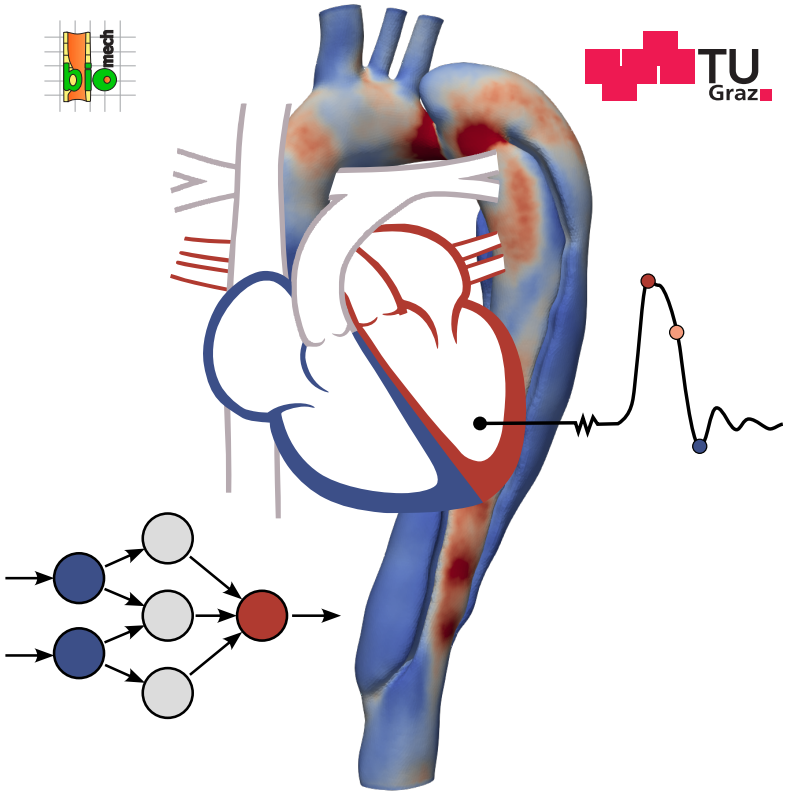
11th Summer School on

PHYSICS-INFORMED MODELING, SIMULATION AND EXPERIMENTS WITH EMPHASIS ON THE CARDIOVASCULAR SYSTEM

Graz University of Technology, Austria
September 15–19, 2025



Coordinated by

Gerhard A Holzapfel
Graz University of Technology, Austria

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Editorial

Welcome Message

This is the 11th Summer School on Biomechanics in the series we have organized since 2001. Its aim is to provide a state-of-the-art overview of physics-informed modeling, simulation and experiments on the cardiovascular system, the stomach and brain tissues. This 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 whose interests are in the area of biomechanics and mechanobiology of proteins cells, soft tissues and organs. Future directions for research in physics-informed biomechanics and mechanobiology will also be identified during the lectures, which offers significant challenges for the advancement of knowledge of mechanical, biological, electrical effects and fluid-structure interactions.

We are glad to welcome around 100 participants from over 20 nations – from China, Europe, Africa, the USA, and South America. However, the majority of participants come from Italy, followed by France. Most participants are doctoral students, but a fairly large number are postdocs as well as assistant, associate, and full professors. A guided city tour will take place on Monday evening, and on Tuesday we will all meet for a reception in the City Hall of Graz. On Wednesday and Thursday afternoons, participants will present their posters (there are 48 posters on display). The three best posters will receive prizes.

At this point, we would like to express our sincere gratitude to Ms. *Sanne Kwakman*, who has helped shape this summer school from the very beginning. Further thanks go to Ms. *Kristina Rosmann*, our office manager, and my entire research team, especially *Maximilian Wollner* and Dr. *Michele Terzano*. Thank you very much!

Enjoy this week, meet new friends, and if you enjoyed your time here in Graz, please come back!

Gerhard A Holzapfel
Ray W Ogden

Social Program

Lunch

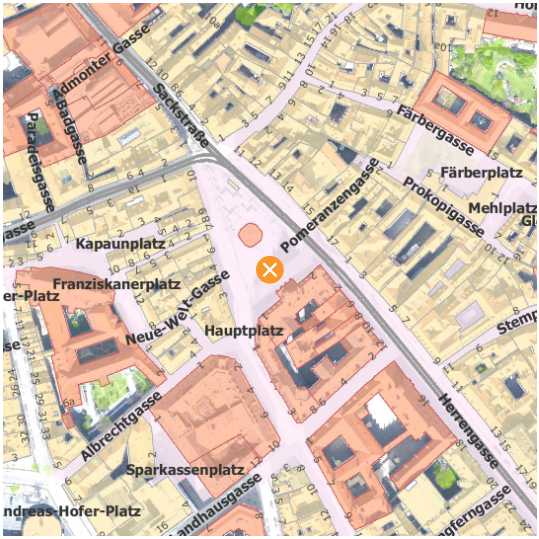
Lunch is included in the registration fee. You should have received vouchers for four meals (Monday through Thursday). These vouchers entitle you to one soup or dessert, one main dish, and one non-alcoholic beverage of your choice at the Mensa Rooftop Restaurant. Please present the voucher at the cashier. The restaurant is located on the 5th floor of the Biomedical Engineering Building, in the same building as the Summer School.

Events

There are two social events planned:

(i) Guided City Tour:
Monday, September 15
at 7:00pm

(ii) Reception by the Mayor:
Tuesday, September 16
at 7:30pm



For event (i) we will meet at 6:45 p.m. at the Rathaus (City Hall) on the main square (Hauptplatz), marked with ⊗ in the adjacent map, for event (ii) at 7:15 p.m. at the same location.

Everyone is welcome – participation is free of charge!

Lecture Overview

Time	Monday	Tuesday	Wednesday	Thursday	Friday
08:00	Registration				
09:00	Holzapfel	Nordsletten	Holzapfel	Cyron	Avril
09:45	Quarteroni	Holzapfel	Holzapfel	Ogden	Nordsletten
10:30	Break	Break	Break	Break	Break
11:00	Nordsletten	Quarteroni	Cyron	Quarteroni	Ogden
11:45	Nordsletten	Quarteroni	Nordsletten	Quarteroni	Holzapfel
12:30	Lunch	Lunch	Lunch	Lunch	
14:30	Cyron	Ogden	Quarteroni	Nordsletten	
15:15	Ogden	Avril	Avril	Avril	
16:00	Break	Break	Break	Break	
16:30	Avril	Cyron	Posters	Posters	
17:15	Avril	Cyron	Posters	Posters	
Evening	Guided City Tour	Reception in City Hall			

All lectures take place in the Biomedical Engineering Building, Room ‘HS BMT’ on the ground floor.

Lecturers

Stéphane Avril

Mines Saint-Étienne, France

Professor **Stéphane Avril** is a full professor at the Institut Mines Télécom, affiliated with Mines Saint-Étienne and the University of Lyon. He is director of the CIS Center for Engineering and Health (more than 75 staff members) and deputy director of SAINBIOSE (an INSERM laboratory with more than 100 researchers). Professor Avril received his PhD in mechanical and civil engineering from Mines Saint-Étienne (France) in 2002. After working at Arts et Métiers ParisTech (France) and Loughborough University (UK), where he developed virtual field methods, Professor Avril returned to his alma mater in 2008 and extended his extensive experience in inverse problems to soft tissue biomechanics, particularly with regard to aortic aneurysms, in close collaboration with vascular surgeons. He was a visiting professor at the University of Michigan in Ann Arbor (USA) in 2008, a visiting professor at Yale University since 2014, a visiting professor at TU Wien (Austria) between 2020 and 2022 and at TU Graz (Austria) in 2021 and 2022. Professor Avril has received numerous awards and distinctions, including the ICCB Best Paper Award (2017), was a finalist for the ASME Journal of Biomechanical Engineering Editor's Choice Award (2016), and the ESB Best Poster Award (2015). He has led two national ANR-funded projects on soft tissue biomechanics and supervised over 25 PhD students. In 2015, Professor Avril was awarded an ERC Consolidator Grant for the five-year BIOLOCHANICS project, which focused on localization phenomena in the biomechanics and mechanobiology of aneurysms: towards personalized medicine. He received a second ERC Proof of Concept Grant for his MECHANOMICS-POC project, which supported the technology transfer of an imaging technique used in BIOLOCHANICS, called optical coherence tomography (OCT).

Professor Avril's research primarily aims to improve the treatment of cardiovascular diseases by supporting physicians and surgeons with computational biomechanical simulations. In 2017, he co-founded Predisurge, which offers innovative software solutions for the personalized digital simulation of surgical procedures. Its application to the endovascular treatment of aortic aneurysms enables the automatic design of fully customized fenestrated stents. Preliminary evaluations show enormous benefits for the 20,000 patients who require fenestrated stents each year: faster procedures, greater precision, and virtually no risk of complications.

Professor Avril has received a third ERC Grant, an Advanced Grant, which started in 2024. The focus is on controlling mechanical wear to reverse the effects of aging on arteries. This grant marks a new phase in his interdisciplinary research at the interface of engineering and biology.

Christian J Cyron

Hamburg University of Technology, Germany

Professor Dr.-Ing. **Christian J Cyron** studied mechanical engineering at the Technical University of Munich. He has received several prestigious scholarships, including one from the German Academic Scholarship Foundation and one from the German Academic Exchange Service. During his academic career, he has worked at several renowned universities around the world, including the California Institute of Technology (USA), École Polytechnique (France), the National University of Singapore (Singapore), and Yale University (USA). He is currently a full professor at the Hamburg University of Technology and Director of the Institute for Material Systems Modeling at the Helmholtz-Center Hereon. He is a member of the Think Tank of the Helmholtz Association of German Research Centers, Germany's largest public research organization.

In 2024, he and Professors Gerhard A Holzapfel and Sebastian Kozerke received one of the prestigious ERC Synergy Grants from the European Research Council with the title *'Mechanical Characterization of Soft Tissue in vivo by Microstructural Imaging and Physics-Informed Neural Networks: Bridging the Gap between Biomechanics and Clinical Practice'*, which runs from 2025 to 2031 with a budget of 10 million euros.

Professor Cyron is also one of the three spokespersons of the Cluster of Excellence *'BlueMat: Water-Driven Materials'*. The German Research Foundation (DFG) will fund this project with a total of 50 million euros from 2026 to 2032. The project aims to develop 'blue materials', a completely new class of engineering materials. While classical engineering materials mainly rely on specific and often rare elements to realize advanced functions such as energy storage, sensing, or actuation, 'blue materials' will achieve this exclusively through sophisticated interactions between water and a solid matrix at the nanoscale. 'Blue materials' are inspired by nature, where many biological materials are based on a similar philosophy. In this sense, the idea of 'blue materials' demonstrates how the study of life sciences and biomechanics can also have a transformative impact on many fields of classical engineering science. Professor Cyron has played a pioneering role in integrating advanced computational methods into materials science, thus making progress in understanding and developing new materials with enhanced properties.

Professor Christian J Cyron's former doctoral students and postdocs have received prestigious awards and honors, including the Richard von Mises Prize from the International Association of Applied Mathematics and Mechanics. Four of them have been appointed lecturers or professors at prestigious academic institutions around the world in the past five years.

Gerhard A Holzapfel

Graz University of Technology, Austria
Norwegian University of Science and Technology, Norway

Gerhard A Holzapfel is Professor of Biomechanics and Head of the Institute of Biomechanics at Graz University of Technology (TUG), Austria, since 2007. He is also Adjunct Professor at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway, and Visiting Professor at the University of Glasgow, Scotland. Until 2013 he was Professor of Biomechanics at the Royal Institute of Technology (KTH) in Stockholm, Sweden, for 9 years (7 years as an Adjunct Professor). After his PhD in Mechanical Engineering in Graz he received an Erwin-Schrödinger Scholarship for foreign countries to be a Visiting Scholar at Stanford University (1993-95). He achieved his Habilitation at TU Vienna in 1996 and received a START-Award in 1997, the most prestigious research award in Austria for young scientists.

Among several awards and honors in the past years he is listed in *'The World's Most Influential Scientific Minds: 2014'* (Thomas Reuters), he received the Erwin Schrödinger Prize 2011 from the Austrian Academy of Sciences for his lifetime achievements, was awarded the 2021 William Prager Medal and the 2021 Warner T Koiter Medal. He received an Honoris Causa Doctorate from the École des Mines de Saint-Étienne, France, in 2024 and an Honorary Degree in Mechanical Engineering from the University of Parma, Italy, in 2025. In 2025, he received the Huiskes Medal for Biomechanics from the European Society of Biomechanics and the EUROMECH Solid Mechanics Prize. He was elected a Fellow of the European Academy of Sciences: Engineering Division in 2024 and an International Member of the United States National Academy of Engineering (NAE) in 2025. In 2024, together with Professors Christian Cyron and Sebastian Kozerke, he received a Synergy Grant from the European Research Council (ERC).

Professor Holzapfel's research includes experimental and computational biomechanics and mechanobiology with an emphasis on soft biological tissues, the cardiovascular system including blood vessels in health and disease, therapeutic interventions such as balloon angioplasty and stent implantation, polarized light and second-harmonic imaging microscopy; nonlinear continuum mechanics, constitutive (multi-scale) modeling of solids at finite strains such as cross-linked actin networks, growth and remodeling, nonlinear finite element methods, fracture and material failure.

Professor Gerhard A Holzapfel has authored a graduate textbook entitled *'Nonlinear Solid Mechanics. A Continuum Approach for Engineering'* (John Wiley & Sons), and co-edited seven books. He contributed chapters to 31 other books, and published over 300 peer-reviewed journal articles with an h-index of over 100. He is the co-founder and co-editor of the International Journal *'Biomechanics and Modeling in Mechanobiology'* (Springer).

David Nordsletten

University of Michigan, USA

Professor **David Nordsletten**'s career began at the age of 16 when he started studying at the University of Minnesota where he graduated *summa cum laude* in biomedical engineering and mathematics. In 2005, he began a PhD at the Auckland Bioengineering Institute in New Zealand, where he worked with Professors Nicolas Smith and Peter Hunter on fluid-solid coupling in the heart. In 2006, he moved to the Computing Laboratory at the University of Oxford, where he worked with Dr. David Kay on the analysis of fluid-solid coupling schemes. His PhD Thesis entitled *'Fluid-Solid Coupling for the Simulation of Left Ventricular Mechanics'*, was approved in 2009. After graduating, he carried out postdoctoral work at MIT with Professor C Forbes Dewey while also conducting active research at the University of Oxford. In 2010, he became a lecturer in the Department of Biomedical Engineering at King's College London.

Roots of the CHeart project began from the parallel multi-physics finite element solver he developed during his PhD for fluid-solid modeling in cardiac mechanics. Recognizing the broader utility of this developed functionality, he launched the CHeart Project in 2011 together with Professor Nicolas Smith and Dr. Jack Lee. Their overarching goal was to unify multi-physics cardiac research into a single parallel framework. Today, CHeart has evolved from its beginnings in fluid-solid interaction to support numerous physical phenomena such as 1D blood flow, Darcy flow, Navier-Stokes, ALE-Navier-Stokes, Eikonal equations, scalar reaction-diffusion, monodomain, finite elasticity, periodic wave equations and periodic nonlinear wave equations.

His research interests span the entire spectrum from numerical methods, numerical analysis, scientific computing, and mathematical modeling to clinical translation. Although he is involved in a number of research projects, the focus of his research is on the application of novel numerical/modeling techniques to problems in fluid mechanics, solid mechanics and fluid-solid coupling.

Professor David Nordsletten's primary role is leading the CHeart development team. He is also actively involved in the development of the CHeart infrastructure. His main responsibilities have included developing CHeart's parallelization strategy, core finite element support routines, and a broader software architectural design for the optimized integration of new physics modules and the solution of various multi-physics problems. More recently, he has worked on the implementation of higher-level solvers and parameter estimation procedures.

In July 2016, he participated as a postdoc in the 7th Summer School on *'Biomechanics of Soft Tissues: Multiscale Modeling, Simulation and Applications'* at Graz University of Technology and is now, after 2023, serving as a lecturer at the Summer School for the second time.

Ray W Ogden

University of Glasgow, UK

Professor **Ray W Ogden** received his BA in mathematics in 1966 and his PhD in solid mechanics from the University of Cambridge under the supervision of Rodney Hill in 1970. He was a Science Research Council Research Fellow at the University of East Anglia (1970-72), a lecturer/reader in mathematics at the University of Bath (1972-76), a Professor of mathematics at Brunel University (1981-84), the George Sinclair Professor of Mathematics at the Department of Mathematics and Statistics at the University of Glasgow (1984-2010, 2012-22), the Head of the Mathematics Department at the University of Glasgow (1986-94), and the 6th Century Chair in Solid Mechanics at the University of Aberdeen (2010-12). Since 2022, he has been the George Sinclair Emeritus Professor of Mathematics at the University of Glasgow.

Professor Ogden is a Fellow of the Royal Society (FRS) of Edinburgh (elected 1987), a Lansdowne Lecturer at the University of Victoria, Canada 1991, and a Russell Severance Springer Distinguished Visiting Professor at the University of California, Berkeley 1997. He received the Warner T. Koiter Medal (ASME) in 2005, was a lecturer at the Mid-West (USA) Mechanics Seminar Series in 2004/05, is a FRS of London (elected 2006), and he received the E.T.S. Walton Visitor Award (Science Foundation Ireland) from the UC Dublin in 2009/10. He is the recipient of the William Prager Medal (SES) in 2010, the IUTAM/Elsevier Rodney Hill Solid Mechanics Prize in 2016, and the Timoshenko Medal (ASME) in 2016.

He was the Executive Editor of the IMA Journal of Applied Mathematics (1988-98), the Solid Mechanics Editor of the International Journal of Non-Linear Mechanics (2005-15), and he currently serves on the editorial boards of 12 other international journals.

His research focuses on the nonlinear elasticity theory and its applications. His theoretical contributions include the derivation of exact solutions to nonlinear boundary value problems for compressible and incompressible materials, the analysis of linear and nonlinear stability of prestressed bodies, and related studies of elastic wave propagation. He has worked on modeling the (in)elastic behavior of rubber-like solids and also made contributions to the biomechanics of soft biological tissues, the electroelasticity and magnetoelasticity of electromechanically sensitive elastomeric materials, and the effects on residual stress in materials capable of large elastic deformations. His book, *'Non-Linear Elastic Deformations'*, published in 1984 and reissued in 1999, has become a standard reference in this branch of solid mechanics.

Professor Ogden has published over 300 papers in international journals and several books. He had held various visiting professorships in Austria, Australia, Canada, France, Greece, Ireland, Italy, Poland, South Africa, Spain, Sweden, and the USA.

Alfio Quarteroni

Politecnico di Milano, Italy

Alfio Quarteroni is Professor Emeritus at the Politecnico di Milano and at EPFL in Lausanne. He is the founder of MOX at the Politecnico di Milano (2002) and its first director (2002-22), the founder (2010) and first director (2010-15) of MATHICSE at EPFL, and co-founder (and president) of MOXOFF. From 1998 to 2017, he held the Chair of Modeling and Scientific Computing at EPFL. Previously, he was a full professor at the University of Minnesota (2000-02) and a full professor and department chair at the Catholic University of Brescia (1986-89).

He is the author of 24 books (some of which have been published in multiple editions and translated into several languages), editor of 12 books, author of over 400 papers published in international scientific journals and conference proceedings, member of the editorial board of 25 international journals, and editor-in-chief of two book series published by Springer.

His awards include: the NASA Group Achievement Award for pioneering work in computational fluid dynamics in 1992, the Fanfullino della Riconoscenza 2006, Città di Lodi, the Premio Capo D'Orlando 2006, the Ghislieri Prize 2013, the International Galileo Galilei Prize for Science 2015, the Euler Lecture 2017, the Euler Medal 2021-22 from ECCOMAS, the Lagrange Prize 2020-23 from ICIAM, the Blaise Pascal Medal 2024 in Mathematics from the European Academy of Sciences, the Ritz-Galerkin Medal 2021-24 from ECCOMAS and the Ralph E Kleinman Prize 2025 from SIAM.

He is the recipient of two ERC Advanced Grants: 'MATHCARD' in 2008 and 'iHEART' in 2017, and of two ERC Proof of Concept Grants: 'Math2Ward' in 2012 and 'Math4AAARisk' in 2015; recipient of the Galileian Chair from the Scuola Normale Superiore, Pisa, Italy, 2001; Doctor Honoris Causa in Naval Engineering from the University of Trieste, Italy, 2003; SIAM Fellow (first row) since 2009; IACM Fellow since 2004. He is a member of the Italian Academy of Science (Accademia Nazionale dei Lincei), the European Academy of Science, the Academia Europaea, the Lisbon Academy of Sciences and the Instituto Lombardo di Scienze e Lettere, an Honorary Member of the ECMI and an EAMBES Fellow. He was a member of the IMU Fields Medal Committee for the International Congress of Mathematicians 2022.

Professor Alfio Quarteroni's research interests lie in the areas of mathematical modeling, numerical analysis, scientific computing, scientific machine learning, and their applications in fluid mechanics, structural analysis, geophysics, biomechanics, medicine, and improvement of sports performance. His group has performed the mathematical optimization of the early Solar Impulse (a solar-powered aircraft) and the simulation performance optimization of the Alinghi yacht, which won the America's Cup in 2003 and 2007.

Preliminary Suggested Readings

S Avril. Hyperelasticity of soft tissues and related inverse problems, in: S Avril and 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, 2017, 37-66

S Budday, TC Ovaert, GA Holzapfel, P Steinmann and E Kuhl. Fifty shades of brain: a review on the mechanical testing and modeling of brain tissue. *Arch Comput Methods Eng*, 27:1187-1230, 2020

CJ Cyron, RC Aydin and JD Humphrey. A homogenized constrained mixture (and mechanical analog) model for growth and remodeling of soft tissue. *Biomech Model Mechanobiol*, 15:1389-1403, 2016

M Fedele, R Piersanti, F Regazzoni, M Salvador, PC Africa, M Bucelli, A Zingaro, L Dede and A Quarteroni. A comprehensive and biophysically detailed computational model of the whole human heart electromechanics. *Comput Methods Appl Mech Engrg*, 410:115983, 2023

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

GA Holzapfel and RW Ogden. An arterial constitutive model accounting for collagen content and cross-linking. *J Mech Phys Solids*, 136:103682, 2020

GA Holzapfel and RW Ogden. On fibre dispersion modelling of soft biological tissues: a review. *Proc R Soc Lond A*, 475:20180736, 2019

GA Holzapfel and RW Ogden. On planar biaxial tests for anisotropic nonlinearly elastic solids. A continuum mechanical framework. *Math. Mech. Solids*, 14:474-489, 2009

B Lane, S Sherifova, VA Santamaría, J Molimard, GA Holzapfel and S Avril. Novel experimental methods to characterize the mechanical properties of the aorta. in: TC Gasser, S Avril and JA Elefteriades, eds., 'Biomechanics of the Aorta', Academic Press, 2024, 91-108

K Linka, M Hillgärtner, KP Abdolazizi, RC Aydin, M Itskov and CJ Cyron. Constitutive artificial neural networks: A fast and general approach to predictive data-driven constitutive modeling by deep learning. *J Comput Phys*, 429:110010, 2021

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

SJ Mousavi, S Farzaneh and 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 and 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 and RW Ogden, eds., 'Biomechanics: Trends in Modeling and Simulation', Springer, 2016, 83-156

A Quarteroni, L Dede, A Manzoni and C Vergara. Mathematical Modelling of the Human Cardiovascular System. Data, Numerical Approximation, Clinical Applications. Cambridge University Press, 2019

M Rolf-Pissarczyk, R Schussnig, T-P Fries, D Fleischmann, JA Elefteriades, JD Humphrey and GA Holzapfel. Mechanisms of aortic dissection: from pathological changes to experimental and in silico models. *Prog Mater Sci*, 150:101363, 2025

A Wineman. Nonlinear viscoelastic solids—a review. *Math Mech Solids*, 14:300-366, 2009

A W Zhang, M Jadidi, SA Razian, GA Holzapfel, A Kamenskiy and DA Nordsletten. A viscoelastic constitutive framework for aging muscular and elastic arteries. *Acta Biomater*, 188:223-241, 2024

Download these papers from the website:
www.summerschool.tugraz.at/objectives

Lecture Sessions

DAY 01—MON

09:00–09:45
GA Holzapfel

An Introduction to Soft Tissue Biomechanics: from Structure to Macroscopic Response

The terminologies of biomechanics, mechanobiology, and mechanotransduction are introduced. The structure and function of arteries, as well as a building block for constitutive modeling are presented. Phenomena such as residual stress, hypertension, aging, and pathological changes are outlined.

09:45–10:30
A Quarteroni

Introduction, Motivations, and Methodological Approach

This lecture introduces the course by explaining how digital models based on physical laws and data-driven machine learning algorithms can effectively solve complex biophysical problems.

11:00–12:30
D Nordsletten

Viscoelastic Materials and Models

Here we start by examining material viscoelasticity – a feature of nearly all biological materials! We explore sources of viscoelasticity, simple model forms and common experiments to test viscoelastic response.

Fractional Viscoelasticity

Here we introduce the idea of fractional viscoelasticity for biological materials, reviewing the theory behind this approach and its advantages for representing complex viscoelastic behaviors.

14:30–15:15
CJ Cyron

Constitutive Artificial Neural Networks (CANNs)

Introduction into the theoretical background of CANNs, which are one of the most widely used architectures for data-driven constitutive modeling in mechanics.

15:15–16:00
RW Ogden

Basic Continuum Mechanics

From kinematics to stress tensors to elasticity, strain-energy functions and material symmetry, including transverse isotropy and orthotropy.

16:30–18:00
S Avril

Need of Full-Field Measurements in Soft Tissue Mechanics

This lecture introduces challenges of soft tissue mechanics and highlights why spatially resolved full-field measurements are essential for understanding biological behavior.

Performing Full-Field Measurements in Soft Tissue Mechanics

This lecture covers experimental methods like Digital Image Correlation and Optical Coherence Tomography for acquiring precise deformation fields in soft biological tissues.

DAY 01—MON

DAY 02—TUE

09:00–09:45
D Nordsletten

Fractional Viscoelastic Models for the Heart

In this lecture we examine the viscoelasticity of the heart, present a fractional viscoelastic approach, and highlight the complexity of living tissues.

09:45–10:30
GA Holzapfel

Modeling of Healthy Arterial Walls: Considering Non-Symmetric Fiber Dispersion

A basic constitutive model for anisotropic fiber-reinforced materials is reviewed and then extended to include non-symmetric fiber dispersion, which is suitable for capturing the mechanical response of soft fibrous tissues such as arteries, myocardium, heart valves, stomach tissue, and skin, to name a few.

11:00–12:30
A Quarteroni

Modeling Cardiovascular Flows: Basic Principles

The second lecture focuses on the fundamental equations behind fluid-structure interaction problems in circulatory system analysis. It will cover the key principles of their numerical approximation.

Core Mathematical Models of Cardiac Function Based on Physics

This lecture derives the fundamental mathematical models used to simulate the physical processes governing heart function.

14:30–15:15
RW Ogden

Modeling of Fiber-Reinforcement

Application to the deformation of a planar sheet with symmetrically disposed fiber families and to the extension and inflation of a circular cylindrical tube (representing an artery).

15:15–16:00
S Avril

Identifying Constitutive Models of Soft Tissues from Full-Field Measurements

This lecture explains inverse approaches to derive constitutive parameters from experimental strain data, enabling accurate biomechanical modeling of complex tissues.

16:30–18:00
CJ Cyron

Hands-On Workshop on CANNs

In this workshop you will learn how to use CANNs yourself on your own laptop via Jupyter notebook.

DAY 02—TUE

DAY 03—WED

09:00–10:30
GA Holzapfel

Crack Phase-Field Modeling to Predict the Progression of Aortic Dissection

The focus of this lecture is on modeling aortic dissection. A clinical motivation and a failure hypothesis of the aorta are presented, while the phase-field method is explained. Finally, a fluid-structure interaction simulation of a patient-specific aortic dissection is analyzed to pave the way for future developments.

Cross-Link Models for Collagen Fibers: the Inverse Poynting Effect

Using the example of an arterial wall, we demonstrate how the microstructure controls the macroscopic response. In addition, the collagen structure and the associated cross-links are discussed in detail. A simple (and an extended) cross-link model is presented, focusing on the inverse (negative) Poynting effect.

11:00–11:45
CJ Cyron

Biomechanics of the Stomach

Introduction to the biomechanics of the human stomach and how to model it using computational methods.

11:45–12:30
D Nordsletten

Fractional Viscoelastic Models for the Arteries

Here we extend fractional viscoelasticity to the study of arteries, highlighting its relevance in looking at different phenomena such as residual stress.

14:30–15:15
A Quarteroni

Data-Based Algorithms from Machine Learning and Artificial Neural Networks

This lecture covers machine learning, discussing its principles, algorithms, strengths, and weaknesses from a mathematical standpoint.

15:15–16:00
S Avril

Characterizing Structure-Function Relationships in Arteries using Full-Field Measurements

This lecture focuses on combining imaging, modeling, and inverse analysis to link arterial microstructure with mechanical function and pathological changes.

DAY 03—WED

DAY 04—THU

09:00–09:45
CJ Cyron

Growth and Remodeling in Soft Biological Tissues

Review of key experimental observations and modeling approaches in the field of soft tissue mechanobiology.

09:45–10:30
RW Ogden

Modeling Fiber Dispersion

The generalized structure tensor and angular integration approaches and their comparison, with application to simple tension and simple shear.

11:00–12:30
A Quarteroni

Combining Data-Based and Physics-Based Algorithms

This lecture explores Scientific Machine Learning, which combines physics-based models and machine learning algorithms, focusing on solving PDEs in computational mechanics with applications to cardiac simulation.

Application to Clinically Relevant Problems

The final lecture presents clinical problems successfully addressed through the iHEART project, illustrating real-world applications.

14:30–15:15
D Nordsletten

Viscoelastic Biomechanics of Aging

In this lecture we examine how biomechanics evolve with age, with particular emphasis on elastic and muscular arteries.

15:15–16:00
S Avril

Modeling the Progression of Aortic Aneurysms

This lecture discusses patient-specific growth and remodeling models, linking biomechanics, imaging, and clinical data to predict aneurysm progression and rupture risk.

DAY 04—THU

DAY 05—FRI

09:00–09:45
S Avril

Relating Tissue Mechanics and Cell Mechanobiology

This lecture explores how vascular smooth muscle cells sense mechanical cues, regulate extracellular matrix, and contribute to vascular adaptation and disease.

09:45–10:30
D Nordsletten

Modeling Engineered Myocardium

In this final lecture, we look at ways to extend these modeling concepts to engineered heart tissues and explore the bounds of constrained mixtures.

11:00–11:45
RW Ogden

Residual Stresses

The influence of residual stress on the mechanical response of soft tissues, with particular reference to arteries.

11:45–12:30
GA Holzapfel

Brain Mechanics: Experimental Evidence, Modeling Aspects and Recent Advances

An introduction to brain mechanics is provided, focusing on the analysis of tension/compression experiments and corresponding material models. Using oedometer tests, it is demonstrated that brain tissue is a biphasic material following Terzaghi's consolidation theory. Advances in hydrogels with the aim of mimicking brain tissue are discussed.

Poster Presentations

The poster presentations will be held at the Foyer in front of the lecture hall 'HS BMT'. Poster walls will be made available.

Poster 1	**Flexible framework to integrate new hyperelastic material models in cardiovascular fluid-structure interaction simulations** *Divya Adil, Alison L Marsden, Ellen Kuhl*
Poster 2	**On the hypothesis of quasi-stationarity in the mechanical characterization of arteries** *Francesca Bogoni, Maximilian P Wollner, Gerhard A Holzapfel*
Poster 3	**A new meshless fluid-structure interaction particle method: experimental validation with a novel cardiovascular benchmark** *Alessandra Monteleone, Sofia Di Leonardo, Marco Correnti, Enrico Napoli, Giorgio Micale, Gaetano Burriesci*
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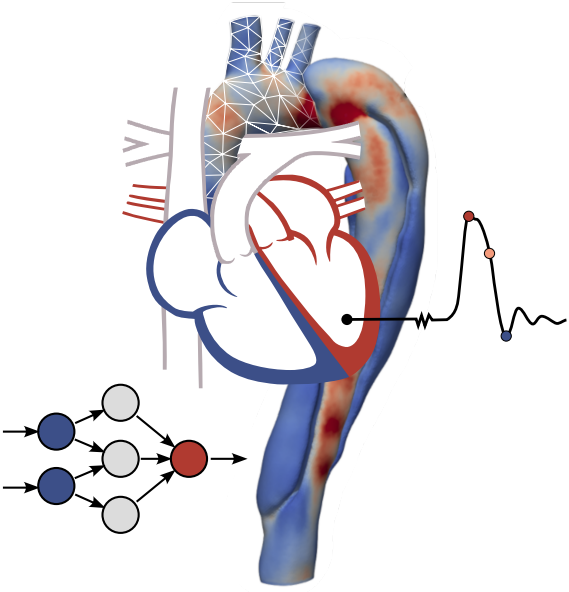

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