modified to incorporate bioactive compounds of both natural and synthetic origin, enabling the design of advanced therapeutic systems. The objective of this study was to develop and characterize hydrogel matrices incorporating graphene oxide (GO). Graphene oxide, a two-dimensional nanomaterial consisting of single layers of sp<sup>2</sup>-hybridized carbon atoms, locally containing sp<sup>3</sup>-hybridized carbon atoms and oxygen-containing functional groups. Its combination of large surface area, mechanical strength and chemical stability provides a versatile platform for subsequent modification [1]. GO was introduced into matrices composed of sodium alginate and aloe vera extract. Hydrogels enriched with graphene oxide nanodispersion were evaluated for cytotoxicity testing, which was carried out in collaboration with the University of Silesia using normal human dermal fibroblasts (NHDF), to determine the safe concentration range of GO within the matrix. Additionally, physicochemical characterization was conducted, including swelling tests and gel fraction measurements, as well as FT-IR and SEM analyses. The findings revealed that incorporation of graphene oxide nanodispersion at a concentration of 0.83% v/v reduced the swelling capacity of the hydrogels. Structural analysis confirmed the presence of characteristic functional groups, with GO enhancing hydrogen-bonding interactions. SEM imaging further demonstrated the porous morphology of the obtained materials. Collectively, these results highlight the potential of GO-modified hydrogels and provide a basis for their continued investigation in biomedical contexts.

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## New 1,3,5-Triazine Derivatives with Potential Cholinesterase Inhibitory Activity

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Cholinesterase inhibitors play a major role in the treatment of Alzheimer's disease (AD). According to the *cholinergic hypothesis*, cognitive decline – one of the main symptoms of AD – may result from the degradation of acetylcholine by acetylcholinesterase (AChE) and butyrylcholinesterase (BuChE) [1, 2]. Currently, the treatment of this disease relies on four FDA-approved drugs: donepezil, galantamine, rivastigmine and memantine, with the first three acting as cholinesterase inhibitors [2]. However, these agents only alleviate symptoms and do not cure AD, which causes the demand for further development of effective AD treatment [2].

In recent years, numerous studies have investigated the activity of 1,3,5-triazine derivatives towards AChE and BuChE inhibition [2, 3, 4]. Some of the analyzed compounds demonstrated significant inhibitory properties, which indicates the potential of 1,3,5-triazines in the search for new drug candidates for AD [3, 4].

The aim of this research was to synthesize a series of compounds structurally based on tryptamine-1,3,5-triazine scaffold, potentially exhibiting acetylcholinesterase and/or butyrylcholinesterase inhibitory activity. The compounds were obtained through a three-step protocol, with the final stage performed under microwave irradiation, providing a more environmentally friendly alternative compared to conventional methods used for the synthesis of 1,3,5-triazine derivatives [5, 6]. All designed compounds were successfully synthesized, with the majority obtained in yields exceeding 50% and purity levels above 97%. Subsequently, *in silico* screening was conducted to predict ADME (absorption, distribution, metabolism, excretion) parameters. The evaluation of compliance with Lipinski's Rule of Five and Veber's Rules showed that all synthesized derivatives meet at least three of the four Lipinski criteria and both Veber criteria, highlighting their suitability as orally available drug candidates [7]. Obtained compounds will

undergo further biological evaluation to assess their inhibitory activity against acetylcholinesterase and butyrylcholinesterase.

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## Enhanced Polyhydroxyalkanoate (PHA) Biosynthesis; Bioreaction Design and Process Optimization

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Polyhydroxyalkanoates (PHAs) are biologically synthesized, biodegradable polymers with great application potential as replacement to fossil-based polymers. Their commercialization currently faces hindrances due to their capital-intensive biosynthesis and the high demand for lignocellulosic resources for various applications in today's emerging global bioeconomy.

Recent developments in PHA biosynthesis are focused on exploring waste and other non-food competitive substrates targeted at reducing the raw material cost component in the total PHA production cost. The HELVA project (<https://helva.eu/>), explores the electrosynthesis of acetate from anthropogenic carbon dioxide (CO<sub>2</sub>) alongside green extraction techniques to achieve optimal and improved PHA biosynthesis.

This study explores enhanced PHA biosynthesis through an optimized bioprocess using a green, low-cost and non-food competitive substrate, sodium acetate. Taguchi Orthogonal method was employed in the modeling and the performance of PHA biosynthesis using *Escherichia coli* DH5<sup>-</sup>, *Cupriavidus* sp. and *Pseudomonas* sp. LBFC01 with sodium acetate. Optimized operating conditions effectively reduced reaction time by 48 h for low sodium acetate concentrations ( $\leq 5$  g/L) and 24 h for  $\geq 10$  g/L for all strains used, while maintaining yields (29.5%) and minimizing energy cost. The scalability of the established optimal conditions was verified through the gradual upscaling of the bioreaction across 250 mL, 500 mL, and 1L shake flasks, and 5L Minifors 2 bioreactor. The biosynthesized PHA was confirmed as poly(3-hydroxyalkanoate-co-3-hydroxyvalerates) (PHBVs) for all

three strains, depicting competitive structural similarities to conventional fossil-derived polymers and conducive thermal properties;  $T_g$  (21–32°C) and  $T_m$  (162–170°C) suitable for industrial applications. Further process optimization and upscaling with material testing is currently ongoing to explore their application as drug delivery systems and for tissue engineering.

**Keywords:** Polyhydroxyalkanoates (PHAs), Carbon dioxide (CO<sub>2</sub>), Sodium acetate, Bioprocess optimization, Microbial strains.

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# INTERDISCIPLINARY RESEARCH IN HUMAN SCIENCES



## Foreign-accented speakers – not always discriminated against? Evidence from Poland and the UK

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Language is our everyday medium of communication. When we hear someone speak, we notice not only what they say, but also how they say it. A foreign accent is a powerful signal that can shape how speakers are perceived and how they are treated. While many studies conducted in the US and other Western countries show that foreign-accented speakers are often seen as less competent or less suitable in professional settings, very little is known about how this plays out in other countries and in languages that are not known worldwide and taught as main foreign languages. To address this gap, we studied this phenomenon in Poland and compared the results to the situation in the UK.

We conducted an online experiment on a relatively large, demographically diverse sample (N = 698). Half of the participants were from Poland, half from the UK. They all listened to recordings of speakers with a strong and weak non-native accent in their respective languages. We expected that the disadvantage associated with speaking with a strong accent would be greater in the UK than in Poland, especially for measures of competence and hireability. We also expected levels of discrimination to be shaped by factors such as contact with foreigners and the perceived status of the local language. Our expectations were only partly confirmed. The disadvantage of speaking with a strong accent was similar in Poland and the UK when it comes to competence and hireability, but

UK participants discriminated more strongly than Polish participants in judgments of subjective comprehension and language level of the speaker.

Participants in the UK reported more contact with immigrants, higher status of their language, and weaker second language skills, but expectations of immigrants' language ability were similar in both countries. Of these measures, two played a role for evaluations: contact and language expectations. Poles with more contact with immigrants evaluated strongly accented speakers better than those with less contact. Furthermore, Brits who expected a higher language level from immigrants evaluated strongly accented speakers worse.

These results show that the social context can shape how foreign-accented speakers are judged. Potentially, these evaluations can change over time as social and political contexts in societies are changing. Further research is needed to understand these cultural differences and their shifts over time. This understanding would help in designing strategies to reduce language-based discrimination.

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## Reseaching/ Writing Differently

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The academic community is becoming increasingly aware of the fact that, due to a number of obstacles and issues, we are more and more writing for the statistics or metrics, and less and less for the readers. Our writing has become formulaic and devoid of meaning.

As a community reaction to this unsettling trend there recently emerged a new turn – of *writing differently*, which is rapidly gaining momentum. The academic discourse is revived by the vibrant yet still marginal turn. Its roots are to be found in feminist writing which has been drawing attention to the non-linear and personal. One of the founding mothers, Heather Höpfl, used to say that the social, the organizational, the political is always personal and a social science that does not resonate with the personal is meaningless. To write differently, academic authors need to embrace alterity and complexity, and to reject reductionism. It is a kind of writing that involves the personal and the experiential, and that is intended to be read by the yet unknown Other – the Reader. As an author's guiding star this idea, judged by the rapid development of the turn, works very well. However, there are practicalities that need to be acknowledged and addressed if an author wants to dedicate and improve herself in the craft (and perhaps also art) of writing differently, such as: how to make an argument and not slide into reductionism? How to engage with literature and why? How to

describe important issues such as empirical research and insights? Can academic writing be done in a meaningful way?

This presentation intends to engage with these questions and to shed some light on some aspects of writing differently.

## Early Maps in Modern World: Digital Editions of Cartographic Historical Sources

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Early maps, once bound to archives and often associated with poor facsimiles, are increasingly reborn as dynamic digital editions that connect material heritage with modern geospatial and historical scholarship. This presentation explores how digital methods redefine the critical editing of cartographic sources, tracing a methodological evolution from analogue reproductions to interactive, data-driven editions. Drawing upon recent works the talk outlines a conceptual framework for the “model digital edition” of historic maps encompassing the critical digital representation of a map. Such editions combine four essential layers: the digital facsimile, georeferenced map, spatial database, and comprehensive editorial commentary. These components transform a map from a static image into an interoperable research environment, supporting both historical and geographical analyses. The presentation situates these developments within broader debates on authenticity, metadata standardization, and interoperability between digital humanities (“modelling of”) and history of cartography (“modelling for”). By examining cases where incomplete, uncertain or vague sources are digitally re-contextualized, it highlights how editorial interpretation and technical design together construct new forms of historical evidence. Ultimately, I would like to argue that digital editions do not merely preserve old maps but re-activate them as critical instruments for understanding the social, political, and spatial imagination of the past – bridging the gap between early modern cartography and twenty-first-century digital scholarship.

## Adapting Global Supply Chains in Poland and Europe to Military Shocks Through Business Relocation

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Armed conflicts have become one of the main geopolitical risks for global trade today. These risks are further increased by other forms of international tensions, such as trade wars, sanctions, and growing protectionism. Political instability often leads to disruptions in global supply chains, increases uncertainty in financial markets, and deters investors. Like ordinary people, investors tend to flee crises and barriers by relocating assets and fragmenting supply chains. Has Poland become a “safe haven” for entrepreneurs migrating from neighboring eastern countries?

Accordingly, this study focuses on the following research problem: What is the impact of entrepreneurs relocating from war-affected countries on the configuration of global supply chains in Europe? Has Poland managed to adapt to military shocks better than other European countries after three years of full-scale war between Russia and Ukraine?

This work lies at the intersection of several research fields: supply chain management, transportation, economic geography, international business, and migration economics. While each of these areas has addressed military conflict and its effects to some extent, the link between war, business relocation, and their influence on supply chains remains significantly underexplored.

The research shows that although Poland accepted a large number of refugees at the beginning of the war, this alone was not enough to ensure that relocated capital remained in the country or that the foreign trade activity of businesses increased more than in other European nations. Poland is among the countries that performed significantly better than the EU average during the war. However, it did not rank among the top ten European countries that benefited most from supply chain reconfiguration.

In terms of foreign direct investment and overall economic growth, Poland ranked higher, but still failed to break into the top five. Among the reasons for

these shortcomings are insufficient incentives for relocating foreign professionals, including challenges related to visa issuance. Furthermore, the surge in foreign investment occurred as early as 2021—before the war began—as the inflow of Ukrainians and Belarusians had started earlier, driven by other circumstances.

## Knowledge Alchemy in Global Projects: Transforming Tacit Insights into Explicit Capacity across Borders

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Global projects, especially in IT and transformation sectors, increasingly operate across national, cultural, and organizational boundaries. They involve distributed teams working in multiple time zones and require integrating diverse client expectations. In such contexts, knowledge becomes the most critical resource. While explicit knowledge can be documented and transferred relatively easily, tacit knowledge—rooted in personal experience, intuition, and local practices—often remains unspoken. The failure to capture and transfer this tacit dimension undermines trust, complicates collaboration, and frequently results in delays, cost overruns, and weakened project outcomes. Although theoretical models such as Nonaka’s SECI framework emphasize the transformation of tacit into explicit knowledge, empirical studies highlight persistent barriers that prevent organizations from realizing this potential in practice.

Despite extensive scholarship on knowledge management, less attention has been given to *how knowledge imbalances materialize in global, cross-border projects* and what mechanisms make tacit insights particularly difficult to integrate. This research addresses the question: *Which mechanisms limit effective knowledge transfer in international projects, and how can tacit insights be transformed into explicit organizational capacity that enhances project success?*

The study follows an interpretive, qualitative research design. A case study of global IT projects carried out by Company X was conducted, combining three data sources: (1) review of project documentation and internal records, (2) participant observation of project planning and implementation processes, and (3) sixteen semi-structured interviews with diverse project participants, including project and program managers, solution architects, subject matter experts, engineers, and consultants. The data were analyzed through open and axial coding to identify patterns of knowledge gaps. Additionally, fault-tree analysis was applied to trace root causes of schedule failures and to visualize how small deficiencies in knowledge transfer escalated into systemic project delays.

The analysis revealed three recurring categories of knowledge barriers:

1. **Client explicit knowledge withheld** during bidding and contracting stages, leading to incomplete or unrealistic project specifications.
2. **Internal knowledge not adequately transferred** between phases due to fragmented documentation, lack of shared repositories, and high turnover of project team members.
3. **Non-explicit knowledge unrecognized** by both client and provider—especially local operational practices or undocumented routines—resulting in costly rework and misaligned solutions.

These barriers were particularly damaging in the early project phases, when misunderstandings and incomplete requirements set trajectories that later proved difficult to correct. The findings confirm that balancing tacit and explicit knowledge is not merely a technical matter of documentation but a **social process** requiring trust, structured communication, and organizational routines that encourage informal insights to be systematically shared.

For theory, this study extends the application of knowledge management frameworks to the interdisciplinary domain of human sciences, showing how cultural, social, and organizational practices shape knowledge flows in global projects. For practice, it suggests concrete measures: introducing standardized procedures for identifying knowledge gaps, integrating reflective workshops into project lifecycles, and establishing digital repositories that capture not only formal data but also experiential narratives. By institutionalizing these practices, organizations can improve collaboration, reduce risks, and significantly increase the effectiveness of cross-border projects.

**Keywords:** tacit knowledge, explicit knowledge, knowledge transfer, project management, cross-border collaboration

## The State of Digital Health Technologies in Pakistan; Analyzing Adoption Drivers, Affordability Challenges, and Barriers to Widespread Utilization among the Local Population

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Digital health technologies have the potential to revolutionize healthcare delivery in developing countries like Pakistan, yet their adoption remains limited. The present study examined the current state of digital health technologies in Pakistan, focused on factors influencing their affordability and adoption, and identifying the main barriers to their widespread use. The research problem stems from the gap between the growing availability of digital health solutions and their relatively low utilization among the population. A descriptive analytical approach was employed to assess adoption rates, affordability, and public perceptions of digital health technologies. Data were collected from sixty patients and analyzed on variables such as costs, infrastructure, digital literacy, and cultural resistance. The results revealed that while digital health technologies are viewed positively, adoption levels remain low due to high costs, inadequate infrastructure, and limited digital literacy. However, there is a strong willingness among individuals to adopt these technologies if affordability and accessibility improve. The study concluded that targeted policy interventions, capacity-building initiatives to enhance digital literacy, and culturally sensitive awareness programs are essential to improve adoption. Addressing affordability and data privacy concerns can further strengthen public trust and utilization. The research contributes to the growing literature on digital health in low- and middle-income countries by providing context-specific insights from Pakistan and offering practical recommendations for policymakers, healthcare providers, and technology developers.

**Keywords:** Adoption, Affordability, Digital Health Technologies, Barriers, Utilization, Perception, Pakistan.

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## Shifting Grounds: How Technological Change Reshapes Global Labour Migration

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This research examines how technological change influences international labour migration by altering the structure of labour demand across countries. While migration models have considered wages, demographics, and institutions, the role of technology has remained under-theorized and empirically underexplored. Automation, digitalization, and artificial intelligence are transforming skill demand by raising the premium on high-skilled labour while reducing opportunities for routine-intensive work, thereby conditioning both the scale and the composition of global migration flows.

To test this, I construct a panel dataset that links migration inflows, outflows, and stocks with indicators of national technological development, including ICT adoption, R&D intensity, and measures of AI diffusion. A gravity model with country-year fixed effects is employed to estimate the impact of technological factors on migration dynamics, disaggregated by skill level. The analysis is expected to show that technologically advanced economies attract more high-skilled migrants while reducing reliance on low-skilled labour, whereas economies with limited technological adoption experience persistent outflows of both. By systematically integrating technological indicators into migration economics, this research extends theoretical models of labour migration to account for structural technological change and provides empirical evidence on how technology shapes skill-selective migration. The findings also offer concrete implications for policies addressing labour shortages, demographic decline, and the governance of migration in the context of rapid digital transformation.

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