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UNIVERSITÀ DEL SALENTO

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Scientific Program - Timetable

Sunday 22	Time	Monday 23	Tuesday 24	Wednesday 25	Thursday 26	Friday 27
	9:15		Contributed sessions (15 in parallel)	Plenary Lecture Moritz Diehl	Contributed sessions (15 in parallel)	Contributed sessions (14 in parallel)
	9:30					
	9:45					
	10:15	Registration		von Mises prize lecture		
	10:30					
	10:45					
	11:15		Coffee Break	Coffee Break	Coffee Break	Coffee Break
	11:30					
	11:45					
	12:15		Plenary Lecture Thomas Böhlke	General Assembly	Plenary Lecture Ferdinando Auricchio	Contributed sessions (11 in parallel)
	12:30					
	12:45					
	13:15	Opening	Lunch	Lunch	Lunch	
	13:30					
	13:45	Univ. Chorus Performance				Closing
	14:15	Prandtl Lecture Keith Moffatt	Plenary Lecture Enrique Zuazua	Contributed sessions (15 in parallel)	Plenary Lecture Daniel Kressner	
	14:30					
	14:45					
	15:15	Plenary Lecture Giovanni Galdi	Plenary Lecture Nikolaus Adams		Plenary Lecture Stanislaw Stupkiewicz	
	15:30					
	15:45					
Registration pre-opening	16:15	Coffee Break	Coffee Break Poster session	Coffee Break	Coffee Break Poster session	
	16:30	Minisymposia & Young Reseachers' Minisymposia (10 in parallel)	Contributed sessions (14 in parallel)	Contributed sessions (15 in parallel)	Contributed sessions (15 in parallel)	
	16:45					
	17:15					
	17:30					
	17:45					
	18:15		Public lecture Francesco D'Andria			
	18:30					
	18:45					
	19:15	Opening reception at Castle of Charles V				
	19:30					
	19:45					
	20:15			Conference dinner at Hotel Tiziano		
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GAMM 2015

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MS5: Mechanics in an Inter., Multiphysics Env., Transforming Materials Sciences and Biology

Mechanics belongs to the oldest branches of physics, being characterized by an exceptional degree of maturity, and having fostered innumerable technological advancements, pervading daily life as well as breathtaking engineering deeds. In this context, mechanics sometimes appears as a closed, somehow "completed" discipline, in contrast to emerging branches of science, such as life sciences or biotechnology.

This symposium is to show concrete examples that the aforementioned appearance may be regrettable, but more importantly, that it is actually not supported by reality: In fact, engineering mechanics has turned out as a game changer in topics where it would not be expected in the first place: examples at the mini symposium will cover bio-nano-technology, systems biology, molecular chemistry, and bio-physics, to name just a few.

Mechanics of biological interfaces under stretch and across scales: lipid bilayer membranes and epithelia

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Biological interfaces hierarchically partition our body at different scales. In cells and within cells, these interfaces are molecularly thin biomembranes. At the tissue scale, epithelia are cohesive two-dimensional sheets of cells, which line free surfaces and cavities. From the point of view of mechanics of materials, these two biological interfaces are multifunctional active materials, which are capable of dealing with conflicting mechanical requirements. On the one hand, they must be malleable to adopt functional shapes, or to self-repair. On the other hand, they must be resilient to provide structural integrity in a mechanically active environment. I will present recent work trying to understand how these material interfaces perform these mechanical functions when adhered to a substrate and subject to stretch. In all these studies, continuum models and simulations of membrane [1] and hydrogel [2] mechanics have been very important.

I will first describe how synthetic bilayers passively regulate stress and shape in response to lateral and osmotic stresses [3]. The mechanoadaptation of biomembranes in living cells is commonly though to involve active cell processes like endocytosis and exocytosis or the formation and flattening of membrane invaginations/evaginations. Strikingly, in recent work we have shown that the passive, purely mechanical mechanism identified on synthetic membranes are also exploited by biological membranes to cope with sudden stresses [4]. I will then describe how structural integrity of epithelia is challenged under stretch, creating interfacial cracks at cell-cell junctions [5].

References

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The fiber reorientation problem revisited in the context of Eshelbian micromechanics: theory and computations

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Constitutive modeling of soft biological tissues has been the topic of an abundant literature, trying to capture the complex mechanical behavior of tissues, made of an assembly of loose collagenous fibrils, which are stretched by application of a mechanical loading. This complex, non-linear, mechanical behavior originates in geometrical changes in the tissue microstructure, the initially crimped and variously oriented collagenous fibrils being progressively decrimped and reoriented so as to reinforce the tissue in the direction of the applied load [1].

We here propose to model the fibrillar decrimping and reorientation through extension of the classical framework of continuum micromechanics [2], exploiting the famous Eshelby inhomogeneity problem [3]. A Representative Volume Element of a collagenous soft tissue contains an arrangement of variously oriented, infinitely long, linear elastic inclusions embedded in a linear elastic, soft matrix. The rotations of the inclusions resulting from the application of a macroscopic strain field are deduced from use of the aforementioned inhomogeneity problem: in more detail, we employ the antimetric part of this problem's displacement gradient so as to compute the second-order spin tensor. In this context, we first derive an analytical expression for what we call "Eshelby rotation operator" (considered as the equivalent to the Hill tensor for the microscopic strain tensors), which relates the microscopic spin tensor to the inclusion eigenstress. On this basis, we can relate the spin-tensor to remote strains subjected to the infinite solid matrix, which we then combined with the strain average rule, as to arrive at a micro-spin-to-macro-RVE-strain relation. The latter quantifies load-induced micro-configurational changes [4], which completes our new random homogenization schemes.

The resulting multiscale model for fibrillar tissue allows to qualitatively reproducing the macroscopic response of soft tissues, as well as the evolution of the fibrillar inclination during loading, opening a new framework for the development of 3D multiscale constitutive laws for soft tissues, able to quantify the specific contribution of each constituent on the overall response of the tissue.

The long-term application of such models, coupled to proper failure mechanisms is foreseen for the failure risk-assessment of vascular diseases, such as aneurysms.

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Multiscale hierarchical mechanics in soft tissues

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Soft tissues are throughout the whole human body and they include tendons, ligaments, skin, fibrous tissues, muscles, blood vessels. They link, support, and are part of other bio-structures and organs, playing a key role in the biomechanics of many body systems (e.g., musculo-skeletal, respiratory, cardiovascular). Soft tissues are generally fibrous connective tissues which can be either dense or loose, depending on the collagen amount. They consist primarily of elastin, amorphous ground substance, cells and collagen fibers. As confirmed by well-established studies [1], the highly nonlinear constitutive response of soft tissues at the macroscale is strictly related to the hierarchical organization of collagen from nano (namely, molecular arrangement) up to the microscale (fibrils and fibers). Accordingly, different collagen patterns and amounts induce different mechanical responsesvat the macroscale, in terms of stiffness and strength features. As a result, functional values of compliance for arterial walls in cardio-vascular system, of stiffness for pulmonary tissues in respiratory system, and of extensibility for tendons in musculo-skeletal system, are experienced. Moreover, altered tissue response in disease (e.g., aneurism, keratoconus, arthofibrosis) arises from pathological tissue remodeling and arrangement alterations at the nano and microscale, inducing unphysiological histology and biochemical composition.

In this scenario, the development of theoretical results and computational methods for effectively correlating mechano-regulated physio-pathological processes occurring at very different length scales, as well as to identify relationships among alterations and diseases, represents an open challenge at the cutting edge of modern biomechanics.

In this paper, mechanics of soft tissues is modeled by describing tissue structured hierarchical arrangement, reducing model complexity by means of multiscale homogenization techniques. Such an approach, employed for example in [2–6] , is referred to as a structural multiscale method. It consists in regarding the tissue at the macroscale as a fiber-reinforced composite material, wherein properties of reinforcement phase are recovered by mechanical models at smaller (than the macro one) length scales, coupled each other by means of consistent inter-scale relationships. Accordingly, the equivalent responses of tissue substructures at different scales, including possible damage and inelastic mechanisms [7, 8], are analytically derived and consistently integrated and upscaled, allowing to include at the macroscale the dominant mechanisms occurring at smaller scales.

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The theory of mechanobiological stability: on the theoretical foundations of mechanobiology in soft tissue

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In living tissue, the relation between load and deformation can be understood on short time scales (up to minutes) largely from a handful of well-known and simple principles such as Newton's axioms or Hooke's law (including its generalizations). On long time scales, however, it is often governed by mechanobiolgy, that is, mechano-regulated, cell-driven growth and remodeling. Although recent experimental findings have underlined more and more the overwhelming importance of mechanobiology in biomechanics, its mathematical foundations remain poorly understood to date.

In this presentation, we introduce the theory of mechanobiological stability [1, 2] as a simple conceptual framework to understand continuum mechanobiology in soft tissue. Though mainly based on but two simple assumptions, the presence of mass turnover and the existence of a state of tensional homeostasis, it provides natural explanations for a host of salient features of living soft tissue such as the virtual omnipresence of prestress and mechanoregulated growth and remodeling, as well as the often observed creeping loss of geometric integrity (e.g., in aneurysms).

The presentation will be concluded by a number of examples demonstrating the excellent agreement between the theory of mechanobiological stability and well-known clinical and experimental observations.

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Coupling X-ray physics and engineering mechanics, for enhanced analysis of Computer Tomographic images

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Since its invention in the 1960s, Computed Tomography has become one of the most powerful and versatile non-destructive imaging tools, with applications ranging from biomedicine to concrete technology. For about two decades, it is also common to use CT images as the basis for Finite Element modeling of the scanned objects. Thereby, the main focus has been classically laid upon the accurate representation of geometrical details, while particularly for solids made up of natural non-homogeneous materials, the question of material property assignment has remained an open challenge over the years.

Since 2008 [1], our group, in cooperation with colleagues from Germany, Italy, Russia, Poland, Belgium, and Iceland [1, 2, 3, 4, 5, 6], has been deeply involved in overcoming this challenge, by more deeply studying the X-ray physics underlying Computed Tomography: we developed increasingly mature methods to retrieve, from the grey value-defined voxel characteristics given in CT images, the actually underlying physical property, called X-ray attenuation coefficient. The latter contains information on the chemical composition of the material making up the considered voxel, and combining this information with known chemical characteristics of the material class making up the scanned object, gives access to important microstructural information inside the voxel, such as microporosity, or contents of known chemical substances. The latter then enter, as input values, experimentally validated micromechanical formulations representing the material inside the voxel, so as to reliably determine the voxel's mechanical properties. Corresponding CT-to-mechanics conversion schemes will be presented in appropriate detail, with applications ranging from various ceramics [2, 3, 6] and polymer-ceramic composites [4] used in tissue engineering, to organs made up of the natural material bone [1, 5].

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Look different, better understand: computational multphysics enhanced imaging and measuring in biomedicine

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Computational modeling can obviously not only be used to analyze or design new technical systems. It can also be used to allow unprecedented scientific insight in cases when experimental or theoretical approaches reach their limits. Just one example from our recent work is sub-cellular biophysics, where systems are far too complex to be studied theoretically but also experimental methods are limited in their ability to create well defined configurations or measure every detail [1, 2]. But the same is also true in modern, highly sophisticated imaging and measurement techniques in medicine. New and advanced (multiphysics) models and respective computational methods can boost insight and value of these methods, while both exposure of the patients as well as financial investments are unaltered. In this talk we will give two examples we are currently working on: photoacoustic tomography and electrical impedance tomography.

Photoacoustic tomography is a medical imaging technique which combines diffuse optical tomography and ultrasonography. An object of interest is illuminated by a short time laser pulse and the light propagates within the object according to its optical properties. At areas of high absorption, the optical energy is transformed into heat followed by thermal expansion. This expansion initiates pressure waves which are eventually measured by acoustical detectors. The recorded acoustical signal allows for conclusions on optical and mechanical properties of the underlying material. The explanatory power of the recorded signals depends among others on the accuracy of the used reconstruction algorithm. We have developed and will report on a novel approach for this purpose that is based upon an efficient simulation approach for wave propagation in heterogeneous media via the hybridizable discontinuous Galerkin (HDG) method [3] and the formulation of the inverse problem by use of the adjoint method for the discretized photoacoustic problem.

It is extremely difficult to obtain insight into important physiological quantities and states of the lung during breathing or ventilation. This hampers medical therapy but also the development and evaluation of lung models that in turn could be used for improved therapies. One key parameter in respiratory imaging is the magnitude of regional lung aeration which is optimized during mechanical ventilation trials. One non-invasive and radiation-free approach is electrical impedance tomography (EIT). It is based on the measurement of potential differences between electrodes on the surface of a body when small alternating currents are sent into the studied subject at high frequency. While current injections take place at adjacent pairs of 16 self-adhesive surface electrodes placed around the patient's chest, an image showing local tissue bioimpedance can be reconstructed by solving the inverse electrical problem for N=208 voltage measurements. EIT performs especially well in lung imaging as tissue bioimpedance considerably changes with local aeration due to the insulating properties of the enclosed air in the alveoli. Based on the alveolar microstructure, we have derived a link between air content and measured bioimpedance [4] and by solving the highly ill-posed EIT reconstruction problem, new insights into the lung's local structure and function are provided. We believe this information will result in more protective ventilation protocols, especially in such pathophysiology where patient-specific trial-and-error methods are at high risk for respiratory failure.

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