Thursday, September 19th	9:30am	**Welcome @ LIPhy**	
	10:00 – 10:15	**Introductory speech**	
	10:15 – 10:55	E. Kolb	[Keynote] Motions of a plant root subject to various mechanical stresses
	10:55 – 11:15	N. Nakayama	Going deeper: the inside story of plant biomechanics
	11:15 – 11:35	B. Moulia	The control of gravitropic mouvements in plants
	11:35 – 11:55	S. Robinson	Visualising mechanics
	11:55 – 12:20	**Poster flash presentations**	
		Lunch	
	2:00 – 3:00pm	**P. Fratzl**	**Invited lecture: Plant movements and biomimetic actuators**
	3:00 – 3:20	C. Coutand	Phototropic and gravitropic responses of young poplars
	3:20 – 3:40	C. Eloy	Mechanical model of a growing tree
	3:40 – 4:00	S. Douady	Unfolding Motions of leaves
	4:00 – 4:20	J. Derr	Swinging and fluttering of growing simple leaves
	4:20 – 4:50	**Coffee break**	
	4:50 – 5:20	K. Razghandi	[Keynote] Bio-inspired honeycomb devices for movements and stress generation
	5:20 – 5:40	S. Turcaud	Patterns of Shape Change
	5:40 – 6:00	C. Ybert	Experimental studies of active colloidal suspensions
Friday, September 20th	9:00 – 9:20am	D. Peysson	ABC. Machines Without Motors: the Artist and the Behavior of its moving Creatures.
	9:20 – 9:40	M. Rüggeberg	Convertible wooden elements for architectural design
	9:40 – 10:20	R. Elbaum	[Keynote] Structure and Function in Plant Tissues:Understanding Hygroscopic Coiling
	10:20 – 10:40	S. Digiuni	Probing the dynamics of mechanical response of cells with atomic force microscopy
	10:40 – 11:10	**Coffee break**	
	11:10 – 11:30	L. Beauzamy	Turgor pressure measurements using Atomic Force Microscopy
	11:30 – 11:50	X. Noblin	Fast motion of fern sporangia
	11:50 – 12:10	A. Ponomarenko D. Bienaimé	Spores triathlon: walk, jump and flight
		Lunch	
	1:40 – 2:00pm	A. Fargette	Elastocapillary-driven snap-through instability
	2:00 – 2:20	E. Virot	Popcorns have legs for jumping
	2:20 – 3:00	P. Peyla	[Keynote] Flow of active suspensions and biased swimming
	3:20 – 3:40	H. Chaté	Statistical physics of collective motion
	3:40 – 4:00	N. Waisbord	Zero Force rheology of an active fluid
	4:00 – 4:15	**Conclusion of the Workshop**	

Growth	**Biomimetic design**	**Surface tension and hygroscopy**	**Many-body systems**

A. Kempe	Reorientation in leaning stems of papaya by unilateral stem contraction
E. Reyssat	Drying hydrogel cylinders
F. Rioual	transport of particles along a polydisperse granular substrate
L. Heux	Bioinspired microcapsules based on layer by layer assembly of cellulose nanocrystals and xyloglucans
P. Vazquez-Montejo	Force dipoles and stable local defects on fluid vesicles
C.Quilliet	Hydrostatics and elasticity
N. Rivier	Motion by non-slip rotation of convex grains

Léna	Beauzamy	Turgor pressure measurements using Atomic Force Microscopy	The ability of plant cells to sustain high turgor pressure is an important feature allowed by the resistance of their cell wall. Inside a cell, the turgor pressure can vary over time, allowing movements to occur, such as growth or closing/opening of stomata. Measurements of turgor pressure are possible by using a pressure probe. But this technic is destructive and requires the cells to be large enough. Our goal is to develop a new pressure sensor based on Atomic Force Microscope (AFM). By comparison with theoretical predictions (Vella et al., PRL 109, 144302 (2012)), the force-displacement curves given by an AFM on a specific cell allow us to deduce the turgor pressure inside this cell. Results obtained on onion epidermis cells will be showed, as well as our recent work on stomata in Arabidopsis.
Julien	Derr	Swinging and fluttering of growing simple leaves.	We have been observing an universal motion in a wide variety of growing simple leaves. It is a combination of a swinging motion of the midrib, and succession of transverse buckling of the blade. To investigate this phenomenon, we focused experimentally on the case of the avocado tree. We developed a 3D stereoscopic tool to reconstitute the evolution of the blade surface as a function of time. We find that an increase of local curvature of the midrib is not associated with a decrease of transverse curvature as one would expect for a passive surface. On the contrary, the transverse opening angle of the blade shows a linear dependency with the midrib curvature. We understand this behaviour by showing that an eccentric differential growth of the midrib is the cause of both swinging and fluttering.
Stéphane	Douady	Unfolding Motions of leaves	Leaves can grow folded in buds, in order to reach a good packing efficiency, the maximum leaf surface in the fixed bud volume. Then it unfold in the spring. This unfolding is accompanied with different types of movements, of different geometry and frequencies. In fact the first folding is already the beginning of the leaf motion. Sometimes these motions can be preserved for night/day movements, and sensitivity. The questions are: what are the origin and the use of such motions ?
Aurelie	Fargette	Elastocapillary-driven snap-through instability	The snap-through instability, which is present in a wide range of systems, ranging from carnivorous plants to MEMS, is a well-known phenomenon in solid mechanics. Here, we revisit this phenomenon by studying snap-through under capillary forces. A drop deposited on a thin buckled elastic strip induces snapping, possibly even against gravity at millimetric scales. We studied both theoretically and experimentally this phenomenon, including its dynamics, and performed a condensation-induced spin-off version of the setup, where an hydrophylic strip snaps above a given moisture threshold, and a macroscopic (centimer-scale) soap-bubble-driven experiment.
Andreas	Kempe	Reorientation in leaning stems of papaya by unilateral stem contraction	Papayas (Carica papaya L.) are fast growing plants and have the capability to reorientate fast from a leaning position by bending upward the basal stem region. This seems to be a necessary adaptation to grow erect and reach light after tilting. Interestingly the stem anatomy of papaya is characterised by highly parenchymatous wood (secondary xylem), being under substantial turgor pressure, which is enclosed by a lattice like mesh of lignified fibres in the bark (secondary phloem). We found that the stem deforms by the couple effect due to local xylem enlargement affecting the peculiar phloem fibre arrangement. The xylem extends by directed radial growth on the upper side of leaning stems or lateral branches and generates an outward pointing force. The phloem fibre mesh expands in tangential direction. As a result, the structure contracts in axial direction and may generate a pulling force on the upper side. To investigate this unusual adaptation mechanism, a set of mechanical measurements were conducted on tissue sections of secondary phloem and xylem for comparative analysis of Young's modulus and turgor pressure of upper and lower side of leaning stems. We found that Young's modulus differs significantly between upper and lower side in these tissues due to morphologic adaptations. Microscopic analyses revealed pronounced radially directed cell growth in upper side of xylem unlike the lower side. Experimental data showed that turgor pressure remained constant during cell expansion, throughout the erecting process. Thus cell growth and turgor pressure sustaining water inflow are in state of equilibrium.

Bruno	Moulia	The control of gravitropic mouvements in plants	Gravitropism is a key determinant of the form and posture of land plants. Shoot gravitropism is triggered when statocysts sense the local angle of the growing organ relative to the gravitational field. Lateral transport of the hormone auxin to the lower side is then enhanced, resulting in differential gene expression and cell elongation (or shrinkage in woody plants) causing the organ to bend. However, little was know about the dynamics, regulation, and diversity of the entire bending and straightening process. Recently, using vital kinematic imaging of the gravitropic movement of different organs from 11 angiosperms sampling the phylogenic tree of land angiosperms, we found that gravitropic straightening shares common traits across species, organs, and orders of magnitude. Surprisingly, the minimal dynamic model accounting for these traits is not the widely cited gravisensing law but one that also takes into account the sensing of the local curvature, i.e. a proprioception. A minimal dynamical model of the movement of the plant during gravitropism and posture control , called the AC model has been designed , that can explain most of the diversity observed in experiments. Moreover the entire dynamics of the bending/straightening response is described by a single dimensionless "bending number" B that reflects the ratio between graviceptive and proprioceptive sensitivities, and defines both the final shape of the organ at equilibrium and the timing of curving and straightening. Proprioceptive sensing is thus as important as gravisensing in dynamical gravitropic control. The issue of motion control in plants (and its relataion with motion actuation) will be discussed. R. BASTIEN, T. BOHR, B. MOULIA[†] *, S.DOUADY[†], 2013. A unifying model of shoot gravitropism reveals proprioception as a central feature of posture control in plant. PNAS 110 (2): 755–760 († co-PI last authors, * corresponding author) J DUMAIS 2013 Beyond the sine law of plant gravitropism. PNAS 110, 391 (commentary of the paper by Bastien et al 2013)
Naomi	Nakayama	Going deeper: the inside story of plant biomechanics	Morphogenesis is a well-coordinated sequence of tissue deformation, and thus regional variations in tissue mechanical properties directly impact growth and shape change. Recently technological breakthroughs and multidisciplinary collaborations have enabled in vivo mechanical characterization of tissues with complex 3D morphology, such as shoot and root apices. For example, regional differences in deformability were revealed within the shoot apical meristem by osmotically induced tissue inflation and deflation. Analysis of the response using computer simulations showed that simple changes of the cell wall material properties could explain the differential growth rates characteristic of the two functional domains. This work, as well as other studies utilizing micro-indentation methods (e.g. Atomic Force Microscopy), have focused on mechanical characterization of tissue surface, based on the assumption that plant tissues are like balloons and thus that their morphology is determined by the outermost layer. But are they really like balloons? In other words, is the epidermis – especially the outer cell wall of the epidermis – significantly stiffer than internal tissues? Some cell types (e.g. xylem and sclerenchyma) are thought to be much stiffer than others (e.g. pith parenchyma cells); what is their deformability? Since plant cells are physically connected with one another, how could such local differences affect growth coordination? Do such mechanical interactions among cells have instructing roles in plant development and morphogenesis? In order to address these questions, we are currently comparing the mechanical properties of inner and outer tissues, using a micro-compression-based protocol and an associated mechanical model, and the latest findings will be presented.
Philippe	Peyla	Flow of active suspensions and biased swimming	It is a challenge to understand the hydrodynamics associated with individual or collective motion of microswimmers through their fluid-mediated interactions in order for instance to manipulate the cells efficiently for some applications purposes. The motion of these micro-organisms can be often affected by the presence of gradients leading to a biased random walk (chemotaxis in the presence of chemicals, gyrotaxis in a gravity field, phototaxis under light exposure). In this study, we present our experimental results concerning the coupling of a Poiseuille flow with the biased random walk of Chlamydomonas Reinhardtii, a green unicellular micro-alga. This is done by illuminating the microswimmer suspension while flowing in a microchannel device. We show that one can obtain a spontaneous and reversible migration and separation of the microalgae suspension from the rest of the suspending medium under illumination and then dynamically control the concentration of the suspension with light. We present a simple model that accounts for the observed phenomenon.

Dominique	Peysson	MWM:ABC. Machines Without Motors: the Artist and the Behavior of its moving Creatures.	Contemporary artists also work on movement of living beings, biomimicry, emergence of collective effects in complex systems and nastic movements as in the work of Daan Roosegaarde, Lotus Dome. This talk will present some representative artistic works inspired by natural systems and which contributes in their own way to the emerging field of individual and collective moving. It will then outline my present artistic work on The projection of behavior on collective motions, which is part of the The Behavior of Things research program of the H2H Labex.
Etienne	Reyssat	Drops and bubbles in wedges	Confined drops or bubbles may exhibit spontaneous motion when placed in spatially varying geometries. We use a sharp wedge formed by two plates as a model confined medium. We will discuss the migration dynamics of drops and bubbles in this situation, and will explore trapping, repulsion and transport phenomena.
Sarah	Robinson	Visualising mechanics	Development requires the modification of mechanical properties and may also be influence by mechanical signals. The growth rates of plants are influenced by the high turgor pressure contained in the cells and by the material properties of the cell wall surrounding it. The mechanical properties of plants have been extensively studied, however, the link between these properties and the precise mechanisms regulating developmental patterning are less clear. In order to better characterise the mechanical response of plants to hormones and the subsequent response of the inter-cellular components we have constructed methods for measuring mechanical properties that are compatible with confocal microscopy. This enables us to measure the pressure and wall properties of living plants while observing them. Using this new technique we have been able to observe microtubule orientation while stress or strain is applied and also to determine the mechanical responses to hormone application.
Markus	Rüggeberg	Convertible wooden elements for architectural design	The hygroscopic nature of wood leads to dimensional changes of wooden elements when exposed to changing relative humidity. Commonly, this effect is of disadvantage for the use of wood in architecture and construction. However in many plant systems such as pine cones or wheat awns the hygroscopic nature is used to generate flexible elements which are able to perform desired and defined movements. Such defined movements are generated by adjusting shape, layer structure and geometry of the organ. Simple dimensional changes can be transferred into bending and twisting movements by building bi-layers with specific fibre orientation in the single layers. We transfer these principles to wooden structures and develop convertible wooden elements for architecture and construction. These convertible elements could be used as facade elements or carrier of solar panels. Since both, sensor and actuator are intrinsically incorporated in the wood itself, the movement of these elements is self-controlled and solar driven.
Pablo	Vazquez-Montejo	Force dipoles and stable local defects on fluid vesicles	We present an exact description of an almost spherical fluid vesicle with a fixed area and a fixed enclosed volume locally deformed by external normal forces bringing two nearby points on the surface together symmetrically. The conformal invariance of the two-dimensional bending energy is used to identify the distribution of energy as well as the stress established in the vesicle. While these states are local minima of the energy, this energy is degenerate; there is a zero mode in the energy fluctuation spectrum, associated with area and volume preserving conformal transformations, which breaks the symmetry between the two points. The volume constraint fixes the distance S, measured along the surface, between them; if it is relaxed, a second zero mode appears, reflecting the independence of the energy on S; in the absence of this constraint a pathway opens for the membrane to slip out of the defect. Logarithmic curvature singularities in the surface geometry at the points of contact signal the presence of external forces. The magnitude of these forces varies inversely with S and so diverges as the points merge; the corresponding torques vanish in these defects. The geometry behaves near each of the singularities as a biharmonic monopole, in the region between them as a surface of constant mean curvature, and in distant regions as a biharmonic quadrupole. Comparison of the distribution of stress with the quadratic approximation in the height functions points to shortcomings of the latter representation. Radial tension is accompanied by lateral compression, both near the singularities and far away, with a crossover from tension to compression occurring in the region between them.

Nicolas	Waisbord	Zero Force rheology of an active fluid	We study here an active fluid that can be forced to flow without any pressure. The active part of the fluid is a dense population of north seeking magnetotactic bacteria, strain MC-1, suspendend in a biocompatible buffer solution, the passive part of the fluid. Such a bacterium can be driven with a magnet, as it has a magnetic cristals chain on its membrane. A dead bacterium would move only in a magnetic gradient: it would be dragged passively by the magnetic force due to the gradient. But a living one will move even in a uniform magnetic field, passively aligned by the field and actively swiming. In a Glass-PDMS Micro Channel aligned with a uniform magnetic field, we obtain a confined flow of this active fluid, without any exterior force: the flow will come from the self-propelled motion of bacteria, the magnetic field exerting only a torque on the bacteria, to make it go along the channel. The stronger the magnetic field, the straighter the trajectory of one bacterium: this provides a control parameter. We present here PIV measurements of the velocity profiles of the suspension for different magnetic field and bacteria densities. We show the influence of the bacteria density and of the geometry of the walls on the shape of the velocity profile measured.
Christophe	Ybert	Experimental studies of active colloidal suspensions	We have investigated experimentally the non-equilibrium state of a dilute active colloidal suspension under gravity field. The active particles are phoretic swimmers that show self-propulsion in the presence of an added fuel hydrogen peroxide. We measure with optical microscopy the microdynamics of individual colloids and the global stationary state of the suspension under gravity. This yields a direct measurement of the effective temperature of the active system as a function of the particle activity, on the basis of the fluctuation-dissipation relationship. We have also explored the phase behavior of a dense active suspension of phoretic self-propelled colloids. In addition to a solid-like and a gas-like phase observed for high and low densities, a novel cluster phase is observed at intermediate densities. This takes the form of a dynamical assembly of dense aggregates, with a stationary flux of self-propelled colloids going in and out the clusters. Although several scenarii can be raised to account for these observations we show that the experimentally observed linear dependence of the mean cluster size versus the bare self-propelling velocity is reproduced by a chemotactic aggregation mechanism, originally introduced to account for bacterial aggregation.

Pour badges

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