Timetable

Time	Monday September 11	Tuesday September 12	Wednesday September 13	Thursday September 14	Friday September 15
08:00 - 09:00	Registration				
09:00 - 09:45	Holzapfel	Kuhl	Ogden	Kuhl	Avril
09:45 - 10:30	Avril	Holzapfel	Avril	Nordsletten	Goriely
Break					
11:00 - 11:45	Goriely	Nordsletten	Nordsletten	Goriely	Ogden
11:45 - 12:30	Kuhl	Nordsletten	Goriely	Avril	Holzapfel
Lunch					
14:30 - 15:15	Nordsletten	Avril	Kuhl	Holzapfel	
15:15 - 16:00	Nordsletten	Avril	Kuhl	Holzapfel	
Break					
16:30 - 17:15	Ogden	Ogden	Presentations of Participants*	Presentations of Participants*	
17:15 - 18:00	Ogden	Goriely			
19:30	Reception City Hall	Guided City Tour			

*Participants are encouraged to present their work, ask questions and stimulate discussion. Please send a title of the presentation to office.biomech@tugraz.at or pukaluk@tugraz.at by August 15, 2023.

Audience

The Summer School is addressed to PhD students and postdoctoral researchers in biomedical engineering, biophysics, mechanical and civil engineering, applied mathematics and mechanics, materials science and physiology and more senior scientists and engineers (including some from relevant industries) whose interests are in the area of biomechanics and mechanobiology of soft

Registration

The registration fee is 595 €. The fee covers the attendance at all lectures, and a book of lecture notes. In addition, lunch and light refreshments will be provided throughout the days; a guided city tour and welcome reception will also be included. Payment is required by August 21, 2023. The fee for payments after this date is 660 €. Arrangements for registration and payment are posted on the Summer School website.

Accommodation

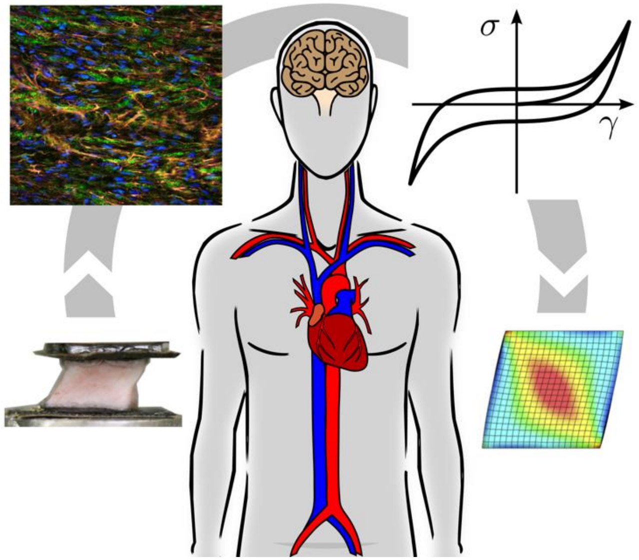
Participants are asked to make their own reservations. Rooms are pre-reserved for participants at some Student Hostels and Hotels around the venue of the Summer School. More detailed information about reservation modalities, including a list of accommodations is available on the Summer School website.

Organization

Gerhard A. Holzapfel
Graz University of Technology
Institute of Biomechanics
Stremayrgasse 16/2
8010 Graz, Austria
E-mail: holzapfel@TUGraz.at

10th Summer School on

Biomechanics of Soft Tissues: from the Heart to the Cardiovascular System to the Brain



Graz University of Technology
Austria
September 11-15, 2023

TU Graz

Summer School coordinated by

Gerhard A. Holzapfel
Graz University of Technology, Austria

Ray W. Ogden
University of Glasgow, UK

WEBSITE:
www.summerschool.tugraz.at

Image created by D Haspinger

Objectives

This is the 10th Summer School on Biomechanics that we have organized in the series that started in 2001. The aim is to provide an up-to-date overview of biomechanical modeling, simulation and experimental methods on different length scales.

The lectures will include some essential ingredients of continuum mechanics, especially nonlinear elasticity. The focus is on the mechanical and structural modeling of fiber-reinforced materials, including collagen fiber dispersion with the inclusion of collagen cross-links and residual stresses. Applications to artery walls in health and disease such as aneurysms and aortic dissections will be illustrated. Lectures will also cover cardiac biomechanical modeling, touching on the nonlinear anisotropic and viscoelastic nature of the myocardium, the synthesis and integration of these concepts into whole-organ models, and the assimilation of image-based data for patient-specific modeling. Advanced topics on modeling the entire cardiovascular system, hemodynamics, engineered heart tissue and modeling will also be discussed. Vascular adaptation during disease and treatment will be discussed along with measurements of strain fields using imaging techniques and digital image correlation in soft tissues. The important area of parameter identification will be covered by full-field optical measurements using the virtual fields method in elasticity.

Another focus will be brain mechanics, including the unusual response of brain tissues and axons under loads, the shaping of the brain and skull during development, and the study of brain trauma and diseases. It will be shown that the gyrification patterns occurring in the human brain are the result of elastic instabilities. Finally, and most importantly, all participants will receive the code, datasets, and documented examples for brain, skin, and arteries, and may bring their own stretch-stress data for analysis.

Future directions and challenges will be identified in lectures for research in multiscale biomechanics and mechanobiology involving mechanical, biological, electrical and fluid-structure interactions.

Invited Lecturers

Stéphane Avril

Mines Saint-Étienne, France

Parameter identification using full-field optical measurements; digital image/volume correlation; optical coherence imaging; virtual fields method; elastography; vascular remodeling and adaptation; mechanics of VSMCs; tensional homeostasis; mechanotransduction; mechanobiology of aneurysms; computer modeling of endovascular aneurysm repair

Alain Goriely

University of Oxford, UK

Brain modeling; brain tissue and mechanics; neuromechanics; shaping of the brain and skull during development; axonal rheology; nonlinear inelasticity; morphogenesis; ageing; brain trauma and disease; multiphase theory; contact mechanics

Gerhard A. Holzapfel

Graz University of Technology, Austria

Main aspects of mechanical/structural modeling of biological soft tissue; identification of collagen fiber dispersion and associated modeling, including fiber recruitment and damage – pros/cons; modeling/simulation aspects of aortic dissection; negative Poynting effect and its connection with collagen cross-links

Ellen Kuhl

Stanford University, USA

Automated discovery of models, parameters, and experiments for soft tissues; from continuum mechanics to constitutive artificial neural networks; comparing invariant and principal-stretch based networks; Bayesian networks, uncertainty quantification; discovering models, parameters, and experiments for brain, skin, and arteries

David Nordsletten

University of Michigan, USA

Cardiac biomechanics; patient-specific modeling; image-based modeling; model personalization; data assimilation; biomechanics of engineered heart tissues; fractional viscoelasticity; numerical methods; finite element methods; hemodynamic modeling; fluid-structure interaction; elastography; relative pressure estimation

Ray W. Ogden

University of Glasgow, UK

Continuum mechanics required for application to soft biological tissue constitutive modeling; fiber-reinforced materials, fiber dispersion, cross-linking; importance of residual stresses and their influence on the elastic response of arteries; modeling errors to be avoided

Preliminary Suggested Readings

S Avril. Hyperelasticity of soft tissues and related inverse problems, in: S Avril, S Evans, eds., Material Parameter Identification and Inverse Problems in Soft Tissue Biomechanics, CISM Courses and Lectures No. 573, International Centre for Mechanical Sciences, Springer, 37-66

A Goriely, S Budday, E Kuhl. Neuromechanics: from neurons to brain. Adv Appl Mech, 48:79-139, 2015

A Goriely, MGD Geers, GA Holzapfel, J Jayamohan, A Jérusalem, S Sivaloganathan, W Squier, JAW van Dommelen, S Waters, E. Kuhl. Mechanics of the brain: perspectives, challenges, and opportunities. Biomech Model Mechanobiol, 14:931-965, 2015

GA Holzapfel, RW Ogden. On fiber dispersion models: exclusion of compressed fibers and spurious model comparisons. J Elasticity, 129:49–68, 2017

GA Holzapfel, RW Ogden, S Sherifova. On fibre dispersion modelling of soft biological tissues: a review. Proc Royal Soc A, 475:20180736, 2019

K Linka, A Buganza Tepole, GA Holzapfel, E Kuhl. Automated model discovery for skin: Discovering the best model, data, and experiment. doi:10.1101/2022.12.19.520979, 2023

K Linka, SR St Pierre, E Kuhl. Automated model discovery for human brain using constitutive artificial neural networks. doi:10.1101/2022.11.08.515656, 2023

R Miller, E Kerfoot, C Mauger, TF Ismail, AA Young, DA Nordsletten. An implementation of patient-specific biventricular mechanics simulations with a deep learning and computational pipeline. Front Physiol, 1398, 2021

SJ Mousavi, S Farzaneh, S Avril. Patient-specific predictions of aneurysm growth and remodeling in the ascending thoracic aorta using the homogenized constrained mixture model. Biomech Model Mechanobiol, 18:1895-1913, 2019

D Nordsletten, A Capilnasiu, W Zhang, A Wittgenstein, M Hadjicharalambous, G Sommer, R Sinkus, GA Holzapfel. A viscoelastic model for human myocardium. Acta Biomater, 135:441-457, 2021

RW Ogden. Nonlinear continuum mechanics and modelling the elasticity of soft biological tissues with a focus on artery walls, in GA Holzapfel, RW Ogden, eds., Biomechanics: Trends in Modeling and Simulation, Springer, 2016, pp. 83- 156

S Teichtmeister, GA Holzapfel. A constitutive model for fibrous tissues with cross-linked collagen fibers including dispersion – with an analysis of the Poynting effect. J Mech Phys Solids, 164:104911, 2022

Download these papers, and some more, from the website:
www.summerschool.tugraz.at/objectives