Plenary Talks

Mon. 31 May 10:00-10:40	Ludovic Berthier	Yielding of amorphous solids
Mon. 31 May 15:30-16:10	Joris Sprakel	Feel the Force: Visualising and unravelling mechanical cues in plants and their attackers
Tue. 01 June 10:00-10:40	Anwesha Sarkar	Lubrication performance of microgels: an oral perspective
Tue. 01 June 15:30-16:10	Luisa De Cola	Hybrid nanoparticles and hydrogels for biomedical applications
Wed. 02 June 10:00-10:40	Petra Schwille	Make biology simple again
Wed. 02 June 17:20-18:00	Eric Dufresne	Mechanics of Macromolecular Interfaces

Yielding of amorphous solids

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Understanding how amorphous solids yield in response to external deformations is crucial both for practical applications and for theoretical reasons. We have shown [1, 2] that despite large differences in the materials' microscopic interactions, a degree of universality emerges as there are only two ways in which amorphous solids respond to a deformation: One, typical of well-annealed materials, is characterized by an abrupt failure with a macroscopic stress drop and the sudden emergence of sharp shear bands; the other, typical of poorly annealed materials, shows merely a smooth crossover. By varying the preparation protocol, one can change the response of a given material from one to the other, and this change is controlled by a random critical point.

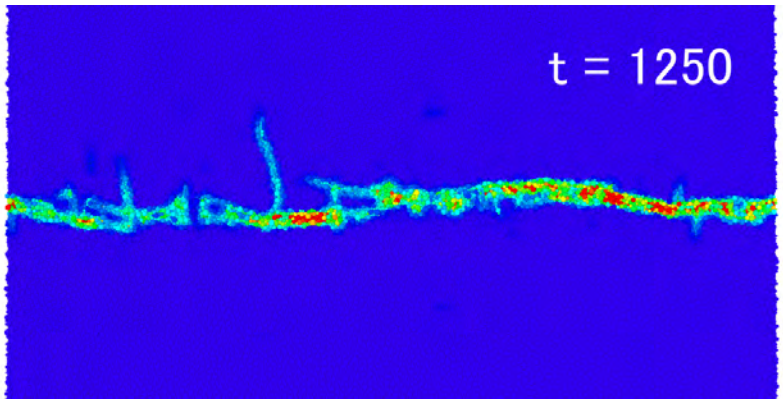

Figure 1: *Brittle yielding and shear-band formation in a two-dimensional amorphous solid.*

We have also shown that brittle yielding originates at rare soft regions, similarly to Griffiths effects in disordered systems [3]. We numerically demonstrated how localised plastic events in such soft regions trigger macroscopic failure via the propagation of a shear band, see Fig. 1. This physical picture, which no longer holds in poorly annealed ductile materials, allows us to discuss the role of finite-size effects in brittle yielding and reinforces the similarities between yielding and other disorder-controlled nonequilibrium phase transitions such as depinning and hysteresis.

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Feel the Force; Unravelling mechanical cues in plants and their attackers

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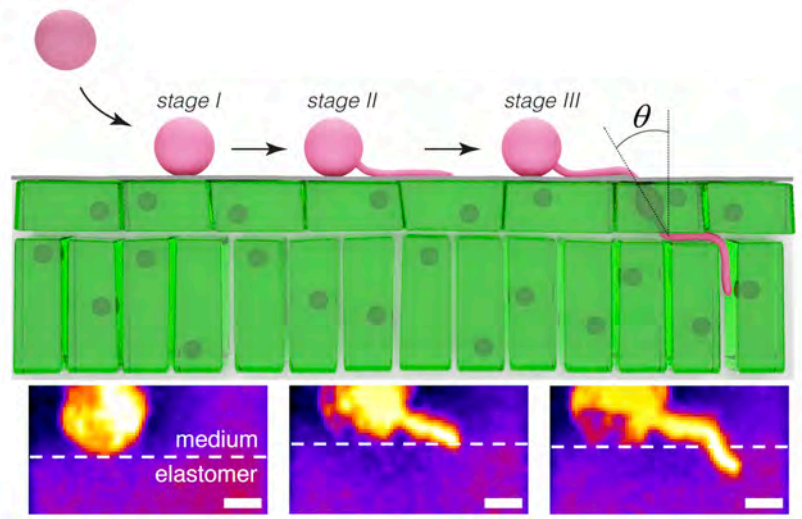
Mechanical forces are crucial morphogens in a wide variety of phenomena in the growth, development and function of plants and in the way they are placed under siege during pathogenic attack. Plant cells internalize mechanical signals and couple these to their intrinsic biochemical and genetic machinery, giving rise to complex mechano-chemical feedback mechanisms that control a vast array of biological processes. Plant pathogens, which have devastating effects on crop yields and food security, utilize mechanical stress to invade their hosts. Mechanical host entry is the gateway for many microbial plant diseases to commence. Until recently, it remained highly challenging to unravel these processes as direct approaches to measure mechanical features inside plant tissues, with sub-cellular resolution, or at the pathogen-host interface were lacking.

Here I will discuss work from our team over the past 5 years aimed at resolving these issues by applying notions of soft matter and mechanochemistry to problem sets in plant and phytopathogen biology. I will discuss how molecular mechanoprobes, molecule-scale mechanical testers tailored for use in living plants, can be used to obtain nanomechanical maps of intact and growing tissues and illuminate mechanical inhomogeneities that underly mechano-biological signalling. I will then discuss how we used these, and other micromechanical imaging tools, to unravel the mechanical pathways of host entry by one of the most devastating phytopathogens, *Phytophthora infestans*, the causative agent of late potato blight and one of the root causes of large famines such as the great Irish famine. By unravelling the mechanics of host entry, we could identified new physical targets for control that offer opportunities to combat these pathogens that until now remain notoriously challenging to erradicate. I will conclude with an outlook of ongoing work, that uses this toolbox to address novel challenges in plant biology and physical phytopathology.



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Lubrication performance of microgels: an oral perspective

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Oral tribology has emerged as a key paradigm in the tribology field to quantify friction in soft sliding oral contact surfaces such as tongue-palate, tongue-food etc[1,2] and is providing fundamental insights into the physics of oral processing and sensory perception. In this field, biocompatible microgels have been recently demonstrated to act as excellent lubricants in oral tribological contacts, with applications in dry mouth therapy and design of fat mimetics[3]. Using a combination of experimental techniques and theoretical considerations, this talk will cover three case studies[4-6] on tribology of soft elastomeric surfaces (with different wetting properties and surface roughness) in the presence of biopolymeric microgels with well-defined deformability, composition, cross-linking densities and particle sizes. Some of these microgels show aqueous 'ball-bearing' abilities depending upon their volume fraction[4]. A case study[5] will be presented on how these microgels can act as viscosity modifiers of the continuum particularly in case of complex fluids, where the lubrication performance can be quantitatively described using the second Newtonian plateau value (η_∞). Finally, recent fabrication of novel 3D soft tribo-surfaces of optimized topography, wettability and deformability to emulate the highly sophisticated tongue surfaces engineered by the nature will be highlighted[6].

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Hybrid nanoparticles and hydrogels for biomedical applications

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Advancements in the use of nanoparticles for biomedical applications have clearly shown their potential for the preparation of improved imaging and drug-delivery systems. However, only a few successfully translate into clinical practice, because, a common "barrier" preventing nanoparticles from delivering efficiently their payload to the target site after administration, is related to the nanoparticle uptake by macrophages. We have recently reported disulfide-bridged organosilica nanoparticles with cage-like morphology, and assessed in detail their bioaccumulation *in vivo*. [1] The fate of intravenously injected 20 nm nanocages was investigated in both healthy and tumor bearing mice. Interestingly, the nanoparticles exclusively co-localize with hepatic sinusoidal endothelial cells (LSECs), while avoiding Kupffer-cell uptake (less than 6%), in both physiological and pathological condition. Our findings suggest that organosilica nanocages hold the potential to be used as nanotools for LSECs modulation, potentially impacting key biological processes such as tumor cell extravasation and hepatic immunity to invading metastatic cells or a tolerogenic state in intrahepatic immune cells in autoimmune diseases.

Recently we have also shown that nanoparticles can be an interesting component for hybrid hydrogels. [2,3] We have shown that injectable nanocomposite hydrogel able to form *in situ* a tissue mimicking matrix as an innovative material can be employed for the treatment of esophageal fistulas. [4]

The hydrogel is based on hyaluronic acid (HA), the cross-linking process occurs at physiological conditions leading to a hydrogel made of >96% by water and with a large-pore microarchitecture. The material, easily injectable with an endoscopic needle, is formed in a time compatible with the surgical procedure and has final mechanical properties suitable for cell proliferation. The *in vivo* experiments (porcine model) on esophageal-cutaneous fistulas, showed improved healing in the animals treated with the hydrogel compared with the control group.

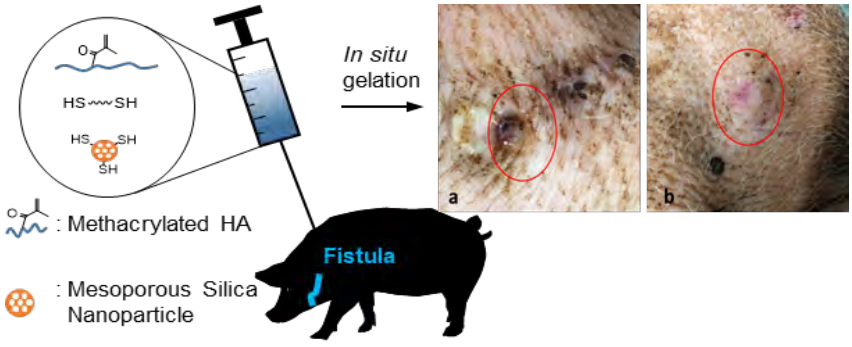

Figure 1: *Schematic representation of the hybrid hydrogel and of the fistula treatment.*
The in vivo results showing the treated and untreated fistulas

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Make biology simple again

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In the past years, a growing selection of ultrasensitive analytical techniques have been applied to established biological systems, either cell cultures or model organisms. While they have much contributed to the quantitative understanding of these systems and generated loads of data that remain to be digested by cutting-edge bioinformatics, little progress has been made on a more first-principle based understanding of living entities. Thus, in the past decade, we proposed and have since been pursuing a fully new approach towards biology, i.e., "bottom-up synthetic biology". The underlying idea is that only a radical simplification and abstraction of a biological cell will allow us to understand the distinctive features of life, because even the simplest life forms on earth have accumulated a huge degree of redundance in order to remain viable in a hostile and competitive environment. Abstracting from this massive and in large parts non-hierarchical complexity of interactions in a living system, otherwise being the hallmark of the physicist's approach, is doomed to failure. Thus, in order to arrive at a self-sustaining minimal system of molecular interactions with the ability to evolve – a minimal living system - we likely need to build it from scratch. Technically speaking, we need to assemble functional modules from the bottom-up until the system emerges basic functions of life.

Mechanics of Macromolecular Interfaces

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The mechanical properties of interfaces underly a huge array of phenomena, from wetting and adhesion to the stability of emulsions and foams. When the bulk phases are simple fluids and/or stiff solids, the essential mechanics seem to have been worked out. The soft matter community has revealed a lot of fascinating and useful phenomena when interfaces between simple fluids are decorated with surfactants.

Here, I will focus on interfaces of macromolecular solids and fluids.

In the first part, I will describe experiments with gels: polymer networks swollen with a liquid solvent. I will address two fundamental questions. 1. Does surface tension change as the material is deformed? If the solvent dominates, the answer should be no. If the network dominates, the answer could be yes. 2. What is the equilibrium contact angle of a droplet on a gel when the droplet and gel's solvent have the same composition?

In the second part, I will briefly describe experiments on phase-separated protein droplets. I will sketch how a classical method from interfacial science can be applied to quantify the ultra-low surface tension of these systems, and give examples of how these interfacial properties can be manipulated.