Timetable

Time	Monday August 30	Tuesday August 31	Wednesday September 1	Thursday September 2	Friday September 3
08:00 - 09:00	Registration				
09:00 - 09:45	Holzapfel	Wall	Ogden	Wall	Lim
09:45 - 10:30	Lim	Holzapfel	McCulloch	McCulloch	Wall
Break					
11:00 - 11:45	Avril	McCulloch	Avril	Avril	Ogden
11:45 - 12:30	Wall	McCulloch	Avril	Lim	Holzapfel
Lunch					
14:30 - 15:15	McCulloch	Lim	Wall	Holzapfel	
15:15 - 16:00	McCulloch	Lim	Wall	Holzapfel	
Break					
16:30 - 17:15	Ogden	Ogden	Presentations of Participants*	Presentations of Participants*	
17:15 - 18:00	Ogden	Avril			

*Participants are encouraged to present their work, ask questions and stimulate discussion. Please send a title of the presentation to bettina.strametz@tugraz.at by August 15, 2021.

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 proteins, soft tissues and organs.

Registration

The registration fee is 595 €. The fee covers the attendance at all lectures, and a book of lecture notes. In addition, light refreshments and snacks will be provided in the morning and afternoon breaks; a guided city tour with a subsequent welcome reception are also included.
Payment is required by July 18, 2021. 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

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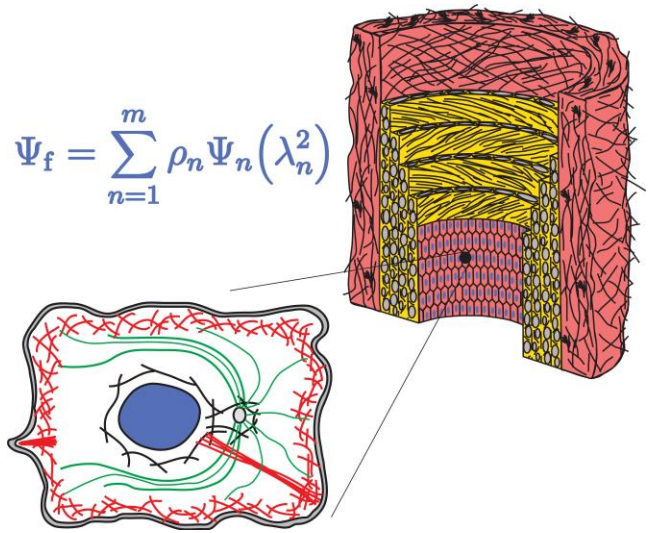
9th Summer School on

BIOMECHANICAL MODELING, SIMULATION AND EXPERIMENTAL METHODS: FROM CELLS TO ORGANS



GRAZ UNIVERSITY OF TECHNOLOGY
AUSTRIA
AUGUST 30 – SEPTEMBER 3, 2021

Summer School coordinated by

Gerhard A. Holzapfel
Graz University of Technology, Austria

Ray W. Ogden
University of Glasgow, UK

WEBSITE:
www.summerschool.tugraz.at

Objectives

This is the 9th Summer School on Biomechanics in the series we have organized. Its aim is to provide a state-of-the-art overview of biomechanical modeling, simulation and experimental methods at different length scales.

The lectures will cover essential ingredients of continuum mechanics, nonlinear elasticity, and the finite element method including fluid-structure interactions (FSIs), with an emphasis on various aspects of mechanical and structural modeling of fiber-reinforced materials. Applications to soft tissues, arterial walls, aortic aneurysms (mechanics, mechanobiology and pathogenesis), aortic dissections and the heart are highlighted. Particular interest is also focused on the continuous and discrete mechanical modeling of collagen fiber dispersion including cross-linking, fiber recruitment and damage, and on cardiac cells with a focus on mechanosignaling, growth, remodeling and excitation-contraction.

In addition, the mechanics of collagen and elastin networks and the non-local damage and healing of soft tissues are studied. Applications of FSIs to the respiratory system are also discussed. Moreover, quantitative characterization and reduction of uncertainties in complex biomechanical applications are investigated (uncertainty quantification).

Experimental techniques for the determination of the mechanical properties of tissues, cells, cellular components, and proteins will be described. In particular, cell mechanics studies of malaria and cancer are presented and cell mechanics-based microfluidics for disease diagnosis and precision therapy are discussed. The important area of parameter identification is covered by using full-field optical measurements with the virtual fields method in elasticity.

Future directions and challenges will be identified during the lectures for research in biomechanics at multiple scales, 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; virtual fields method in hyperelasticity; mechanics of collagen and elastin networks; non-local damage and healing of soft tissues; mechanics of vascular smooth muscle cells; mechanobiology of thoracic aortic aneurysms

Gerhard A. Holzapfel
Graz University of Technology, Austria
The main aspects of mechanical/structural modeling of soft tissues; modeling non-symmetric collagen fiber dispersion; discrete fiber dispersion method including fiber recruitment and damage; aortic dissection – modeling and simulation; mechanics and pathogenesis of abdominal aortic aneurysms

Chwee Teck (C.T.) Lim
National University of Singapore
Mechanical models of living cells; experimental techniques in cell and molecular biomechanics; cell mechanics study of malaria; cell mechanics study of cancer; cell mechanics-based microfluidics for disease diagnosis and precision therapy

Andrew D. McCulloch
UCSD, La Jolla, USA
Multi-scale biomechanics and systems mechanobiology of heart/cardiac cells; Markov state models of contractile protein interactions; cell biophysical models excitation-contraction coupling; systems models of cell mechanosignaling; cardiac growth models and remodeling; statistical shape atlases for clinical applications

Ray W. Ogden
University of Glasgow, UK
Essential ingredients of continuum mechanics and nonlinear elasticity; constitutive modeling of fiber-reinforced materials, fiber dispersion and cross-linking; the danger of modeling errors; residual stresses and their influence on the elastic response of arteries

Wolfgang A. Wall
Technical University of Munich, Germany
Fluid-structure interaction in Biomechanics – introduction to essential modeling (resolved, homogenized, mixed-dimensional) and computational approaches; uncertainty quantification (UQ) for complex problems in biomechanics; computational modeling of the respiratory system

Preliminary Suggested Readings

Y Aboelkassem, JD Powers, KJ McCabe, AD McCulloch. Multiscale models of cardiac muscle biophysics and tissue remodeling in hypertrophic cardiomyopathies. *Curr Op BME*, 11:35-44, 2019

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

J Biehler, MW Gee, WA Wall. Towards efficient uncertainty quantification in complex and large scale biomechanical problems based on a Bayesian multi fidelity scheme. *Biomech Model Mechanobiol,* 14:489-513, 2015

GA Holzapfel, JA Niestrawska, RW Ogden, AJ Reinisch, AJ Schriefl. Modelling non-symmetric collagen fibre dispersion in arterial walls. *J R Soc Interface*, 12:20150188, 2015

GA Holzapfel, RW Ogden. An arterial constitutive model accounting for collagen content and cross-linking. *J Mech Phys Solids,* in press

GA Holzapfel, RW Ogden (eds), Biomechanics: Trends in Modeling and Simulation, Springer, 2016

W Krasny, C Morin, H Magoariec, S Avril. A comprehensive study of layer-specific morphological changes in the microstructure of carotid arteries under uniaxial load. *Acta Biomater,* 57:342-351, 2017

K Li, GA Holzapfel. Multiscale modeling of fiber recruitment and damage with a discrete fiber dispersion method. *J Mech Phys Solids*, 126:226-244, 2019

CT Lim, EH Zhou, ST Quek. Mechanical models for living cells—a review. *J Biomech,* 39:195-216, 2006

CT Lim, EH Zhou, A Li, SRK Vedula, HX Fu. Experimental techniques for single cell and single molecule biomechanics. *Mater Sci Eng C,* 26:1278-1288, 2006

AD McCulloch. Systems biophysics: Multiscale biophysical modeling of organ systems. *Biophys J,* 110:1023-1027, 2016

CJ Roth, L Yoshihara, M Ismail, WA Wall. Computational modelling of the respiratory system: Discussion of coupled modelling approaches and two recent extensions. *Comput Meth Appl Mech Eng,* 314:473-493, 2017

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