The M3 lab is collectively fascinated by skeletal muscles, which are the motors for all the wide range of voluntary movements in the human body. Each muscle's properties are beautifully tuned for a specific function in the body, which can be easily disrupted by misuse or disease, such as cerebral palsy. We seek to gain new insights into the form, function, biology, and diseases of muscles. Much of our work has the ultimate goal of improving treatments and quality of life for individuals with neuromuscular and musculoskeletal impairments. We integrate a variety of computational and experimental approaches to achieve this goal.

We create computational models of the musculoskeletal system that describe the complex three-dimensional architecture and geometry of muscles. We also develop nonlinear constitutive relationships for muscle that represent the properties of muscle cells and extra-cellular connective tissues. Using dynamic magnetic resonance imaging techniques we study the deformation and motion of muscles during joint movement. Anatomical measurements and tissue testing are used to characterize the arrangements of proteins in muscle and to determine the material properties of muscle tissue. Our models and experiments are applied to a range of muscles in the lower limb, upper limb, abdomen, and mouth.

“The goal of our work is to reveal the characterizing the relationships between muscle structure, mechanical properties, biology, and function while providing student mentees with a superior educational and research experience.”

Silvia Salinas Blemker
ssb6n@virginia.edu
www.bme.virginia.edu/muscle/

Dept. of Biomedical Engineering
University of Virginia
Charlottesville, VA
434.924.6291
3D Finite-Element Muscle Modeling
We have developed an image-based computational framework for characterizing the complex three-dimensional architecture and geometry of skeletal muscles. We have gained a number of insights regarding the structure-function relationships of skeletal muscle using 3D muscle models. For example, analyses of 3D models identified the effects of aponeurosis morphology on muscle tissue strains and the effects of complex fiber trajectories on fiber excursions. We are now using these tools to create models of the hamstrings to investigate the mechanisms for strain injury and of the triceps surae muscle to investigate the mechanics of muscle contractures in cerebral palsy.

Musculoskeletal Modeling
Using motion capture technologies and a custom-built instrumented wall, we are studying the biomechanics of rock climbing as part of a multi-institutional project with the goal of developing advanced climbing tools for soldiers. We use digitized motion data in conjunction with state-of-the-art musculoskeletal models of the body to study the interaction between muscle function and human movement.

Muscle Imaging
We are using a variety of imaging techniques to characterize the structure and behavior of muscle in vivo. These measurements provide valuable data to build and validate 3D models of muscle and study musculoskeletal function.

Ray Biomechanics and Bio-inspired Design
Using computerized tomography (CT) imaging and computational methods we are conducting a multi-species study of ray skeletal architecture to elucidate the form-function relationship between ray skeletal architecture and locomotion. Ultimately, we intend to use the imaging and modeling results to inform the mechanical design of Autonomous Underwater Vehicles (UAVs).

Modeling Muscle Microstructure
We are creating finite-element models that describe the morphology and mechanics of muscle fibers and the extracellular matrix. Our goal is to understand how the micro-scale structure influences the overall function and behavior of muscle.

Cleft Palate Repair Surgery
We are using dynamic MRI in conjunction with our finite-element muscle models to understand the function of the palate muscles during speech and improve the outcomes of cleft palate repairs.

RECENT RESEARCH DEVELOPMENTS
- Computational model created of hamstring uncovered the mechanisms that cause strain injury.
- Computational model of the palate muscles reveal a new improved cleft palate repair surgery.

RECENT GRANTS
- The Hartwell Foundation
- National Science Foundation
- Wallace R. Coulter – UVA Translational Partnership
- DARPA/Draper labs
- U.S. DoD, Navy Spawar Systems Center Pacific