IS2M annual meetings

Biomimetic systems and bioinspired materials across scales

Conference Handbook

Faculté des Sciences et Techniques
Université de Haute-Alsace, Mulhouse, France
01-02 June 2023

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IS2M Annual Meetings

Each year, IS2M organizes its own scientific meeting and invites the entire scientific community of EUCOR space to share their knowledge on topics of interest. This annual meeting bring together an average of 100 students, academicians, researchers, and industrialists. An artist is systematically invited to illustrate the theme of the meeting with a work of art and lead a reflection in the field of art and science.

2023 Theme:

BIOMIMETIC SYSTEMS AND BIOINSPIRED MATERIALS ACROSS SCALES

Humans have always tried to replicate biological systems. The flying machine designed by Leonardo da Vinci, inspired by the flight of birds, is a classic example of biomimicry.

Constant progress in science has resulted in knowledge and skills that enable us to develop technologies that go far beyond mimicking nature. Superhydrophobic materials, nano-swimming machines, human organoids, and artificial intelligence are just a few examples of modern biomimetics.

On the other hand, Humans have severely damaged ecosystems through industrialization and resource exploitation, causing global climate change and biodiversity decline.

At this conference, we will look at a wide range of concepts and technological advances inspired by the living world, ranging from molecular mechanisms to architecture and social innovation, from both scientific and artistic perspectives. We will also discuss how biological systems that defy the dogmas of performance and optimization can inspire us a third way of life in the Anthropocene and aid in ending the cycle of over-exploitation.

IS2M Institut de Science des Matériaux de Mulhouse

Scientific Programme

Thursday, 01 June 2023			
10:00 - 10:15	Introduction		
10:15 - 11:00	Ali Miserez	Singapour	Biomimetic Materials – From Curiosity Driven Research to Next-Generation of Sustainable and Biomedical Materials
11:00 - 11:30	Charlotte Vendrely	Grenoble	Protein self-assembly for bio-inspired adhesives
11:30 - 12:00	Hatice Mutlu	IS2M, Mulhouse	Harnessing the possibilities of sulfur-decorated polymers towards biomimetic systems and bioinspired materials
12:00 - 12:30	Vincent Ball	Inserm U1121, Strasbourg	Polydopamine films and particles: bioinspiration and complexity behind simplicity
12:30 - 14:00	Lunch		
14:00 - 14:30	Igor Kulić	ICS, Strasbourg	Surface Rolling Propulsion of Influenza Viruses and its Biomimetic Analogues
14:30 - 15:00	Laurent Vonna	IS2M, Mulhouse	Wetting dynamics in nature
15:00 - 15:30	Antonio Stocco	ICS, Strasbourg	Active and driven particles interacting with lipid membranes
15:30 - 15:45	Hasna Maayouf	IS2M, Mulhouse	Virus-Like Particle as a nano-signaling platform to control cell behavior
15:45 - 16:30	Break		
16:30 - 17:15	Matthias Lütolf	RITB, Basel	Engineering Organoid Development
17:15 - 17:45	Cécile Bidan	MPI Colloid & Interfaces	Materials properties of bacterial biofilms
17:45 - 18:15	Hiroshi Umakoshi	Osaka, Japan	"Bio-inspired" chemical engineering utilizing self-organizing system
18:15 - 18:30	Invited artist		
18:30 - 20:00	Artistic exhibition + dinner food truck		

Friday, 02 June 2023			
09:30 - 10:15	Thomas Speck	Botanic garden, Freiburg	Plant movements – Inspiration for soft robotics and soft machines in technology, architecture and medicine
10:15 - 10:45	Falk Tauber	FIT, Freiburg	Artificial Venus flytrap demonstrators – multi-material systems responding to the environment with a snap
10:45 - 11:00	Eya Aloui	Inserm U1121, Strasbourg	Albumin-based biomaterials for the delivery of anti-tumor drugs: towards a targeted approach
11:00 - 11:45	Olivier Hamant	ENS Lyon	Suboptimality, a third way of life in the Anthropocene
11:45 - 12:15	Debate		
12:15 - 14:00	Lunch		

KEYNOTE SPEAKERS

Ali Miserez
Nanyang Technological University, Singapore

Matthias Lütolf
Roche Institute for Translationall Bioengineering & EPFL, Switzerland

Thomas Speck
Botanic Garden @ FIT, University of Freiburg

Olivier Hamant
RDP – INRAE, CNRS, UCBL1, ENS de Lyon

SCIENTIFIC AND ORGANIZING COMMITTEE

University of Haute-Alsace –

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Laurent Pieuchot

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Laurent Vonna

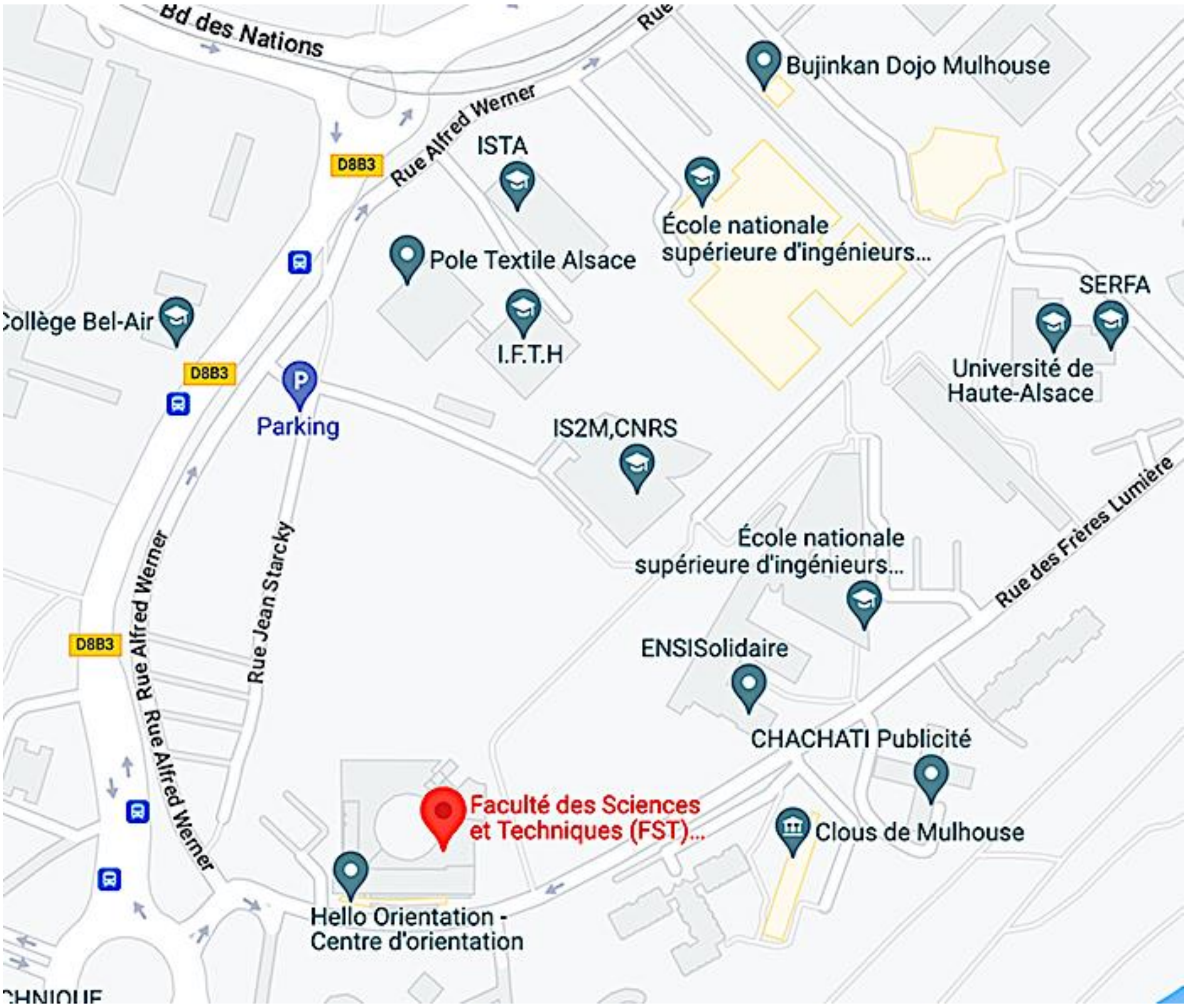
VOLUNTEERS

Sidzigui Ouedraogo, Hasna Maayouf, Ariane De Espindola, Giorgio De Avelar Francisco, Marie-Ly Chapon, Louise Abbou, Tatiana Petithory, Isabelle Brigaud, Eve Randrianaridera

VENUE

The meeting will be held at the Amphitheatre Gaston Berger, Faculté des Sciences et Techniques (FST) on the UHA campus.

Address: **18 Rue des Frères Lumière, 68200 Mulhouse**



You may contact Laurent Pieuchot laurent.pieuchot@uha.fr / 0782981924 (French) or Hernando Salapare hernando.salapare@uha.fr/ 0652286607 (English) for additional information.

ABSTRACTS

Biomimetic Materials – From Curiosity Driven Research to Next-Generation of Sustainable and Biomedical Materials

Prof. Ali Miserez

Nanyang Technological University, Singapore

Bio-based polymers hold great potential as alternative sources of petro-chemical based polymers. They are eco-friendly, non-toxic, and their degradable products are harmless, such as amino acids in the case of protein materials. However, biopolymers still represent a tiny fraction compared to the market of synthetic polymers, despite the fact that they often exhibit remarkable load-bearing performance that can compete with the best synthetic polymers. Silk fibers are the most notorious example, and there exists other natural hard extra-cellular materials made entirely of organic blocks, such as the squid beak[1] and sucker ring teeth (SRT)[2,3] from cephalopods. If one wants to replicate these load-bearing proteins artificially, it is critical to determine their primary structure. This task has historically been a major bottleneck exacerbated by the lack of genomic data from many model organisms. In this talk, I will describe our pioneer efforts in establishing Next-Generation sequencing (RNA-Seq) combined with high-throughput proteomics in the context of biomimetic materials engineering[4,5], which enables the rapid discovery of novel protein materials.

I will illustrate our efforts in deploying this platform towards the intriguing squid SRT, a type of protein-based materials with excellent mechanical performance. We have shown that SRT are entirely made of modular “suckerin” proteins self-assembling into a supramolecular network reinforced by nano-confined β-sheets[3]. SRTs exhibit thermoplastic properties, which can be exploited to re-process the proteins into complex shapes by simple lithographic techniques[6] and make SRT a promising material as “bio-ink” for 3D bioprinting [7] or as eco-friendly adhesives[8].

Protein polymers also hold attractive potential for biomedical applications. As a representative example, I will describe squid beak-derived phase-separating peptides [9] that we have engineered to deliver any type of macromolecular therapeutics (mRNA, pDNA, proteins, CRISPR/Cas9, etc…) intracellularly[10]. These peptides self-assemble into coacervate microdroplets[11] by pH-triggered Liquid-Liquid Phase Separation (LLPS), during which the therapeutics are instantaneously recruited within the droplets. The loaded microdroplets cross the cell membrane by a non-classic endocytosis pathway, are cargo-agnostic, non-cytotoxic, and capable to release their cargo in the cytosol while maintaining their bioactivity[10]. Overall, this platform represents a general and robust strategy for the intracellular delivery of a range of macromolecular modalities with promising potential in oncology, gene therapy, or metabolic diseases.

1 Miserez, A., Schneberk, T., Sun, C., Zok, F. W. & Waite, J. H. The Transition from Stiff to Compliant Materials in Squid Beak. ***Science*** **319**, 1816-1819 (2008).

2 Hiew, S. H. & Miserez, A. Squid Sucker Ring Teeth: Multiscale Structure–Property Relationships, Sequencing, and Protein Engineering of a Thermoplastic Biopolymer. ***ACS Biomaterials Science & Engineering*** **3**, 680–693 (2017). https://doi.org:10.1021/acsbiomaterials.6b00284

3 Guerette, P. A. *et al.* Nanoconfined β-sheets Mechanically Reinforce the Supra-Biomolecular Network of Robust Squid Sucker Ring Teeth. ***ACS Nano*** **8**, 7170–7179 (2014). https://doi.org:10.1021/nn502149u

4 Guerette, P. A. *et al.* Accelerating the Design of Biomimetic Materials by Integrating RNA-Seq. with Proteomics and Materials Science. ***Nature Biotechnology*** **31**, 908–915 (2013). https://doi.org:doi:10.1038/nbt.2671

5 Miserez, A., Yu, J. & Mohammadi, P. Protein-Based Biological Materials: Molecular Design and Artificial Production. ***Chemical Reviews*** **123**, 2049-2111 (2023). https://doi.org:10.1021/acs.chemrev.2c00621

6 Ding, D. *et al.* Squid Suckerin Microneedle Arrays for Tunable Drug Release. ***Journal of Materials Chemistry B*** **5**, 8467–8478 (2017). https://doi.org: http://doi.org/10.1039/c7tb01507k

7 Latza, V. *et al.* Multi-Scale Thermal Stability of a Hard Thermoplastic Protein-Based Material. ***Nature Communications*** **6: 8313** (2015). https://doi.org:10.1038/ncomms9313

8 Deepankumar, K. *et al.* Supramolecular β-Sheet Suckerin–Based Underwater Adhesives. ***Advanced Functional Materials*** **30**, 1907534 (2020). https://doi.org:10.1002/adfm.201907534

9 Tan, Y. P. *et al.* Infiltration of a Chitin Scaffold by Protein Coacervates Defines the Squid Beak Mechanical Gradient. ***Nature Chemical Biology*** **11**, 488–495 (2015). https://doi.org:10.1038/nchembio.1833

10 Sun, Y. *et al.* Phase-Separating Peptides for Direct Cytosolic Delivery and Redox-Activated Release of Macromolecular Therapeutics. ***Nature Chemistry*** **14**, 274-283 (2022). https://doi.org:10.1038/s41557-021-00854-4

11 Liu, J., Spruijt, E., Miserez, A. & Langer, R. Peptide-Based Liquid Droplets as Emerging Delivery Vehicles. ***Nature Reviews Materials*** (2023). https://doi.org:10.1038/s41578-022-00528-8

Protein self-assembly for bio-inspired adhesives

Charlotte Vendrely

Laboratoire des Matériaux et du Génie Physique, Grenoble, France

Tissue adhesives or surgical glues are interesting alternatives to sutures and staples because they can be applied quickly, with little material and are relatively painless. The adhesives currently in use have certain disadvantages such as immunogenic properties, poor bioadsorption or unsuitable mechanical properties. These disadvantages encourage the search for alternative products, particularly those inspired by nature. Indeed, several animals produce very powerful adhesives necessary for their development or survival in a wet environment or in the air. Some arthropods are able to glue to various materials thanks to a protein complex resembling the composition of current surgical glues. The adhesion mechanism seems to be linked to the self-assembly of proteins secreted by the animal, forming a network of fibers onto material surfaces. We chose to focus on a marine barnacle named *Megabalanus rosa*, a sessile organism that secrete an adhesive cement made of proteins allowing their adhesion to diverse materials. In particular, the Mrcp19k protein is supposed to be important for the interactions with the surfaces. We used genetic engineering to produce and purify a recombinant variant inspired from Mrcp19k. To understand the function of this protein, we investigated its self-assembly in different physico-chemical conditions and in presence of material surfaces. We show that acidic conditions are important for this process and the fibrillar nature of the self-assemblies has been confirmed by atomic force microscopy. In addition to pH, the nature of the surfaces in contact with the protein seems to have an influence on their self-assembly and we analyzed the adsorption of the protein onto surfaces using surface plasmon resonance. We conducted first experiments to determine the adhesion capacity of this protein. Our results show that the use of recombinant proteins can help to gain insight into the structure-function relationships of proteinaceous biological glues.

Harnessing the possibilities of sulfur-decorated polymers towards biomimetic systems and bioinspired materials

Cuong Mih Quoc Le, Hatice Mutlu

Institut de Science des Matériaux de Mulhouse,
UMR 7361 CNRS/UHA, 15 rue Jean Starcky, 68057 Mulhouse Cedex

Polymer chemistry has attained the sophistication necessity to produce macromolecules with diverse structure, composition, and properties by implementing manifold reactions that are both exceptionally versatile as well as tremendously useful. In this regard, sulfur and its functional groups have been major players in this area of exciting research, and further have been utilized for the design and preparation of polymeric materials that lead to a plethora of applications.[1], [2] Noteworthy, a current trend focuses on the development of novel routes for the preparation of less-recognized sulfur-containing polymers which can be utilized as biomimetic systems and/or bioinspired materials. Hence, it is in great urgency and highly desirable nowadays to find cost-effective reaction conditions to prepare these desired materials. Respectively, to realize this aim, we developed synthesis protocols which proceeds with the merits of mild conditions, broad substrate scope, operation simplicity, metal-free and ambient conditions.[3], [4] Aside, in terms of environmental issues caused by waste plastic, the utilization of sulfur-containing polymers also appears to be appealing from the aspect of degradability. Thus, we are reporting promising methods for the (catalytic) recycling or upcycling of the developed sulfur decorated polymers in order to reduce their potential environmental impact.

[1] H. Mutlu, E. B. Ceper, X. Li, J. Yang, W. Dong, M. M. Ozmen, P. Theato, *Macromol. Rapid Commun.* **2019**, 40, 1800650.

[2] H. Mutlu, P. Theato, *Macromol. Rapid Commun.* **2020**, 41, 2000181.

[3] 4. M. E. Duarte, B. Huber, P. Theato, H. Mutlu, *Polym. Chem.* **2020**, 11, 241.

[4] T. Sehn, B. Huber, J. Fanelli, H. Mutlu, *Polym. Chem.* **2022**, 13, 5965.

Polydopamine films and particles: bioinspiration and complexity behind simplicity

Vincent Ball

Université de Strasbourg, Faculté de Chirurgie Dentaire
8 rue Sainte Elisabeth-67000 Strasbourg
and Institut National de la Santé et de la Recherche Médicale-Unité mixte de recherché 1121

Inspired from the amino acid composition of the mussel foot proteins, rich in L-DOPA and in L-lysine, which allow strong adhesion in an aqueous environment and under strong shear stresses, dopamine was thought to be an excellent candidate to develop universal coatings. This idea has been validated [1] and opened a new research domain in surface science: thin polydopamine films. It is the aim of this presentation to show the real complexity (influence of the dopamine concentration [2], the used oxidant [3], the nature of the buffer, pH dependency, role of added proteins in the dopamine solution [4]) behind the apparent simplicity of the polydopamine deposition. Hypothetical molecular mechanisms allowing to produce such materials will be discussed. Finally the concept of versatile polydopamine deposition will be extended to other catechol amines and catechols in particular using electrochemical deposition methods [5] to yield graphitic films.

[1] Lee, H.; Dellatore S.M., Miller W.M; Messersmith, Ph. (2007) *Science* **318**, 426-430

[2] Ball, V.; Del Frari, D.; Toniazzo, V.; Ruch, D. (2012) *J. Colloid Interf. Sci.*, **386**, 366-372.

[3] El Yakhlifi, S. ; Alfieri, M.-L. ; Arntz, Y. ; Eredia, M. ; Ciesielski, A. ; Samori, P. ; d'Ischia, M. ; Ball, V. *Colloids and Surf. A. Physicochem. Eng. Asp.* (2021) **614**, art 126134

[4] Bergtold, C. Hauser, D.; Chaumont, A.; El Yakhlifi, S.; Mateescu, M.; Meyer, F.; Metz-Boutigue, M.-H.; Frisch, B.; Schaaf, P.; Ihiawakrim, D.; Ersen, O.; Monnier, C.A.; Petri-Fink, A.; Rothen-Rutishauser, B.; Ball, V. (2018) *Biomacromolecules*. **19**, 3693-3704.

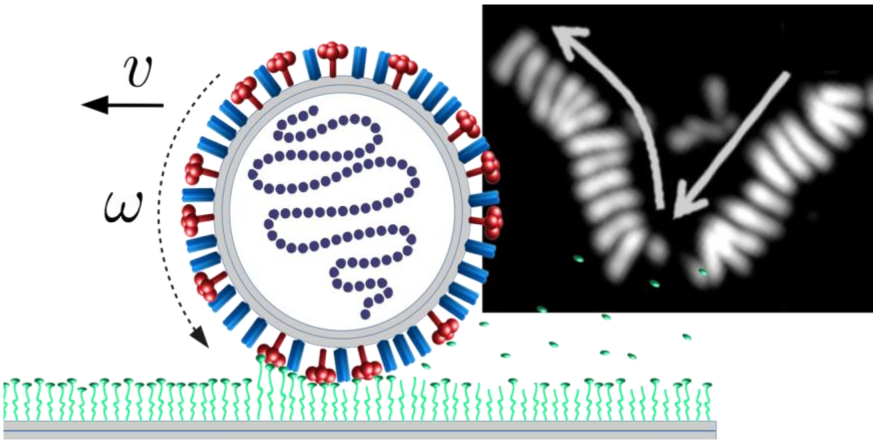
[5] Ortiz-Pena, N, Ihiwakrim, D.; Ball, V.; Stanescu, S.; Rastei, M.; Sanchez, C.; Portehault, D.; Eresen (2020*) J. Phys. Chem. Lett*. **11**, 9117-9122.

Surface rolling propulsion of influenza viruses and its biomimetic analogues

Igor M. Kulić

CNRS, Institut Charles Sadron, Strasbourg, France

While often believed to be only a passive agent that merely exploits its host's metabolism, the influenza virus has recently been shown to actively roll across glycan-coated surfaces. In this talk we present what we currently know about this new form of motility and develop a quantitative physical model. We conclude by discussing the general concept and various instances of a monowheel engine. We show that many filaments beyond influenza, from fishing line to spaghetti, exhibit active rolling propulsion across surfaces when driven out of equilibrium by fluxes traversing the surface.



[1] F. Ziebert and I. M. Kulić, How Influenza's Spike Motor Works, Phys. Rev. Lett. 126, 218101 (2021)

[2] P.A. Soria Ruiz, F.Ziebert and I.M. Kulić, The Physics of Self-Rolling Viruses, Phys Rev E, 105, 054411 (2022)

[3] A. Baumann, A. Sánchez-Ferrer, L. Jacomine, P. Martinoty, V. Le Houerou, F. Ziebert and I.M.Kulić , Motorizing fibres with geometric zero-energy modes , **Nature Materials**, 17, 523 (2018)

[4] A. Bazir, A. Baumann, F. Ziebert and I. M. Kulić, Dynamics of Fiberboids, Soft Matter, 16, 5210 (2020)

01 June 2023 (14:30 – 15:00)

Wetting dynamics in nature

Laurent Vonna

Université de Haute-Alsace, IS2M-CNRS 7361, F-68100 Mulhouse, France

Understanding how plants and animals interact with water is of paramount importance as it directly affects their survival, growth, and reproductive success. They have evolved remarkable adaptations to manage the complex process of wetting, enabling them to optimize water uptake or minimize interaction for example, and maintain a favorable microenvironment for their physiological processes.

During this talk, I will discuss various aspects of wetting in plants and animals, starting with an overview of the fundamental principles governing wetting phenomena. A particular emphasis will be placed on dynamic wetting, which involves the spreading or retracting of liquid on their surfaces. I will discuss the underlying mechanisms that enable plants and animals to dynamically control wetting, focusing on the role of surface texture, such as roughness. Furthermore, we will examine in details different examples of textured surfaces found in both plants and animals that exhibit peculiar wetting dynamics.

Insights into the control of wetting behavior have inspired researchers to develop synthetic surfaces that mimic the strategies observed in nature. By emulating the evolutionary solutions found in plants and animals, artificial materials with controlled wetting behaviors have been created. Different example of such synthetic surfaces that find applications in various fields, such as self-cleaning coatings, microfluidics, biomedical devices, and advanced manufacturing, will be presented.

Active and driven particles interacting with lipid membranes

Antonio Stocco

CNRS, Institut Charles Sadron, Strasbourg, France

Interaction between micro- or nano- particles and lipid membranes controls processes such as endocytosis, drug delivery and microbial infections. Dramatic changes in particle motion and membrane properties can be observed when a particle approaches a membrane. A shape transition of the membrane may occur to accommodate the particle, and partial or complete particle wrapping by the membrane will happen as a function of the energy of adhesion, membrane tension and bending. Furthermore, the interaction between a hard particle and a soft membrane may lead to complex dynamics when the system is driven out of equilibrium. Here, I will present experiments showing complex dynamics such as the physics of particle wrapping by a membrane, the transport of vesicles by active particles, and the orbital motion of active colloids around vesicles. Recent optical tweezers experiments on particle penetration inside giant vesicles will be presented and discussed in the limit of a vanishing adhesion energy [1]. In a wide range of experimental conditions, we have observed that a self-propelled Janus colloid is able to perform orbital motion around a giant vesicle remaining in a non-wrapped state [2]. Still, the active particle is able to impart a force of the order of 0.01 pN on the vesicle, which is however too small to trigger membrane wrapping. By applying external forces in the 1-100 pN range, we were able to observe membrane wrapping of bare and Janus colloids by a giant vesicle, which leads to the transport of vesicle by an active colloid, see Figure 1 [3].

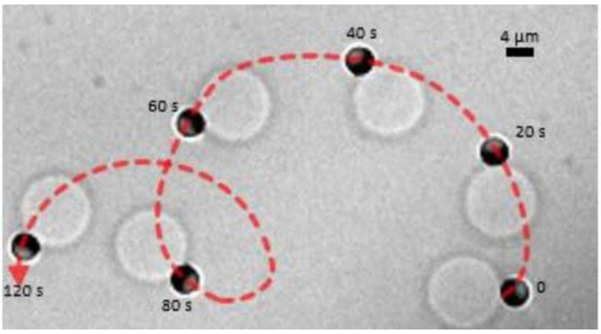


Figure 1: Active transport of a self-propelled Janus colloid partially wrapped by a giant vesicle membrane

[1] F. Fessler, V Sharma, P Muller, A Stocco. (2023) Entry of Microparticles into Giant Lipid Vesicles by Optical Tweezers, https://arxiv.org/abs/2301.02504.

[2] V Sharma, E Azar, AP Schroder, CM Marques, A Stocco. (2021) Active colloids orbiting giant vesicles, Soft Matter.

[3] V Sharma, CM Marques, A Stocco. (2022) Driven Engulfment of Janus Particles by Giant Vesicles in and out of thermal equilibrium, Nanomaterials.

Virus-Like Particle as a nano-signaling platform to control cell behavior

Hasna Maayouf*, Thomas Dos-Santos, Isabelle Brigaud, Tatiana Petithory, Karine Anselme, Carole Arnold and Laurent Pieuchot

Université de Haute-Alsace, IS2M-CNRS 7361, F-68100 Mulhouse, France
**hasna.maayouf@uha.fr*

Virus-Like Particles (VLPs) are self-assembled protein-based nanoparticles that provide versatile delivery platforms for a variety of biomedical applications thanks to their biocompatibility and their ability to encapsulate therapeutic molecules[1,2]. However, they have not yet been employed in the field of biomaterials. Here we show that VLPs can be used to develop cell-signaling nanoscaffolds for the control cell behavior. Using cloning techniques, we fused short bioactive peptides to the C-terminus of the AP205 coat protein. We produced recombinant particles expressing adhesion (RGD, YIGSR) and osteogenic (BMP2) peptides at their surface and purified them by affinity and size exclusion chromatography techniques. We show that VLP-RGD particles stimulate adhesion and spreading of C2C12 myoblast cells with the same efficacy as native fibronectin whereas VLP-BMP2 particles do not. With similar methods, we were able to produce heteromeric particles co-expressing RGD and BMP2 peptides. We showed that the presence of RGDs on our multifunctional particles can promote cell adhesion similarly to VLP RGD-BMP2. These results demonstrate that it is possible to combine bioactive peptides on the AP205 particle surface in order to create multifunctional signaling nanoscaffolds that control different facets of cell biology.

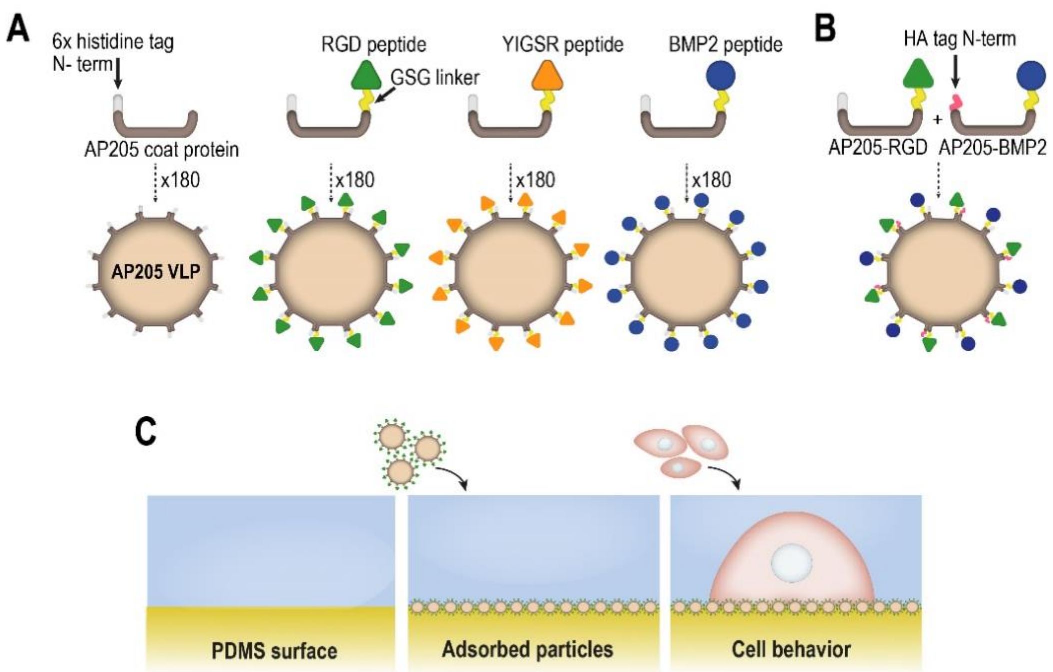


Fig. 1: Virus-Like Particle as a signaling platform to concentrate nanoscale ligands for the control of cell behavior

[1] Shirbaghaee, Z. and Bolhassani, A. (2016), *Biopolymers*, 105(3), pp. 113–132.

[2] Pushko, P., Pumpens, P. and Grens, E. (2013), *Intervirology*, 56(3), pp. 141–165.

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01 June 2023 (16:30 – 17:15)

Engineering organoid development

Matthias Lütolf

Roche Institute for Translationall Bioengineering, Basel, Switzerland and Swiss Federal Institute of Technology in Lausanne (EPFL)
**matthias.lutolf@epfl.ch*

Most organoids form through poorly understood morphogenetic processes in which initially homogeneous ensembles of stem cells spontaneously self-organize in suspension or within permissive three-dimensional extracellular matrices. Yet, the absence of virtually any predefined patterning influences such as morphogen gradients or mechanical cues results in an extensive heterogeneity. Moreover, the current mismatch in shape, size and lifespan between native organs and their in vitro counterparts hinders their even wider applicability. In this talk I will discuss some of our ongoing efforts in developing next-generation organoids that are assembled by guiding cell-intrinsic self-patterning through engineered stem cell microenvironments.

Materials properties of bacterial biofilms

Cécile Bidan

Max Planck Institute of Colloids and Interfaces, Am Mühlenberg 1, 14476 Potsdam, Germany

As bio-sourced materials are raising interest for their sustainability, using bacteria to produce biofilms made of a protein and polysaccharide matrix has become a new strategy to make engineered living materials. Our group contributes to this emerging field by clarifying how bacteria adapt biofilm materials properties to the environment. For this, we culture *E. coli* producing curli amyloid and phosphoethanolamine-cellulose fibers on nutritive agar substrates with varying physico-chemical properties and study the growth, morphology and mechanical properties of the resulting biofilms. We demonstrated that changing the properties of the agar substrates with polyelectrolyte coatings or by varying their water content, affects E. coli biofilm growth, morphology and mechanical properties. We also used *E. coli* producing only amyloid fibers to focus on the matrix structural and functional changes at the molecular scale. To assess the contribution of each matrix component to the macroscopic biofilm materials properties, we compared the characteristics of biofilms produced by a collection of *E. coli* mutants differing in the matrix they produce. The results indicate that *E. coli* biofilm matrix is a composite made of rigid and brittle curli amyloid fibers assembled within a mesh of soft and adhesive phosphoethanolamine-cellulose fibers. Finally, we explored how tuning the chemical environment of the bacteria can lead to biofilm biomineralization and expand the range of materials properties reachable with biofilm-based materials.

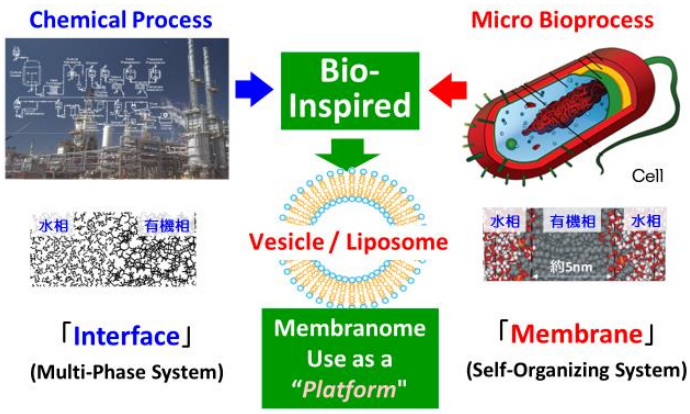
01 June 2023 (17:45 – 18:15)

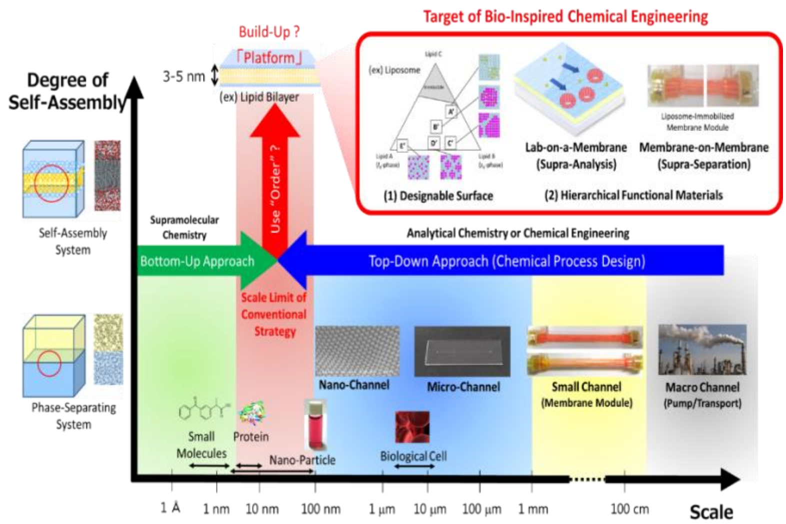
"Bio-Inspired" Chemical Engineering Utilizing Self-Organizing System

Hiroshi Umakoshi

Division of Chemical Engineering, Graduate School of Engineering Science, Osaka University

A "*Biomembrane*" is a highly-organized self-assembly of biomolecules (i.e. lipid, protein etc.) and a key interface for the survival of biological cell. The "*Membranome*" can be defined as the properties of vesicle (or liposome), which arise from the bilayer molecular assembly of amphiphiles, focusing on "*emergent properties*" which are not present in the individual components, and is gradually recognized as an important research methodology to investigate the potential functions of vesicles (or liposome) and to apply them for the bioprocess design. "*Self-Organizing System*", such as liposome or vesicle, possesses several benefits in the recognition of (bio)molecules, where it can recognize them with (i) electrostatic, (ii) hydrophobic interaction, and (iii) stabilization effect of hydrogen bonds at its surface. A key of next chemical engineering is the use of "*Self-Organizing System*", where "enthalpy-driven" nature of chemical process would be converted to "entropy-driven" one. We call this strategy as "*Bio-Inspired Chemical Engineering*". I would like to introduce the basic and applied aspect of the self-organizing system: (1) Phase Equilibrium and Physicochemical Properties of Self-Organizing System, (2) Functions of Self-Organizing System (i.e. Chiral Recognition Function etc.), and (3) Its Application to the Development of the Chemical Process Devices (i.e. Membrane Module for Optical Resolution etc.).





[Publications] *Langmuir*, 24(3), 350-354 (2008) / *Langmuir*, 24(9), 4451-4455 (2008) / *Langmuir*, 24(19), 10537-10542 (2008) / *Langmuir*, 25(9), 4835–4840 (2009) / *J. Appl. Electrochem.*, 39(10), 2035-2042 (2009) / *Colloid Surface B*, 88, 221-230 (2011) / *Nucleic Acid Res.*, 39, 8891-8900 (2011) / *Biochem. Biophys. Res. Comm.*, 426(2), 165-171 (2012) / *AIChE J.*, 57(12), 3625–3632 (2012) / *Langmuir*, 29(6), 1899–1907 (2013) / *Langmuir*, 29 (15), 4830–4838 (2013) / *Chem. Comm.*, 50, 10177-10197 (2014) / *Anal. Chem.*, 87, 4772-4780 (2015) / *Lab on a Chip*, 15, 373-377(2015) / *J. Phys. Chem. B*, 119, 9772-9779 (2015) / *ACS AMI*, 7, 21065−21072 (2015) / *Langmuir*, 31, 12968–12974 (2015) / *Langmuir*, 32, 3630–3636 (2016) / *J. Phys. Chem. B*, 120, 2790–2795 (2016) / *Biomacromolecules*, 18 (4), 1180-1188 (2017) / *Langmuir*, 34 (5), 2081-2088 (2018) / *J. Chem. Eng. Japan*, 52 (3), 311-316 (2019) / *Biophys. J.*, 116, 874-883 (2019) / *Langmuir.*, 36 (12), 3242-3250 (2020) / *J. Phys. Chem. B*, 124 (44), 9862-9869 (2020)./ *Langmuir*, 37 (14), 4284–4293 (2021) / *Langmuir*, 37 (22), 6811–6818 (2021) / *Langmuir*, 37 (38), 11195-11202 (2021) / *J. Phys. Chem. B*, 125 (23), 6192-6200 (2021) / *ACS Applied Nano Materials*, 5 (7), 9958-9969 (2022) / *ACS Applied Polymer Materials*, 4(10), 7081-7089 (2022) / *Langmuir*, 38(48), 14768-14778 (2022) / *ACS Omega*, 8(1), 829-834 (2023) .

Artistic Exhibition

Invited Artist

Gaspard & Sandra BÉBIÉ-VALÉRIAN are two visual artists focusing on social and environment issues such as energy production, interspecism symbiosis, and cooperation for survival. They believe in the power of care to foster more empathy and a better understanding of ecosystems. For that purpose, they include in their researches living organisms as agents for change, involving both a respectful and humble position towards the complicated diversity of life. For this event, they will propose a performative « Conference on a Sofa » with Manuel FADAT, curator and art critic, to lively discuss on one of their latest artwork « Humatker » : a hybrid sculpture and installation which combines three entities that embodies the cohabitation regime of our time : one biological, one software and one synthetic.

https://sgbv.net/humatker-physarum-an-agent-for-remediation.html

Plant movements – Inspiration for soft robotics and soft machines in technology, architecture and medicine

Thomas Speck

Plant Biomechanics Group @ Botanic Garden and Cluster of Excellence Living, Adaptive and Energy-autonomous Materials Systems (livMatS) @ FIT, University of Freiburg

Today, biomimetics attracts increasing attention as well from basic and applied research as from various fields of industry and building construction. Biomimetics has a high innovation potential and offers possibilities for the development of sustainable technical products and production chains. Novel sophisticated methods for analysing and simulating the form-structure-function-relation on various hierarchical levels allow new fascination insights in multi-scale mechanics and other functions of biological materials systems. Additionally, new production methods enable for the first time the transfer of many outstanding properties of the biological models into innovative biomimetic products at reasonable costs.

In recent decades, plants have been recognized as valuable concept generators for biomimetic research in many field of application in technology in general, and architecture and medicine in particular. Plant-inspired developments in the fields of soft machines and soft robotics are demonstrated by research projects currently carried out in the Cluster of Excellence *liv*MatS and the Plant Biomechanics Group Freiburg. Examples include liana-inspired soft robots, leaf- and flower-inspired façade shading systems, demonstrators for pine cone-inspired self-adaptive building hulls and artificial Venus flytraps. As example for a medical application a prototype for an adaptive wrist-forearm splint developed in collaboration with the ICD at the University of Stuttgart is presented. A particular focus of current research is on embodied energy and physical intelligence found in moving plant organs, which offer a huge potential for a new generation of materials systems for soft robots, bioinspired architecture and technical applications in general.

[1] T. Speck, T. Cheng, F. Klimm, A. Menges, S. Poppinga, O. Speck, Y. Tahouni, F. Tauber & M. Thielen (2023): Plants as inspiration for material-based sensing and actuation in soft robots and machines. MRS Bulletin, 48: 1-16. DOI.org/10.1557/s43577-022-00470-8

02 June 2023 (10:15 – 10:45)

Artificial Venus flytrap demonstrators – multi-material systems responding to the environment with a snap

Falk Tauber, Philipp Auth, Joscha Teichmann, Laura Riechert, Fabian Scheckenbach, Thomas Speck

Plant Biomechanics Group @ Botanic Garden and Cluster of Excellence Living, Adaptive and Energy-autonomous Materials Systems (livMatS) @ FIT, University of Freiburg

Plants, as sessile organisms, are exposed to their environment without any protection but still cope with changing conditions. Especially in soft robotics, properties like adaptation to environments, ingenious materials systems, and energy-effectiveness of plants provide an extremely rich source of inspiration to develop new technologies – and many of them are still in the beginning of being discovered or transferred. Snap traps plants are of particular interest here, as these are to catch fast-moving insects without any central control unit. The translation of the functions of snap traps enables the development of systems with embodied (physical) intelligence and embodied energy. Current artificial Venus flytraps inspired by carnivorous snap-trap plants enable fast, hinge-less movements in plant-inspired robotic systems.

Our novel bioinspired "artificial Venus flytrap" demonstrators incorporate snap-trap motion principles of two carnivorous plants (Venus flytrap and watertrap) in one system, exhibiting adaptive responses to various environmental triggers. The presented systems are examples of a successful implementation of several principles based on plant motion and deformation in a versatile, adaptive, and technically compliant multi-material system. The systems and novel motion sequences are characterized in terms of kinematics, energy requirements and overall performance. Highlighting not only novel actuation system but also novel meta-material systems.

The aim of our project is to showcase the practicality of our material systems, which have dynamic, life-like, and non-equilibrium properties, through the use of bioinspired technical devices such as an "artificial Venus flytrap". This will serve as an initial step towards introducing innovative technologies into industrial products and everyday life applications.

Albumin-based biomaterials for the delivery of anti-tumor drugs: towards a targeted approach

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[1]*Laboratory of Design and Application of Bioactive Molecules (CAMB) – Biovectorisation - UMR 7199, University of Strasbourg*
[2]*Biomaterials and BioEngineering - Inserm UMR_S 1121, University of Strasbourg*

Albumin is an excellent candidate for developing drug delivery systems applied to cancer. This protein is a native ligand carrier that supports both hydrophilic and hydrophobic drugs. Moreover, albumin also allows tumor targeting via the overexpression of albumin-related receptors by cancer cells. In this context, biomaterials releasing albumin binding an antitumor agent could improve the treatment of cancer [1]. We created highly biocompatible biomaterials entirely made of albumin using an innovative and patented technology (Albupad technology). These materials are obtained through the salt-induced compaction of albumin and they can be designed with tunable properties [2]. Doxorubicin, a DNA intercalant, is a reference treatment for several types of cancer. This active ingredient suffers from a narrow therapeutic index and is therefore an excellent candidate for albumin-bound delivery [3]. Doxorubicin loaded materials were formulated with loading rate up to 10% w/w and an encapsulation efficiency higher than 85%. The release kinetics of doxorubicin was shown to be sustained without burst effect. The cytotoxicity of the doxorubicin-loaded materials was demonstrated, *in vitro*, on three human cancerous cells strains (HCT-116, MCF-7, U-87). Finally, the therapeutic efficacy of doxorubicin-loaded materials was conducted on a subcutaneous tumor model on mice. These assays showed that using the materials we developed to deliver doxorubicin led to a higher concentration of this molecule in the tumor in comparison to doxorubicin administered intravenously.

[1] E. N. Hoogenboezem, C. L. Duvall, *Adv. Drug Deliv. Rev.* 2018, *130*, 73.

[2] E. Aloui, M. De Giorgi, B. Frisch, P. Lavalle, P. Schaaf, 2021, EP3811982A1.

[3] A. Spada, J. Emami, J. A. Tuszynski, A. Lavasanifar, *Mol. Pharm.* 2021, *18*, 1862.

02 June 2023 (11:00 – 11:45)

Suboptimality, a third way of life in the Anthropocene

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The marks of humanity are omnipresent on Earth: the Anthropocene is above all the age of performance and control. In turn, the multiple impacts on our environment question the values of this "progress" and its trajectory. Thus, what to do? Many sustainable development solutions seem counterproductive. The perspective of a general slowdown does not mobilize either. By studying living systems, we could learn a different way to be Earthlings. While modern human societies have focused on efficiency and efficacy for individual comfort, life is instead built on heterogeneity, slowness, fluctuations, incoherence... for the resilience of the group in a fluctuating environment. This "third way of life" already has its pioneers in society: participative housing, agro-ecology, repair workshops, citizen science,... It may open another path to build the age of robustness and cooperation, against the dogma of performance. Needless to say, this also completely changes how research is done, organized and evaluated.