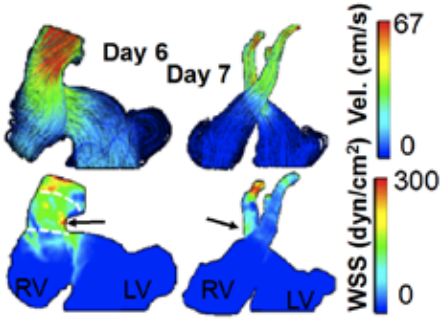
CornellEngineering
Meinig School of Biomedical Engineering

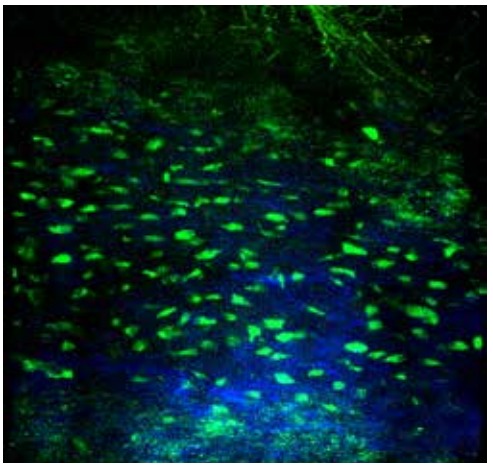
Biomechanics and Mechanobiology

Mechanical forces play critical regulatory roles in many physiological and disease processes. Cornell's program in Biomechanics and Mechanobiology includes collaborations between engineers, life scientists, veterinary, and medical professionals and continues to pioneer new fundamental and applied research.

A research portfolio of top ranked engineering, veterinary, and medical schools has enabled Cornell to pursue unparalleled breadth and depth in biomechanical and mechanobiological inquiry. Our research topics extend across 10 orders of magnitude in length, from nanoscale mechanics in individual cells and extracellular matrices to whole organ function in large animal models. Cornell is also pushing the frontiers of mechanobiology by linking cell and molecular biology to tissue structure at the meso-scale, creating new theories and experimental test systems that are integrated with genetic and molecular tools to discover functional principles in biological structures with the long-term goal of improving human health.



Wall shear stress profiles within the embryonic heart outflow tract during septation and valve formation. (Butcher)



Multiphoton image of fluorescently labeled osteocytes in vivo. These cells can be observed live under mechanical load to interrogate how they turn mechanical load into biological signals. (Lewis)

Faculty research interests

Steven Adie's lab develops OCT-based imaging technologies for volumetric time-lapse imaging of cellular traction forces and extracellular matrix mechanics, with a focus on extending single-cell investigations to the study of cell collectives. His group also combines computational and adaptive optics approaches to improve the speed and imaging depth of OCT and three-photon microscopy.

James Antaki's lab focuses on five main application areas: circulatory support systems for children, decision-support tools for severe heart failure, diagnostic technology for the home and point-of-care to improve patient engagement, multi-scale modeling of thrombosis in artificial circulation, and development of medical devices for global health.

Larry Bonassar's lab focuses on elucidating mechanisms by which the complex microstructure of cartilage gives rise to its ability to resist multiaxial loading and minimize friction. They then apply these multiscale structure-property paradigms toward understanding the bio-mechanical uniqueness of different cartilages,

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including articular cartilage, auricular cartilage, airway cartilage, meniscus, and intervertebral disc.

Jonathan Butcher's lab integrates multi-scale computational modeling and micro scale experimental approaches to study the biomechanics and mechanobiology of cardiovascular soft tissue development, growth, remodeling, and disease. He pioneered the use of MicroCT for quantitative dynamic analyses of live embryonic growth and cardiac function. His group also uses molecular gain/loss strategies to understand how changes in adhesive signaling control heterogeneous cellular interactions critical for proper tissue architecture assembly in vitro and in vivo.

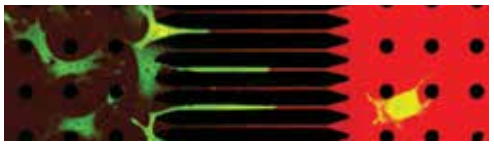
Benjamin Cosgrove's lab studies the mechanobiology of skeletal muscle stem cells. They build tunable-rigidity synthetic biomaterials to control muscle stem cell manufacturing and optimize cell yields by tuning the elastic modulus of these materials..

Jan Lammerding's lab is developing and applying novel experimental techniques to probe subcellular mechanics and the cellular response to mechanical stimulation, with a particular focus on the cell nucleus. They are investigating to what extent impaired nuclear mechanics and increased cellular sensitivity to mechanical strain contribute to human diseases such as muscular dystrophy and cardiomyopathies, and whether increased nuclear deformability could also aid metastatic cancer cells to spread through the human body.

Esak (Isaac) Lee's lab aims to understand the morphogenesis, homeostasis and disease pathogenesis of lymphatic vessels and blood vessels and their microenvironments to provide new strategies for regenerative medicine and treatment of cancer, immune diseases, and edema. Dr. Lee is working to develop novel three-dimensional (3D) organ-on-chip systems to better understand the mechanisms by which endothelial cells, immune cells, and cancer cells regulate and respond to biological and mechanical cues.

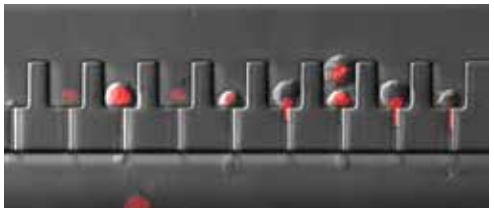
Karl Lewis's lab combines custom engineering and cutting edge imaging techniques to research the way musculoskeletal cells use mechanical forces for biological processes. They are presently using multiphoton microscopy to investigate changes in osteocyte mechanobiology in health and disease with the goal of identifying novel therapeutic targets. Additionally, the Lewis Lab is developing a novel technique for investigating bone-cartilage mechanotransduction events in live animals, a powerful tool for understanding joint disease.

Marjolein van der Meulen's research focuses on musculoskeletal mechanobiology and tissue mechanics. Her laboratory studies adaptation to mechanical loading during development, maintenance, disease and repair of bone and other musculoskeletal tissues. Her lab is also interested in the determinants of whole bone strength and skeletal load-bearing function based on microscale tissue properties. Experiments in her laboratory combine in vivo models with in vitro testing, imaging and computational simulations.

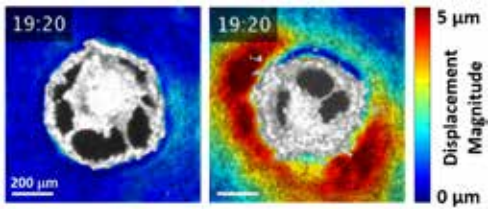


Fluorescently labeled cells (green) migrating through 3-um wide microfluidic channels along a chemotactic gradient (red). (Lammerding)

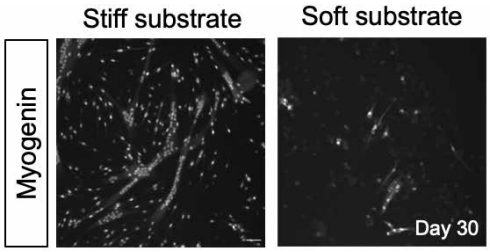
Sections from loaded (left) and control (right) proximal tibiae of 10-week-old female mice after two weeks of daily loading. (van der Meulen)



A microfluidic micropipette aspiration device to measure the mechanical properties of cell nuclei. (Lammerding)



Cell-induced collagen deformations from spheroid co-cultures consisting of lean adipose stromal cells (ASCs) + MCF10AT1 cancer cells (left), and from obese ASCs + cancer cells (right), acquired 19 hrs and 20 min after embedding the spheroids into 3D collagen. (Adie, Fischbach)



Skeletal muscle stem cell differentiation is influenced by the elastic modulus of cell culture substrate. (Cosgrove)

BME department faculty

Steven Adie, sga42@cornell.edu
James Antaki, jfa79@cornell.edu
Lawrence Bonassar, lb244@cornell.edu
Jonathan Butcher, jtb47@cornell.edu
Benjamin Cosgrove, bdc68@cornell.edu
Claudia Fischbach, cf99@cornell.edu
Jan Lammerding, jan.lammerding@cornell.edu
Esak (Isaac) Lee, el767@cornell.edu
Karl Lewis, kjl235@cornell.edu
Marjolein van der Meulen, mcv3@cornell.edu

Graduate field faculty

Nelly Andarawis-Puri, na424@cornell.edu
Eve Donnelly, eld26@cornell.edu
Lara Estroff, lae37@cornell.edu
Christopher Hernandez, cjh275@cornell.edu
Toshi Kawate, tk499@cornell.edu
Amit Lal, lal@ece.cornell.edu
Suzanne Maher, mahers@hss.edu
Susan Pannullo, scp2002@med.cornell.edu
Matthew Paszek, mjp31@cornell.edu
Heidi Reesink, hlr42@cornell.edu
Timothy Wright, wrightt@hss.edu
Mingming Wu, mw272@cornell.edu

www.bme.cornell.edu