CurvoBio 2019

6th-8th February 2019
Salzburg, Austria

Preliminary Scientific Program

Wednesday 06 February 2019

12:30 - 13:00 Welcome / Introduction

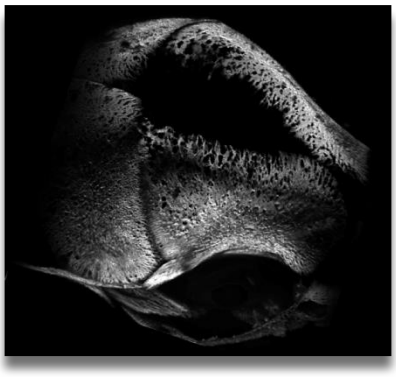
Cécile Bidan (MPIKG) / **John Dunlop** (PLUS) / **Barbara Schamberger** (PLUS)

Peter Fratzl (MPIKG)

13:00 - 14:00 Session 1 - The Tool Box - 1/2

13:00 **Jacqueline Tabler** (MPI Dresden)

Understanding cellular mechanisms driving skull morphogenesis through *ex vivo* imaging



As an organ's physiology and function are often linked to its shape; understanding how tissue shape is generated is, therefore, essential and a core question in developmental biology. A common feature in shape generation, or morphogenesis, is anisotropic growth, where tissues do not grow equally in all directions, however, the cellular and physical cues that drive anisotropy in developing tissues are poorly understood. Amongst the simplest tissue shapes are sheets which can be derived either from epithelia or mesenchyme. While epithelial sheets have been well studied, shape generation in mesenchymal sheets has been entirely overlooked. Such sheets include the intramembranous bones of the skull which are indispensable for human life. The frontal bone is an example of one such understudied skeletal element that is particularly intriguing as it undergoes anisotropic expansion from the base of the brain to the apex of the head. To address the cellular mechanisms that drive expansion of the frontal bones, we developed a novel live imaging system for performing quantitative *ex vivo* analyses of early skull growth. We find that oriented cell division, spatiotemporally controlled progressive differentiation and possibly tissue stiffness cooperate to drive the collective movement of osteoblasts during anisotropic skull expansion. Our *ex vivo* imaging system provides insights into mechanisms of morphogenesis in a mesenchymal-derived, sheet-shaped tissue.

13:30 **Andy Sageman-Furnas** (TU Berlin)

Geometry in buckled elastic gridshells

We are surrounded by curved surfaces that are built from discrete units, from biological polymer membranes to large architectural structures. In this talk I will describe recent collaborative work on an elastic gridshell system, which arises from the buckling of an initially planar grid of rods. The interaction of elasticity and geometric constraints makes the shape of actuated elastic gridshells difficult to predict using classical methods. However, many biological systems buckle by exploiting underlying geometry. Here, we show that a geometric model, originally for woven fabric, can be used to rationalize shapes of elastic gridshells.

14:00 - 14:30 Coffee Break

14:30 - 16:00 Session 1 - The Tool Box - 2/2

14:30 **Rhoslyn Coles** (TU Berlin)

Curvature Measures of Tubular Structures

Our motivating problem is the dynamics of polyatomic molecules, such as proteins, in solution. Changes in the fluid environment have fundamental effects on both the shape and the biological function of a protein.

Modeling the shape of a protein as a series of fused spheres, it is possible to calculate the free energy of solvation via curvature measures from convex analysis with remarkable accuracy.

The simplicity of this approach, in comparison to traditional modeling techniques from statistical physics, make it possible to investigate energetically the dynamic role of shape in solution.

More complicated protein configurations, in particular tangled tubes, as well as the free configurations of computational experimentation, require appropriate extensions of classical curvature measures. The curvature measures have their origin in the theory of convex bodies or sets of positive reach. In this talk I will explain how one may associate curvature measures to a larger class of surfaces and inparticular to objects such as self intersecting tubular structures. This is ongoing work with Myfanwy Evans.

15:00 **Simon Blatt** (PLUS)

Curvature energies and what they are good for

Curvature energies like the wellknown Willmore or elastic energy are used in so different areas of the sciences like general relativity, stringtheory and - as many speakers of this workshop know much better than I do - in the live sciences.
We will discuss different curvature energies - e.g. the Willmore energy and new fractional and non-local versions - their historic background, as well as recent trends, results, and applications.

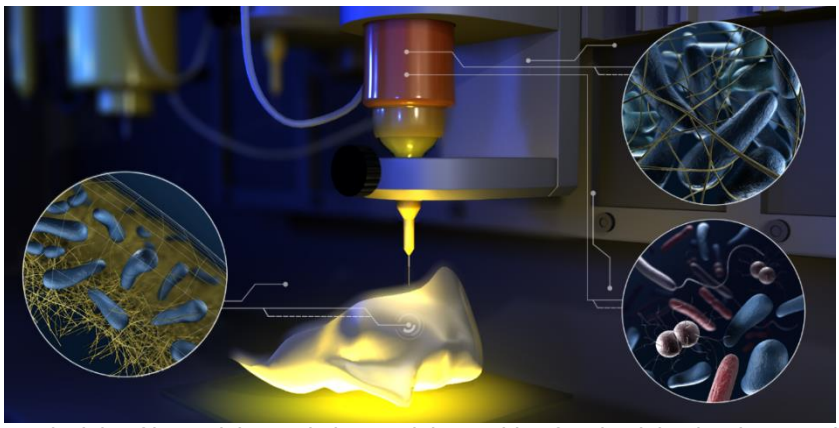
15:30 **Marco R. Binelli** (ETH Zurich)

Three-Dimensional Printing of Bacteria

Marco R. Binelli[1], Manuel Schaffner[1], Patrick A. Rühs[1] and André R. Studart[1]

[1] Complex Materials, D-MATL, ETH Zurich

The three-dimensional localization of bacterial cultures still remains a challenging feat to achieve, which could open up the way to new applications and provide a valuable tool for studying the behavior of microbes. Recent efforts have been made to precisely define the position of bacteria into support materials[1], by tailoring the properties of an ink to enable 3D printing while sustaining the growth of the microbes. We choose bacteria that have a potential for functional applications or for the synthesis of materials. Amongst these, bacteria capable of synthesizing bacterial cellulose such as *G. xylinus* are particularly interesting to us as they allow the production of personalized biomaterials with outstanding properties such as biocompatibility, tensile strength, and high chemical purity[2]. Moreover, we have shown the potential of the developed technique for biotechnological applications by immobilizing strains of *P. putida* into functional structures for the degradation of phenolic compounds.



Cartoon showing the principle of bacterial 3D printing: an ink capable of maintaining its shape and sustain the growth of microbes is used to generate arbitrary shapes using a 3D printing setup. Illustration: science animated by Bara Krautz

At times, the particular rheological features required for an ink to be successfully printed do not match the needs of the bacterial strain of choice and hinder the growth of the microorganisms. To circumvent this obstacle, we developed another 3D printing approach that allows us to directly deposit bacteria suspensions into a matrix that both supports free-form printing and allows for oxygen diffusion. Using this approach, we are able to print freeform bacteria suspensions and, when using *G. xylinus*, directly form complex 3D cellulose structures.

The use of bacteria to directly grow functional materials in accurate 3D shapes opens the way to a new generation of personalized biomaterials for a wide variety of applications as, for instance, in wound dressing and drug delivery.

1. *Schaffner, M., Rühs, P. A., Coulter, F., Kilcher, S. & Studart, A. R. 3D printing of bacteria into functional complex materials. Sci. Adv. 3, eaao6804 (2017).*
2. *de Oliveira Barud, H. G. et al. A multipurpose natural and renewable polymer in medical applications: Bacterial cellulose. Carbohydr. Polym. 153, 406–420 (2016).*

18:30 Dinner

Thursday 07 February 2019

8:00 - 9:30 Session 2 - Single Cell/Organism

08:00 **Karine Anselme** (Institut de Science des Matériaux de Mulhouse)

Curvature-dependent mesenchymal cells and epithelial tissue migration and orientation

L. Pieuchot[1,2], P. Rougerie[3], M. Vassaux[4], J. Marteau[5], P-F. Chauvy[6], T. Petithory[1,2], I. Brigaud[1,2], A. Ponche[1,2], J-L. Milan[4], M. Farina[3], M. Bigerelle[5], K. Anselme[1,2]

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[4]Aix Marseille Univ, CNRS, ISM, Inst Movement Sci, Marseille, France.
[5]Université de Valenciennes et du Hainaut Cambrésis, LAMIH, UMR-CNRS 8201, Le Mont Houy, Valenciennes, France.
[6]Micropat S.A., Lausanne, Switzerland.

A large body of studies have highlighted that cells are sensitive to nanotopographies or geometrical cell-scale structures. However, natural biotopes also exhibit much larger topographical cues that are often curved and smooth, such as walls of blood vessels, bone cell cavities, or other cell bodies. Very little is known about how isolated cells and tissues read and integrate cell-scale curvatures, and the mechanisms leading to the integration of such physical cues.

Herein we develop a two-step fabrication method to produce a series of edge-free cell-scale anisotropic and isotropic sinusoidal landscapes with very low micro roughness. We employ these new model surfaces to investigate the mesenchymal stem cell and epithelial cell layers' response to cell-scale curvature variations. We combine live imaging, biochemistry and modeling approaches to decipher integration mechanisms at the cellular and tissue levels.

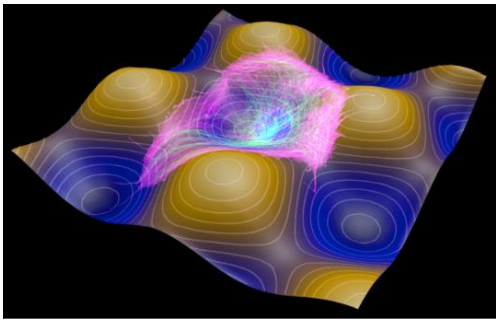


Figure: Mesenchymal stem cell surfing a 3D sinusoid 1

First, we report a new cellular sense which we term "curvotaxis" that enables the isolated cells to react to cell-scale curvature variations, a ubiquitous trait of cellular biotopes. We show that cells avoid convex regions during their migration and position themselves in concave valleys. Computational modeling, pharmacological assays and live imaging show that curvotaxis relies on a dynamic interplay between the nucleus and the cytoskeleton - the nucleus acting as a curvature sensor that guides cell migration towards concave curvatures[1].

Further, we report the curvature-modulated anisotropic growth of unconfined epithelia over cell-scale grooves and ridges of various transversal curvature. Curved regions of the substrate work as "topographical barriers", causing heterogeneity and reorientation of the nuclei and F-actin position. As a result, the epithelium displays a spatial bias in various morphogenetic processes such as migration or mitosis. Altogether, this work establishes cell-scale curvature as a major tuning parameter to regulate the growth of epithelia and opens new possibilities for tissue engineering research.

1. *Pieuchot L. et al. (2018) Nature Communications, 9:3995*

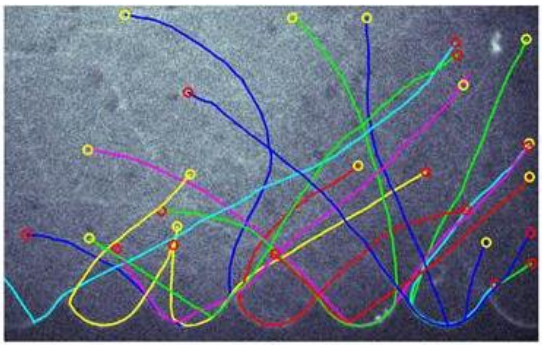
08:30 **Notburga Gierlinger** (Universität für Bodenkultur Wien)

The puzzle of the walnut shells: curvature for interlocking

Plant epidermal cells with an elaborate, jigsaw puzzle-like shape are an attractive system for investigating cell-shape control. These pavement cells have thin primary cell walls and are arranged in 2D. Recently we elucidated in the developing walnut shells similar polylobed cells, but interdigitated in 3D. The cells have irregular cell shapes with many lobes (convex areas) and indentations (concave areas) and represent the only building block of the walnut shell. Every cell is surrounded by 10 to 15 adjacent neighbours and the exceptional individual fitting of each cell into all the surrounding ones results in exceptional interlocking. The assembly of such a 3D puzzle is only feasible through the growth process and decisively extending the concept of so far introduced interlocking materials. Understanding the nutshell structure and its development has potential to open new avenues for biomimetic material development, but also for the utilization of nutshells in terms of food waste valorisation in a sustainable bio economy. After extraction of valuable components the remaining lobed cellulosic building blocks with high surface area and a pervious channel network have tremendous potential for developing new high performance and functional materials, like recently reported for wood.

09:00 **Vasily Kantsler** (University of Warwick)

Geometric control of bacterial surface accumulation



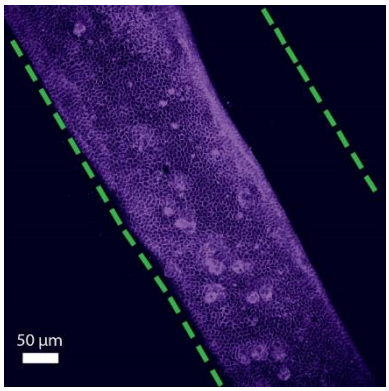
Controlling and suppressing bacterial accumulation at solid surfaces is essential for preventing bio lm formation and biofouling. Whereas various chemical surface treatments are known to reduce cell accumulation and attachment, the role of complex surface geometries remains less well understood. Here, we report experiments and simulations that explore the effects of locally varying boundary curvature on the scattering and accumulation dynamics of swimming Escherichia coli bacteria in quasi-two-dimensional microfluidic channels. Our experimental and numerical results show that a non-convex periodic boundary geometry can decrease the average cell concentration at the boundary by more than 50% relative to a flat surface.

9:30 - 10:00 Coffee Break

10:00 - 11:30 Session 3 - Cell sheets (2D / 2,5D) - 1/2

10:00 **Caterina Tomba** (Uni Geneve)

Mimicking tubular environments to study epithelial sensing to curvature



During embryogenesis, epithelial tissues fold to establish the final shape of the different organs. These shape changes at the tissue level involve processes at the cellular scale, like cell shape changes and proliferation.

We developed two complementary approaches based on microfabrication techniques to control epithelium shape under cylindrical confinements and to quantitatively study the cell response to 3D curved environments. The main difference between the two methods is to be a passive or an active constraint. For instance, we showed that contractility in the epithelium drives tissue remodeling, which can be enhanced by local curvature.

We expect our results and these simple and reproducible tools will contribute to provide useful insights for new quantitative studies of cell adaptation to curved and more bio-mimetic environments.

10:30 **Nicholas Kurniawan** (TUE)

Substrate curvatures larger than cell size direct mesenchymal stromal cell migration

The intrinsic architecture of tissues and of implanted exogenous biomaterials provides cells with mesoscale geometrical cues. While the effect of topographical cues with sizes smaller or comparable to cell size on cell migration have been well studied, little is known about the cellular response to substrate curvatures larger than cell size. To study the effect of substrate curvature in a systematic and high-throughput manner, we developed a microfabricated chip containing arrays of concave and convex cylindrical surfaces with a large range of diameters (µm to mm) and investigated the migration behavior of human mesenchymal stromal cells on these structures.

We found that on concave cylindrical structures cells lifted upwards off the surface and showed an undirected but fast migration, whereas migration on convex cylindrical surfaces was persistently directed towards the longitudinal axis of the cylinder. Further, we observed that mesoscale curvature guidance from cylinders of diameter up to 1000 µm can intriguingly overrule nanoscale contact guidance effect. We will discuss how these findings can be explained in terms of the interplay between the dynamics of actin stress fiber (re)organization and force generation, nuclear mechanics, adhesion morphology, and the perceived substrate curvature.

11:00 **Luis M. Escudero** (Universidad de Sevilla)

Scutoids, the building blocks of curved epithelia.

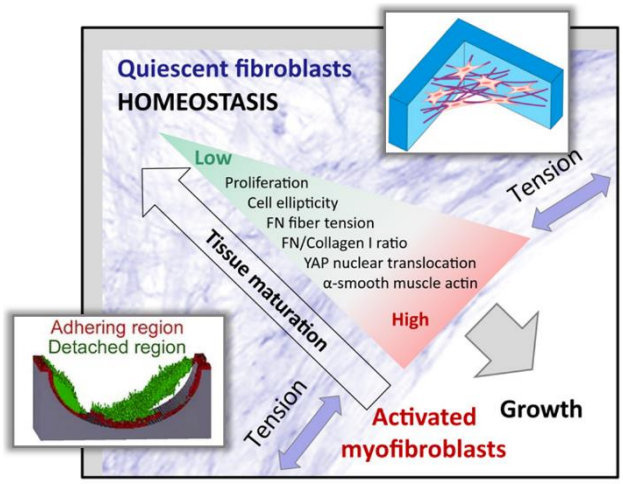
A new geometric shape has been described in epithelial cells. This type of cells blocks, called Scutoids, are necessary for curving the epithelial tissues and enables the cells packing efficiently into three-dimensional structures. Our study paves the way to understand the biomechanics of morphogenesis in developing organisms and sheds light on the underlying logic of 3D cellular organization. This is fundamental not only for an understanding of tissue architecture during development and disease, but to the fields of tissue and organ engineering. In this talk we will show unpublished data from new theoretical, cellular and molecular approaches that we are carrying out in the lab

11:30 - 12:30 Lunch

12:30 - 13:30 Session 4 - Tissues (3D) 1/2

12:30 **Philip Kollmannsberger** (Uni Würzburg)

How curvature and contractility impact cell fate and tissue structure



Throughout our lifetime, most of our tissues remodel and regrow to adapt to changing requirements and to regenerate from damage or disease. Tensile forces are increasingly recognized as cues for controlling cell fate and tissue structure, in addition to growth factor signaling. How cell-generated contractile tension is distributed and sensed by other cells depends on the curvature of the substrate and of the tissue boundary. We investigated two aspects of this interplay between curvature and tension: the detachment of contractile smooth muscle sheets from semi-cylindrical channels as a function of adhesion strength and curvature [1], and the proliferation and differentiation of fibroblasts in maturing microtissues as a function of contractility, matrix conformation and tissue age [2]. The combination of experiments, automated image analysis pipelines and computer simulations results in quantitative insights on the feedback between curvature and contractility that controls growth and regeneration in the context of wound healing, tissue engineering and development.

[1] Cell sheet mechanics: How geometrical constraints induce the detachment of cell sheets from concave surfaces. Yamashita, Tadahiro; Kollmannsberger, Philip; Mawatari, Kazuma; Kitamori, Takehiko; Vogel, Viola in Acta Biomaterialia (2016). 45 85 - 97.
[2] Tensile forces drive a reversible fibroblast-to-myofibroblast transition during tissue growth in engineered clefts Kollmannsberger, Philip; Bidan, Cécile M; Dunlop, John; Fratzl, Peter; Vo-gel, Viola. in Science Advances (2018). 4(1) eaao4881.

13:00 **Ansgar Petersen** (JWI Charité)

Using biomaterial architecture to heal bone via endochondral ossification

For a long time biomaterials for bone regeneration have aimed to support direct ossification e.g. by the incorporation of calcium phosphates. Due to the limited success, an alternative route of bone formation, so-called endochondral ossification (EO), has lately been discussed as a promising strategy to regenerate bone tissue. However, a pure biomaterial solution for this approach, that would allow a straight-forward translation to the clinics, is lacking so far.

We have recently shown how an unfavorable self-patterning of collagen fibrils impedes the healing of critical-size bone defects and have used a specifically architectured biomaterial that modulates this pattern to revive development-like EO[1]. As this approach does not depend on progenitor cell transplantation or exogenous growth factors, it might represent a safe and cost-effective alternative to current strategies. In my talk I will discuss aspects of extracellular matrix organization and cell composition that we found to be key in biomaterial-induced EO and how we envision to use hybrid scaffolds for a mechanobiologically optimized treatment of bone and bone-cartilage defects.

[1] Petersen et al., Nat Commun. 2018 Oct 25;9(1):4430.

13:30 - 14:00 Coffee Break

14:00 - 15:30 Session 4 - Tissues (3D) 2/2

14:00 **Sebastian Ehrig** (MPIKG)

The impact of 3D curvature during bone tissue morphogenesis

Sebastian Ehrig[1*], Cecile M. Bidan[1, 2], Alan West[1], Cornelius Jacobi[1], Karen Lam[1], Philip Kollmannsberger[3], Ansgar Petersen[4], Pavel Tomancak[5], Krishna Kommareddy[1], Franz D. Fischer[6], Peter Fratzl[1], and John W. C. Dunlop[1, 7]

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[2]Université Grenoble Alpes, CNRS, Laboratoire Interdisciplinaire de Physique (LIPhy), Grenoble, France
[3]Center for Computational and Theoretical Biology, University of Würzburg, Germany
[4]Julius Wolff Institute, Charité, Berlin, Germany
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[6]Montanuniversität Leoben, Institute of Mechanics, Leoben, Austria
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1. INTRODUCTION: An intrinsic property of many biological growth processes such as embryonic development or morphogenesis is the active force generation of cells that result in stress fields which can be sensed by cells over multicellular distances. Tissues thereby often undergo large deformations that change the geometric boundary conditions of the cells which themselves alter the tissue shape by the production of extracellular matrix (ECM). Our research revolves around an understanding of how geometry influences the self-organization of cells to form large scale tissue structures such as bone. Specifically, we are interested in a better understanding of how cells collectively respond to the curvature of their environment [1]. In this contribution we explore tissue growth on doubly curved surfaces that mimic geometries found in trabecular bone.

2. METHODS & RESULTS: Substrates of varying mean curvature were fabricated using a method adapted from Wang and McCarthy [2] and were subsequently functionalized with fibronectin to facilitate cell attachment. Tissue growth from pre-osteoblast cells was then monitored via phase contrast microscopy over several weeks. Fixed tissues have been visualized using light-sheet microscopy imaging to obtain 3D images of the tissue structure.

Using these substrates, we are able to demonstrate that the surface mean curvature has a strong impact on the rate of tissue growth and on the organization of the tissue structure. We show that the tissue behaves like a viscous fluid that flows on sufficiently long time-scales and obtains an equilibrium shape that can be described by the Laplace-Young-law [3].

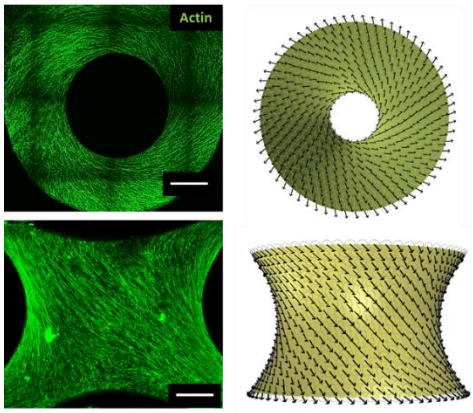

Figure 1: Fluorescence images of tissues grown on two different constant mean curvature surfaces: inside a doubly-curved pore (top-left) and on the outside of an anticlastic scaffold (bottom-left). Actin pattern closely resemble directions of zero normal curvature suggesting liquid crystal-like ordering (images on the right). Scale bars: 400um.

The amount of tissue formed on these surfaces varies significantly with more tissue being deposited on highly concave surfaces indicating a curvature-controlled mechanism. Furthermore, we find remarkably symmetric actin stress fibre patterns (see Figure) that closely resemble geodesics. Such self-organized pattern formation might be originating from the liquid–crystal like behaviour of cells previously been reported for fibroblast cells [4].

3. DISCUSSION & CONCLUSIONS:

Our results demonstrate that 3D surface curvature has a strong impact on the self-organized long-range structuring of growing tissues. Insights into the design principles of the tissue and the role of the underlying substrate on growth may have important implications for the understanding of healing processes and scaffold design in tissue engineering.

4. REFERENCES:

[1]Bidan, et al., How linear tension converts to curvature: geometric control of bone tissue growth. Plos One, 2012
[2]Wang and McCarthy, Capillary-bridge–derived particles with negative Gaussian curvature. PNAS, 2015
[3]Ehrig, et al., Surface tension determines tissue shape and growth kinetics. BioRxiv, 2018
[4]Duclos, et al., Topological defects in confined populations of spindle-shaped cells. Nat Phys, 2016

14:30 **Amaia Cipitria** (MPIKG)

Scaffold curvature-mediated biomineralization in-vivo

A myriad of shapes are found in biological tissues, often evolved to fulfil a particular function. In the field of tissue engineering, substrate geometry influences cell behavior and tissue formation in-vitro, yet little is known how this translates to an in-vivo scenario. We used clinically relevant bone regeneration experiments to study how the scaffold mean surface curvature may guide collagen fiber organization and subsequent mineralization in-vivo. Soft tissue formation followed a curvature-driven growth model. Geometrical constraints imposed by this endogenous soft matrix lead to a non-standard form of biomineralization, whereby the pre-existing organic matrix was mineralized without collagen remodeling and without an intermediate cartilage ossification phase. Micro- and nanoscale analysis using second-harmonic generation imaging and synchrotron small angle X-ray scattering allowed quantitative characterization of the continuous soft-hard tissue microstructure. These findings on in-vivo tissue growth under geometric confinement provide fundamental knowledge on scaffold design for musculoskeletal tissue engineering.

15:00 **Claire Beauchesne** (EM2C / MSSMat Laboratories)

Tissue growth analysis in a perfusion bioreactor

Claire Beauchesne[1,2], Bertrand David[2], Benoît Goyeau[1]

[1] Laboratoire EM2C, CNRS, CentraleSupélec, Université Paris-Saclay, 3, rue Joliot-Curie, 91192 Gifsur-Yvette cedex, France
[2] Laboratoire MSSMat, CNRS, CentraleSupélec, Université Paris-Saclay, 3, rue Joliot-Curie, 91192 Gif-sur-Yvette cedex, France

Tissue engineering proposes to associate an absorbable scaffold with osteocompetent cells in order to produce a tissue *in vitro* for medical purpose. In particular, perfusion bioreactors step in as a promising alternative to the reference techniques autografts and allografts. In this context, our objective is twofold. We wish to understand the impact of the fluid flow in the porous scaffold on cell proliferation, especially regarding the heterogeneities of the scaffold. Second we aim at producing a model at the bioreactor scale of tissue growth and cell proliferation, taking into account the biophysical phenomena at the lower scales.

We performed cell culture experiments in a perfusion bioreactor which scaffold consists of a stack of uniformly sized beads. After different culture times, the cellular phase is visualized by X-ray microtomography. First we observe the formation of an envelop all around the scaffold as a consequence of a c*hanneling effect*. In addition, local numerical simulations allowed us to identify the regions were the cells were more likely to proliferate [3].

The next step is to propose a model for cell proliferation and tissue production at the bioreactor scale. Because of the different length scales of the transport phenomena, the hierarchical nature of the problem has to be taken into account. At the tissue scale, the tissue can be modeled as an equivalent homogeneous region with a moving interface and effective properties. In this presentation, we will focus on the upscaling of cell transport from the tissue scale to the bioreactor scale considering the tissue-medium moving interface.

[1] Baroli, B. (2009). From natural bone grafts to tissue engineering therapeutics: brainstorming on pharmaceutical formulative requirements and challenges. Journal of pharmaceutical sciences, 98(4), 1317-1375.
[2] David, B., Bonnefont-Rousselot, D., Oudina, K., Degat, M. C., Deschepper, M., Viateau, V., Bensidhoum, M., Oddou, C., Petite, H. (2011). A perfusion bioreactor for engineering bone constructs: an in vitro and in vivo study. Tissue Engineering Part C: Methods, 17(5), 505-516.
[3] Beauchesne, C., Chabanon, M., Smaniotto, B., Ladoux, B., Goyeau, B., David, B. Analysis of tissue growth and morphology in a perfusion bioreactor by X-Ray microtomography (submitted to Tissue Engineering).

16:00-18:30 Evening Event

18:30 Dinner

Friday 08 February 2019

8:30 - 10:30 Session 5 - Dynamic Curvature (4D)

08:30 **Aranzázu Del Campo** (INM)

Increasing dimensionality in synthetic cellular microenvironments: from 1D to 4D

09:00 **Ernest Latorre** (IBEC Barcelona)

Active superelasticity in three-dimensional epithelia of controlled shape

Ernest Latorre[1,2], Sohan Kale[2], Laura Casares[1], Manuel Gómez-González[1], Marina Uroz[1], Léo Valon[1], Roshna V. Nair[3], Elena Garreta[1], Nuria Montserrat[1,4], Aránzazu del Campo[3,5], Benoit Ladoux[6,7], Marino Arroyo[1,2]* and Xavier Trepat[1,4,8,9]*

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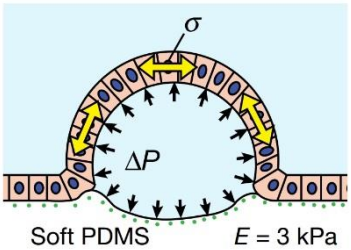
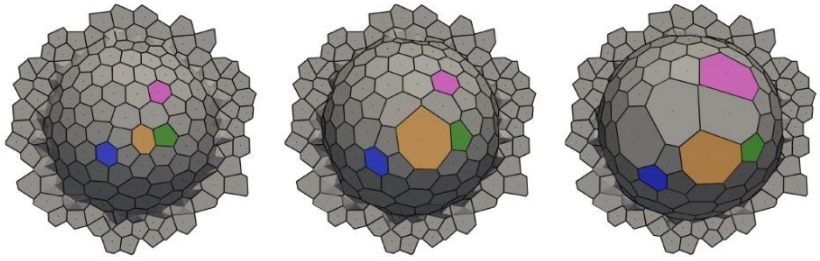
[2] Universitat Politècnica de Catalunya-BarcelonaTech, Barcelona, Spain.
[3] INM-Leibniz Institut für Neue Materialien, Saarbrücken, Germany
[4] Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales y Nanomedicina, Barcelona, Spain
[5] Chemistry Department, Saarland University, Saarbrücken, Germany
[6] Institut Jacques Monod (IJM), Université Paris Diderot, Paris, France
[7] Mechanobiology Institute (MBI), National University of Singapore, Singapore, Singapore
[8] University of Barcelona, Barcelona, Spain
[9] Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelon, Spain.

* Corresponding authors

Fundamental biological processes are carried out by curved epithelial sheets that enclose a pressurized lumen. How these sheets develop and withstand three-dimensional deformations has remained unclear. Here we combine measurements of epithelial tension and shape with theoretical modelling to show that epithelial sheets are active superelastic materials. We produce arrays of epithelial domes with controlled geometry. Quantification of luminal pressure and epithelial tension reveals a tensional plateau over several-fold areal strains. These extreme strains in the tissue are accommodated by highly heterogeneous strains at a cellular level, in seeming contradiction to the measured tensional uniformity. This phenomenon is reminiscent of superelasticity, a behaviour that is generally attributed to microscopic material instabilities in metal alloys. We show that in epithelial cells this instability is triggered by a stretch-induced dilution of the actin cortex, and is rescued by the intermediate filament network. Our study reveals a type of mechanical behaviour—which we term active superelasticity—that enables epithelial sheets to sustain extreme stretching under constant tension.





09:30 **Michaela Eder** (MPIKG)

Temperature triggered seed pod opening is controlled by internal curvature

Fire is a component of the natural Australian landscape since millions of years. As a consequence, vegetation has adapted to these natural “harsh” conditions with some organisms developing strategies for re-establishment after fire, eg resprouting and/or germination from seeds. For the later strategy seeds are accumulated between fires and stored in the soil or in the canopy. Species of the genus Banksia are prominent examples for the latter. However, pronounced difference regarding duration of storage exist. Some species release their seeds upon maturity whereas others rely on elevated temperatures, eg during fires. Even within one species both strategies and transitions between them are possible.

To explore the underlying mechanisms for seed release we investigated *Banksia attenuata*, a species known for both spontaneous and fire-triggered seed release. The seed pods (follicles) which contain two winged seeds and a separator in between develop on infructescences (see Figure) after pollination of a showy spike which contains several thousand flowers. We collected infructescences with mature follicles without metabolism along the west Australian coast line from Perth to Eneabba (approximately 250 km, black dots in the map in Figure, green shows distribution range of *B. attenuata*). Infructescences from the southern sampling sites contained many open follicles, whereas most of the follicles from the northern sites remained closed (see Figure). Interestingly, follicle opening temperatures of the collected samples changed gradually from 54°C in the south to 72°C in the north. Detailed analyses of the follicle material revealed that follicle opening is controlled by internal curvature. These findings do not only provide inspiration for the development of simple “self-moving” or sensing devices but have direct implications for plant conservation in fire-prone ecosystems.

10:00 **Speaker will be announced soon**

Topic will be announced soon

10:30 - 11:00 Coffee Break

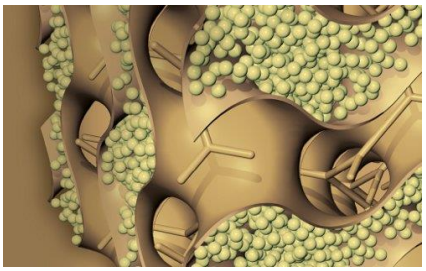
11:00 - 11:30 General Talk

11:00 **Gerd Schröder-Turk** (Murdoch University)

Negatively curved three-periodic structures: What can variations and integrals of curvatures tell us about the physics?

Bicontinuous geometries are fascinating structures that are characterised by spatially extended highly-ordered arrangements on the nanoscale. Allan Schoen's Gyroid minimal surface is in many ways the ideal archetype of these geometries, being a surface that divides space into two identical domains, each of which is an ordered maze-like infinite labyrinth. For the Gyroid and all other bicontinuous forms, the characteristic defining feature is that all components – the lipid membranes, the aqueous channels, the inner-cellullar and the extra-cellular components– all 'percolate' throughout space, i.e., they allow macroscopic and fast transport. This is for example evident in the diffusion constants of the 'inverse cubic' lipid/water bicontinuous phases which is orders of magnitude faster than in other lipid/water phases such as micelles or lamellae.

In this talk, I will discuss the important role of curvature in these systems, alluding to both 'local curvatures' and to 'integral curvatures'. The former relates to key concepts in self-assembly such as the 'molecular shape parameter' and, through variations of curvature, to the geometric frustration inherent in any 3D negatively curved continuous interface. The latter relates to the topology index and hence to the large-scale connectivity. I will touch on geometric and theoretical approaches that use these key concepts to understand the self-assembly and the thermodynamic properties of these systems.



11:30 - 12:00 Final Brainstorming & Wrap

Cécile Bidan (MPIKG) / **John Dunlop** (PLUS)

12:00 End of the meeting