2nd ANNUAL MEETING

GDR 2088 BIOMIM

Biomimicry and Bioinspiration

cnrs

15-16 NOVEMBER 2021
VIRTUAL MEETING

https://gdr-biomim.com/2nd-annual-meeting/

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GDR 2088 Missions

GDR 2088 « BIOMIM » - Biomimicry and Bioinspiration was established by the Institute of Chemistry of CNRS in January 2020 to unite all French actors working in the field of Bioinspiration and Biomimicry. It brings together 97 research teams and laboratories with more than 700+ researchers and doctoral students, from all over France and with different scientific backgrounds and specializations to address important scientific and societal challenges through solutions inspired by nature.

The **general missions** of GDR 2088 are as follows:

1. Bring together all French players working in this field by relying on a network of researchers and university lecturers-researchers;
2. Create and promote internationally a mapping of research activities and initiatives in France;
3. Select the themes promoting complementarity for innovation;
4. Monitor calls for projects in this area and send them to members;
5. Constitute an effective structure for the response to calls for projects;
6. Organize once a year a national conference to shed light on a theme of this network (thematic conference);
7. Participate in organizing at least once every two years in an international conference in this field;
8. Collect innovations and major facts in this field and disseminate them using an electronic newsletter (technology watch and work from members) or a scientific journal;
9. Establish a reference center for European and international players working in this field;
10. Carry out a mapping of technical resources and scientific expertise;
11. Promote exchanges between academics and industries on research;
12. Develop the international influence of initiatives carried out in France and ensure their promotion;
13. Become an innovation support for scientific departments, public organizations, and government ministries involved.

Scientific Challenges

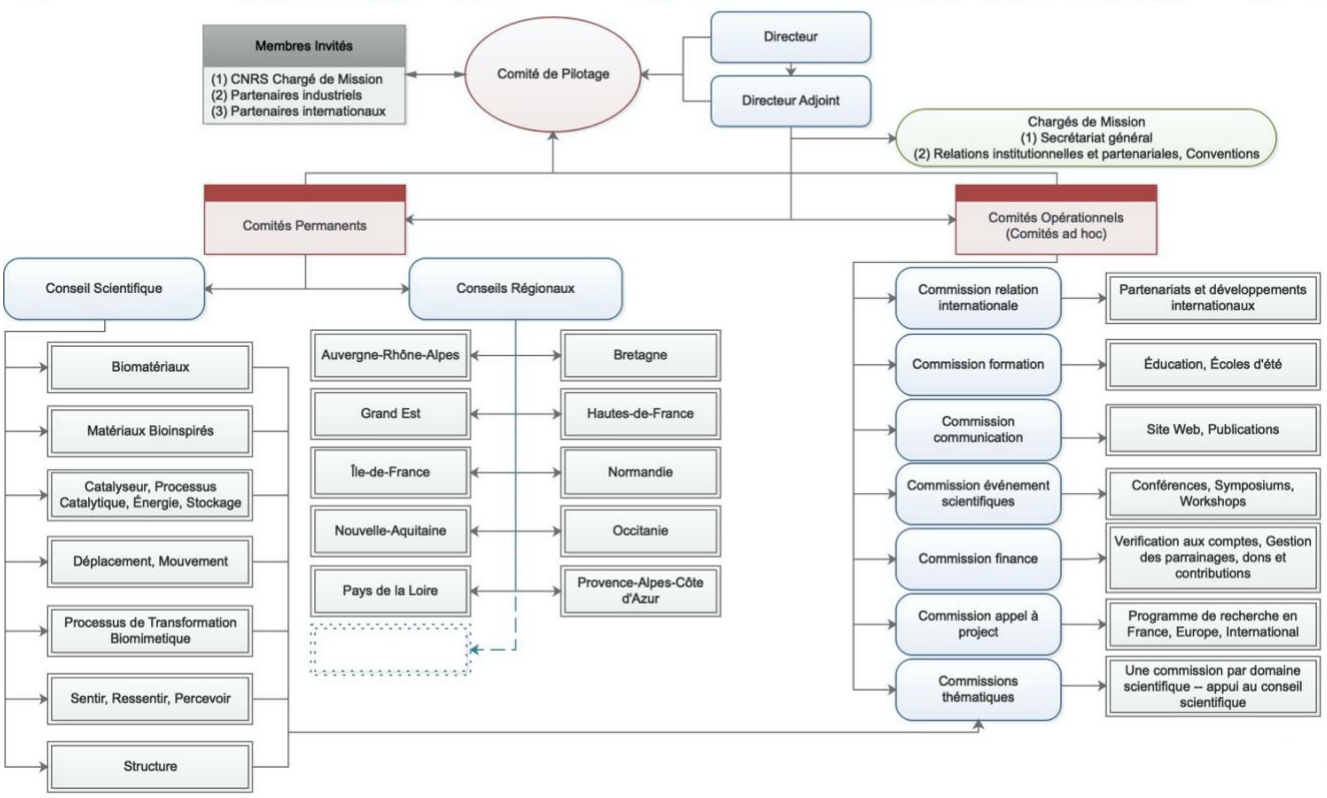
- Feel, experience, perceive (sensor, biosensor, recognition, integration of the signal into matter, etc.)
- Biomimetic transformation process, biosynthesis, natural process, ...
- Displacement, movement (robot, artificial insect, biorobotics, biomechanics, stealth, etc.)
- Structure (nano, micro, macro, 2D-3D self-assembly, molecular architecture, porous system, porous hybrid, membrane, bio-skeleton, LbL surface, miniaturization, metamaterials, meta-surface, protection, shielding, lightening of structures, etc.)
- Catalyst, catalytic process (protein enzyme, etc.), energy and storage (photosynthesis, biobattery, etc.)
- Bioinspired materials (Biopolymers, bio-based polymers, ionic polymers, marine chemistry, biocolla, molecular borrowing, etc.)
- Biomaterials (biofilm, antibacterial, biocontaminant, tissue engineering, bioinspired sensors, 3D bioprinting, etc.)

Societal Challenges

- Mobility (movement, transport, movement, etc.)
- Habitat (materials, fluid, fluid flow, control, regulation, structure)
- Health (Antibacterial, biofilm, etc.)
- Energy (production, process, storage, etc.)
- Smart city (sensor, self-regulation, signal integration, data processing, etc.)
- Communication and signal processing
- Environment (bioresource, biopolymer, degradation, pollution, ecosystem, etc.)

Organizational Chart

GDR 2088 « Biomimétisme et bioinspiration » (BIOMIM)
Organigramme



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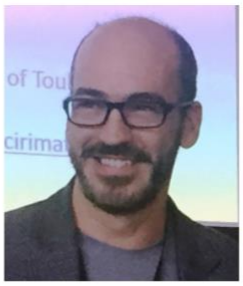

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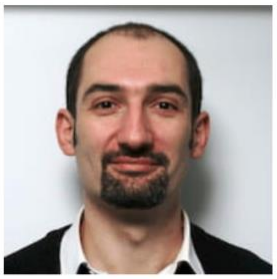

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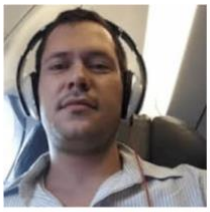

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Summary of Session Links

15 November 2021

SESSION LINK : https://bit.ly/3C33Cr4
- Opening Remarks (14:00-14:20)
- Bioinspired Materials (14:20-15:30)
- Catalysis (15:45-16:45)

SESSION LINK : https://bit.ly/3F6FhlV
- Modelling and Simulation (14:20-15:20)
- Displacement and Movement (15:45-16:35)

16 November 2021

SESSION LINK : https://bit.ly/3C33Cr4
- Biomaterials A (10:00-12:00)
- Biomaterials B (14:00-15:30)
- Closing Program

SESSION LINK : https://bit.ly/3F6FhlV
- Structure A (10:00-11:10)
- Structure B (14:00-15:30)

CONFERENCE PROGRAM

Monday, November 15

14:00 - 14:20	**Opening Remarks** **Session Link: https://bit.ly/3C33Cr4**	
14:20 - 15:30	**Bioinspired Materials** **Session Link: https://bit.ly/3C33Cr4** **Session Chair: Olivier FELI**	**Modelling and Simulation** **Session Link: https://bit.ly/3F6FhlV** **Session Chair: Yannick COFFINIER**
	Natasha HEIL & Valentina PERRICONE - KN5 (14:20-14:50) Bioinspired materials for sustainable architecture and construction learning from Echinoids (Sea Urchins): new research avenue	**Rogelio GOMEZ-PINEIRO - OR5 (14:20-14:40)** Decoding an ambiguous EPR signal in PIAA10 LPMO enzyme by construction of active site models using DFT
	Hernando SALAPARE III - OR15 (14:50-15:10) Bioinspired self-cleaning surfaces for car interior applications	**Chunmei LIU - OR4 (14:40-15:00)** Comparison of topology optimization based on classical and bio-inspired objectives
	Salomé BASSET - OR16 (15:10-15:30) Effect of laser texturing environment media on wetting of biomimetic superhydrophobic surfaces designed by femtosecond laser pulses	**Jordan Drapin - OR3 (15:20-15:20)** Biomimetism and hexapodal gait, a first step in ant
15:30 - 15:45	Coffee Break	
15:45 - 16:45	**Catalysis** **Session Link: https://bit.ly/3C33Cr4** **Session Chair: Thierry DARMANIN**	**Displacement and Movement** **Session Link: https://bit.ly/3F6FhlV** **Session Chair: Pierre MORETTO**
	Manon PUJOL - OR8 (15:45-16:05) Engineering of a copper metalloenzyme for new-to-Nature reactivities	**Swaminath VENKATESWARAN & Damien CHABLAT - KN2 (15:45-16:15)** Comparison of three Motion Generators for a 3-SPS-U Tensegrity Mechanism
	Olfa ZAYENE - OR6 (16:05-16:25) Cooperativity between hydrogen bonding and anion-π interaction in anion recognition and catalysis	**Weijia WANG - OR9 (16:15-16:35)** How individual perceptual and cognitive factors affect collective motion in a data-driven fish school model
	Jonathan BACHIR - OR7 (16:25-16:45) Combining Biopolymer and Metal-Organic Framework for Protein Encapsulation	

Tuesday, November 16

10:00 - 12:00	**Biomaterials A** **Session Link: https://bit.ly/3C33Cr4** **Session Chair: Emmanuel BELAMIE**	**Structure A** **Session Link: https://bit.ly/3F6FhlV** **Session Chair: Stéphane VALETTE**
	Christophe DROUET -KN3 (10:00-10:30) Calcium phosphate: from biominerals to biomaterials	**Olivier FELIX - KN1 (10:00-10:30)** Anisotropic properties of bio-inspired nanocomposite materials
	Bernd SCHÖLLHORN - KN4 (10:30-11:00) Fluorescence of natural biomatter in Asian paper wasp nests	**Yu WU - OR18 (10:30-10:50)** Cubosomal lipid nanoparticles encapsulating plasmalogens with neuroprotective effects
	Julius SEFKOW-WERNER - OR11 (11:00-11:20) In situ and ex situ characterization of biomimetic platforms used for the analysis of heparan sulfate-mediated BMP biological activity	**Manon SAGET - OR2 (10:50-11:10)** Surface engineering of stainless steel to limit dairy fouling adhesion
	Ana FERRANDEZ-MONTERO - OR10 (11:20-11:40) 4D Smart electroactive porous scaffold as innovative cell culture platform	
	Alicia Alejandra MIER GONZALEZ - OR20 (11:40-12:00) Solid-Phase Synthesis of Molecularly Imprinted Polymer Nanogels- Synthetic Antibody Mimics for the Recognition of Protein Biomarkers	
12:00 - 14:00	Lunch Break	
14:00 - 15:30	**Biomaterials B** **Session Link: https://bit.ly/3C33Cr4** **Session Chair: Elisa MIGLIORINI**	**Structure B** **Session Link: https://bit.ly/3F6FhlV** **Session Chair: Angelina ANGELOVA**
	Tristan BAUMBERGER - KN6 (14:00-14:30) Structural Hints from the study of Syneresis of Calcium Alginate hydrogels	**Vincent FORGE - KN7 (14:00-14:30)** Protein self-assembly for bio-inspired electronics
	Mathilde GUERIN - OR12 (14:30-14:50) Peptide-decorated bio-inspired apatite nanoparticles: towards wound healing applications	**Xxx SEDAO - OR 17 (14:30-14:50)** Multi-wavelength LIPSS generation on titanium alloy and comparative study of their effect on cell adhesions
	Jean-Yves RUNSER - OR13 (14:50-15:10) Micropatterning Controlled By Enzyme Assisted Self Assembly Through a Liesegang-like Process	**Anne-Sophie VAILLARD - OR1 (14:50-15:10)** Elaboration of transparent, robust and repellent surfaces based on molded and lubricated PDMS
	Anissa DIEUDONNÉ - OR14 (15:10-15:30) Bioinspired grinding for anaerobic digestion	**Quentin LEGRAND -OR19 (15:10-15:30)** Anisotropic wetting behavior on bioinspired textured surfaces
15:30 - 15:45	Coffee Break	
15:45 - 17:00	**GDR2088 Business Meeting, Closing and Awarding Ceremonies for the Graduate Student Awards** **Session Link: https://bit.ly/3C33Cr4**	

Bioinspired materials

Bioinspired materials for sustainable architecture and construction learning from Echinoids (Sea Urchins): new research avenue

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Keywords: bio-inspired materials, echinoids, architectural design and construction, sustainability

Creating and manufacturing materials that respond to both socio-economic and environmental issues are major challenges for architecture and industry **[1]**. The issue of lightening structures to save material and consumed energy is a today challenge. This requires research on new lightweight and multifunctional materials and / or new combinations and architecture of materials in order to improve their performance. The architecture must be designed at a relevant scale of matter: at the nanometer scale for polymers, if we are interested in the properties of chemical-physical barriers/interaction or at the centimeter scale for metal alloys if we want flexible materials but able to keep their properties at high temperature (for example at 800 °C in aerospace). In the same way, the replacement of existing materials with rare or polluting primary resources requires the development of new materials or to revise old ones. Bio-based polymers are beginning to replace petroleum-based polymers in some applications. In architecture, vegetal fiber concrete is making its appearance. The stone saves the ground compared to the concrete in the construction of work as well as the wood which it is possible to make translucent.

Biomimicry is a promising path on which interdisciplinary research teams in biology, engineering and architectural design, are starting to work within UMR MAP MAACC CNRS collaborating with external experts: in biomimetics from *Transarch: biomimetics + transdisciplinary design*, Vienna, Austria **[2]** and in biology and engineering from the University of Campania “Luigi Vanvitelli” and Federico II of Naples, Italy **[3,4]** to develop new multi-functional materials, optimizing the properties of existent materials and structures to minimize energy consumption during the production and manufacturing **[5]**.

In our initiative research, we have chosen Echinoids, known as sea urchins as a biological role model. The echinoid skeleton (test) presents interesting functional features on their macro and micro architectures, mechanical performances and material properties. This hierarchical design fulfils several functional principles acting as a lightweight and load-bearing system adapted to withstand biotic and abiotic stresses. Due to its functional strategies, the echinoid test has a long history as an inspiring model for engineering structures and materials **[6]**. We aim to study the sea urchins and use biomimetic methodologies to transfer their interesting aspects to create new bio-inspired material / or develop existing materials which have lightweight, material efficiency, multi-functional qualities and be able to adapt to large scale architectural design. We are also aware of the durability of the new type of materials to the real-world construction requirements.

The research works require a fine understanding of the material at different scales and multidisciplinary skills in materials sciences, instrumentation including in data analysis. This initial research on bio-inspired materials for sustainable architecture and construction is part of the research theme on biomimetic strategies for architectural design at the laboratory MAACC within the framework of GDR 2088 « BIOMIM » – Biomimicry and Bioinspiration.

[1]. Chayaamor-heil, N.; Guéna, F.; Hannachi, N. Biomimétisme en architecture. État, méthodes et outils, les Cahiers de la recherche Architecturale Urbaine et Paysagère, 2017, https://journals.openedition.org/craup/309
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[3]. Perricone, V. Ph.D in “Environmental, Design and Innovation”. Title of thesis: Mechanical design of the echinoid endoskeleton and inspired industrial details for design engineering in the Industry 4.0 Era, November 2017
[4]. Marmo, F.; Perricone, V.; Langella, C.; Pontillo, G.; Rosati, L. Bioinspired design of shell structures: a lesson from echinoids. In Proceedings of *IASS Annual Symposia* (Vol. 2019, No. 26, pp. 1-7), International Association for Shell and Spatial Structures (IASS), 2019
[5]. Chayaamor-heil, N.; Hannachi, N. Towards a Platform of Investigative Tools for Biomimicry as a New Approach for Energy-Efficient Building Design, Building Journal, Vol.7 issue 1, 6, march 2017, Switzerland, MDPI AG, Basel, DOI: https://doi.org/10.3390/buildings701001952
[6]. Perricone, V.; Grun, T.; Marmo, F.; Langella, C.; Candia Carnevali, M.D. Constructional design of echinoid endoskeleton: main structural components and their potential for biomimetic applications. Bioinspiration & Biomimetics, 2020 (doi: 10.1088/1748-3190/abb86b)

Bioinspired self-cleaning surfaces for car interior applications

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Keywords: bioinspiration, plasma, nanostructures, catalysis, mobility

The rapid development of new types of mobility and transportation based on car sharing, with frequent change of drivers and occupants of vehicle, and with the constant threats of microbial contamination of surfaces, as highlighted by the recent COVID-19 pandemic, reinforces the need for the development of innovative car interior materials surfaces with self-cleaning, easy-to-clean, omniphobic, and anti-fingerprint properties. In this work, we considered different techniques to attain self-cleaning materials based on photocatalysis, superhydrophilicity, and omniphobic principles. First, we examined the natural photocatalysis provided by the chlorophyll of plants and we were able to coat plasma-processed polymeric materials with functional thin films involving TiO_2. Photocatalytic and self-cleaning tests were performed and results revealed enhanced degradation of aqueous dye pollutants on the TiO_2-coated polymeric substrates. The second technique takes inspiration from the hydrophilic and superhydrophilic properties observed from the nanostructures present on the leaves of plants such as *Alocasia odora, Calathea zebrina,* and *Ruelia devosiana.* Cupric oxide (CuO) nanoparticles were synthesized from the plasma surface modification of copper (Cu) that exhibits underwater self-cleaning hydrophilic and superhydrophilic properties[1]. This study also shows the possible mechanisms on how CuO, CuO_2, and Cu_2O_3 were formed from Cu based on the varying the plasma parameters. Lastly, based on bioinspired models of oleophobic to omniphobic surface texture and composition, from natural species such as springtails, bronchosomes on the surface of leafhoppers, filefish, and shark skin, we developed different post-functionalization techniques to achieve functional properties on polymeric surfaces that are commonly used on automotive interior. For example, the plasma-treated copper substrates were post-functionalized using self-assembled monolayers to attain superhydrophobicity for dropwise condensation applications. Different fluorination techniques were also performed on polymeric substrates to attain different functional properties. For all the techniques used in this work, the surface chemistry and the surface micro- and nano-structures, like the one shown in Fig. 1, had played a major role to obtain self-cleaning properties.

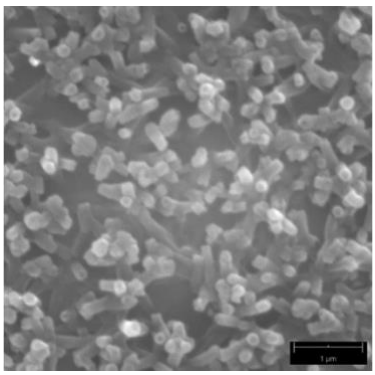

Fig. 1: Nanostructures observed from the surface of polymeric substrates that exhibit self-cleaning properties.

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Effect of laser texturing environment media on wetting of biomimetic superhydrophobic surfaces designed by femtosecond laser pulses

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Keywords: biomimetics, wetting, superhydrophobicity, femtosecond laser

Superhydrophobic surfaces are found extensively in nature and have attracted attention over the past years due to their wide range of potential applications including the prevention of biofilm development and ice formation. Superhydrophobicity can be reached by tuning the topography and chemistry of a surface to mimic occurrences in nature. One of the challenges is to find a way to make superhydrophobic surfaces without changing the characteristics of the material and without using chemicals. In this study, to achieve superhydrophobicity, femtosecond laser texturing is chosen as it has the particularity of having little, if not any, effect on the material itself [1] and without post chemical treatment.

Inspired by *Euphorbia* leaves, multi-scaled micrometric square pillars are textured on stainless steel 316L with a femtosecond laser in ambient air and under a constant CO_2 gas flow. Independently of the environment, both surfaces have similar topographic parameters, including height and width of the micrometric square pillars, and are visually consistent (Figure 1). However, Figure 2 reveals that the surfaces aged differently when textured in ambient air or under CO_2. The steady state contact angle (SSCA) increases faster and reaches a higher value when the surface is textured under CO_2: 142° vs 119° for the surface textured in ambient air. This 23° difference implies that surface chemistry has a significant impact on wetting. Kietzig et al. [2] showed that storing samples in different environments has an impact on their SSCA. Here, we demonstrate that direct exposition to CO_2 during laser processing not only plays a role in the SSCA but also in the rate at which the transition between the hydrophilic and hydrophobic regimes occurs.

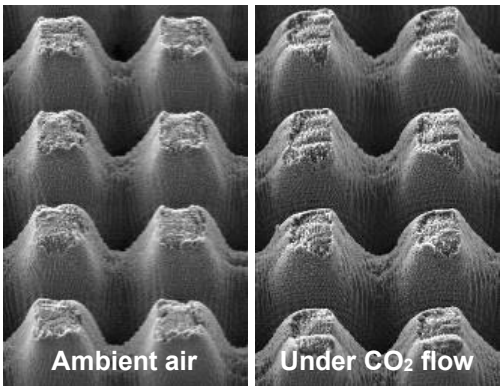

Fig. 1: SEM images of micrometric square pillars.

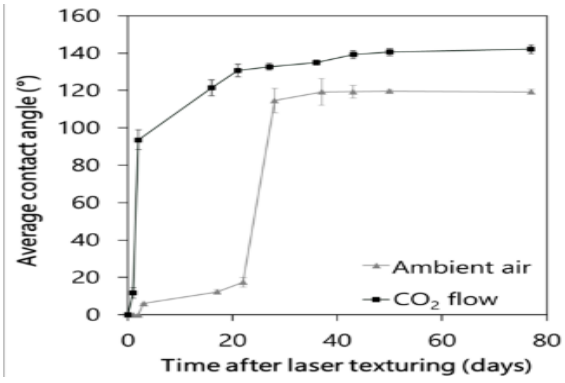

Fig. 2: Average contact angle as a function of time

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Modelling and Simulation

Decoding an ambiguous EPR signal in *Pl*AA10 LPMO enzyme by construction of active site models using DFT

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Keywords: Lytic polysaccharide monooxygenase, density functional theory, electronic paramagnetic resonance.

Lytic polysaccharide monooxygenase enzymes (LPMOs) are capable of degrading recalcitrant polysaccharide and are greatly studied for their application in biomass conversion. Understanding the structure-function properties of the LPMO's active site will give great insight for the development of new biomimetic models. LPMOs contain a mononuclear copper center in their active site which coordinates the terminal histidine amino acid in a bidentate fashion with the primary amine in what is known as the histidine brace motif. A second histidine and two water molecules complete this coordination sphere. The paramagnetic Cu(II) resting state of the active site is probed by means of electronic paramagnetic resonance (EPR). The electronic and geometrical information of these centers are encoded within the g- and A- tensors of the EPR spectrum. Munzone *et al.* purified and characterized the *Pl*AA10 LPMO enzyme by X-band EPR and two species were found in solution.[1] The major species displays a set of rhombic EPR parameters while the EPR spectrum of the minor species is of axial symmetry. Chaplin *et al.* observed similar features in the study of the *Sli*LPMO10E LPMO enzyme and suggested that the minor species arises from the decoordination of the primary amine combined to the coordination of chloride anions from the buffer solution.[2] In Munzone's study, chlorine anions are not present. What is the origin of this ambiguous EPR signals? How is this minor species generated?

By means of density functional theory (DFT) and making use of our benchmark study for the prediction of EPR parameters in copper complexes,[3] we constructed multiple models of the *Pl*AA10 active site starting from the expected LPMO geometry and undergoing several modifications: decoordination of a water molecule, decoordination of the primary amine, and single or double deprotonation to form one or two hydroxyl ligands. Our results indicate that neither the decoordination of a water ligand, nor the decoordination of the primary N-terminal amine, reproduce the minor species. These events alone are not responsible for the presence of the minor species. However, the presence of hydroxyl ligands coordinating the copper center fully shift the EPR parameters and reproduce those of the minor species. This observation stands in the case of chloride ligands. Our findings in the calculation of the EPR parameters of the constructed models will be presented.

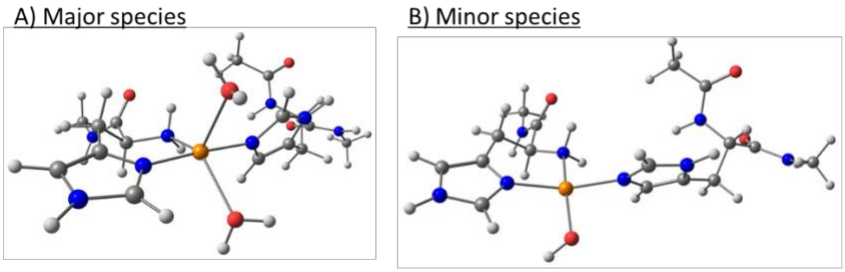

Fig. 1: Proposed LPMO active site models of the A) major and B) minor species.

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Comparison of topology optimization based on classical and bio-inspired objectives

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Keywords: topology optimization, bio-inspired, compliance, uniform strain

Abstract: Biological structures usually generate a uniform strain field to avoid over-loading or under-utilising material. This research presents the topology optimization of a cantilever beam used as a structural model of a plane wing. We compare the bio-inspired optimality criteria of a uniform strains distribution with the classical objective function of compliance minimization. Associated finite element simulation results based on bio-inspired optimization show more uniform the stains distribution and strains of each element decreasing. This research provides new ideas for structural design principles.

Biomimetism and hexapodal gait, a first step in ant

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Pierre Moretto *,[1]

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Keywords: Ant; motion capture; multibody; biomechanics; exoskeleton.

Insects are known to show a high variety of locomotor patterns [4]. Although hexapody is certainly a key for this diversity, it is also often assumed that this could be due to the properties of their musculoskeletal system. Understand how small animals can articulates each body segment during a given movement and how muscles actuations are applied for a given task could be useful in the development of engineering applications. According to these applications bio-inspired robot architecture [3], bio-inspired control strategies for legged robots [3] and bio-inspired actuation systems [1], are emerging. Yet, the link between the kinematics of insect locomotion and the biomechanical properties of their muscles and exoskeleton has rarely been investigated.

Using the seed harvesting ant *Messor barbarus* (Fig 1.a), we are currently developing a multibody simulation model with the software OpenSim representing its whole-body locomotor system (Fig 1.g). First, we built a polyarticulated model using ITK-SNAP (version 3.6.0). This model integrates the organization of its entire exoskeleton, as well as the different types of joints (hinge or ball-and-socket) between its body segments and muscle groups identified by the cross-checking of images obtained from histology and microtomography (Fig. 1.d, e, f). We then enriched this model with 3D kinematics data obtained by filming walking ants with 5 high speed synchronized video cameras and by tracking 47 control points at strategic locations on their body during a gait cycle (Fig 1 b, c) with the motion analysis software Vicon motus (version 10).

The model will be used to generate realistic simulations to estimate the forces and constraints developed by the muscles and joints of an ant during free locomotion. It will also allow us to make the mechanical link between the internal and external structures of ant exoskeleton in different conditions in order to lay the foundations for the building of a biomimetic exoskeleton that could be used in hexapod robots or human.

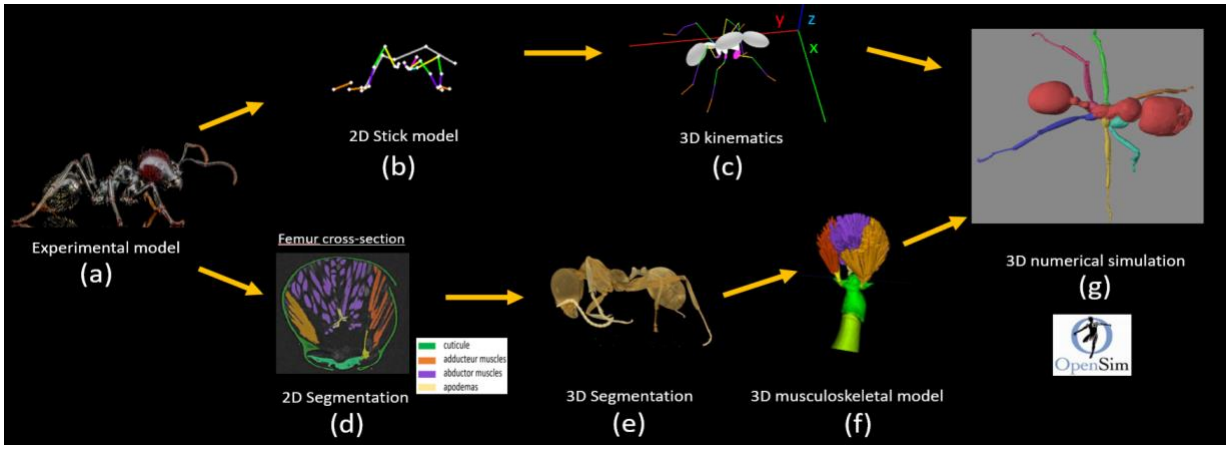

Figure 1 : Experimental protocol followed to obtain a 3D numerical simulation on Opensim

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Catalysis

Engineering of a copper metalloenzyme for new-to-Nature reactivities

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Keywords: LPMOs, abiological catalysis, mutagenesis, biomimicry

In the context of sustainable development, chemical industries turn progressively towards processes respecting the criteria of green chemistry and notably biocatalysis by mimicking Nature's catalysis. However, lots of industrial reactions (such as those catalyzed by transition metals) do not exist in Nature. As a result, enzymes are not able to catalyze them, which restricts the use of enzymes in industrial processes. Chemists try therefore to repurpose enzymes activity and more particularly metalloenzymes activity for non-natural metal-catalyzed reactions. For instance, several hemoproteins have been engineered by directed evolution for abiological carbene and nitrene transfers [1]. Few non-heme iron-dependent enzymes were also evolved for nitrene transfers [2] but no non-ferric protein is reported for these transformations whereas other metals catalyze them as copper. We thereby aimed at repurposing the activity of a class of copper metalloenzymes, the Lytic Polysaccharide MonoOxygenases (LPMOs), to develop new biocatalysts for new-to-Nature reactivities.

LPMOs are involved in the degradation of recalcitrant polysaccharides (Fig. 1a). Their active site harbors a very unusual metal coordination motif known as "histidine brace", consisting of two fully conserved histidines, one of which is located at the *N*-terminus and binds copper by both its side chain nitrogen and the free amino-terminal group (Fig. 1b) [3]. The LPMOs active species being isoelectronic to copper-carbene/nitrene species, we hypothesized that LPMOs also catalyze carbene and nitrene transfers (Fig. 1c). We modulated the copper environment by site-directed mutagenesis of active-site residues and evaluated the LPMO mutants for non-natural reactivities. We have shown that LPMOs can catalyze several abiological reactions, including carbene and nitrene transfers, making LPMOs the very first copper-dependent enzymes for carbene and nitrene transfers (Fig. 1d). Some mutations improving the LPMOs abiological activity, we will continue to further engineer LPMOs by mimicking Nature's evolution (by directed evolution) to create a panel of LPMOs for non-natural reactivities.

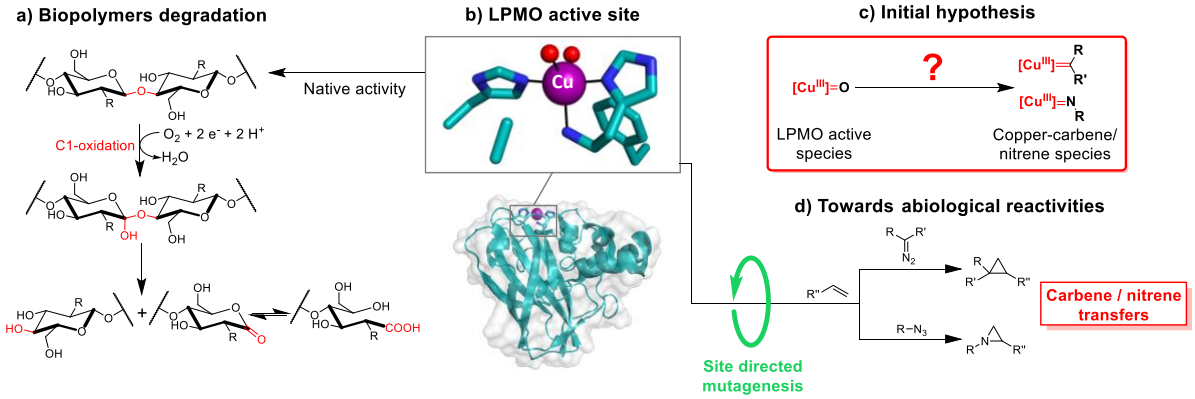

Fig. 1: Engineering of LPMO copper active site for abiological reactivities

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Cooperativity between hydrogen bonding and anion-π interaction in anion recognition and catalysis

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[2] *LAMBE, Université Paris-Saclay, UEVE, CNRS, 91025 Evry, France*
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The dysfunction of anion channels is caused by the misregulation of anion transport through cell membranes. Several genetic diseases, such as cystic fibrosis, originate from such phenomenon.[1] The mechanism of some natural ion channels has inspired scientists to mimic nature and develop new artificial anion carriers (anionophores).[1],[2a] Therefore, selective anion binding, based on weak interactions, is of current interest. The concept of anion binding, was also applied to catalysis.[2] The ultimate goal is to control the stereoselectivity of a process involving a cationic reaction intermediate within a pair of ions. Binding the anion in such reactions, helps not only to exacerbate the associated cation's reactivity, but also to create a non-racemic environment as close as possible to the reaction site.

In this context we have designed a series of anion receptor platforms comprising both a hydrogen-bond donor and a π-deficient heterocycle acting both as □-anion donor and a probe.[3] Firstly, we will discuss the efficiency and the cooperative effects between noncovalent interactions in anion binding thanks to the combination of theoretical calculations (Fig. 1) and photophysical experiments (Fig. 2) in a model receptor.[3] Secondly, we also envisioned the use of such anion receptors in catalysis. Finally, preliminary results in selected catalytic transformations will be presented (Fig. 3).

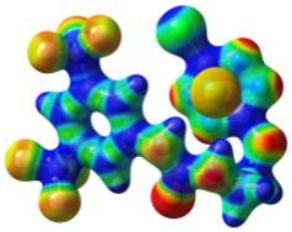

Fig. 1: ESP of a chloride complex

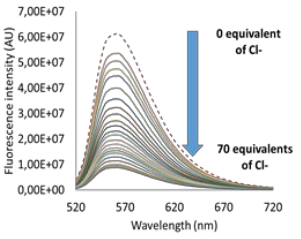

Fig. 2: Fluorescence titration with chloride

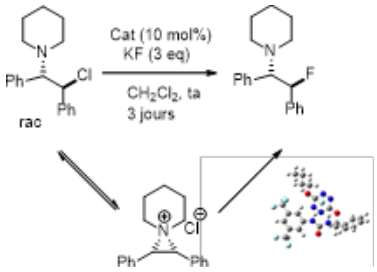

Fig. 3: Enantioselective synthesis of β-fluoroamines

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Combining Biopolymer and Metal-Organic Framework for Protein Encapsulation

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Keywords: Bio-hybrid materials, Metal Organic Framework, biopolymer, bio-catalysis, bio-immobilization

Alginate is a well-known polysaccharide used for a diversity of applications such as immobilization of biomolecules. It has the property of forming a hydrogel upon crosslinking with di or trivalent cations. This alginate is an efficient bio-immobilisation matrix since It allows an easy control of the final shape and is inherently biocompatible.[1] However, it can suffer from low mechanical stability, but this can be overcome by association with inorganic materials, such as silica however their low porosity is a sensitive point, since it can hamper reactants diffusion.

In this work, we propose to use Metal-Organic Frameworks (MOF) to address these limitations. MOFs are porous crystalline hybrid materials, built-up by assembly of inorganic nodes and organic linkers through strong coordination bonds. MOFs are highly porous materials that can exhibit BET surface area up to ~7.000 $m^2.g^{-1}$,[2] and have shown promising properties for bio-immobilization.[3,4] Herein, we selected a water stable MOF, the microporous aluminum polycarboxylate, MIL-53(Al)-FA (MIL = Matériaux de l'Institut Lavoisier), and optimized synthetic conditions to form MOF-Alginate hybrid materials. Obtained materials were characterized by various technics (PXRD, infra-red spectroscopy, SEM, TGA, nitrogen porosimetry). The hybrid material was then successfully used for immobilization of an enzyme, a laccase. The catalytic activity of the laccase upon immobilization was investigated, showing promising results as it was preserved, stable and recyclable.

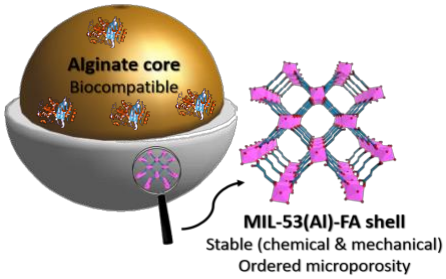

Figure 2: schematique representation of bio-hybrid material

References:

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Displacement and Movement

Comparison of three Motion Generators for a 3-SPS-U Tensegrity Mechanism

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Keywords: Tensegrity mechanism, motion generators, parallel robots, EtherCAT

In this presentation, we will generate trajectories for a 2-DOF tensegrity mechanism that uses three tension springs and a passive universal joint. This mechanism is proposed to be incorporated as an articulation unit for a piping inspection robot in order to overcome pipe bends and junctions. In the event of a junction, an external actuation is required to allow the mechanism and the robot to follow a certain direction. Using DC-motors coupled with encoders and an EtherCAT drive, experiments are carried out on a test bench of the tensegrity mechanism. The actuation of the mobile platform is performed using cables that pass through each spring. By correlating the architecture to a 3-SPSU parallel mechanism, the singularity-free workspace of the mechanism is analyzed to identify the tilt limits. With the help of a closed-loop PID controller, linear trajectories are generated within the singularity free workspace. Three types of motion generators are tested to solve the Inverse Kinematic Problem (IKP) by passing the input tilt angles to the controller. Using a force control algorithm, the experiments are carried out under no-load conditions for vertical orientation of the mechanism. The error data of the joint positions and the motor torques are then interpreted and compared for the three motion generators.

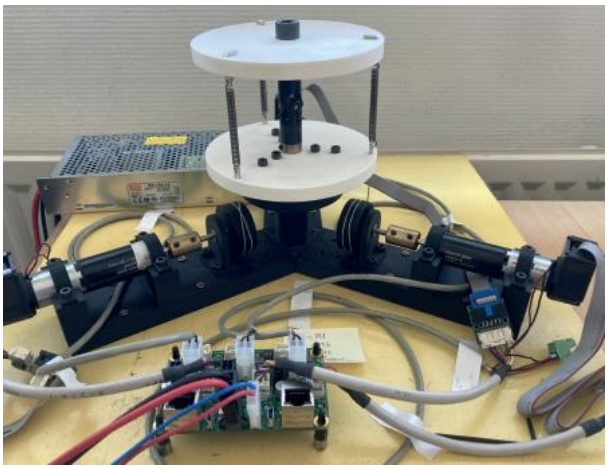

Fig. 1: Representation of the experimental setup of the tensegrity mechanism

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How individual perceptual and cognitive factors affect collective motion in a data-driven fish school model

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Keywords: Collective behavior, Flocking, Fish school, Computational modeling, Data-driven model

In moving animal groups, social interactions play a key role in the ability of individuals to achieve coordinated motion. However, a large number of environmental and cognitive factors are able to modulate the expression of these interactions and the characteristics of the collective movements that result from these interactions. In this work we use a data-driven fish model [1,2] to quantitatively investigate the impact of perceptual and cognitive factors on collective swimming patterns. The model precisely describes interactions involved in the coordination of burst-and-coast swimming in groups of rummy nose tetras (*Hemigrammus rhodostomus*), a small tropical freshwater fish. In this species, fish only pay attention to one or two neighbors that exert the largest influence on their behavior and the interactions consist for a fish to be attracted and aligned with these neighbors. We perform a comprehensive investigation of the respective impacts of two interactions strategies between fish based on the selection of the most or the two most influential neighbors, of the range and intensity of social interactions, of the intensity of individual random behavioral fluctuations, and of the group size, on the ability of groups of fish to coordinate their movements. We find that fish are able to coordinate their movements provided that a minimal level of attraction between fish exists to maintain group cohesion. Increasing the interaction range has a similar impact on collective dynamics as increasing the interaction strengths. A minimal level of alignment is also required to allow the formation of schooling and milling. However, increasing the strength of social interactions does not necessarily enhance group cohesion and coordination. When attraction and alignment strengths are too high, or when the heading random fluctuations are too large, schooling and milling can no longer be maintained and the school switches to a swarming phase. Our results also show that a moderate level of behavioral fluctuations in fish can induce spontaneous transitions between schooling and milling. Finally, in this species that performs burst-and-coast swimming, we find that coordination occurs for a wider range of interaction strengths only in small group sizes. These results will serve as a basis for the development of distributed algorithms to coordinate collective motion in swarms of drones. Indeed, one of the great challenges of collective robotics consists in designing self-organized groups of autonomous drones with the ability to carry out collective tasks such as monitoring forest fires or rescue operations in emergency situations.

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Biomaterials A

Calcium phosphate: from biominerals to biomaterials

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Keywords: Biomineralization, Biomimetic apatites, Calcium phosphates, Bone mineral, Bioceramics

Biominerals are inorganic compounds built up by cells. The advent of biomineralization in the evolution of life has allowed a high diversification of species by allowing new opportunities (organ protection, enhanced mobility…). Several types of biominerals may be encountered in living organisms, including silica, calcium carbonates and calcium phosphates (CaPs) [1]. The latter are especially important as they are present in all vertebrates as the mineral part of bones and teeth. The apatite structure (Fig. 1) can accommodate ion vacancies (non-stoichiometry) and a large variety of ionic substituents allowing adaptations to *in vivo* requirements. While tooth enamel (consisting of coarse-grained, fluorinated hydroxyapatite close to stoichiometry) has to resist acidic attacks from bacterial activity, bone mineral (i.e. non-stoichiometric and polysubstituted nanocrystalline apatite) should easily undergo bone resorption for microfractures self-healing and skeletal development, and needs to exhibit a high surface reactivity for interacting with surrounding body fluids components (homeostasis). This compositional flexibility can be thought as one superior feature compared to SiO_2 or $CaCO_3$-based biominerals for example, where non-stoichiometry and ionic substitutions are generally not permitted.

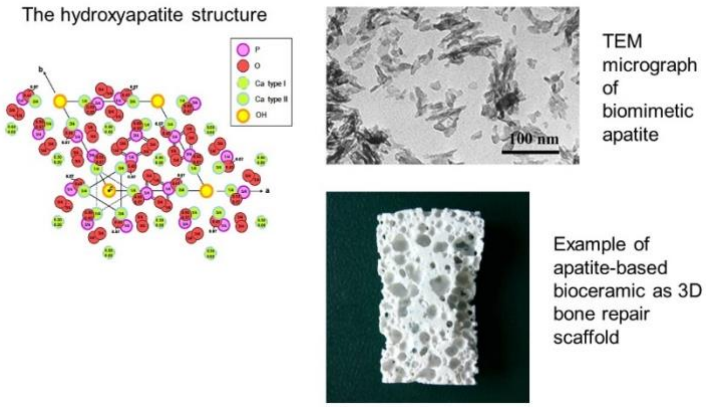

Fig. 1: Apatite: structure, TEM micrograph of biomimetic analog and example of bioceramic

In this talk, the composition of bones and teeth will be reminded. Then, the specific characteristics of apatite nanocrystals composing bone mineral (as well as synthetic biomimetic analogs) will be described and commented, both from a physicochemical and thermodynamic point of view. These considerations will allow setting the background for the development of highly bioactive biomaterials based on biomimetic apatites, exploiting in particular (surface/bulk) ionic exchanges and molecular adsorptions for tailoring the properties of the obtained (multi)functional advanced biomaterials [2]. Several new functionalities may indeed be conferred such as antimicrobial, antitumoral, hemostatic, antiresorptive… by adequately associating bioactive ions and (bio)molecules/drugs. These aspects will be illustrated in link with applicative domains, for bone regeneration but also in nanomedicine (e.g. oncology, dermatology, hematology...) [3] using the intrinsic biocompatibility of bio-inspired apatites and the possibility to tailor "*à la carte*" their properties for a wealth of biomedical applications.

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Fluorescence of natural biomatter in Asian paper wasp nests

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Keywords: fluorescence, biomatter, quantum yield, *Polistes*

Up to date fluorescence of terrestrial animals is far from being fully explored. [1-2] In contrast to marine organisms not many terrestrial species have been reported yet to show strong fluorescence emission in the visible range detectible to the human eye. In the present communication we will describe the context and the unprecedented discovery and characterization of the exceptionally bright fluorescence of oriental paper wasp nests (Fig.1). To the best of our knowledge it represents one of the strongest green fluorescence phenomena of natural terrestrial biomatter that has been reported up to date. Remarkable Stokes shifts of around 160 nm and most importantly particularly high fluorescence quantum yields of up to 35.6 % were measured. [3] These interesting and unique photo luminescence properties of diurnal social insects can be attributed to fluorophores incorporated in the silk proteins of the cocoon caps fabricated by the larva prior to its metamorphosis. Potential biological functions of the fluorescence properties are discussed. Only the relatively recent availability of portable LED UV flashlights made this discovery possible, via a systematic infield search for terrestrial fluorescent organisms. We are convinced that such an approach will boost in an unprecedented way the quest for novel photoluminescent biomaterials during the next decade. Besides the expected discovery of new classes of fluorescent compounds with potential applications in biological and biomedical domains, quantitative studies of biological tissues are still longed for. The discovery of this striking example of a fluorescent terrestrial biomaterial may contribute to the debate on adaptive biological functions of natural fluorescence and falls in line with the growing interest in biodiversity and the bio-inspired development of new functional structures and materials.

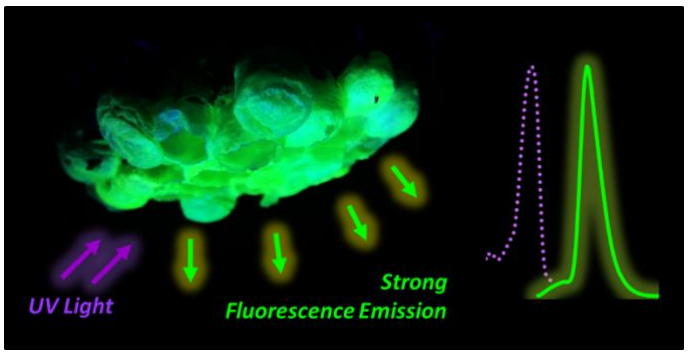

Fig. 1: UV excitation and fluorescence emission of the cocoon caps of *Polistes brunetus*.

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In situ and *ex situ* characterization of biomimetic platforms used for the analysis of heparan sulfate-mediated BMP biological activity

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Keywords: surface characterization, heparan sulfate, BMPs, image correlation spectroscopy

Over the last decade, there has been a growing interest in the development of new materials to improve bone morphogenetic proteins (BMPs) delivery for tissue regeneration. *In vivo*, BMP2, 4, 6 and 7 are bound to the extracellular matrix components, mostly to fibronectin and heparan sulfate (HS) and with less extent to chondroitin sulfate. The development of materials, which are able to control BMPs molecular presentation by mimicking its *in vivo* presentation is an essential approach for a deeper understanding of BMPs functions and the modulation of its biological activity. Streptavidin (SAv)-based biomimetic platforms have proven their high capability to study this interface between the ECM and cells by immobilization of biotinylated molecules such as adhesion peptides (cRGD), HS and adsorbed BMP2 [1]. To conclude on the role of each immobilized molecule, precise surface characterization of the molecular surface density is compulsory. The surface sensitive techniques spectroscopic ellipsometry and quartz crystal microbalance with dissipation monitoring deliver kinetic molecular binding data and areal mass density on auxiliary model surface. These *ex situ* techniques allow design and control of experimental conditions. Surface characterization *in situ* inside functionalized 96-well plates used for cellular studies was a challenge, so far, due to surface properties, geometrical constraints or only semi-quantitative tools. We introduced fluorescence-based image correlation spectroscopy combined with photobleaching to characterize biomimetic platforms *in situ* inside glass-bottom 96-well plates [2]. We measured a homogeneous SAvAlexa555 monolayer with 336 ± 34 ng/cm^2, in line with *ex situ* spectroscopic ellipsometry measurements. Then, we functionalized a full 96-well plate presenting BMP2/4/6 and 7 in different concentrations adsorbed on to immobilized HS to study the effect of HS on different BMPs bioactivity in C2C12 myoblasts. Well-controlled, flexible and precisely characterized biomimetic SAv-platforms are a great candidate to study the role of glycosaminoglycans, peptides and growth factors on cell differentiation.

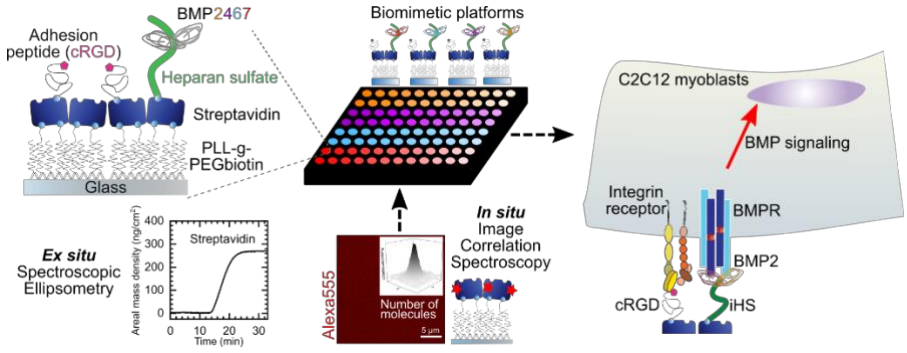

Fig. 1: Biomimetic platforms present heparan sulfate, adhesion peptides and BMPs to cells. Platforms were characterized for molecular surface density with photobleaching image correlation spectroscopy *in situ* and with spectroscopic ellipsometry *ex situ.*

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4D Smart electroactive porous scaffold as innovative cell culture platform

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Keywords (5 maximum): Engineered cell microenvironment; polyHIPE; conductive polymers; In situ cells stimulation

The cell micro-environment is a dynamic network that determines the cell functions and behavior in physiological and pathological processes. Reproduce the cell micro-environment properties *in vitro* is a key challenge in fields of physiopathological research, drug screening and tissue engineering. Tremendous advancements on 3D cell culture models have been made to better mimic them, but they generally remain passive structures which do not allow *in situ*/real time monitoring, thus lacking the *in vivo* dynamics. The objective of this work is to develop a dynamic 4D cell culture platform by tailoring a passive porous 3D polyHIPE scaffold to an electroactive scaffold using PEDOT poly(3,4-ethylene dioxythiophene) conductive polymer[1]. 4D electrostimulable PolyHIPE/PEDOT scaffolds are compliant with cell culture platform requirements without modifying their mechanical response in cell culture media. They display a high porosity which allow fibroblasts colonization from the first hours after cell seeding. Cells adhere on the surface as well as inside the PolyHIPE/PEDOT scaffolds and they display typical membranes protrusions of spread cells such as lamellipodia and filipodia. Scaffolds allow the in-situ stimulation of cells without inducing cytotoxicity. Finally, it was possible to monitor *in situ* and in real time the changes in cell morphology under a mechanical stimulus resulting from volume variation of the dynamic polyHIPE/PEDOT scaffolds. The 4D-cell culture scaffold could pave the way to more realistic in vitro cell microenvironment integrating biophysical cues in a dynamic way.

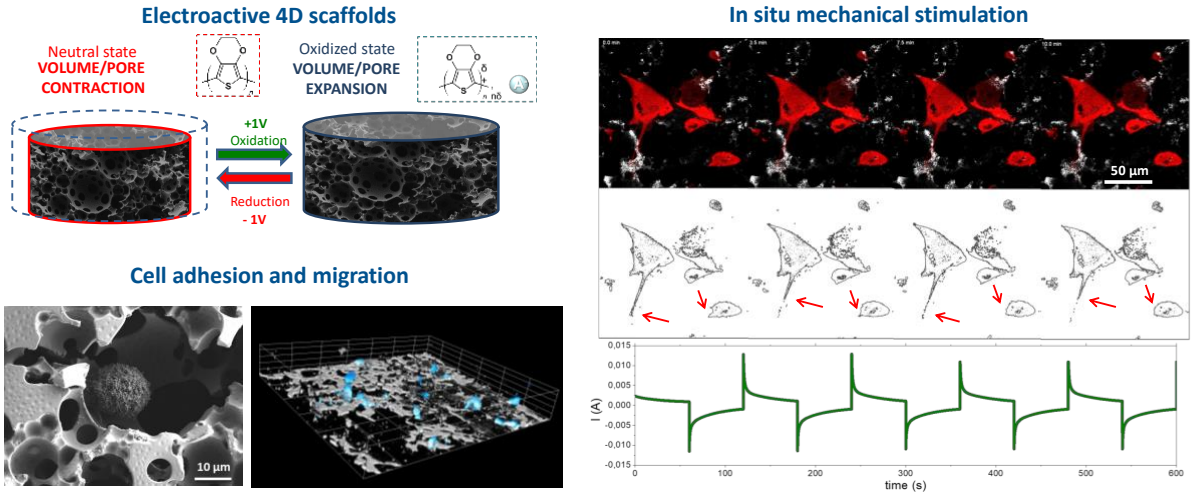

Fig. 1: 4D electroactive scaffolds present a tailored volume variation response, allow the cells adhesion and migration, and support the monitoring *in situ* of the cell behavior under a mechanical stimulus as a volume variation.

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Solid-Phase Synthesis of Molecularly Imprinted Polymer Nanogels-Synthetic Antibody Mimics for the Recognition of Protein Biomarkers

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Keywords (5 maximum): antibody mimics, epitope imprinting, molecularly imprinted polymers, biomarkers.

Abnormalities in the expression of cell surface proteins or receptors are promising biomarkers of human diseases. However, the detection and quantification of these biomarkers are often challenging. Molecularly imprinted polymers (MIPs) are tailor-made synthetic receptors (antibody mimics), able to specifically recognize target molecules. They are synthesized by copolymerization of functional and cross-linking monomers in the presence of a template molecule, resulting in the formation of binding sites with affinities and specificities comparable to those of antibodies.

In the present project, we demonstrate the targeting of the protein Hepatitis A Virus Cell Receptor-1 (HAVCR-1), with MIP nanoparticles. This protein was selected because of its ubiquitous implication in numerous pathologies. MIPs were synthesized using a solid-phase approach in which a fragment of the protein (an epitope) was selected by molecular modelling. The epitope peptide was chemically synthesized and used as the imprinting template. It was immobilized on glass beads (solid support) via click chemistry. This allows an oriented immobilization of the template upon which thermoresponsive MIP nanoparticles are synthesized. The binding sites of the resulting MIPs all have the same orientation, thus MIPs synthesized by the solid-phase approach can be considered analogous to monoclonal antibodies.

MIPs were found to bind the epitope with high affinity (nanomolar K_D) and selectivity as demonstrated by equilibrium binding assays with the fluorescently labeled peptide. Specific binding of the epitope template to the MIPs was confirmed by NMR Saturation Transfer Difference and WaterLOGSY spectroscopies. The application of MIPs as diagnostic and therapeutic agents is being studied.

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Structure A

Anisotropic properties of bio-inspired nanocomposite materials

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Keywords: complex bio-inspired nanostructures, wood-like materials, anisotropic optical/mechanical properties, layer-by-layer assembly, nanocellulose

The remarkable properties of natural composite materials (e.g. plant cell wall, animal exoskeleton) have attracted a wealth of research to understand their structure-properties relations at all length scales and to design novel materials with superior performance. However, while nature masters the organization of anisotropic nano-objects like nanocelluloses into complex superstructures, the development of synthetic nanocomposite materials with complex and precisely controlled architectures (e.g. helical) has proven to be difficult due to the lack of suitable approaches for their preparation.
With respect to the preparation of multimaterial thin films with a high level of control over the spatial positioning of their constituents, Layer-by-Layer (LbL) assembly [1,2] has gained its merits as a simple and highly versatile nanofabrication method. While the sequence of components in layered multimaterial films can be very well controlled by LbL-assembly, tuning of the in-plane anisotropy has not yet been achieved. Recently, we have introduced a method called “Grazing Incidence Spraying” for the in-plane alignment of anisotropic nanoparticles (cellulose nanofibrils, metallic nanowires and nanorods, …) on large areas [3]. Its combination with the LbL-approach permits to extend it toward the preparation of complex (e.g. helical) multilayer films in which the composition and orientation can be controlled independently in each layer.

The talk will illustrate some of our recent results on the design of complex bio-inspired nanostructured materials combining hard anisotropic elements like nanocelluloses with soft polymer building blocks. The preparation of such thin films will be presented and their optical and mechanical properties will be discussed as function of the film composition and geometry,[2,4] with a special emphasis on helical superstructures, which display chiroptical activity.

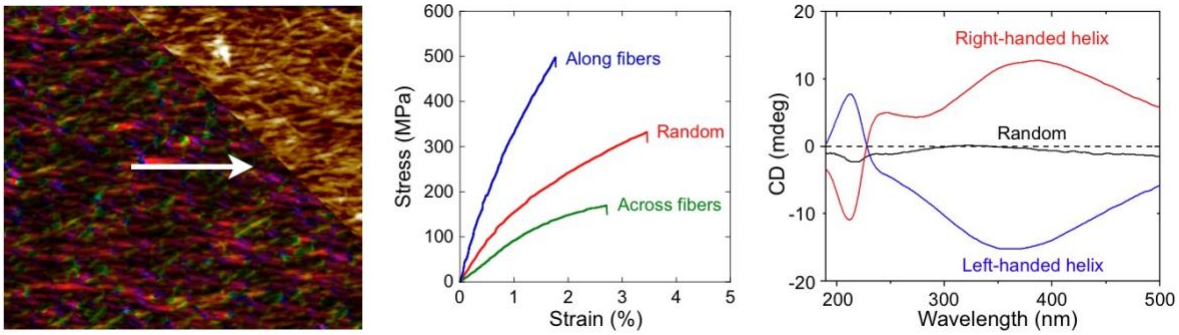

Fig. 1: (left) In-plane alignment of cellulose nanofibrils. (center) Tensile properties of random and oriented nano-composites . (right) CD spectra of random and helically oriented films.

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Cubosomal lipid nanoparticles encapsulating plasmalogens with neuroprotective effects

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Keywords : Structure, Plasmalogen, Cubosome, Neurodegenerative disorders

Lipid membrane-derived liquid crystalline nanoparticles, fabricated from biodegradable natural sources, provide safety profiles for targeted drug delivery [1]. Brain is vulnerable to reactive oxygen species (ROS), which damage functional biomolecules in the neuronal cells. Development of smart nanocarriers of antioxidant compounds is of strong current need for protection against oxidative stress and retarding the progression of the neurodegenerative disorders [2]. Plasmenyl-phospholipids (plasmalogens) are a class of ether-type (1-alkyl-1'-enyl, 2-acyl) glycerophospholipids, which modulate the membrane fluidity and dynamics, influence the membrane protein organization, and provide reservoirs of secondary messengers or precursors of inflammatory mediators. Decreased ethanolamine plasmalogen levels have been established with the progression of Alzheimer's (AD) and Parkinson's (PD) diseases, psychiatric disorders, in neuromuscular impairments, glaucoma, coronary artery disease and acute myocardial infarction [3]. However, the instability of plasmalogens essentially limits their therapeutic use. For this reason, we designed novel lipid nanoparticles as nanoscale carriers for transport and delivery of plasmalogens.
Plasmalogen-loaded lipid nanoparticles were prepared by self-assembly of PUFA-chain derivatives, nonlamellar lipids and lipophilic antioxidants. They were characterized by synchrotron small-angle X-ray scattering (SAXS) and quasi-elastic light scattering. Cellular viability experiments and confocal microscopy imaging characterized the interaction of the obtained nanoparticles with a neuronally-derived cellular model. Furthermore, we evaluated the *in vitro* neuroprotective capacity of cubosome and liposome nanoparticles as a function of their composition and structural organization.

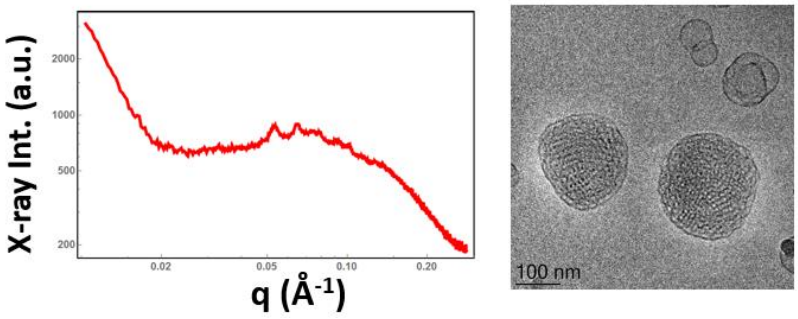

Fig.1: SAXS patterns and cryo-TEM image of plasmalogen-loaded cubosome nanoparticles.

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Surface engineering of stainless steel to limit dairy fouling adhesion

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Keywords: Slippery liquid-infused surface, Hydrophobic nano-structured coating, Anti-fouling, Biomimetic, Dairy processing

Unwanted fouling deposits are formed on heat exchangers' surface during mandatory thermal treatments (pasteurization, sterilization) of dairy products in food processing industries. These deposits can contaminate dairy products to pasteurize and also impair heat transfer mechanisms by creating a thermal resistance, thus leading to regular shut down of the processes. Therefore, periodic and drastic cleaning-in-place (CIP) procedures are implemented. These CIP involve the use of chemicals and high amount of water, thus increasing environmental burden. It has been estimated that 80% of production costs are owed to dairy fouling deposit. To reduce dairy fouling, stainless steel surface is modified to either inhibit attachment of depositing species or to ease their removal during cleaning. Here, we focus on this latter approach, by developing specific coatings (Slippery Liquid-Infused Surfaces (SLIS) and atmospheric plasma coatings) of low contact angle hysteresis to limit fouling adhesion onto stainless steel surfaces. First, SLIS are inspired by *Nepenthes* plant by designing slippery interface between the substrate and the fouling providing very efficient fouling-release surfaces. Slippery surfaces were elaborated in three steps: (i) femto laser surface structuring, (ii) silanization and (iii) lubricant impregnation. In order to maximize lubricant retention, laser manufacturing parameters were optimized. Second, plasma nano-structured coatings intend to mimic lotus leave surfaces, by creating a dual-scale roughness preventing adhesion of denatured dairy proteins. Hydrophobic silane-based coatings were sprayed by atmospheric pressure plasma (Lab-Scan, Axcys Technologies) and conditions were optimized depending on the fouling test results obtained. Finaly promising fouling-release performances have been obtained for both SLIS and plasma nano-structured coatings.

Fig.1: SEM images of hydrophobic plasma coating (left) and laser textured surface (right)

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The authors thank Region Hauts-de-France for its financial support through the ECONETIAA project, the French National Agency (ANR) for its financial support (ECONOMICS Project ANR-17-CE08-0032) and the french Renatech network (Micro Nano Fabrication Plateform and NearField Platform)

Biomaterials B

Structural Hints from the study of Syneresis of Calcium Alginate hydrogels

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Keywords (5 maximum): Alginate, biopolymers, hydrogels, syneresis, 3D-Printing

Alginate hydrogels are widely used in tissue engineering, wound dressing, drug delivery…
The ability of these polysaccharides to crosslink via “egg-box” chelation of calcium ions makes them suitable for 3D-printing processes. Syneresis, i.e. solvent expulsion out of the gel matrix, reveals the slow shrinking of the polymer network as crosslinking proceeds. It is the main limitation to the practical use of alginate gels.
We have used an extrusion setup to systematically characterize the kinetics of gelation and syneresis of alginate gel fibers in presence of an excess of calcium chloride**Error! Reference source not found.**.
We observe a fast gelation regime followed by a slow syneresis one, spanning decades of time. Amazingly, as syneresis finally reach completion, the equilibrium shrinking ratio of the fiber is very close to ½, whatever the polymer and ion concentration.
We tentatively ascribe this “magic ratio” to the slow “piling-up” of two nearest neighbor “eggboxes” preserving the statistical ratio of crosslinks to elastically active strands while ultimately halving their number by the dimerization process.
We identify the kinetic clock-time for gelation and syneresis depending on the fiber diameter, alginate and ion concentrations, and show that syneresis can be stopped at any stage by decreasing the ion content of the gelation bath.
These findings should be of practical importance for 3D printing processes.

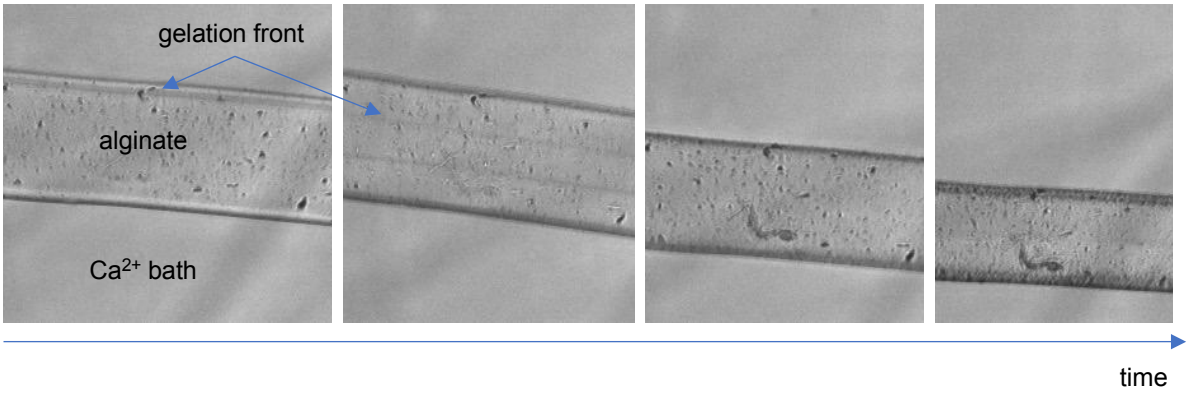

Fig. 1: Evolution of an extruded gel fiber portion (initial diameter 500 µm) as gelation from a calcium bath and the subsequent syneresis proceed.

[1] Da Silva Pinto B., Ronsin O. and Baumberger T. (2021) *in preparatio*

Peptide-decorated bio-inspired apatite nanoparticles: towards wound healing applications

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Keywords: Bio-inspired apatites, Calcium phosphate, Nanoparticles, Peptides, Wound healing

Besides bone regeneration, bio-inspired calcium phosphate apatites exhibit an intrinsic biocompatibility and submicron to nanoscale dimensions that open the way to other biomedical fields as in nanomedicine (hematology, oncology, dermatology…). Previous data demonstrated the possibility to prepare colloidal apatite nanoparticles (NPs) stabilized by an organic corona of aminoethylphopsphate (AEP) or phosphonated ethyleneglycol (PEGp); and *in vitro* evaluations confirmed their very low cytotoxicity, good hemocompatibility and non-proinflammatory potential [1-3]. Such NPs were recently envisaged for dermatological applications in relation with skin disorders like acne [4]. Another appealing field in dermatology relates to wound healing, especially for patients at high risk of infection and/or with healing disorders (e.g. diabetic, immunodepressed, heavily burnt, aged patients…). In this context, the present work aimed at associating for the first time two types of bio-inspired compounds, namely peptides and apatites, to develop bioactive hybrid NPs ultimately capable of presenting antimicrobial, pro-healing and/or anti-inflammatory properties via the selection of the peptides and the possible incorporation of bioactive ions within the apatitic structure. Such hybrid NPs could thus combine the advantages of both components (organic and inorganic) and may promote optimal local release for synergistic effects while being an alternative approach to antibiotics which may lead to deleterious bacterial resistance. We will here present this bio-inspired peptide/apatite NPs proof of concept as well as selected results pointing to the relevance of these systems in the general context of complex wound healing. The authors thank the *Chimie Balard CIRIMAT Carnot Institute* for PhD thesis financing.

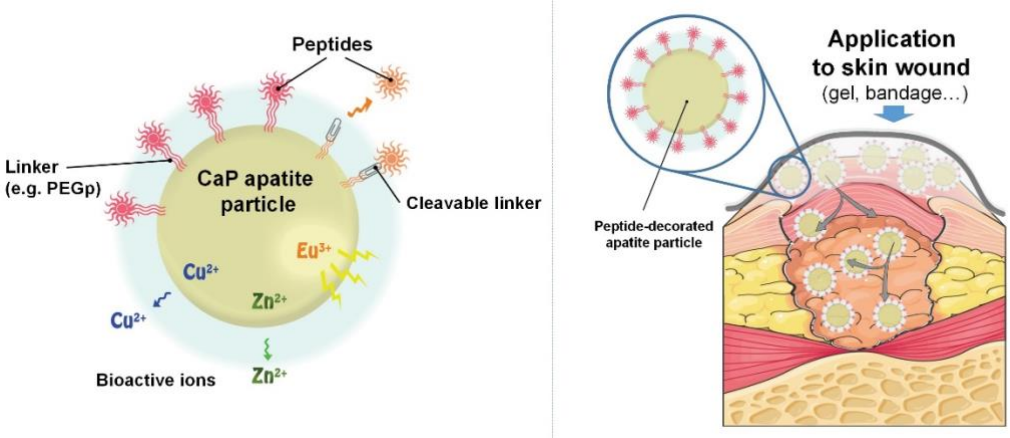

Fig. 1: Multifunctional peptide-decorated apatite NPs for wound healing

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Micropatterning Controlled By Enzyme Assisted Self Assembly Through a Liesegang-like Process

Jean-Yves RUNSER,[1,2] Miryam CRIADO-GONZALEZ,[1,2] Fatima FNEICH,[3] Morgane RABINEAU,[1] Bernard SENGER,[1] Pierre WEISS,[3] Loïc JIERRY,[2] Pierre SCHAAF* [1]

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Keywords : Peptide, Self-Assembly, Supramolecular Chemistry, Hydrogels, Reaction-Diffusion.

Reaction-Diffusion (RD) phenomena are responsible for surface and in-depth micropatterning in living matter and should therefore be taken into account in bottom up approaches used to mimic the Extra Cellular Matrix since a fine tuning of chemical cues releases and spatial mechanical variations is of paramount importance for the production of structures featuring ECM that will allow a better understanding of various biological phenomena such as cell migration, cell differentiation, mechanotransduction or even morphogenesis.

Self-assembly processes that take place in well defined spatiotemporal ways in nature (e.g. actin fibers formation) are of great inspiration in this scope. Thereby, our group has specialized in mastering Enzyme-Assisted Self-Assembly (EASA) through the creation of localized supramolecular self-assembled networks,[1] but also the localization of such EASA networks inside host hydrogels,[2] as well as the demonstration of the potential use of EASA networks as supports for cell adhesion.[3] From these works opening the way to the design of a new generation of 3D cell culture scaffolds, we present our last results (submitted) highlighting EASA as a tool to design organic Liesegang-like microstructured materials in which patterns characteristics can be modified playing on parameters such as enzyme or peptide concentrations. Based on experimental observations of the RD mechanism at stake in HPMC (an highly tunable beyond biocompatible hydrogel),[4] an effective mathematical model accounting for the pattern formation is proposed.

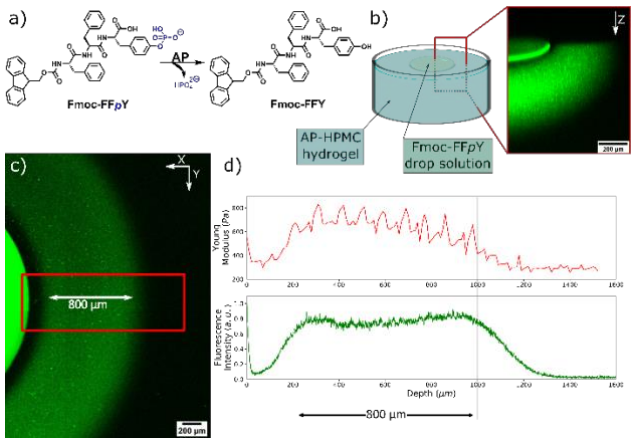

Fig. 1: *(a) Enzymatic hydrolysis of Fmoc-FFpY in Fmoc-FFY in presence of Alkaline Phosphatase (AP). (b) Cross-sectional view of the AP-HPMC hydrogel observed by CLSM, 12 hours after the drop deposition of Fmoc-FFpY solution and (c) Top view of the Fmoc-FFpY drop solution. Thioflavine T was used to reveal the Fmoc-FFY β-sheet assemblies through their green fluorescence emission. The red box in (b) corresponds to the area analyzed by (d) nanoindentation (top) and fluorescence emission measurements (bottom).*

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[4]. Rederstorff, E.; *et al*. Enriching A Cellulose Hydrogel With A Biologically Active Marine Exopolysaccharide For Cell-Based Cartilage Engineering. J. Tissue Eng. Regen. M. 2017, 11, 1152-1164

Bioinspired grinding for anaerobic digestion

Anissa DIEUDONNE,[1] Jean-Philippe STEYER,[1] Renaud ESCUDIE,[1] Hélène CARRERE,[1] Audrey BATTIMELLI,[1] Jean-Jacques GODON *,[1]

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Keywords (5 maximum): anaerobic digestion, grinding, bioinspiration, biomass, metazoan phylogeny.

One of the main drivers of evolution is the competition between living organisms: on the one hand to be able to feed, on the other hand to develop strategies to defend themselves and not become a food source. This dynamic has pushed living beings to innovate both to protect themselves and to circumvent the protections of food.

The emergence of metazoans in the living world corresponds to the emergence of the first digestive systems. The objective of these digestive systems is to break down complex foods into molecules that can be assimilated by the cells. To do so, they are composed of different compartments that will degrade food either mechanically, chemically, or enzymatically.

The objective of our project is to optimize an anaerobic digestion process by applying mechanical pretreatments inspired by animal grinding systems. So, we inventoried how animals mechanically degrade their food. We reviewed all the organs involved in food accessibility for digestion.

Despite a wide variety of shapes for organs and appendages, the function of accessibility of the food can be summarised in five mechanisms (drilling, cutting, breaking, crushing, abrading). We have observed three locations for these functions: (i) external; (ii) associated with the collecting organ (e.g. mouth); (iii) internal. All of these mechanisms and their locations are found throughout the phylogeny of metazoans. One of our perspectives is to establish a correlation between the type of grinding and the type of food processed, in order to find the most efficient grinding for the biomass used in anaerobic digestion.

Structure B

Protein self-assembly for bio-inspired electronics

Vincent FORGE[1]

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Keywords: Protein self-assembly, electron hopping, bioelectronics

The recent discovery of conduction in bacterial nanowires (Pili system) connected to electrodes makes it possible to envisage the development of protein-based electronics. Inspired by the architecture of these bacterial systems, we have developed a conductive nanowire consisting solely of known proteins. The nanowire in question is made from a chimeric protein obtained by biochemical methods. This protein comprises a prion domain and a domain (a rubredoxin) whose function is electron transport. The presence of the prion domain allows the formation of a fibre by self-assembly. The latter then exposes rubredoxins on its surface that are sufficiently close to each other (less than 1 nm) to transport electrons by successive jumps between redox centres. The conductivity and mode of electron transfer were demonstrated by electrochemistry [1]. Just as bacterial nanowires allow electron exchange between the external environment and enzymes within the bacteria, we have shown that our protein nanowires allow electron transport between a glassy carbon electrode and an enzyme over a distance of several microns (Figure 1) [1,2].

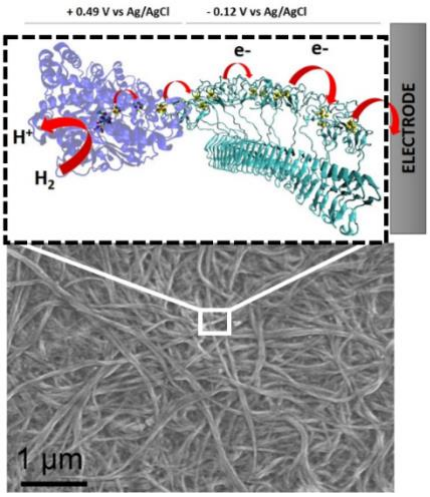

Fig. 1: Hydrogenase wiring by protein nanowires

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[2]. Rengaraj S et al. Interprotein Electron Transfer between FeS-Protein Nanowires and Oxygen-Tolerant NiFe Hydrogenase. *Angew. Chem. Int. Ed. Engl.* **56**: 7774-7778 (2017). doi:10.1002/anie.201702042.

Multi-wavelength LIPSS generation on titanium alloy and comparative study of their effect on cell adhesions

Alain Abou-Khalil [1], Steve Papa [2], Nicolas Compère [3], Yoan Di Maio [3], Alain Guignandon [2], Virginie Dumas [2, 4], Alina Pascale Hamri[3], Xxx Sedao *[1, 3]

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Keywords (5 maximum): ultrafast laser, laser induced Periodic structures (LIPSS), wettability, bio compatibility, cell adhesion

Femtosecond laser processing is a robust and industrial method widely used for surface functionalization allowing for enhancing the properties of the materials. For instance, Titanium and titanium alloys are mostly used for bio-medical applications for their excellent bio compatibility and superior mechanical strength. However, titanium based dental implants, could suffer sometimes from the lack of osseointegration in the jaw bone and lead to failure. Therefore, increasing the osseointegration of dental implants is of interest. The creation of Laser induced Periodic structures (LIPSS) on metals using femtosecond laser has been extensively used for surface functionalizing during the last decades. Also, it's known that biological cells are sensitive in the nanoscale and their behavior is highly affected by the presence of LIPSS pattern on surfaces as shown by previous studies. In this work, we study the effect of multi-wavelength LIPSS on Human mesenchymal stem cells (hMSCs) and Osteoblasts on cell adhesion. First, we study the formation of LIPSS on titanium alloy (Ti6AlV) using three different femtosecond lasers with wavelengths of 1030, 515 & 257 nm exhibiting three different LIPSS periodicities of 600, 400 and 180 nm respectively. Then, wettability tests were performed prior and post wet sterilization of the samples, knowing that surface wettability is crucial to the cell adhesion properties. Following that, peeling tests were performed by a new technique to quantify and compare the cell adhesion between polished/unstructured titanium and LIPSS covered titanium exhibiting different LIPSS periodicities.

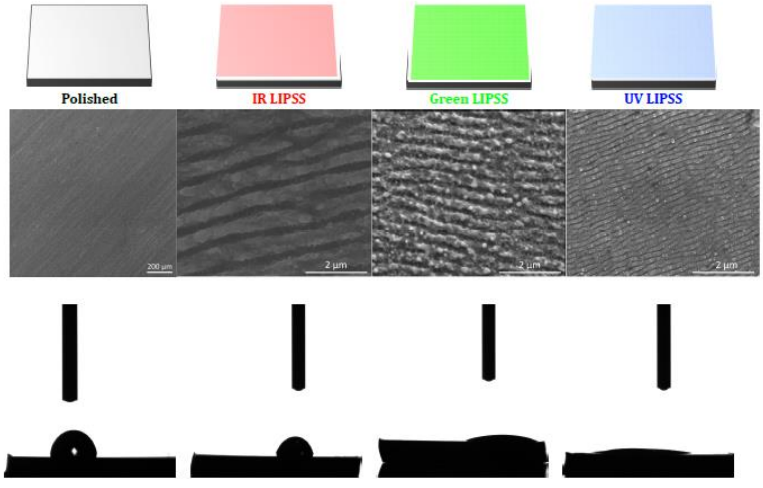

Fig. 1: LIPSS generation using multi-wavelength IR, G & UV; Green & UV LIPSS are more hydrophilic compared to IR one, as well as polished surface; Hydrophilicity promotes protein adsorption, therefore better cell adhesion expected

[1] A. Klos, et al., Ultrafast Laser Processing of Nanostructured Patterns for the Control of Cell Adhesion and Migration on Titanium Alloy, Nanomaterials, 2020

Elaboration of transparent, robust and repellent surfaces based on molded and lubricated PDMS

Anne-Sophie Vaillard, Yannick Coffinier, Vincent Thomy,

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Keywords: SLIPS, omniphobic, polymer molding, lubricant retention

This study is dedicated to the elaboration of transparent easy-to-do Slippery Liquid Infused Porous Surfaces (SLIPS) surfaces for industrial applications such as transport, housing or solar cell. These surfaces are inspired by the carnivorous plant Nepenthes, whose inner surface is covered with micrometric pockets impregnated with a liquid [1]. This liquid interface greatly reduces the anchoring effect of liquids, giving Nepenthes excellent non-wetting and non-stick properties. Within this scope, we successfully realized and transferred flexible SLIPS onto glass substrate. These surfaces have been achieved by Polydimethylsiloxane (PDMS) simple or double molding process. This technique allows to faithfully reproduce the microscale topography of stainless steel molds textured by laser ablation even after a second molding on negative PDMS replica surfaces (Figure 1). The aforementioned surfaces combined microgrooves with either microspikes or microholes structures that can be customized by varying laser ablation parameters of the stainless steel mold [3]. Contact angle hysteresis of water–ethanol mixtures droplets were investigated as function of the laser parameters before and after impregnation with a perfluoropolyether based oil. In addition, samples weighing and numerical microscopy observations allowed to quantify the oil retention. Super-omniphobic properties have been recorded for all impregnated surfaces, whereas the lubricant depletion phenomena, known as the main SLIPS drawback, decrease their performance. Although the lubricant volume is 30% lower for positive replica than for negative ones, they have shown to drastically limit the depletion and to favor the replenishment thanks to their microholes structures. Moreover, positive replica led to more significant recovering of the PDMS transparency after oil impregnation (Figure 1d).

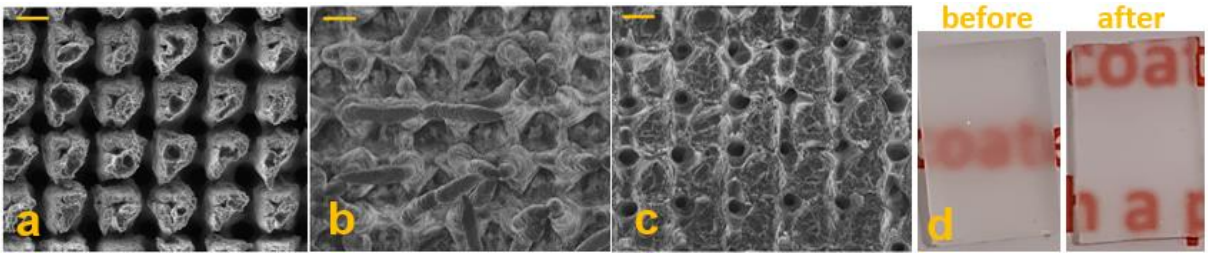

Fig. 1: SEM images of textured stainless steel surface (a) negative PDMS replica (b) positive PDMS replica (c) - the yellow scale represents 20 µm. Positive PDMS replica before and after oil impregnation (d).

[1]. T.S. Wong, S.H. Kang, S.K.Y. Tang, E.J. Smythe, B.D. Hatton, A. Grinthal, J. Aizenberg, Bioinspired self-repairing slippery surfaces with pressure-stable omniphobicity. Nature 2011, 477, 443–447

[3]. D. Gong, J. Long, D. Jiang, P. Fan, H. Zhang, L. Li, M. Zhong, Robust and Stable Transparent Superhydrophobic Polydimethylsiloxane Films by Duplicating via a Femtosecond Laser-Ablated Template. ACS Appl. Mater. Interfaces 2016, 8, 17511–17518

This research work was partially supported by the French RENATECH Network and receive funding from the StartAIRR program - Région Hauts-de-France

Anisotropic wetting behavior on bioinspired textured surfaces

Quentin Legrand,[1] Stephane Benayoun,[1] Stephane Valette *,[1]
[1]*Univ Lyon, École Centrale de Lyon, Laboratoire de Tribologie et Dynamique des Systèmes, UMR CNRS 5513, Ecully, France;*

Keywords: Wetting, Bioinspiration, Surface texturing, Anisotropic Spreading

Vegetal surfaces often present anisotropic textures (Fig. 1a). These textures sometimes generate an anisotropy in the spreading of droplets. This spreading anisotropy and its origin are poorly understood and are not explained by models linking wettability to texturing [1]. The present work proposes an issue to assess the anisotropic wetting properties of anisotropic textured model surfaces.

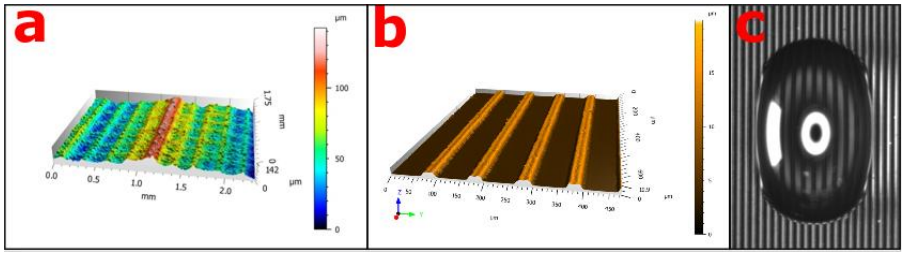

Fig. 1: (a)Sasa bamboo leaf. (b)PMMA stripes. (c)Droplet on PMMA stripes.

The surfaces are manufactured by polymer replication of femtosecond-laser textured molds (Fig. 1b). Various morphologies and chemistries (PMMA, PP, PDMS) are investigated and compared. Wetting experiments are performed with a homemade 3D-goniometer which allows the measurement of the contact angle in all directions by rotating the surface. The classical side view is completed by a top view of the droplet (Fig. 1c) that enables anisotropic spreading evaluation. The Extrand's model is involved in all analyzed surfaces to provide an interpretation in function of wetting state [2].

The contact angle measurements present an anisotropic spreading of Wenzel's type wetting. In this configuration, contact angles in Longitudinal (θ_L) and Transversal (θ_T) directions are different and linked by a gaussian evolution as function of α the orientation of surface. A model describing this gaussian evolution is proposed:

$$\theta(\alpha) = (\theta_T - \theta_L) e^{-\frac{(\alpha-\alpha_0)^2}{2\sigma^2}} + \theta_L$$

In first approach this model is calculated with experimental values and shows a good agreement with the experimental data (Fig. 2). In second approach, these parameters θ_T, θ_L and σ are evaluated from surface roughness. Due to contact angle hysteresis, it is not possible to predict a unique value of θ(α): Young's and advancing angles enable to propose an interval of contact angles that perfectly encloses experimental values.

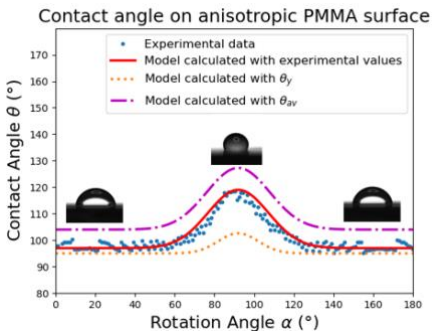

Figure 2: Contact angle on PMMA stripes.

[1] Bliznyuk, O. and al, "Scaling of anisotropic droplet shapes on chemically stripe-patterned surfaces", Phys. Rev. E, 79, 2009

[2] Extrand, C. W., "Criteria for Ultralyophobic Surfaces", Langmuir, 20, 12, 2004

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2nd Annual Meeting of GDR2088 "BIOMIM"
Scientific Programme

15 November 2021 (Monday)		
14:00 - 14:20	**Opening Remarks**	
14:20 - 15:30	**Bioinspired Materials**	**Modelling and Simulation**
	Natasha HEIL & Valentina PERRICONE - KN5 (14:20-14:50) Bioinspired materials for sustainable architecture and construction learning from Echinoids (Sea Urchins): new research avenue	**Rogelio GOMEZ-PINEIRO - OR5 (14:20-14:40)** Decoding an ambiguous EPR signal in PlAA10 LPMO enzyme by construction of active site models using DFT
	Hernando SALAPARE III - OR15 (14:50-15:10) Bioinspired self-cleaning surfaces for car interior applications	**Chunmei LIU - OR4 (14:40-15:00)** Comparison of topology optimization based on classical and bio-inspired objectives
	Salomé BASSET - OR16 (15:10-15:30) Effect of laser texturing environment media on wetting of biomimetic superhydrophobic surfaces designed by femtosecond laser pulses	**Jordan Drapin - OR3 (15:20-15:20)** Biomimetism and hexapodal gait, a first step in ant
15:30 - 15:45	Coffee Break	
15:45 - 16:45	**Catalysis**	**Displacement and Movement**
	Manon PUJOL - OR8 (15:45-16:05) Engineering of a copper metalloenzyme for new-to-Nature reactivities	**Swaminath VENKATESWARAN & Damien CHABLAT - KN2 (15:45-16:15)** Comparison of three Motion Generators for a 3-SPS-U Tensegrity Mechanism
	Olfa ZAYENE - OR6 (16:05-16:25) Cooperativity between hydrogen bonding and anion-π interaction in anion recognition and catalysis	**Weijia WANG - OR9 (16:15-16:35)** How individual perceptual and cognitive factors affect collective motion in a data-driven fish school model
	Jonathan BACHIR - OR7 (16:25-16:45) Combining Biopolymer and Metal-Organic Framework for Protein Encapsulation	

16 November 2021 (Tuesday)		
10:00 - 12:00	**Biomaterials A**	**Structure A**
	Christophe DROUET -KN3 (10:00-10:30) Calcium phosphate: from biominerals to biomaterials	**Olivier FELIX - KN1 (10:00-10:30)** Anisotropic properties of bio-inspired nanocomposite materials
	Bernd SCHÖLLHORN - KN4 (10:30-11:00) Fluorescence of natural biomatter in Asian paper wasp nests	**Yu WU - OR18 (10:30-10:50)** Cubosomal lipid nanoparticles encapsulating plasmalogens with neuroprotective effects
	Julius SEFKOW-WERNER - OR11 (11:00-11:20) In situ and ex situ characterization of biomimetic platforms used for the analysis of heparan sulfate-mediated BMP biological activity	**Manon SAGET - OR2 (10:50-11:10)** Surface engineering of stainless steel to limit dairy fouling adhesion
	Ana FERRANDEZ-MONTERO - OR10 (11:20-11:40) 4D Smart electroactive porous scaffold as innovative cell culture platform	
	Alicia Alejandra MIER GONZALEZ - OR20 (11:40-12:00) Solid-Phase Synthesis of Molecularly Imprinted Polymer Nanogels- Synthetic Antibody Mimics for the Recognition of Protein Biomarkers	
12:00 - 14:00	Lunch Break	
14:00 - 15:30	**Biomaterials B**	**Structure B**
	Tristan BAUMBERGER - KN6 (14:00-14:30) Structural Hints from the study of Syneresis of Calcium Alginate hydrogels	**Vincent FORGE - KN7 (14:00-14:30)** Protein self-assembly for bio-inspired electronics
	Mathilde GUERIN - OR12 (14:30-14:50) Peptide-decorated bio-inspired apatite nanoparticles: towards wound healing applications	**Xxx SEDAO - OR 17 (14:30-14:50)** Multi-wavelength LIPSS generation on titanium alloy and comparative study of their effect on cell adhesions
	Jean-Yves RUNSER - OR13 (14:50-15:10) Micropatterning Controlled By Enzyme Assisted Self Assembly Through a Liesegang-like Process	**Anne-Sophie VAILLARD - OR1 (14:50-15:10)** Elaboration of transparent, robust and repellent surfaces based on molded and lubricated PDMS
	Anissa DIEUDONNÉ - OR14 (15:10-15:30) Bioinspired grinding for anaerobic digestion	**Quentin LEGRAND -OR19 (15:10-15:30)** Anisotropic wetting behavior on bioinspired textured surfaces
15:30 - 15:45	Coffee Break	
15:45 - 17:00	**GDR2088 Business Meeting, Closing and Awarding Ceremonies for the Graduate Student Awards**	