National Center for
Physics-Based Simulation of Biological Structures

Physics-based simulation provides a powerful framework for understanding biological form and function. Simulations help biomedical researchers understand the physical constraints on biological systems as they engineer novel drugs, synthetic tissues, medical devices, and surgical interventions. Although individual investigators make outstanding contributions, the field has been fragmented. Tools are usually developed for a specific problem at a single physical scale, and individual investigators typically write their own software. Simbios was established in 2004 to help integrate the field and accelerate biomedical research. It has become a vibrant national center, with collaborators in 20 states and eight countries. Simbios has had a major impact on biomedical research by bringing physics-based simulation software to researchers and hospitals across the nation and the world. Our achievements include:

RESEARCH & CLINICAL IMPACT:

- **Publishing over 230 articles, which have been cited over 5200 times:** Many of these appeared in high impact journals such as Science and the Proceedings of the National Academy of Sciences.

- **Providing the foundation for Heartflow, a new company that could radically change how patients with coronary artery disease are diagnosed:** HeartFlow's technology, spun out from Simbios' cardiovascular driving biological problem, could replace the gold-standard, invasive diagnostic tool for coronary artery disease—fractional flow reserve. Based on physics-based simulations, their new approach offers a non-invasive and thus potentially safer and cheaper diagnostic tool. As of the end of 2011, it had raised approximately $30 million in funding.

COMMUNITY RESOURCES/SOFTWARE/COLLABORATIONS:

- **Creating a powerful multibody dynamics software upon which biological simulation applications across a range of scales can be built:** Our open-source **Simbody** software is at the core of OpenSim, an application for simulating the dynamics of movement, and MacroMoleculeBuilder. It has been downloaded by 1200+ individuals to study diverse systems, from proteins to human motion.

- **Developing a common platform for accelerated calculations that is incorporated into some of the most widely used molecular dynamics packages:** Our **OpenMM** software is open-source and provides very high performance on a wide variety of hardware platforms. It has been adopted by GROMACS, TINKER, and CHARMM, so they can easily take advantage of new algorithms and hardware architectures that may arise in the future. It has been downloaded by 3000+ individuals and has been used to perform some of the most advanced simulations to-date.

- **Enabling hospitals and 1000s of researchers to use advanced simulations to improve our understanding of and plan treatments for movement disorders:** Our **OpenSim** software has become a standard in the field, enabling researchers to easily share and reproduce models and simulation studies of human and animal movement. Downloaded by over 9000+ individuals (including ~30 hospitals), OpenSim enables them to study and plan treatments for movement issues due to a variety of causes, including cerebral palsy, stroke, spinal cord injury, osteoarthritis, and obesity.

- **Building a web portal with 22,000+ members to share and develop biocomputational tools and data:** The **Simtk.org** website hosts hundreds of projects, including the knowledge base, simulations, and code for the first whole-cell computational model of the entire life cycle of a living organism and high quality experimental data sets for the grand challenge competition for predicting *in vivo* knee loads.

- **Identifying and supporting a network of collaborators:** The Simbios seed grant program funded 11 projects, which resulted in four R01 grants and an NSF career award. We are also collaborators for eight collaborating R01s.

TRAINING & DISSEMINATION:

- **Providing deep training in biophysical simulation to 48 graduate students and postdoctoral fellows—10 of which have assumed faculty positions:** Our alumni are currently faculty members at places such as the University of North Carolina, the University of Virginia, and Columbia University. Many others have taken leadership positions with biomedical institutions ranging from startups to well-established organizations like Merck and St. Jude Medical to government agencies like the FDA.

- **Training more than 1000 people in the use of our software:** We have sponsored workshops for all the software listed above to make sure that biomedical scientists and physicians can use Simbios software productively.

Just as simulation has revolutionized other areas of science and engineering, Simbios has begun to transform biomedical research by enabling advanced simulations of complex biological structures.