The Institute for Computational Engineering & Sciences

Center for Cardiovascular Simulation

Department of Biomedical Engineering
The University of Texas at Austin

The University of Texas at Austin
201 E 24th St, Austin, TX 78712

Phone: 512-232-5784, **Fax:** 512-471-8694
www.ices.utexas.edu

Center for Cardiovascular Simulation

Mission

The overarching goal of the Center for Cardiovascular Simulation (CCS) is to provide cardiovascular scientists and clinicians with advanced simulations for the rational development of treatments for cardiovascular disease. Such simulations can ultimately lead to reduction in development time, lowering of morbidity and mortality, reduced re-operative rates, and lessened post-operative recovery time. Our specific research focus is the simulation of the biomechanical function of the cardiovascular system at the continuum-cellular, micro-fibrous tissue, and whole organ levels. To achieve this, we utilize integrated computational/experimental approaches that incorporate the latest biomechanical/biomedical data and mechanobiological information to develop an improved understanding of pathophysiology. Fundamental to our approach will be the development and implementation of novel simulation technologies that exploit advances in computational methods to reduce the current trial-and-error approaches. Ultimately, we hope to develop simulation tools that will provide detailed dynamic information on disease progress and allow for "what-if" scenarios to physicians and biomedical engineers to devise new interventions. The development and use of these tools in the context of patient-specific models will ultimately also allow clinicians to craft cardiovascular therapies that are optimized for the cardiovascular system of individuals, with a resulting increase in success and decrease in risk of adverse side effects.

About Our Director

Dr. Michael Sacks is professor of biomedical engineering and holder of the W.A. "Tex" Moncrief Jr. Simulation-Based Engineering Science Chair I. Dr. Sacks formerly held the John A. Swanson Chair in the Department of Bioengineering at the University of Pittsburgh. He earned his B.S. and M.S. in engineering mechanics from Michigan State University, and his Ph.D. in biomedical engineering (biomechanics) from The University of Texas Southwestern Medical Center at Dallas.

Affiliated Faculty

Biomedical Engineering
Dr. Aaron Baker, Assistant Professor
Dr. James Tunnell, Associate Professor

Institute for Computational Engineering & Sciences
Dr. H. Kent Beasley, Cardiologist
Dr. George Biros, Professor
Dr. Omar Ghattas, Professor
Dr. Thomas J.R. Hughes, Professor
Dr. Greg Rodin, Professor

Aerospace Engineering
Dr. Nanshu Lu, Assistant Professor

Research Staff

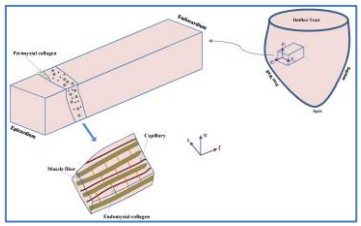
Dr. Andrew Drach, Assistant Director
Dr. Shaolie Hossain, Research Associate (Texas Heart Institute)
Dr. Joao Soares, Research Associate

Postdoctoral Fellows

Dr. Ankush Aggarwal
Dr. Reza Avazmohammadi
Dr. Chung-Hao Lee
Dr. Samarth Raut

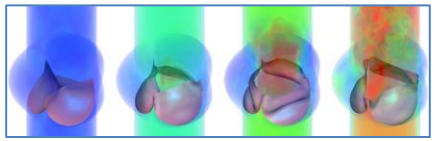
Graduate Students

Salma Ayoub
Rachel Buchanan
Jimmy Carleton
Kristen Feaver
David Kamensky
Amir Khalighi
Bruno Rego
Devesh Sahu
Yusuke Sakamoto
Will Zhang



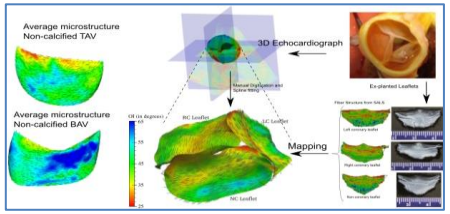
Multiscale Modeling of Myocardium

We are interested in multiscale aspects of the structure-property relation in the myocardium, and in understanding the role of the interaction between the underlying constituents such as myofibers, collagen network and vascular structure on the macroscopic response of the myocardium. This research is particularly useful in understanding the changes in the structure and stiffness of the myocardium in patients with pulmonary hypertension, which is a common cause of heart failure. Our clear understanding of these changes can help to improve techniques for pronosis, diagnosis, and treatment for pulmonary hypertension.



Fluid-Structure Interaction in Bioprosthetic Heart Valves

This project focuses on development and application of a numerical method for fluid-structure interaction (FSI) that is capable of simulating the mechanics of bioprosthetic heart valves operating under physiological conditions. Further planned work on this project includes enhancing the accuracy and stability of the numerical method, optimizing the custom research code implementing it, realistic constitutive modeling of the valve leaflets, experimental validation, and application to problems of biomedical interest.



Inverse Modeling of Heart Valves with Application to Calcific Aortic Valve Disease Patient Stratification

We calculate the population averaged microstructural properties of aortic valve leaflets and use them in creating models. The aim of these studies is to identify patients that are at a higher risk of calcification. The microstructural differences induces interstitial valvular cells to behave abnormally and cause the acceleration of calcification. To identify these changes, we developed an inverse modeling technique. The overall idea is to process the 4D ultrasound of the patient heart and estimate the biomechanical properties of the valve leaflets.

Facilities

The main Computational Engineering Laboratory (CEL) in ICES is located in the Peter O'Donnell Building (POB). Graduate students are provided with state-of-the-art computers loaded with our own custom brew of open source & personally developed code. The building has a 196-seat auditorium providing wireless networking, video conferencing and remote learning capabilities. There are eighteen networked seminar rooms with high-resolution audiovisual systems

Peter O'Donnell Building (POB)

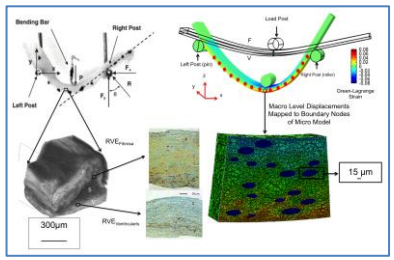
The Biomechanics Experimental Lab (BEL) of the Department of Biomedical Engineering is located in the Biomedical Engineering (BME) building. The BEL is a 1294 ft^2 wet laboratory, and houses specialized devices for mechanical evaluation of biological tissues and biomaterials.

Biomedical Engineering Building (BME)

Featured Research Projects

Mitral Valve Modeling and Mechanobiology

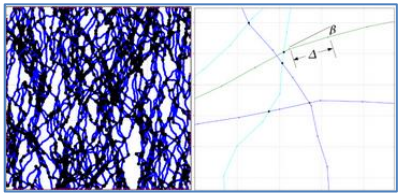
The development of a high fidelity and micro-anatomically accurate computational model for heart mitral valves with applications to the patient-specific modeling. Specific topics include image segmentation of high-resolution MicroCT and/or patient-specific ultrasound data, reconstruction of 3D micro-structurally accurate mitral valve geometry, mapping of collagen fiber architecture onto mitral valve model, and finite element simulations of mitral valve closure.



Down-Scale Modeling of Active Contraction in Aortic Valve Tissues

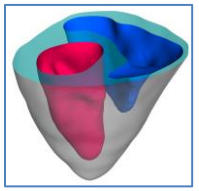
The investigation of cellular contractile behavior on tissue level stiffness in the aortic valve (AV). To effectively correlate cellular level changes to the physical state of the valve, a predictive down-scale computational model has been developed. This approach provides a sensitive method to estimate AVIC and ECM mechanical properties in-situ from tissue-level experimental measurements.

Understanding How Fiber Network Geometry of Engineered Tissue Scaffolds Affects Bulk Mechanical Behavior

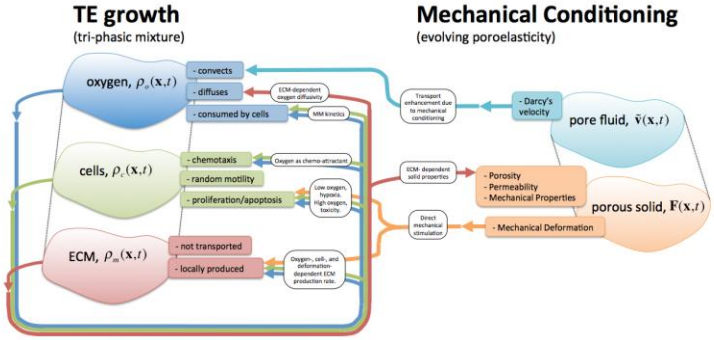


The goal of our work is to develop and use improved computational models, based on realistic fiber geometry, to help understand the mechanisms that translate scaffold fiber network structure into tissue function. We also explore the range of macroscopic material behaviors that are achievable from the domain of producible microstructural geometries and elastomeric fiber properties. Insights gained from these simulations inform macroscale material models that are essential for guiding the design of scaffolds and selecting manufacturing parameters so that the resulting engineered tissues mimic the non-linear mechanical behavior of the native tissues.

Virtual Heart Project



Virtual heart is a cardiac simulation project in collaboration with Medtronic. Computational biomechanical framework for image based patient-specific analysis and medical device prototyping is being developed. This framework will enable exploration into pathophysiology as well as optimal medical device design and surgical intervention.



Computational Models of Dense Connective Tissue Formation for Tissue Engineered Heart Valves

We describe cellular proliferation and ECM synthesis with a triphasic system of reaction-advection-diffusion equations that govern the biomechanical transport and interplay of cells, ECM, and available nutrients. Effective conditioning protocols for TE growth and development are highly dynamic and are described with FE formulations of the evolving porous TE construct with the dynamic exterior flow resolved with CFD. Simulation results compare favorably to existing experimental data obtained in tissue- and organ-level bioreactors, and most importantly, the novel theoretical framework for mechanically conditioned TE growth permits the exploration/optimization of conditioning protocols in silico in a rational and cost effective manner.