9:45 – 10:30

Experimental findings and the beginning of multi-scale explanations of articular Poisson effects encountered during traction of samples of the annulus fibrosus

Keynote speaker: Simon Le Floc'h

LMGC, Univ. Montpellier, CNRS, Montpellier, France

Starting from field measurement analyses done during traction tests on the annulus fibrosus of the pig intervertebral disc (millimetric scale), I will expose particular transverse tensile behaviours (or "Poisson effects"). These behaviours are associated with Poisson's ratio values ranging from largely negative values (auxeticism) to very high values. These particular behaviours can only be partially reproduced by compressible hyperelastic models, which use macroscopic phenomenological modelling of compressible fibrous soft tissues. The weakness of these phenomenological models to reproduce the transverse tensile behaviour of this type of tissues invites us to propose micromechanical approaches, in particular the modelling of the architecture of collagen fibres. Estimating a macroscopic behaviour by homogenisation methods allows us to test certain hypotheses currently proposed in the literature in order to better understand the origin of these particular transverse behaviours. I will show that these macroscopic transverse behaviours, that can be experimentally measured through full-field measurements, can really help at discriminating different microstructures of collagen fibers.

10:30 – 11:15

Driving Musculoskeletal Health Forward: *A journey in mechano-biological characterization and in silico modeling of cartilage*

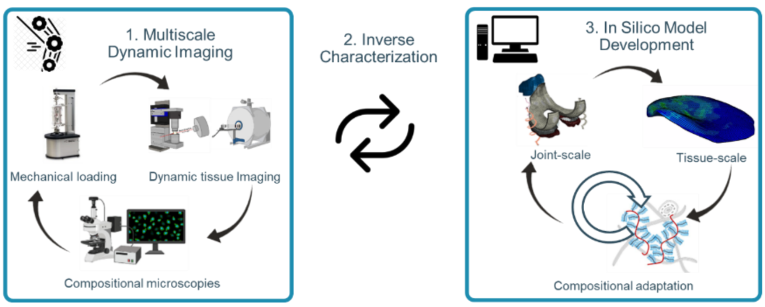
Guest speaker: Seyed Ali Elahi

Department of Movement Sciences and Mechanical Engineering Department, KU Leuven, Belgium

Osteoarthritis (OA) is a debilitating condition affecting millions worldwide, with cartilage degeneration playing a critical role in its progression. Despite extensive research, there remains a lack of curative or preventive treatments for OA. Our current research focuses on addressing this gap by advancing the understanding of cartilage mechanobiology.

This research involves three pillars:

1. **Multiscale Imaging**: We use a variety of imaging modalities, including in vitro and in vivo MRI to capture the evolving nature of cartilage mechanics. Additionally, synchrotron imaging investigates nanoscale details, such as strain in collagen fibrils, while histological microscopies examine tissue structure and constituent dispersion at a microscopic level.
2. **Inverse Characterization**: We develop mathematical models based on experimental observations to characterize cartilage material properties. Techniques such as inverse finite element characterization and virtual fields method are employed using 3D deformation fields obtained from dynamic MRI.
3. **In Silico Model Development**: We integrate insights from multiscale imaging and inverse characterization to develop computational models of cartilage behavior. These in silico models incorporate multi-scale mechanobiological aspects, enabling the exploration of innovative diagnostic tools and treatments for musculoskeletal diseases.



By leveraging this integrative approach, our research aims to pave the way for significant advancements in the diagnosis and treatment of OA, ultimately improving patient outcomes and quality of life.

11:15 – 11:35

An innovative compression system to study the deformation of mice articular cartilage under multiphoton microscopy: development and initial results

Speaker: Sarah-Maud Sombris Picot *(LMGC)*

In order to understand how the articular cartilage of the tibial plateau responds to mechanical loading, it is important to study the micro-mechanisms of deformation and stress that occur in the tissue during movement. An innovative compression system has therefore been designed to monitor the load response of tissue components through imaging.

11:35 – 11:55

On parameterizing the microstructure of soft biological tissues for more informed modeling

Speaker: Cristina Cavinato *(LMGC)*

Constitutive modeling in tissue biomechanics necessitates the identification of targeted microstructural parameters to accurately represent the complex mechanical behavior of biological tissues. However, a significant challenge lies in the lack of standardization in the requests for histological, biochemical, and biophysical data. In this presentation, the current state of the art in parametrization of microstructure for constitutive modelling is discussed, with a particular focus on advanced imaging and image processing techniques. We aim to initiate a discussion between experimental and modeling communities, exploring potential synergies to enhance the accuracy of biomechanical tissue models. The goal is to bridge the gap between experimentation and modeling, utilizing advanced techniques such as Second Harmonic Generation (SHG) microscopy to accurately calibrate mechanical models based on tissue microfibrillar structures.

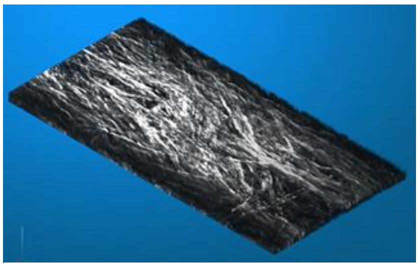


Figure: SHG stack acquisition for volume reconstruction of collagen fibers in aortic tissues.

11:55 – 13:30 LUNCH BREAK

13:30 – 13:50

Durability of vascular stents: development of a test bench combining pulsatile and corrosive loads

Speaker: Emilie Parpaillon *(ANSM – LMGC)*

Vascular stents are medical devices that are required to meet standards regarding their pulsatile durability or their susceptibility to corrosion. Nonetheless, stent failures are still reported.

To create higher standards for market monitoring and to have a better understanding of the failure mechanisms, we developed a bench to test those devices. We aim to show the synergetic effect of corrosion and pulsatile loading on the fatigue of the stent.

Mock vessels play an important part in the pulsatile durability testing of vascular stents according to the standard ASTM F2477. Those tests can require those vessels to demonstrate similar properties to the vessel they are replacing, such as their geometry and their compliance.

In this presentation, the focus will be on how we managed to combine mechanical and corrosive loading on a femoral stent while respecting those physiological conditions.

13:50 – 14:10

Some aspects of modeling, computation, and experimentation on thin membranes

Speaker: Pr. Franck Jourdan *(LMGC)*

In this presentation, some fundamental mechanical aspects of thin isotropic membranes will be discussed. Theoretical, numerical and experimental developments will be presented. The aim is to develop simple, robust methods for the mechanical characterization of soft tissues.

14:10 – 14:55

Lamellar undulation, residual stresses, and homeostasis: a multiscale mathematical approach

Guest Speaker: Claire Morin
Mines Saint-Etienne, Univ Jean Monnet, INSERM, U 1059 Sainbiose, F - 42023 Saint-Etienne, France

Arterial tissues are made of various fiber networks and cell populations. While the decrimping of adventitial collagen fibers has been widely measured and modelled, less importance has been devoted to the gradual crimp of the elastic lamellae in the media, which progressively uncrimp when subjected to a mechanical load. We propose a multiscale model to study the link between the observed crimp, the presence of residual stresses and the cellular homeostasis. An extension is finally proposed to account for growth and remodelling in such a multiscale model.
First, in the framework of continuum micromechanics, representative volume elements (RVE) of the interlamellar space and of the lamellae are defined. This multiscale model is then incorporated in an axisymmetric, finite-element model of the arterial wall and the model predictions are compared to experimental ones. Finally, the impact of lamellar undulation on the mechanical field is studied via the incorporation of a residual stress.

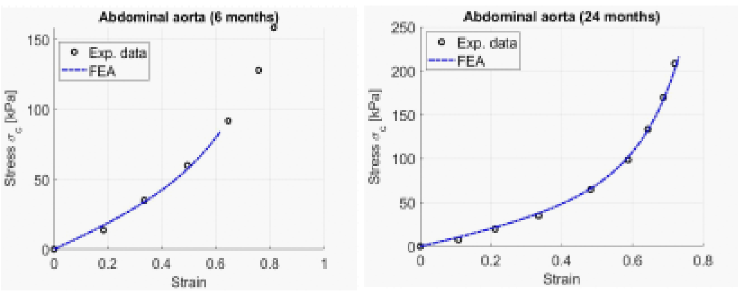


Figure: Comparison between experimental data (dots) and model predictions (lines) for the stress-strain curve from inflation tests on young (left) and aged (right) mice abdominal aorta.

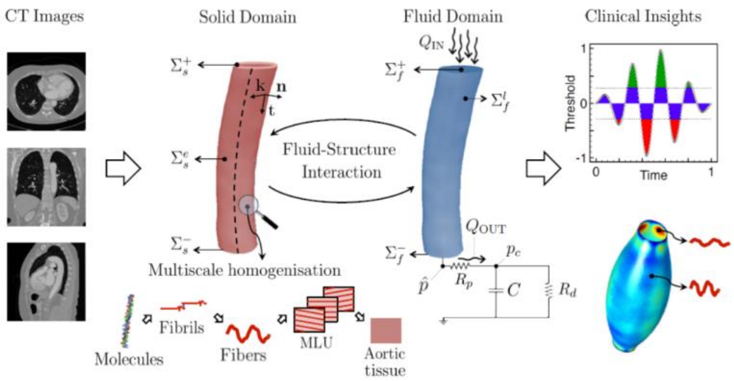
Besides reproducing the experimental observations (taking the microscopic observations as inputs and the mechanical response as output), our approach shows that the gradient in lamellar crimping generates a residual stress field which provides a smooth stress field in the wall, a key ingredient for cellular homeostasis.

14:55 – 15:25

Multiscale and multiphysics modeling of the mechanical response of arterial tissues

Guest Speaker: Daniele Bianchi
Unit of Non-Linear Physics and Mathematical Modelling, Department of Engineering, University Campus Bio-Medico of Rome

The seminar will explore advanced computational approaches for understanding the mechanical behavior of arterial tissues through multiscale and multiphysics modeling. Recent research in biomechanics emphasizes the necessity of developing engineering tools and computational methods for highly personalized diagnostic and clinical treatments. This seminar will delve into multiscale modeling techniques that address the complexity of biomechanical problems spanning a wide range of spatial and temporal scales. The presentation will cover the integration of analytical formulations and numerical treatments to capture dominant mechanisms and biophysical processes from the nanoscale to the macroscale. Key applications will be discussed, including the mechanical response of arterial tissues. Special attention will be given to patient-specific models and their relevance in clinical scenarios such as the coupling of structural models with blood flow simulations to understand fluid-structure interactions in arterial tissues. The seminar aims to provide insights into the potential of these models to enhance surgical planning, optimize therapeutic strategies, and contribute to the understanding of disease etiology and progression.



15:25 – 15:50 COFFEE BREAK

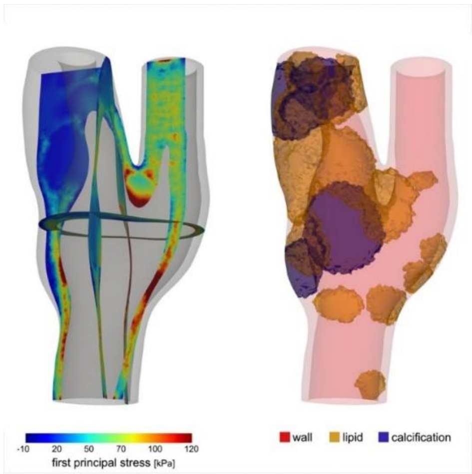
15:50 – 16:35

Growth and remodeling of cardiovascular tissues: novel applications and perspectives

Guest Speaker: Michele Marino

Department of Civil Engineering and Computer Science Engineering, University of Rome Tor Vergata

The physiological behavior of the cardiovascular system is influenced by various factors, including blood flow conditions, passive and active wall mechanics, as well as enzymatic and proliferative processes within tissues. Pathological events trigger signaling pathways that alter tissue histoarchitecture or muscular tone, impacting vessels' mechanical response. Although these changes can help restore homeostasis, they may also be insufficient, leading to disease progression. To better understand both normal and pathological outcomes, we have developed computational models that integrate growth and remodeling algorithms as a multi-field problem across multiple time and length scales.



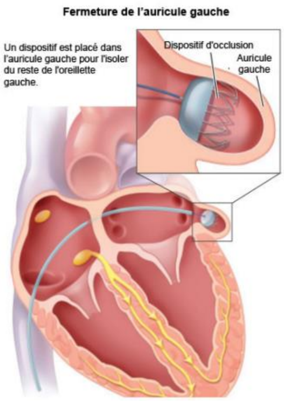
This lecture will present two key examples: first, the influence of growth and remodeling homeostatic principles on the rupture risk of carotid plaques in patient-specific scenarios; second, a chemo-mechano-biological simulation framework linking macroscopic disturbances (e.g., increased blood flow, inflammation, trauma) to cellular mechanobiological responses (e.g., molecular production dynamics, cell behavior modulation), internal stress variations, and tissue growth and remodeling outcomes.

16:35 – 16:55

Patient specific computation of the percutaneous left atrial appendage closure, numerical approach and experimental validation

Speaker: Nathan Colin *(Sim&Cure -LMGC)*

Atrial Fibrillation (AF) is the most common cardiac arrhythmia pathology in the world, with 30 to 60 million of patients. One of its consequences is the creation of thrombus inside the Left Atrial Appendage, highly raising the chances to have an ischemic stroke. The LAA Closure (LAAC) is a minimally invasive surgical operation allowing to contain thrombus inside the LAA by closing it through trans-catheter deployment of an Implantable Medical Device.



Physicians performing other minimally invasive operations through trans-catheter means can rely on patient specific mechanical computation (preoperative or intraoperative) of IMD's deployments inside anatomical structures. The results obtained from such computation can help practicians to choose the type or size of the IMD for a given patient. Mechanical modeling of a minimally invasive surgical operation includes many parameters. In order to betterly know the impact of such parameters on the result of the operation, we are proposing a numerical modeling of the LAAC operation, as well as the experimental validation of the used model.

Figure source: Maryse Lemyre, Institut Universitaire de Cardiologie et de Pneumologie de Québec.

16:55 – 17:15

Development and testing of a patient-specific knee distraction unloader brace

Speaker: Lea Boillereaux *(LIRMM, LMGC)*

The knee is a joint subject to several pathologies, some affecting the articular cartilage. New methods to treat these diseases, such as repair using cartilage neo-tissue implants, are being developed. These implants require modulation of tibiofemoral contact force during rehabilitation, using an orthosis for example. Commercially available orthoses have not been sufficiently evaluated regarding contact force reduction and/or are not very effective. In this study, we propose the design of a new unloading orthosis using the distraction principle, via a specific patient cam-valve system. We then test its effectiveness on a test bench using a robotic arm and reproducing the squat movement. The results obtained are highly satisfactory, but the test bench could be improved to better represent the reality of a human leg, particularly for skin/bone contacts, which play an important role in transmitting the forces generated by the orthosis. The question of the device's interaction with the skin remains also unanswered.

17:15 – 17:35

Magnetic resonance elastography for the characterization of changes in viscoelastic properties

Speaker: El Farid Oussen *(LMGC- L2C BNIF)*

Magnetic resonance elastography (MRE) is a non-invasive modality used to map the mechanical properties of soft materials and tissues such as the liver or brain, from magnetic resonance imaging (MRI) technology.
Specific MRI sequences are developed to measure the 3D displacement fields within the sample.
The data is then processed by an algorithm based on a physical model to determine the mechanical properties, that could be heterogeneous and altered by pathology or treatment.
In this work, we report on the development of guided pressure waves MRE to study the viscoelastic properties of homogeneous plastisol phantoms with the aim of future preclinical investigations in rodents.