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We are hiring 50 new tenure track biomedical engineering and sciences faculty over the next five years. This unprecedented growth opportunity is made possible by the strong support of our current and new partnerships. The ‘molecule’ image on the cover and throughout this newsletter illustrates our partner groups as well as the collaboration across campuses. As you may know, our biomedical engineering program is called the Virginia Tech – Wake Forest University School of Biomedical Engineering and Sciences (SBES), and this school arrangement facilitates and promotes the collaborations.

Starting this August, we welcome our two newest partners in the form of a new medical school, the Virginia Tech Carilion (VTC), and an associated research institution, the Virginia Tech Carilion Research Institute (VTCRI). You can see these two partners on the top right of the ‘molecule.’ Both are located in Roanoke, Virginia, which is 45 minutes northeast of Virginia Tech. VTC will welcome 42 new medical students this fall into a research-focused curriculum, while VTCRI plans to add 300 researchers over the next five years. We are working hard to ensure that their growth dovetails into our growth plans. Much more information about VTC and VTCRI is provided in the following pages, and it is easy to see the excitement generated from this amazing growth opportunity.

Over the past year we added 12 faculty members to SBES so that we currently have 51 tenure track faculty (17 primary and 34 joint) with an additional 68 affiliate faculty appointments. The primary and core biomedical engineering faculty had a very productive year with 204 published journal papers and an additional 216 conference papers. Our externally funded research expenditures grew to approximately $25 million last year with $10 million coming from our primary faculty.

The next year should show continued and accelerated research growth as we were awarded six new contracts over the past year that each have budgets exceeding $2M, in addition to 15 other new research contracts. This newsletter contains information on several of the new large grants including Dr. Ge Wang’s $3.7M NIH BRP award for “Optical Molecular Tomography for Regenerative Medicine,” Dr. Jake Socha’s $2M NSF award for investigating “Internal Fluid Flow of Insects,” a $3M grant from the DOT to examine head and chest injury biomechanics that was awarded to Dr. Joel Stitzel, and a $2M NIH award to Dr. Yaorong Ge to investigate bioinformatics and medical image sharing. I encourage you to read further into this newsletter about these awards, and specifically how they involve collaborating faculty members across Virginia Tech and Wake Forest University.

Finally, I want to draw your attention to the back cover of this newsletter which outlines our program’s 20-year history with the Biomedical Engineering Society (BMES). In 1990 Virginia Tech hosted the very first BMES conference in Blacksburg VA. For the 2010 BMES conference in Austin TX, we have over 100 faculty and graduate students presenting over 100 technical papers and posters. I hope you will have the opportunity to see one of these presentations and to stop by our booth.

Sincerely,

Stefan Duma, PhD
Professor and Head

NIH Funds Dr. Duma’s Helmet Study

The National Institutes of Health (NICHD) awarded a five-year Bioengineering Research Partnership (BRP) to support head injury research by instrumenting college football players. Over the past seven years, Dr. Duma’s group at Virginia Tech has instrumented the player’s helmets with accelerometers and wireless transmitters to record and evaluate all head impacts. The systems transmit the head accelerations to a sideline controller between each play for all games and practices. Over 100,000 head impacts have been recorded at Virginia Tech, and the data will be useful to understanding the biomechanics of concussions and mild traumatic brain injury.

Starting in this fall, an additional system and sensors will be deployed at Wake Forest University for its football team. This will expand the data set and allow for stronger analysis. On October 16th Wake Forest travels to Virginia Tech for the Homecoming game. With the new sensor implementation, this will be one of the first games with both teams instrumented. It is anticipated that this study will result in better understanding of human brain injury tolerance with applications ranging from high school and collegiate sports biomechanics to automobile safety and military impacts. The BRP also includes partners at Brown and Dartmouth as well as SIMBEX. In addition, the Childress Institute for Pediatric Trauma is supporting the project at Wake Forest.
Our Biomedical Engineering Partners

At Virginia Tech
VetMed ................. College of Veterinary Medicine
VBI .................. Virginia Bioinformatics Institute
ICTAS ................... Institute for Critical Technologies and Applied Sciences
VTI-CIB .................. Virginia Tech Transportation Institute - Center for Injury Biomechanics
NCR .................... National Capital Region
VT-Carilion ................. Virginia Tech – Carilion Medical School
VT-CRI .................. Virginia Tech – Carilion Research Institute
VCOM .................. Via College of Osteopathic Medicine

At Wake Forest University
Imaging .................. Center for Biomolecular Imaging, Biomedical Imaging Division
WFIRM ................... Wake Forest Institute for Regenerative Medicine
Cancer ................ Comprehensive Cancer Center
TSI ................ Translational Sciences Institute
CIB ................ Center for Injury Biomechanics
Med Center ................ Wake Forest University Baptist Medical Center
Virginia Tech Carilion School of Medicine Set to Welcome Charter Class

It started as just a vision a handful of years ago, but the Virginia Tech Carilion School of Medicine (VTC) becomes a reality this August when Roanoke will welcome its Charter Class of aspiring physicians to campus. VTC began its first steps in the public spotlight on January 3, 2007, when Virginia Tech President Charles Steger, Ph.D., Carilion Clinic President and CEO Edward Murphy, M.D., and then Governor Tim Kaine came together to announce the creation of the school and research institute. It was the launch of a public-private partnership that has helped shape Virginia Tech Carilion School of Medicine and Research Institute. Progress continued with the appointment of the board of directors as well as the selection of the founding dean in January 2008, Cynda Ann Johnson, M.D., M.B.A.

On October 15, 2008, a groundbreaking ceremony was held at the VTC site. Construction crews already had completed site preparation work the month before. Currently, crews are putting the finishing touches on the building before classes begin in August. The 154,000-square-foot structure is off Jefferson Street in Roanoke and is a dedicated learning and research environment.

A major hurdle was cleared in June of 2009 when VTC received preliminary accreditation from the Liaison Committee on Medical Education. This critical step allowed VTC to begin recruiting its charter class and to be added to the national recruiting list run by the American Medical College Application Service. The following month, VTC achieved another important milestone, by receiving approval from the State Council of Higher Education for Virginia to operate a postsecondary institution in the Commonwealth of Virginia.

Developed at McMaster University, VTC utilizes an innovative interview format called the Multiple Mini-Interview. Students rotate through nine interview stations where they are asked to discuss a scenario. The process is designed to identify skills such as critical thinking, teamwork and moral and ethical judgment among other attributes.

The select group of 42 applicants who were chosen as VTC’s charter class had average MCAT scores of 33; the national average is 30. The class will graduate in four years in 2014 and will enter the healthcare profession as a shortage of physicians is expected to grow. The Association of American Medical Colleges predicts a shortfall of as many as 150,000 doctors in the next 15 years.

VTC students will be taught using a patient-centered curriculum that is only utilized in 15 percent of medical schools nationwide. In addition, VTC’s charter class and all future students will be required to produce a research project of publishable quality. Only 5 percent of medical schools nationwide have research as a key pillar of the curriculum. Finally, interprofessionalism will be emphasized throughout students’ time at VTC so they will be able to more effectively interact in a modern healthcare setting. Collectively, these features make VTC a unique school that will develop physician thought leaders who are adept at addressing health care challenges well into the future.
Exciting things are happening at Virginia Tech and in the Roanoke Valley. Virginia Tech and the Carilion Clinic have joined in a partnership that will result in new and innovative programs in biomedical research and medical education. The compelling feature of this partnership is that it intentionally seeks to combine opportunities in medical education, basic research, and clinical application with a collaborative and interdisciplinary perspective.

The vision of our partnership is now being realized by construction of our new building, scheduled to open by September 2010, which will serve as the centerpiece of an emerging biomedical complex that includes an existing Virginia Tech research center, a new clinical facility, and the Carilion Roanoke Memorial Hospital. We are also excited about expanding our partnership with the Virginia Tech – Wake Forest University School of Biomedical Engineering and Sciences.

Research conducted within the research institute will focus on translational research and the facilities are purposefully designed to maximize research efficiency; encourage collaboration among researchers, clinicians, and visiting scientists; and provide a comfortable, productive, and safe working environment. We consider this to be the best approach towards solving complex problems in contemporary medicine, and we are excited about getting started.

Starting this fall 2010, we will also open the doors with seven teams in neurobiology, cognitive neuroscience, and decision science already at work, to be followed over the first two years by programs in cardiovascular biology and cancer biology. As part of the neuroscience programs, the research teams at the VTCRI will begin a large scale world wide comprehensive study of the development of brain function and behavior throughout the lifespan and the underlying mechanisms of addiction and substance abuse. The cardiovascular focus will be on developmental biology of cardiovascular disorders, environmental effects, lifestyle and nutritional effects, and cardiovascular disease genetics. The cancer focus will encompass several areas of research, including the genotyping of tumors, the cell biological mechanisms of lung cancer and the developing specific diagnoses of genetically different types of tumors, and developing strategies for biomarkers for diagnosis and developing individualized therapeutics utilizing nanoscience-based chemical engineering for the delivery of personalized molecular therapies.

The institute will recruit 25 to 30 research teams over the next five to seven years. Each team will have support staff focused on applying molecular genetics, informatics, physiology, and computational modeling to the study of biological function in human health and disease throughout the lifespan, as well as on developing new approaches to and principles for diagnostics and therapeutics. We have the opportunity to collaborate with clinical practitioners and care providers, and with clinical investigators who are interested in using genomic, molecular, computational, and cognitive approaches to address fundamental mechanisms of human health and major disorders that limit lifespan and quality of life of children and adults.

Lab resources will include state-of-the-art electrophysiological instrumentation, a viral transfection facility, cell culture facilities, molecular biology core facilities, and a high-capacity, high-speed data center for the analysis, storage, and transfer of large sets of genomic, imaging, and computational information. The institute will also carry out cellular and sub-cellular laser-based optical imaging studies, laser-based microscopic cell capture, and computationally based functional magnetic resonance imaging in laboratory animals and humans.
Wake Forest Institute for Regenerative Medicine
Biomedical Engineers Contributing to Growth of New Tissues

With more than 80 projects that focus on translating regenerative medicine technologies to patients, the Wake Forest Institute for Regenerative Medicine in Winston-Salem, N.C., offers a unique opportunity for SBES students to help make a lasting contribution to medicine. The institute works to harness the body’s natural healing powers to promote healing from within or to develop replacement organs and tissues in the laboratory. New therapies have the potential not just to treat symptoms, but to cure disease.

Master’s degree and doctoral students in the Cell and Tissue Engineering Track work under the guidance of institute faculty members and have increasing responsibility as they progress in the program. They bring a unique perspective that complements the expertise of physicians and basic science researchers at the institute.

“The SBES students contribute to a wide variety of projects that involve engineering disciplines such as biomechanics, fluid flow, and material science,” said Anthony Atala, M.D., institute director. “They are productive members of the team and we feel fortunate to be an SBES partner.”

Institute projects range from engineering insulin-producing cells to replacement kidneys. And, as co-leader of an $85-million federally funded military project, the institute also focuses on regenerative medicine projects that can be applied to battlefield injuries.

Engineering a Human Ear: One project with military applications is work to engineer a human ear as part of the Armed Forces Institute for Regenerative Medicine, an $85 million project to apply regenerative medicine to battlefield injuries.

In a modified version of ink jet printing, each cell type is placed in a vial, rather than in cartridges, and are then “printed” through an ink jet printer head. The goal is to print skin cells directly on burn wounds as an alternative to skin grafting.

Institute scientists are working to engineer a human ear as part of the Armed Forces Institute for Regenerative Medicine, an $85 million project to apply regenerative medicine to battlefield injuries.

Printing Skin Cells on Burns: A military-related project with the potential to also benefit civilians is using ink jet technology to “print” skin cells directly on burns. The goal is to develop a treatment that can quickly cover and stabilize a wound. Research has shown that the longer it takes to cover a wound with skin, the higher the risk of infection, complications, and death.

First, a laser scans the wound to determine the size and depth, creating a “map” of the wound. A computer then controls the release of cells into the print head, where they are delivered directly to the burn. The wound map is used as a guide so that the correct type and number of cells can be precisely placed on the wound.

Mice with wounds similar to burn wounds healed in three weeks with this technique. In animals without the treatment, wound healing took five weeks. This project is still in the development stage and will need to be further tested and refined before it is ready for patients.
Optical Molecular Tomography for Regenerative Medicine

NIH-Funded Biomedical Research Partnership between SBES and WFIRM

Today’s most important medical challenges include cardiovascular diseases, stroke, diabetes, kidney failure, battlefield trauma, and other devastating conditions. Regenerative medicine seeks to devise new ways to repair or replace damaged tissues and organs with engineered counterparts for millions of patients who cannot receive transplants. As a core technique of regenerative medicine, tissue engineering involves extensive remodeling of cells and scaffolds. A major barrier to progress has been the inability to monitor this dynamic complex biological process in real-time, which makes control and optimization of regenerative techniques extremely difficult. On the other hand, as defined in the NIH roadmap, molecular imaging plays an increasingly important role in the advancement of medicine. Optical molecular imaging tools have now allowed much better understanding of biological interactions at cellular and molecular levels in models of almost all human diseases, and found several major clinical applications as well. Therefore, we are proposing to integrate these two forefront technologies in biomedical research – tissue engineering and optical molecular imaging – in a unified framework, and drive a paradigm shift from static assays of cellular functions in biopsied tissue or 2D culture models towards systematic analysis of 3D systems in vivo.

The overall goal of this NIH-funded biomedical research partnership (BRP) project is to develop the first-of-its-kind multi-probe multi-modal optical molecular tomography system for regenerative medicine and to demonstrate its utility in assessing bioengineered blood vessels at the pre- and post-implantation stages. Fluorescent probes will be used to label the tubular scaffold and the two main cell types of blood vessels (endothelial cells lining the lumen, and smooth muscle cells in the wall). Optical fibers embedded within the scaffold will deliver laser light for optical coherence tomography and to excite the fluorescent probes for fluorescence molecular tomography. Innovative algorithms will be developed to reconstruct 3D distributions of multiple fluorescent probes. The proposed imaging system will be used to track the development of bioengineered vessels with 100 μm resolution in a bioreactor mimicking blood flow conditions, monitor cell-specific gene expression, and verify physiological responses of cells within the engineered vessel. Then, the vessels will be tested in experimental animal models, and imaged to follow the tissue regeneration and function.

$3.7 M awarded to Ge Wang and Shay Soker as the lead PIs on the BRP project that is funded by NIH for 2010-2014.

The technical expertise includes optical molecular tomography, optical coherence tomography, hollow core fiber technology, and fluorescent labeling and modeling.
Managing the Data Deluge Partnering with the Virginia Bioinformatics Institute

Biology is changing. Increasingly the bottleneck in the biological sciences is data analysis and breakthroughs in mathematics, statistics, and the computational sciences are necessary to make sure that data analysis can keep up with data generation. Managing the data deluge requires new approaches to information analysis, data, and modeling and partnerships between biomedical engineers and computational scientists, like those found at the Virginia Bioinformatics Institute, can make a real difference to the understanding of the natural world.

Harold “Skip” Garner recently joined the Virginia Bioinformatics Institute (VBI) as Executive Director. He is expanding the computational resources available to researchers across the Virginia Tech campus and beyond and leading major new research programs in medical informatics and systems.

Out of Texas

In October 2009, Garner joined VBI from the University of Texas Southwestern Medical Center, where he was professor of Biochemistry and Internal Medicine and the Philip O’Bryan Montgomery, Jr., M.D. Distinguished Chair in Developmental Biology and Chair of Biomedical Engineering. Before coming to the University of Texas Southwestern Medical Center in 1994, Garner served as a senior staff scientist and founder of the Bioscience Division at General Atomics in San Diego. Said Garner: “I came to VBI and Virginia Tech because I saw a huge opportunity for bioinformatics and quantitative biology. The systems that make up life are so complex that to make further progress in our understanding we must be able to generate biological data on a massive scale and then analyze it using sophisticated computational methods. The diverse expertise and critical mass of the research groups at VBI convinced me that it is a great platform for research collaborations with many partners like the Virginia Tech Wake Forest University School of Biomedical Engineering and Sciences.”

“This is a very exciting time for the Virginia Bioinformatics Institute to be working with the Virginia Tech-Wake Forest University School of Biomedical Engineering and Sciences. Many outstanding opportunities exist for pioneering initiatives in translational science that will be supported by state-of-the-art computational resources.”

– Dr. Garner

VBI’s collaborations do not stop at research. The goals of the institute not only span making transformative scientific discoveries, they also target public policy, transitioning scientific research into practical applications, and training the next generation of transdisciplinary researchers.

Researchers at VBI are working hard to deliver innovative computing solutions and environments that will enable scientists to make sense of the tremendous amounts of new data being generated by biological investigations.

Said Garner, “We take our educational responsibilities very seriously. In 2008, for example, we started a groundbreaking educational program called Kids’ Tech University that brings 450 children, accompanied by their parents and teachers, to the Virginia Tech campus and gives them the opportunity to participate in a series of engaging scientific activities.” Kids’ Tech University includes lectures presented by world-renown, scientific researchers and hands-on laboratory experiments. Said Garner, “In April this year, it was great to have Rafael Davalos, Assistant Professor in the Virginia Tech Wake Forest University School of Biomedical Engineering, explain the curious things that happen to nature’s forces when engineering and biology take place on a very small scale. Not only is this a great example of how VBI and the Virginia Tech Wake Forest University School of Biomedical Engineering can work together, this is the type of talk that gets children really excited and encourages them to pursue careers in science when they get older.”

Expanded clinical focus

Garner is forging ahead with VBI’s mission to drive science, facilitate policy and decision-making, and produce meaningful outcomes for society. The institute’s focus is expanding into human disease and clinical operations by building a new Medical Informatics & Systems program area to find new predictive diagnostic tests and therapeutics for cancer, heart disease, neurological disorders and more. VBI is also becoming the nucleus for a sustainable and extensible high-performance computing environment that will impact the competitiveness of Virginia Tech campus wide.
The National Academy of Science has awarded Dr. Clay Gabler two research grants totaling $1.5 million to conduct in-depth investigations of serious and fatal road departure crashes to identify the crash and injury causation mechanisms associated with these traumatic events. In the first study, Dr. Gabler’s team has been awarded a four-year grant to conduct a large scale study involving in-depth crash and injury investigations involving passenger vehicles. In the second study, The National Academy of Science has awarded Dr. Gabler a two-year grant to focus on the specific characteristics of serious injury and fatal motorcycle crashes into traffic barriers through in-depth accident investigations. Both studies will be conducted through the Center for Injury Biomechanics.

Each year in the U.S., more than 10,000 motorists are fatally injured in road departure crashes. Vehicle occupants who depart the roadway are at risk of serious or fatal injury from collisions with the trees, poles, side slopes, and other hazards they may encounter in run-off road accidents. To reduce this toll, the U.S. has installed thousands of miles of guardrail, breakaway luminaries and signs, and other highly engineered safety devices. Unfortunately, even guardrails may not always be a forgiving object to strike. In 2007, there were 1,154 fatal crashes and 34,000 injurious crashes into guardrails in the U.S.

The reasons why road departure crashes sometimes lead to fatality or injury are complex and not completely understood. The CIB study will conduct in-depth investigations of 1000 road departure crashes at 24 sites across the U.S. The study promises to provide fundamental new insights into the crash conditions associated with road departures, e.g. impact speed, impact angles, vehicle road departure orientations, encroachment frequencies, and roadside topography, needed to reduce the severity and frequency of roadside crashes. The study will couple these crash causation factors with complete injury information for each of the crash victims to identify the influence of infrastructure design on injury outcomes.

The second study focuses on motorcycle-traffic barrier crashes. Motorcyclists are at particular risk in road departure crashes. Unlike passenger vehicle occupants, motorcycle riders have neither the protective structural cage nor the advanced restraints which are commonplace in cars and light trucks. Dr. Gabler will partner with Dr. Joel Stitzel and the CIREN team at Wake Forest University to conduct the motorcycle crash investigations in North Carolina. Other partners include Bucknell University and the Medical College of Wisconsin. The initial findings from this study have shown that 1 in 8 motorcyclists who collide with guardrail are fatally injured, 1 in 12 who collide with concrete barrier are killed. By contrast, only 1 in 20 motorcyclists who collide with passenger vehicles are fatally injured.
Faculty

Our Biomedical Engineering program involves 119 faculty:
51 tenure track biomedical engineering faculty (17 primary and 34 joint appointments)
68 affiliate biomedical engineering faculty at Virginia Tech and Wake Forest University.
YongWoo Lee, PhD
Assistant Professor, Biomedical Applications for Nanotechnology & Disease
SBES Core/Primary

Alexander Leonessa, PhD
Assistant Professor, Human robot interactions
SBES Core/ME

Thurmon Lockhart, PhD
Associate Professor, Locomotion Research, Balance, Biomechanics
SBES Core/ISE

Chang Lu, PhD
Associate Professor, Microfluidics for single cell analysis
SBES Core/CHEN

Michael Madigan, PhD
Associate Professor, Dynamics & Control of Human Movement
SBES Core/ESM

Roop Mahajan, PhD
Director, Institute for Critical Technologies and Applied Sciences
Nanomedicine
SBES Core/ICTAS

Abby Morgan, PhD
Assistant Professor Biopolymers, Controlled Release Drug Delivery
SBES Core/CHEN and MSE

Michael Munley, PhD
Associate Professor, Radiation Effects, Molecular Imaging, Radiation Therapy
SBES Core

Amrinder Nain, PhD
Assistant Professor Cellular dynamics
Aligned deposition of polymeric nano/microfibers
SBES Core/ME

Maury A. Nussbaum, PhD
Professor, Occupational Biomechanics & Ergonomics, Balance, Aging
SBES Core/ISE

Padma Rajagopalan, PhD
Assistant Professor, 3D Tissue Mimics, Polymeric Scaffolds, Biopolymers
SBES Core/CHEN

M. Nichole Rylander, PhD
Assistant Professor, Nanotechnology, Bioheat Transfer, Cancer Therapies
SBES Primary

Christopher Rylander, PhD
Assistant Professor, Optical Devices for Imaging & Therapeutics, Biotransport
SBES Primary

Pete Santago, PhD
Professor & Associate Head, Image & Signal Analysis, Mach. Learning & Pattern Recognition
SBES Primary

Ge Wang, PhD
Samuel Reynolds Pritchard Professor, X-Ray Computed & Tomography, Inverse Problems
SBES Primary

Pavlos P. Vlachos, PhD
Associate Professor, Fluid Biomechanics, Cardio and Vascular Flow Analysis
SBES Core/ME

Christopher Wyatt, PhD
Associate Professor, Biomedical Image Analysis
SBES Core/ESM

Yong Xu, PhD
Assistant Professor, Optics, Computational Electrodynamics
SBES Core/ESM

James Yoo, MD, PhD
Associate Professor Tissue Engineering
SBES Core/WFIRM

Dr. Hengyong Yu, PhD
Assistant Professor Computed tomography, medical image processing
SBES Core/Radiology
Aggressive brain cancer is a uniformly fatal disease afflicting more than 13,000 people per year in the United States. Despite active research around the world over the past 70 years, the mean survival rate of a patient with this disease is only 15 months upon diagnosis. Through a partnership with Drs. John Rossmeisl, (veterinary neurosurgeon) and John Robertson (pathologist) at the Vet School, Dr. Tom Ellis (neurosurgeon) at the Wake Forest School of Medicine, Dr. Rafael V. Davalos and his student Paulo Garcia are developing a new form of cancer therapy, Irreversible Electroporation (IRE), for the treatment of brain cancer.

Rafael V. Davalos, an assistant professor in SBES, recently co-invented this new form of cancer therapy in which one-millimeter electrodes are inserted directly into the cancerous tissue and kill the cancer cells by sending a series of electric pulses. IRE has many advantageous aspects such as treating the targeted tissue with minimal scarring while preserving major blood vessels and nerves. In addition, IRE can be imaged in real time using ultrasound, MRI, or CT, giving the physician the means to actively monitor the procedure.

In the spring of 2009, this team was able to demonstrate the safety and potential of the procedure by performing IRE on four canine subjects to test the effects of the procedure on brain tissue. Numerical modeling and ex-vivo experiments on brain tissue were used to determine the IRE parameters for the study. Ultrasound and MRIs demonstrated a clearly distinguishable ablation zone in the surrounding area where the electrodes had been inserted into the brain tissue. After the operation, the canines did not experience any adverse effects and were able to resume normal activities such as eating within hours of the IRE procedure. The results of these experiments showed that IRE can be used safely and effectively to ablate brain tissue. Their studies have been recently featured in the Journal of Neurosurgery and the Journal of Membrane Biology.

In the fall of 2009, Davalos and the doctors treated a canine patient for brain cancer using the IRE procedure. This was the first clinical application of IRE for the treatment of an inoperable, spontaneous malignant intracranial glioma in a canine patient. The IRE ablation was performed safely, it effectively reduced the tumor volume by 75% and associated intracranial hypertension, and it provided sufficient improvement in neurological function of the patient to safely undergo adjunctive fractionated radiotherapy (RT), achieving complete remission 4 months after the initial treatment. The team recently received a Phase II award from the Wallace H. Coulter Foundation. Future plans include refining the parameters of IRE in order to continue to help more canine patients. In the next 3-5 years, after successful canine treatments, hopes are that the IRE technology will be moved to human trials at Wake Forest.
Medical and Imaging Informatics Receives NIH Grand Challenge Award

In the past decades, biomedical engineers have dramatically improved health care technologies. One area of significant development is sophisticated technologies for measuring human body structure and function and detecting diseases. From microarray imaging of DNA expressions to functional analysis of brain activities, new technologies are able to acquire ever more detailed and dynamic signals that reveal structural, functional and genetic changes occurring in human bodies. While these technologies bring great advances in our ability to understand human and human diseases, the explosion of data acquired by these technologies is creating bottlenecks for their effective use. To address this “data explosion” challenge in medicine, Dr. Yaorong Ge and his colleagues at SBES are actively developing informatics theories and systems that effectively integrate, manage, and use a large number of disparate sources of medical and imaging data to improve health care delivery and reduce cost.

This project is supported by a $2 million Grand Challenges (GO) Award from the National Institute of Biomedical Imaging and Bioengineering and is a multi-disciplinary effort involving biomedical engineers, biomedical informaticians, radiologists, health sciences researchers, health economists, and software engineers.

Because medical data are being generated by many devices, in many care units, and often across many institutions, effective integration and use of data must occur at many different levels and across multiple domains. Dr. Ge’s research efforts reflect this nature of data integration needs. At one end of the spectrum, Dr. Ge and colleagues are developing image sharing technologies that allow a patient’s medical images acquired at one hospital to be accessible by all other hospitals and clinics that the patient later visits. By making prior images available for diagnosis and treatment management, this technology will not only improve health care quality and lower patient risk but also dramatically reduce health care cost. This project is supported by a $2 million Grand Challenges (GO) Award from the National Institute of Biomedical Imaging and Bioengineering and is a multi-disciplinary effort involving biomedical engineers, biomedical informaticians, radiologists, health sciences researchers, health economists, and software engineers.

At a slightly smaller scale, Dr. Ge and his team are developing technologies to bring together dozens of clinical and research data sources at Wake Forest University Health Sciences (WFUHS) into a common data warehouse framework. This project is supported by the Translational Sciences Institute of WFUHS and is expected to significantly improve the pace of translational research at this institution. Bringing disparate data sources into a common framework faces many challenges, both technical and political. As a part of this effort, the team has deployed data acquisition modules at 11 Intensive Care Units to collect critical physiological parameters into a real time database. The next steps will integrate these real time physiological parameters with labs, medications and other clinical data to provide ICU physicians with improved clinical protocols and decision support.

One project with a narrower focus is in cardiovascular research. Several nation-wide, multi-center studies have been underway to gather demographics, imaging, physical, psychological, genetic, dietary, and environmental parameters from populations of thousands of subjects over several decades with the hope to discern the main factors that cause and exacerbate cardiovascular diseases, which is the number one cause of death in the US. Dr. Ge and his team are developing systems to manage and integrate these important data and analytical results that are currently stored in disparate media, non-standard formats, and many silos of research centers. In another project, Dr. Ge is working with VT colleagues, Drs. Ge Wang and Chris Wyatt, to solve the informatics challenges facing advanced multi-scale CT technologies currently under development.
Researchers in the Nanotherapeutics and Bioheat Transfer Lab in the School of Biomedical Engineering and Sciences (SBES) at Virginia Tech, led by Dr. M. Nichole Rylander, have recently been awarded over $3.8M in external funding. Together they have formed a multi-institutional and interdisciplinary collaboration to develop novel nanomaterials with the capability for dual diagnostic imaging and multimodal cancer therapy. This highly diverse collaboration involves researchers from Oak Ridge National Laboratories, Institute for Critical Technology and Applied Science (ICTAS), Edward Via Virginia College of Osteopathic Medicine, Wake Forest Comprehensive Cancer Center, and Virginia Tech Departments of Chemistry and Mechanical Engineering and SBES. Although this group is investigating a wide array of nanoparticles, efforts have been recently focused on novel single walled carbon nanohorns (SWNHs) which possess unparalleled potential for diagnostic imaging and therapy. SWNHs are comprised of thousands of carbon nanotubes with individual nanotube diameters of 2-5 nm arranged as agglomerates with overall diameters of 50-100 nm. Unlike many other nanoparticles such as carbon nanotubes, SWNHs are nontoxic and possess extensive and easily customizable surfaces and pores providing an excellent platform for attachment of tumor targeting molecules, imaging agents, and drugs.

Dr. Rylander is partnering with Oak Ridge National Laboratories who are the only US research team capable of synthesizing SWNHs, to produce SWNHs with unique properties tailored for drug delivery, imaging, and therapy. Dr. Harry Dorn, in the Chemistry Department at Virginia Tech, is working with Dr. Rylander to develop and utilize novel functionalization methods to attach quantum dots to SWNH surfaces or within their internal pores. Dr. Tom Campbell in ICTAS is working with Dr. Rylander to characterize these novel nanoparticles. Dr. Rylander’s team has already demonstrated laser irradiation of SWNHs can cause significant temperature elevation, selective photothermal based tumor destruction, and modulation of tumor survival proteins called heat shock proteins (HSPs).

Her team has developed novel methods for measuring the spatial and temporal temperature and cell viability during and following laser irradiation of cells alone or in combination with SWNHs. In collaboration with Dr. James Mahaney in the Edward Via Virginia College of Osteopathic Medicine, Dr. Rylander’s group has shown that laser excitation of SWNHs can also produce toxic free-radicals for photochemical based tumor destruction. Dr. Rylander recently received a National Science Foundation Early CAREER award to develop a novel system to measure spatiotemporal SWNH transport and tumor response to SWNH-enhanced laser therapies. Dr. John Robertson in the Virginia-Maryland Regional College of Veterinary Medicine is assisting Drs. Chris Rylander of SBES and Nichole Rylander in determining the capability of SWNHs for diagnostic imaging and treatment of breast and bladder cancer using animal models. Drs. Chris and Nichole Rylander are utilizing novel fiberoptic microneedle technology and SWNHs to develop a theranostic system for combined cancer diagnosis and treatment. Dr. Nichole Rylander is collaborating with Pavlos Vlachos of mechanical engineering to use particle image velocimetry to measure SWNH motion within blood vessels to enable development of more effective targeting strategies. Dr. Nichole Rylander is also working with Dr. Rafael Davalos in SBES to investigate using SWNHs for more selective irreversible electroporation treatments for cancer. In order to expedite clinical translation of SWNHs for cancer therapy, Dr. Chris and Nichole Rylander are working with a multi-disciplinary team of oncologists including Frank Torti and Steve Akman from the Wake Forest Comprehensive Cancer Center and cancer biologists Suzy Torti and Linda Metheny-Barlow in the departments of Cancer Biology and Radiation Oncology at Wake Forest. The collaborative framework established for this research illustrates how the synergistic interaction of multiple institutions and departments promoted by the School of Biomedical Engineering and Sciences can facilitate and fast track research progress.
NSF Awards Research Project to Study Fluid Flow in Insects: Results to Aid Tissue Engineering Efforts

Insects are about to be dissected in a new way by a host of Virginia Tech engineering faculty. They will be using some fancy state-of-the-art equipment, such as a kilometer-long synchrotron X-ray light source, which might be enough to scare any bug. Insight from this project could be applied to a broad range of areas, from a deeper understanding of how to manage insect pests, to new ideas for how to build better artificial tissues and organs, to the design of new medically implantable microdevices.

The National Science Foundation (NSF), via the Emerging Frontiers in Research and Innovation program, has agreed to support this effort at Virginia Tech with a $2 million award. The project is spearheaded by Jake Socha, an assistant professor in Engineering Science and Mechanics and member of SBES. Virginia Tech’s Institute for Critical Technology and Applied Science has also agreed to support this work as a Grand Challenge project with an award of $298,466. Socha is leading a large multi-disciplinary team, including Raffaella DeVita, Shane Ross, Ishwar Puri, Anne Staples, and Mark Stremler from Engineering Science and Mechanics; Rafael Davalos, from SBES; Masoud Agah, from Electrical and Computer Engineering; Pavlos Vlachos, Mechanical Engineering, and Jon Harrison, from Arizona State University’s School of Life Sciences.

Insects are often considered the most successful group of animals in Earth’s history. With over a million known species, these critters are found in almost every environment and have been around for hundreds of millions of years. Part of their astounding success may lie in their ability to efficiently pump three types of fluids—air, liquid food, and blood—in their tiny bodies. “They possess multiple, exquisite soft-tissue flow networks, all in one tiny package. In essence their internal anatomy serves as multiple microfluidic pumps,” Socha said.

In previous research, Socha and colleagues opened a new window into the inner workings of insects by using synchrotron x-ray imaging to directly visualize internal microstructures in living animals. According to Socha, “a key finding was a new form of convective respiration in which the animal’s tracheal system periodically collapses and reinflates.” This knowledge is leading the team of researchers to ask if the pumping of the insect tracheal system can serve as a bio-inspiration for novel engineered systems such as implantable microdevices and for tissue engineering.

The insects’ circulatory system is also profoundly different, consisting of a simple tube, a muscular vessel that runs most of the length of the body and pushes the insect’s blood into the open body cavity. “Insects pump blood through the heart toward the head, and in some species, reverse the flow. In this open system, once the blood exits the heart or aorta, it courses around tissues and organs to every part of the insect’s body, including the tips of the legs, and somehow returns to the heart,” Socha said.

The study of fluid mechanics is centuries old. But Socha and his team want to apply their knowledge of how insects manage internal fluid flows for bioengineering purposes. In doing so, they envision harnessing “the agility, dynamic range, low power requirements, self-contained nature, and efficiency of the flows in insects respiratory and circulatory systems to revolutionize the design of microfluidic systems,” the team explained. The researchers also have an educational aims as part of the NSF grant. Socha has already appeared on the National Geographic and History channels for his work with flying snakes and insects. National Geographic has expressed interest in this new endeavor. Socha and his colleagues will also work with primary and secondary school teachers in under-resourced classrooms to develop novel replacement lessons that integrate biology and engineering.

A high-resolution synchrotron x-ray image of a beetle showing the complex tracheal system throughout the body.
Each year, nearly 40,000 people are killed on our nation’s roads, and nearly 2.5 million are injured. Since 2005, Wake Forest University School of Medicine and the VT-WFU Center for Injury Biomechanics have been a Crash Injury Research and Engineering Network (CIREN) center. The CIREN program’s mission is to improve the prevention, treatment, and rehabilitation of motor vehicle crash injuries to reduce deaths, disabilities, and human and economic costs. The program was started in 1997, and since then has enrolled over 4,000 cases where individuals in vehicles have sustained severe injuries, where there is a moderate or greater threat to life.

This year, the CIREN program underwent recompetition and Wake Forest University and Virginia Tech together were chosen with a $2.4 million, 5-year award to be one of six federally-funded CIREN centers in the country. The CIREN database and program is unique among crash injury databases in that it contains information about every facet of a crash - from the events leading up to the crash, to the 12-month outcome of the injured vehicle occupant. CIREN includes detailed scene investigation, reviewing medical response, inspection of the vehicle's deformations and energy of impact, detailed medical imaging, injury reconstruction, and long term quality of life. CIREN is the only database that brings all of this information together for each and every case.

Originally supported with funds from Toyota Motor Corporation, WFU’s CIREN center began in 2005 and has since made its impact on the program through several studies. The faculty and students of the CIB have created matching algorithms for comparing CIREN to the National Highway Traffic Safety Administration’s other crash databases to determine the similarity between the databases despite using different enrollment criteria. Ms. Kathryn Loftis, an SBES graduate student, has developed an improved algorithm for assessing the similarity between real-world cases and regulatory test conditions such as those used for vehicle star ratings and IIHS good to poor ratings. Crash test dummies assess the injury risk potential only for certain types of injuries, for certain types of people, in certain types of crashes. Her research will allow quantitative assessment of how similar a crash test dummy’s injury risk prediction is to the actual injuries sustained by occupants in cases similar to crash tests. In conjunction with Dr.

Dr. Joel Stitzel utilizes rapid prototyping technologies to visualize patient’s injuries and determine injury mechanisms.
The National Highway Traffic Safety Administration (NHTSA) awarded $3M over five years to the Center for Injury Biomechanics (CIB). The CIB at both Virginia Tech and Wake Forest is partnering in this effort with the Virginia Tech Transportation Institute (VTTI) to generate gender and age specific models for prediction of injury as a result of motor vehicle crashes. The project is lead by three Principal Investigators: Dr. Joel Stitzel from Wake Forest University, and Dr. Warren Hardy and Dr. Stefan Duma from Virginia Tech.

One component of this research project is to examine rib fractures the result from automobile accidents. Historically, the vast majority of thoracic impact research has focused on developing global criteria for predicting injury such as force, acceleration, and displacement. However, a new method has been developed by Dr. Duma’s research group that utilizes 50 in situ strain gages that measure rib strain and allow for the determination of rib fracture timing. “We have developed an instrumentation package that generates non-censored rib fracture data. This is the first time anyone has been successful at mapping the exact rib fracture timing and strain distribution of the entire thorax during dynamic belt loading” says Dr. Duma.

Another component of this research program investigates brain injury mechanisms and post-injury biochemical cascades. A primary objective of this effort is to better establish the nature and time course of the brain’s response after head impact, with focus on factors important to long-term functional deficit. High-speed biplane x-ray will be used to examine brain injury mechanics and magnetic resonance spectroscopy will be used to examine the chemistry of the brain. Dr. Warren Hardy, director of Virginia Tech’s CIB says, “The knowledge gained from this study will lead to a better understanding of injury tolerance and more effective approaches to injury prediction, mitigation, diagnosis, and treatment.”

Due to their versatility, computational models of the human body have emerged as a promising avenue for research aimed at improving the effectiveness of vehicle safety systems and mitigating crash-related injuries across all age groups. With the proper framework, not only the materials, but also the size and shape of these models, can be adjusted to match any population. To examine this, certified scans of normal individuals from age 0 – 100 years will be collected to observe the aging process via actual CT scans. “The models that are created will be some of the most advanced in computer-aided design for representing the head and chest, the two most frequently injured regions of the body in motor vehicle crashes,” said Dr. Joel Stitzel, program leader and director of the WFU CIB.

It is expected that this approach of continuing research will result in new insight into how to prevent or mitigate injuries in a multitude of at-risk populations, including children and older adults. Risk and epidemiological analysis may be combined with this knowledge to make informed decision about how to effect changes in regulations to improve automotive design and save lives. “This project is a perfect example of how we can coordinate the excellent faculty expertise and physical resources within and across campuses in order to compete and win large federal grants” says Dr. Duma.

Increased life expectancy and declining birth rates are projected to increase the portion of the U.S. population over age 65 by more than 20% by the year 2050, creating an urgent need for further research into the biomechanics of the aging body. Aging is associated with structural and morphological changes that can decrease the body’s ability to withstand traumatic insults. The decreased skeletal and physiological resilience of the elderly make trauma and its after effects one of the top ten causes of death among those 65 and over, with motor vehicle crash as one of the most common sources of such trauma. Individuals in this age group have the second-highest crash-related death rate among all age groups. The research conducted in these projects will result in a better understanding of how to protect the aging drivers.

VTTI Director Tom Dingus said, “We are pleased to continue to partner with the CIB and VT/WFU SBES and are particularly pleased to announce this project. Given the continuing, unacceptably high crash rate in the U.S., it is critical that we continue to be diligent in our efforts to find ways to predict and mitigate injury from motor vehicle crashes thereby effecting policy change to ultimately save lives.”
2 SBES Faculty Take NSF Career Awards

**Marissa Nichole Rylander**

Preliminary research on cancer treatments using nanotechnology and laser therapy has led to a National Science Foundation (NSF) Faculty Early Career Development (CAREER) award for Virginia Tech Assistant Professor Dr. Marissa Nichole Rylander. The CAREER grant will allow Dr. Rylander to develop and utilize a novel sensing system she co-invented called the “holey scaffold.” Her design will characterize the three-dimensional and time dependent motion of nanoparticles and tumor response to photothermal and photochemical based cancer treatments.

Rylander’s research will also illustrate the dynamic, light-activated thermal and chemical response of the tumor to the nanoparticle-mediated laser therapy for varying nanoparticle properties and laser parameters within both *in vitro* and *in vivo* tumor systems. The “holey scaffold” is the first system capable of minimally invasive and non-destructive light sensitive, molecular sensing and control of biological and transport processes within living organisms. Dr. Rylander said the “holey scaffold can be visualized as a miniature microscope used in conjunction with a living system.” The holey scaffold is built from tissue scaffolding and is embedded with a network of hollow microchannels.

**Padma Rajagopalan**

Virginia Tech Assistant Professor Dr. Padma Rajagopalan has won a National Science Foundation (NSF) Faculty Early Career Development (CAREER) award to investigate the fundamental aspects of cell migration. Her research will seek to understand how different and potentially conflicting signals are processed by a cell in order for it to make a decision on the directionality and extent of motion. The results from these studies could provide new insights into tumor metastasis, wound healing, and developmental biology.

“Stimuli that modulate and direct cell locomotion can be chemical, mechanical, electrical, or optical in nature,” said Dr. Rajagopalan. “Cells experience various chemical stimuli due to changes in protein concentrations within a tissue. Changes in tissue elasticity and stiffness represent varying mechanical environments.” Because of the inherent complexity of *in vivo* systems, Dr. Rajagopalan’s research will seek to develop a class of engineered interfaces that will be used as biomimetic substrates to study cell migration. The overall goal is to design polymeric interfaces that exhibit dual and opposing chemical and mechanical gradients and to monitor cellular locomotion and responsiveness on these substrates. Together, these studies will reveal insights into the simultaneous effects of chemical and mechanical stimuli on cellular response.
The Virginia Tech Northern Capital Region (NCR) includes the Arlington Innovation Center (AIC) for Health Research, which convened a Workshop on Medical Home to focus on a Patient Centered Medical Home (PC-MH) health care delivery model designed to facilitate partnerships among individual patients, their families, and physicians. “This primary care model depends on extensive support of care coordinators and uses registries, information technology, health information exchanges, and additional services to assure that patients receive timely, coordinated, and comprehensive care in a culturally appropriate manner,” said workshop chair Seong K. Mun, professor and director of the AIC.

About 85 participants from academia, the military, and the private sector attended the day-long Medical Home Workshop held at The George Washington Masonic Memorial in Old Town, Alexandria. The program was supported by the Telemedicine & Advanced Technology Research Center (TATRC), and sponsored by Carilion Clinic, IMC, and TIAG. CDR Robert Marshall, M.D., U.S. Navy; COL Hon Pak, M.D., U.S. Army; LCDR Steve Steffensen, MD, U.S. Navy, John Wendland, Carilion Clinic, Kenneth Wong, PhD of VT and Jennifer LeFurgy of VT served with Mun on the workshop committee. The workshop featured four scheduled sessions, with speakers addressing these topics: Medical Home from the Healthcare Enterprise Perspective; Lessons Learned from the Medical Homes; Information Technology and Electronic Health Records, and Sustainability and Optimization – Making Medical Home Better. A panel discussion on Future Challenges and Research issues followed the four sessions.

Throughout the day, physicians, nurses, practice groups, educators, researchers, and technology providers, shared their experiences in implementing and sustaining a Medical Home. The panelists confirmed that Medical Home care delivery requires resources, technologies, and staff other than those used in traditional care models. They stressed that implementation, satisfactory operations, and long-term sustainability of Medical Home depend on many factors, including financing models, clinical environment, professional commitment, maturity of technology, and business process re-engineering. Mun said that the Workshop on Medical Home is the inaugural event of the newly formed AIC. “As we prepare to move to the new Virginia Tech Research Center – Arlington when it opens next summer, we are planning more convening activities of conferences and workshops in the building’s conference center,” he said. “These will highlight and foster collaboration in AIC research areas which include health systems, neuroscience, imaging, informatics and robotics.”

AIC Organizes Workshop on Medical Home to Focus on New Primary Care Delivery System

Dr. Mun, Janice Ragland MD, President of the Virginia Academy of Family Physicians, and Dean Johnson from the VTC Medical School.

Creation of Functional Ovarian Tissue Results in $1.9M Grant

Ovaries are the female reproductive organs that contain cells responsible for the secretion of hormones important in numerous physiological functions including regulation of proper bone and cardiovascular health. The follicles of the ovary are also responsible for the production of oocytes, or eggs, which are necessary for conception and live births. A number of conditions can lead to the pre-mature loss of ovarian tissue and its proper functions. These include a condition known as premature ovarian failure (POF) as well as certain types of cancer that require the use of chemotherapy drugs and radiation that injure the ovaries. These conditions can prevent women from having children and can disrupt the proper hormonal balance that is important for maintaining bone and heart health. Regenerative medicine strategies offer the potential to preserve ovarian function through the use of patients’ own cells.

A team of researchers at the Wake Forest Institute for Regenerative Medicine has recently received a $1,900,000 award from the Egan Family Foundation to investigate approaches to preserve ovary function through the use of microencapsulation technology. James Yoo (SBES core) is leading a team including Sang Jin Lee (SBES core), Emmanuel Opara (SBES core), Justin Saul (SBES primary), and Shay Soker (SBES core). The use of biomaterials including complex polysaccharides such as alginate has been effective for the encapsulation of pancreatic islet cells for the production of insulin. These approaches are effective to prevent immune rejection of cells if the donor cells are not obtained from the recipient (non-autologous cells). They also provide a system that can be readily injected into a patient. However, ovarian tissues are more complex than single islet cell encapsulation. The team is therefore investigating different encapsulation approaches to achieve proper three-dimensional positioning of the cells. In order to achieve sufficient numbers of encapsulated cells for hormone replacement applications, the encapsulation must be done in a high-throughput fashion. The team is developing hardware for high throughput production of microencapsulated cells. They are also assessing cell structure within the microcapsules and functional outcomes including production of estrogen and progesterone.

This project aims to obtain functional ovarian tissue that can be used as an approach to achieve hormone replacement and the production of ovarian follicles that can be fertilized for live births.
OUR 20-YEAR HISTORY WITH BMES

1990 BMES

Virginia Tech hosted the first annual fall BMES conference in Blacksburg Virginia two decades ago. Until this time, BMES had combined with other conferences each year. The 1990 conference theme was “Biomedical Engineering: Opening New Doors.”

2010 BMES

We are bringing over 100 biomedical engineering faculty and graduate students from Virginia Tech and Wake Forest University for the BMES conference in Austin TX. These faculty and graduate students will present over 100 papers and posters highlighting their recent research accomplishments. Please look for these papers and stop by our booth (600 - 602) to learn more about our program.