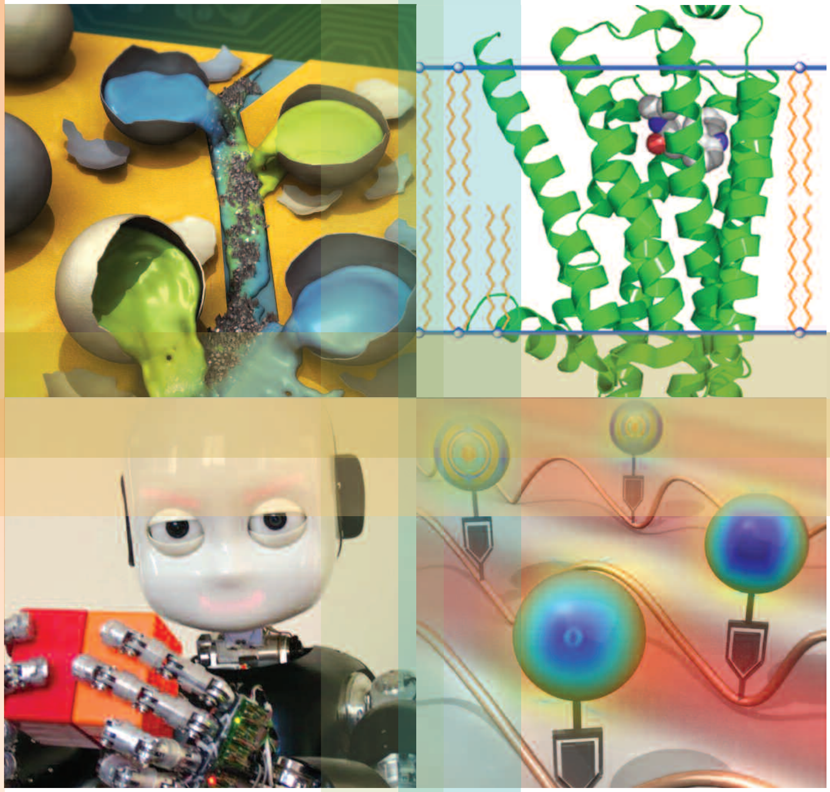
Beckman Institute for Advanced Science and Technology



Annual Report **2009-2010**

ABOUT THE BECKMAN INSTITUTE

The Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign is an interdisciplinary research institute devoted to leading-edge research in the physical sciences, computation, engineering, biology, behavior, cognition, and neuroscience. The Institute's primary mission is to foster interdisciplinary work of the highest quality, transcending many of the limitations inherent in traditional university organizations and structures. The Institute was founded on the premise that reducing the barriers between traditional scientific and technological disciplines can yield research advances that more conventional approaches cannot.

Beckman Institute research is focused around four research themes:

- Biological Intelligence (page 6)
- Human-Computer Intelligent Interaction (page 14)
- Integrative Imaging (page 22)
- Molecular and Electronic Nanostructures (page 28)

The Beckman Institute is also home to two strategic initiatives that seek to unify campus activities in their respective areas:

- Imaging
- Social Dimensions of Environmental Policy

More than 600 researchers from more than 40 University of Illinois departments as diverse as psychology, computer science, electrical and computer engineering, and biochemistry, comprising 14 Beckman Institute groups, work within and across these overlapping areas. The building offers more than 200 offices; specialized, state-of-the-art laboratories and other facilities; and meeting areas.

To assist research efforts, the Beckman Institute provides state-of-the-art resources for faculty, staff, and students, including the:

- Biomedical Imaging Center (page 46)
- Illinois Simulator Laboratory (page 48)
- Imaging Technology Group (page 50)

The 313,000-square-foot building was made possible by a generous gift from University of Illinois alumnus and founder of Beckman Instruments, Inc., Arnold O. Beckman, and his wife Mabel M. Beckman, with a supplement from the State of Illinois.

Additionally, the Arnold and Mabel Beckman Foundation provides ongoing financial assistance for various Institute and campus programs. Daily operating expenses of the Institute are covered by the state and its research programs are mainly supported by external funding from the federal government, corporations, and foundations.

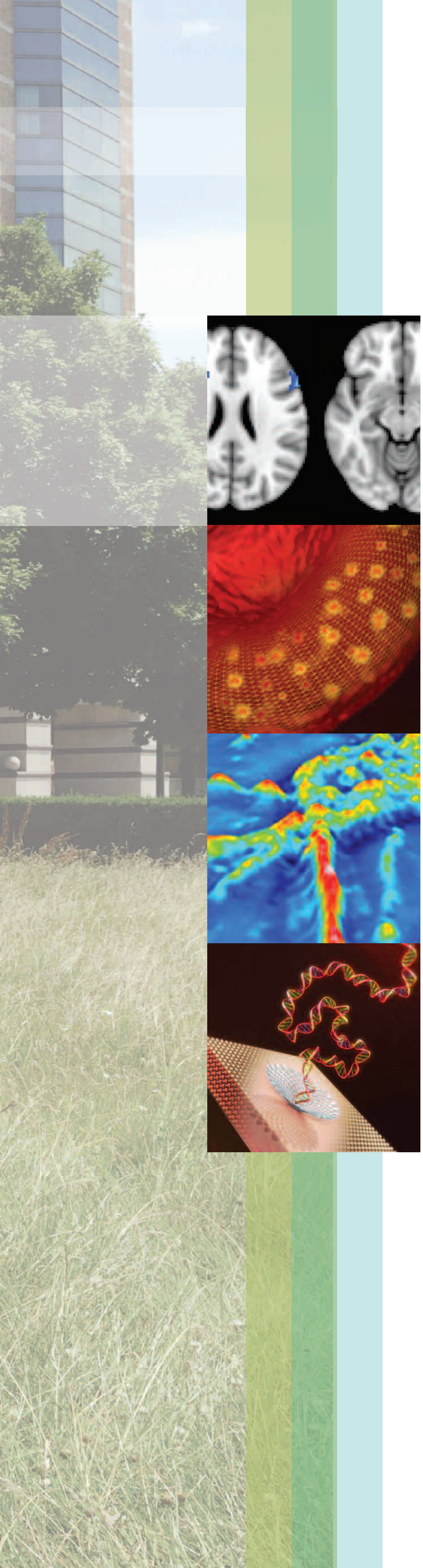


TABLE OF CONTENTS

FROM THE DIRECTOR

It is with great pleasure that I write my first letter as the Director of the Beckman Institute. I am incredibly honored and excited to be named the fourth Director of the Institute. I have been a faculty member at Beckman since it opened in 1989 and have had the pleasure of working with Founding Director Ted Brown, Jiri Jonas, Pierre Wiltzius, and Tamer Başar (interim). I am looking forward to continuing their tradition of excellence as the Beckman Institute enters its third decade as a world-renowned interdisciplinary research institute.

The period this report covers (July 1, 2009-June 30, 2010) was marked with many milestones, discoveries, changes, and challenges.

Milestones included holding our 20th Anniversary Symposium in October, 2009. This two-day scientific symposium was the culmination of our 20th anniversary celebrations and we were pleased that it drew several hundred people to the Beckman Institute. The event featured high profile speakers from our campus and beyond, including Nobel Laureate Susumu Tonegawa from MIT, Thomas R. Insel, the Director of the National Institutes of Health; all of our former directors, award-winning nanoscientist, Charles Lieber, and a myriad of other speakers with past and present connections to the Beckman Institute.

Klaus Schulten and his Theoretical and Computational Biophysics group also celebrated an historic milestone: the 20th anniversary of funding as the National Institutes of Health Resource for Macromolecular Modeling and Bioinformatics. Since 1989, Klaus's group has set the gold standard when it comes to computational modeling and visualization of molecular scale biological structures and processes. To celebrate their two decades of success Schulten's group hosted a two-day symposium titled "Computational Biology of the Cell – the Next Decade." I'd like to congratulate Klaus, his current team members, and all former members for their contributions to this leading-edge group.

Changes were also underfoot at the Beckman Institute this past year. Our Biomedical Imaging Center completed its transition from its south campus location and continued its growth by acquiring new equipment, including the Seimens MAGNETOM Trio Whole-body 3T MRI scanner and a high resolution ultrasound system which was spearheaded by Bill O'Brien, leader of the Bioacoustics Research Laboratory. We will soon be receiving two additional systems, a micro CT-PET system obtained via a proposal written by Steve Boppart and colleagues and a NIRS/EROS system obtained by Gabriele Gratton, Monica Fabani, and their colleagues. These new systems will enable us to add important new imaging capabilities to our world class multimodal imaging facility.

Some notable changes took place in our research theme co-chair positions. Long-time Biological Intelligence research theme co-chairs Monica Fabiani and Bill Greenough stepped down from their duties. Monica is continuing as a full-time faculty member at the Beckman Institute and Bill is transitioning to retirement. I would like to thank both of them for their tremendous service to the Beckman Institute over the years. They both went above and beyond what was required. Taking over for Monica is Jennifer Cole of the Cognitive Science group. Mark Nelson of the NeuroTech group replaces Bill Greenough. My replacement as co-chair for the Human-Computer Intelligent Interaction research theme is Dan Morrow of the Human Perception and Performance group. Dan will join long-time HCII co-chair Tom Huang. Naryana Aluru and Nancy Sottos remain the co-chairs of the Molecular and Electronic Nanostructures group and Stephen Boppart and Zhi-Pei Liang continue as co-chairs for the Integrative Imaging research theme.

Changes were also seen in the Beckman Institute rotunda. In April of 2010 we unveiled the Arnold O. Beckman Rotunda Exhibit. This permanent exhibit was created to illuminate the extraordinary life and achievements of Arnold Beckman. Many people were involved in making this permanent tribute possible, but I would particularly like to thank Pierre Wiltzius for forming the idea; Tamer Başar our interim director for seeing the project through; the Beckman Foundation for funding and support for the project; Pat Beckman, Arnold's daughter, who played an essential role in this process for advice, images, and display material; Beckman Coulter for images and equipment; and the many Beckman Institute staff members who made it all happen. I hope this engaging display can continue to educate us about the man who contributed greatly to the history of science and technological innovation.

As I take over my new position I am also very aware that the Beckman Institute also faced—and will continue to be faced—with many challenges, particularly to our budget. Like every other unit on the University of Illinois campus we are facing difficult budget cuts from the state of Illinois and other funding sources. Efficient planning from Tamer Başar and Associate Director Van Anderson has provided us with the ability to handle these reductions—at least for now. We will continue to develop new sources of revenue to help support our research portfolio. This includes building our development efforts and being creative and competitive in grant funding opportunities.

In spite of these challenges I am looking forward to moving the Beckman Institute into the future. It is a fantastic place for interdisciplinary research and I have no doubt we will continue to stay at the cutting edge of interdisciplinary research.

Art Kramer
Beckman Institute Director

BAŞAR SERVED THE BECKMAN INSTITUTE WELL

Tamer Başar spent more than 20 months as the Beckman Institute Director on an interim basis, departing in May of 2010 when Art Kramer was chosen as Beckman's fourth permanent Director.

After taking over for Pierre Wiltzius in September of 2008, Başar guided the Institute during some of its most historic and most challenging times. The Beckman Institute's 20th Anniversary Year was held in 2009, with a celebration of the official opening in April and a scientific symposium in October marking the occasion. The biennial Beckman Institute Open House was held in March of 2009, while a planned facilities swap of Beckman's Illinois Simulator Laboratory and Biomedical Imaging Center took place during Başar's tenure.

In addition, a long-planned fourth research theme, Integrative Imaging, was added, as were two Strategic Initiatives (Imaging and Social Dimensions of Environmental Policy) and a Developing Initiative called Healthy Bodies, Brains, Minds, and Communities. A Development Office was started at Beckman and a new mentoring program for graduate students and postdocs was created. Başar's term also came during a very serious fiscal crisis at the University of Illinois. All of these, as well as several other happenings, made for a demanding tenure for any Director, interim or not.

Kramer thanked Başar for his service during a critical period in the history of the Beckman Institute.

"Tamer's stewardship of the Beckman Institute during some important and often trying times went above and beyond what anyone could have expected," Kramer said. "I know that I express the feelings of all the people here at Beckman when I say a heartfelt thank you for all that he did."

Başar said that, because of the many challenges and events taking place during his tenure as Director, and because many high-level positions on campus were held on an interim basis during this time, he did not approach his job as if it were an interim position.

"You're there realizing that you'll be making decisions that will have long-term impact on the institution," Başar said shortly before he left Beckman. "In this position, I have tried to make decisions without the constraints of the length of my term, even though I knew that my commitment was only for the interim."

Başar was happy about the accomplishments during his 20-month tenure and with the success of the many events that took place during that time, such as the 20th Anniversary events and the creation of a new development office at Beckman. Başar also pointed to a faculty retreat held in 2009 as a point of pride.

One of the ideas coming out of that retreat was the Healthy Bodies, Brains, Minds, and Communities Developing Initiative. Another idea from the retreat that was implemented was a program in which Beckman faculty members mentor postdocs and graduate students for academic positions.

An important milestone that occurred during Başar's tenure was the implementation of a fourth research theme, Integrative Imaging. The first new research theme in 15 years, Integrative Imaging, had been in the planning stages when Başar arrived, and has already been a success with 22 faculty members on board.

In addition, Başar oversaw the creation of two new campus-wide strategic initiatives located in Beckman: Social Dimensions of Environmental Policy, and Imaging. He also oversaw the completion of the Arnold O. Beckman Rotunda Exhibit, located in the main campus entrance to the building, which was dedicated on April 14, 2010.

The process of moving the Illinois Simulator Laboratory from the Beckman building to the south campus while bringing the Biomedical Imaging Center into the Institute took place over more than a year of Başar's tenure and went smoothly.

Even while serving as Director, Başar continued to teach and keep his other ties to

organizations, on and off campus. Başar is a Swanlund Endowed Chair Professor of Electrical and Computer Engineering at Illinois, with appointments at the Center for Advanced Study, the Coordinated Science Laboratory, and the Information Trust Institute.

After leaving Beckman, Başar returned to his teaching and research duties full-time and to his office at the Coordinated Science Laboratory, located just south and east of the Institute.

"I will spend most of my time there, only a step away from here, but I will always be a friend of the Beckman Institute," he said.

Tamer Başar served as Interim Director for the Beckman Institute from September 2008 - May 2010.

BIOLOGICAL INTELLIGENCE OVERVIEW

The Biological Intelligence (BioIntel) research theme can trace its heritage back to the mid-1980s and the first formulations of the types of research that would be taking place at the soon-to-be-built Beckman Institute. From those early discussions to today, efforts involving biological intelligence have been one of the research pillars at the Beckman Institute.

BioIntel research has evolved over the years, with advanced technologies providing ever-increasing insight into the fundamentals of brain function, down to the molecular level. At the same time, researchers within BioIntel have kept a focus on issues surrounding higher expressions of intelligence such as memory and learning, as well as topics involving behavior like language acquisition.

In 2010, two new co-chairs were chosen to lead the Biological Intelligence research theme, Mark Nelson and Jennifer Cole. BioIntel research is focused around three groups: Cognitive Science, Cognitive Neuroscience, and NeuroTech. The highly-ranked Department of Psychology at the University of Illinois has more faculty members than any other home department in BioIntel, but researchers from departments such as Linguistics, Electrical and Computer Engineering, Speech and Hearing Science, and Cell and Developmental Biology, are also represented in this research theme.

The efforts of BioIntel faculty members involve research topics ranging from studies of amnesia and attention, to exploring how genetics affects our ability to learn, to experiments that investigate brain function using imaging methods.

The wide variety of research involving biological intelligence at Beckman provided new insights this past year into cognitive issues such as the effects of multi-tasking (**Art Kramer** and **Gary Dell**), the relationship between anxiety and depression (**Greg Miller** and **Wendy Heller**), and working memory (**Monica Fabiani, Gabriele Gratton**, and **Brad Sutton**).

There were studies showing how the molecular workings of the brain influence behaviors such as learning vocalization (**David Clayton** and **Stephanie Ceman**) and adolescent drug use (**Justin Rhodes**). Biological Intelligence researchers are also translating their work into real-world solutions such as discovering new drug targets for treating disease (**Charles Cox**).

Ongoing research lines within BioIntel include studies involving linguistics, such as language comprehension (**Susan Garnsey**), language production (**Kay Bock**), computer modeling of language processing (**Gary Dell**), spoken language (**Jennifer Cole**) and spoken language acquisition (**Cynthia Fisher**), speech production (**Chilin Shih**), meaning aspects of language (**Kara Federmeier**), and sentence processing and comprehension (**Kiel Christianson**); memory topics like amnesia (**Neal Cohen**) and the neural bases of memory (**Brian Gonsalves**); and studies of how we learn (**Brian Ross**). Sensory input and how that input is used by the brain is an important area of research in BioIntel. **Al Feng** investigates the neural bases of sound communication through study of a unique frog in China, while **Mark Nelson** uses the electrosensory capabilities of weakly electric fish to understand neural mechanisms.

Researchers who have joined BioIntel in the last few years are adding to this research theme's diverse portfolio of projects. **Torrey Loucks** has a research focus on stuttering, while **José Mestre** tries to understand how students master a complex subject like physics, and **Stephanie Ceman** uses a cellular approach to topics such as understanding Fragile X syndrome.

Technology is also an important part of research within the Biological Intelligence research theme. Many BioIntel researchers employ functional Magnetic Resonance Imaging (fMRI) and optical techniques to study the brain's regions and functions during experiments while others use eye-tracking equipment, and a rare device called an articulometer for measuring movements of speech articulators during speech production. In addition, computational modeling has become an integral part of their work for many researchers in this theme.

The technology complements the theories, experiments, and hard work of Biological Intelligence researchers and their students as they continue to shine a light into the brain, intelligence, and behavior.

A project initiated and led by David Clayton of Beckman's NeuroTech group is sequencing the whole genome of the zebra finch songbird to provide new insights into vocal communication.

PHOTO BY L. BRIAN STAUFFER

Gary Dell and his collaborators published findings that show driving impairs language skills for both the young and old.

Driving Wrecks Conversation

Beckman Institute researchers delivered some sobering news to mobile multi-taskers: either you can drive well or conduct a meaningful conversation, but not do both at the same time. A growing body of research has shown that talking on a cell phone impairs a person's ability to drive; now the Beckman researchers and their collaborators have shown that driving impairs our ability to comprehend and produce language. Their report, titled *Driving impairs talking*, appeared in the *Psychonomic Bulletin and Review.* Authors of the study included Biological Intelligence research theme members **Gary Dell, Kathryn Bock,** and **Susan Garnsey,** as well as Beckman Institute Director **Art Kramer**. The study was conducted using the driving simulator at Beckman's Illinois Simulator Laboratory. The experiment's parameters made both driving and language production priorities for the test subjects, who consisted of 96 drivers and an equal number of conversation partners. The results showed, as the authors write, that when it comes to "whether driving an automobile interferes with the ability to process and remember language" the answer is "unequivocally affirmative." The experiment required test subjects to listen to a story through earphones and then accurately retell it, in 30 seconds or less, to their partners. That task ensured meaningful language production for the test subjects while the driving task challenged drivers to negotiate an urban roadway environment, obey speed limits, and safely cross busy intersections. "Driving negatively impacts story retelling as well as the process of comprehending and encoding stories into long-term memory," the researchers wrote. "In summary, consistency in driving performance while dealing with speech (less driving variability) came at the expense of accuracy in story retelling. When doing the speech task only, drivers and non-drivers were equally good at retelling. When the car was moving, however, drivers displayed a large decline in speech-task performance."

Zebra Finch Proves Useful Model for Study of Human Communication

A project initiated and led by a Biological Intelligence research theme researcher to sequence the whole genome of the zebra finch songbird is providing new insights into vocal communication. As reported in *Nature* this past year, the sequencing of the zebra finch genome—an effort led by NeuroTech group member **David Clayton**—was analyzed in a large multi-university collaboration that, among other findings, showed that song communication in the birds activates complex gene regulatory networks in the brain. The zebra finch is an important animal model for understanding human vocal communication because the birds, like humans, have the rare capacity to learn vocalizations from their elders. In the case of the zebra finch their vocalizations are songs, and the process of learning these songs, the researchers found, activates hundreds of genes that are quickly turned on and off as the song is learned. Clayton said that the findings have significance for understanding our own vocal communication. "There is a functional developmental parallel between the way a bird learns to sing and a human learns to speak," Clayton said. "The avian brain is quite different in superficial detail from the mammalian brain or the human brain, but some striking parallels have emerged."

Working Memory Capacity and the Aging Brain

Beckman Institute researchers **Monica Fabiani, Gabriele Gratton,** and **Brad Sutton,** and student Nils Schneider were co-authors of a 2010 paper that has important implications for theories on cognitive aging and working memory (WM) in the brain. The paper reported on a project that quantitatively investigated predictions made by a theory of WM

PHOTO BY L. BRIAN STAUFFER

Beckman researcher David Clayton led and initiated a large multi-university collaboration that showed song communication in zebra finches activates complex gene regulatory networks in the brain.

PHOTO BY L. BRIAN STAUFFER

Illinois alumna Anna S. Engels (not pictured) and Beckman researchers Wendy Heller and Gregory Miller found that worry and fear alter patterns of brain activity associated with depression.

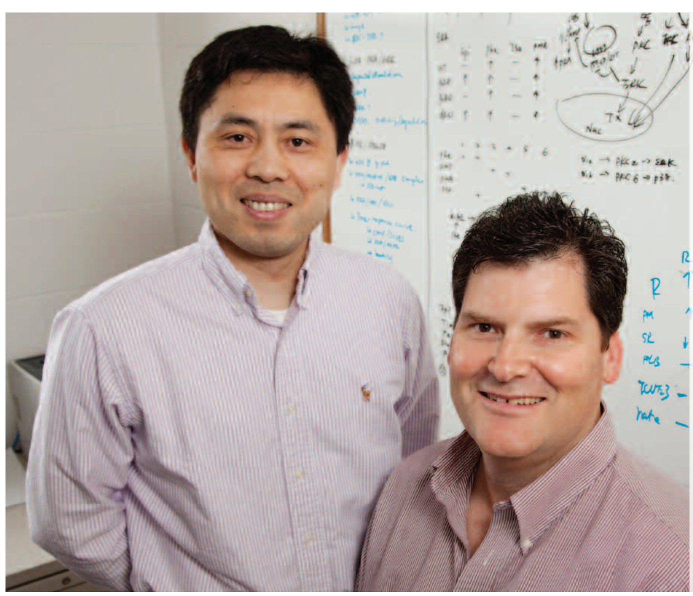
called Compensation-Related Utilization of Neural Circuits Hypothesis, or CRUNCH, using memory search tasks, older and younger test subjects, and functional Magnetic Resonance Imaging (fMRI). The researchers were working with the CRUNCH-based hypotheses that over-recruitment and under-recruitment of brain areas commonly observed between younger and older adults may reflect age-related differences in processing capacity, or ability, and that these differences in recruitment of brain areas in older adults are "explained in terms of the relative activation necessary to cope with the task and to compensate for deficits." Understanding issues such as compensation and age-related differences in processing memory is crucial for researchers investigating cognitive aging, especially when it comes to working memory and cognitive decline. This study found "strong quantitative support for CRUNCH and in particular for the relative utilization of neural networks depending on performance" and that the "individualized span analysis provides an even stronger quantitative support for CRUNCH." The researchers report that the analysis of the working memory span in the subjects "shows that the differences in the brain-activation-by-memory-load function between younger and older adults can be entirely accounted for by differences in span across individuals, regardless of their age. When these differences are taken into account, the curves for younger and older adults are virtually identical." The results mean that they found no special mechanism that accounted for the different pattern of brain activity in older adults with respect to younger adults; rather the differences were explained by relative task difficulty and individual differences, not age differences.

Understanding Effects of Anxiety on Depression

Anxiety and depression are often linked in studies but viewed as separate psychiatric disorders. A recent study led by **Greg Miller** and **Wendy Heller** of the Cognitive Neuroscience group using functional Magnetic Resonance Imaging (fMRI) showed just how much the two disorders are intertwined in the brains of those suffering from them. Using the MRI machines from Beckman's Biomedical Imaging Center, the researchers studied two types of anxiety (worry and anxious arousal) and depression, dividing test subjects into three categories: only anxious, only depressed, and those who had symptoms of both. The results showed many new findings: the type of anxiety a person has modifies the patterns of brain activity in depression; that patterns in the brains of a worried subject were much different than those of an anxious arousal subject; that the combination of depression and which type of anxiety the subject has produces another sort of brain pattern. Miller said the results showed that the particular type of anxiety a person has may help processing in one part of the brain while hurting it in another part. "Sometimes worry is a good thing to do," Miller said. "Maybe it will get you to plan better. Maybe it will help you to focus better. There could be an upside to these things."

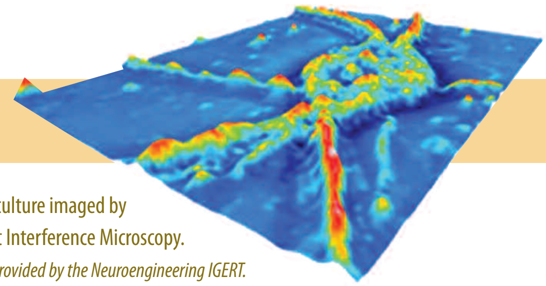
Potential Drug Target for Alzheimer's Disease Discovered

Charles Cox of the NeuroTech group and his collaborator **Kevin Xiang** have found a potential drug target for treating Alzheimer's: a receptor protein that offers a binding target for a protein fragment long associated with the disease. Cox and Xiang, colleagues at the Department of Molecular and Integrative Physiology at the University of Illinois, focused on the beta-2 adrenergic receptor, finding that it binds to the protein fragment, amyloid-beta, that has long been associated with Alzheimer's disease; plaques formed from amyloid-beta aggregation have recently been linked to neuronal toxicity and been shown to impair neuronal function in animal models. Studies have shown that amyloid-beta can lead to increased activity via the AMPA receptor



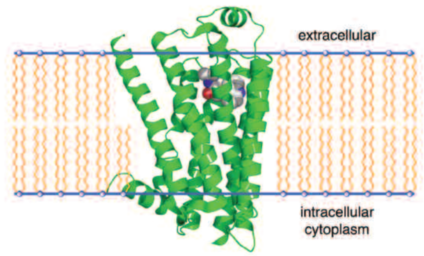
Beckman researcher Charles Cox (right) and his collaborator Yang (Kevin) Xiang have found a potential new drug target for the treatment of Alzheimer's disease.

PHOTO BY L. BRIAN STAUFFER



Rat hippocampal neuron in culture imaged by Spatial Light Interference Microscopy.

Image provided by the Neuroengineering IGERT.



The beta-2 adrenergic receptor (green) spans the cell membrane (orange and blue). In this visualization, a binding pocket in the receptor interacts with a beta-blocker (red, gray and blue molecule near the center). The new study found that amyloid-beta, a protein fragment linked to the detrimental effects of Alzheimer's disease, binds to a different region on the beta-2 adrenergic receptor.

which, like the beta-2 adrenergic receptor, is found in the membranes of neurons and other cells. The problem with finding an effective Alzheimer's drug target receptor is that AMPA receptors bind to the most common neurotransmitter in the brain, glutamate, so drugs targeting AMPA receptors would likely lead to widespread, unwanted side effects because they would not allow glutamate to continue to do its job. Cox and his collaborators made the discovery that amyloid-beta binds to beta-2 adrenergic receptors and alters activity mediated by AMPA receptors, a connection which leads to increased neuronal activity and, ultimately, could lead to neuronal toxicity. By knocking out the beta-2 adrenergic receptors in animal models, the researchers found that amyloid-beta no longer changes the activity mediated by AMPA receptors. Dampening the activity of beta-2 adrenergic receptors with beta blocking drug treatments is currently used as a treatment for heart arrhythmias and hypertension, but had not been studied closely before for its possible role in the association between amyloid-beta and Alzheimer's.

Seeing the World in Waves of Consciousness

A research line at the Beckman Institute is challenging beliefs about how our visual systems interpret the world, showing that we sometimes take in our surroundings in "waves" rather than "streams" of consciousness. Researchers from Beckman's Cognitive Neuroscience group reported in 2009 on the discovery of a pulsed inhibition mechanism in the brain, a finding that showed the visual system often fails to perceive normally detectable visual stimuli from the environment because the brain samples the visual environment in rhythmic "frames" rather than continuously. In 2010 a second paper reported that these rhythmic frames can be entrained to external signals and induce an increase in visual sensitivity at the precise moment in time in which a visual event is expected to happen. Authors of the paper were **Diane Beck, Monica Fabiani,** and **Gabriele Gratton** from the Cognitive Neuroscience group, **Alejandro Lleras** from the Human Perception and Performance group, and graduate student Kyle Mathewson. Their experiments showed that the observed effect of rhythmic frames can be controlled through entraining the brain and that this entrainment may, as they wrote in their paper, "represent a mechanism by which temporal attention is tuned to produce temporally-precise peaks in visual sensitivity, to both anticipate and optimize visual processing of brief visual events. Rhythmic visual entrainment has a dramatic effect on visual sensitivity, providing us with a powerful technique to experimentally control with fine temporal precision whether or not near-threshold stimuli reach conscious awareness." The results are the first evidence that the brain rhythms of the visual system can be entrained to have control over the visibility of stimuli. Beck said that means that "the brain can synchronize its waves of consciousness to predictable rhythmic events."

Image created by Kyle Mathewson to accompany the research on how visual systems interpret the world.

Beckman Researchers Land IGERT Neuroengineering Program

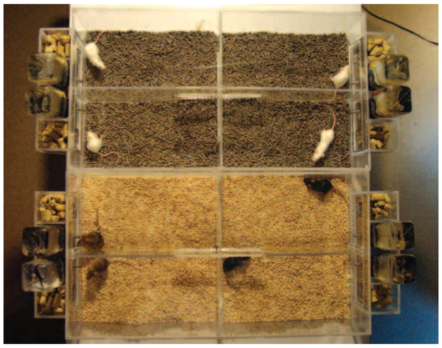
Neuroengineering, the joining together of neuroscience, computation and engineering, is a rapidly emerging field that holds great potential for advancing research in a number of areas, as well as leading to applications like futuristic medical devices based on brain-machine interfaces. In 2009 Illinois became a focal point for this exciting new field when the National Science Foundation awarded a five-year Integrative Graduate Education and Research Traineeship program grant (IGERT) to the University of Illinois to train future researchers how to collaborate in interdisciplinary neuroengineering projects. More than 60 Illinois faculty members are associated with the training program, which is led by Beckman Institute faculty members **Doug Jones** as its principal investigator (PI) and co-PIs **Monica Fabiani** and **Todd Coleman,** along with Bob Wickesberg from the Department of Psychology. In the program, which was launched in the fall of 2009, engineering students learn about neuroscience while students with a neuroscience background learn about facets of engineering that could be applied to neuroengineering research. Students in the program take courses in three successive semesters, beginning with a basic signal analysis course for the neuroscientists and a basic neuroscience course for the engineers. The next semester students specialize in the three research areas of the IGERT program: audition, brain machine interfaces, and neuroimaging. The third semester features pairs of one engineering student and one neuroscience student working on individual

Beckman faculty member, Justin Rhodes (front row, first person on the left), and his research group at the Beckman Institute.

projects. The three research thrusts of the program feature two areas that are strengths at Illinois, audition and neuroimaging, and a third, brain-machine interfaces, that is on the leading edge of where human-technology interaction is headed. The program and grant proposal to NSF had its genesis in informal discussions between Jones and Coleman, leading to the proposal that won out in an intense competition for the IGERT grant, which totals $3M over the five years.

Biological Insight into Patterns of Adolescent Drug Use

Justin Rhodes of the NeuroTech group reported on research showing stark differences in the neural patterns and behavior of adolescent and adult mice given cocaine and methamphetamine, a finding that provides important biological insights into the dangers of youthful drug use in humans. Rhodes and his collaborators showed for the first time that in a part of the brain that plays a role in addiction, adolescent and adult male mice given equal doses of the drugs showed marked differences in locomotor stimulation effects and in neural activity. The findings have implications for understanding the neural mechanisms underlying addiction, especially for those who experiment with drugs at an early age. According to the researchers, adolescents displayed "dramatically reduced sensitivity to the acute locomotor stimulating effects of cocaine and methamphetamine," and greater neural activity compared to adults given the same dose. Other studies have shown that reduced sensitivity is a predictor of future addiction. Rhodes said that by revealing the locale and the differing effects of the drugs on the brains of these two groups, the research is a step toward describing the workings of those mechanisms. The findings were reported in a paper in *Neuroscience.* One of the study's biggest findings is the locale of the neural activity produced by the drugs. Developing brains have more dopamine receptors—key in the body's system of rewards—than those of adults; those receptors project from the ventral mid-brain to nerve cells in the striatum. Rhodes said the fact that the adolescent mice displayed greater neural activity and less sensitivity to the effects of the drugs is important because less sensitivity in an adolescent human brain means there is less chance of an aversive reaction the first time they try a drug like cocaine—a fact that could make it more likely they will try them a second time.



Research in the Rhodes Lab focuses on the neurobiology of physical exercise and drug abuse using laboratory mouse models.

Al Feng

The Beckman organizational structure allowed the Intelligent Hearing Aid project to flourish. Then to solve an engineering problem using a biological principle is just doubly sweet.

FENG A LEADER IN COMBINING BIOLOGY AND ENGINEERING

At an institute dedicated to the proposition that an interdisciplinary approach to research works best, Al Feng might just be the most interdisciplinary researcher of them all. Feng's CV boasts an electrical engineering degree that had a focus on biomedicine, Ph.D. and postdoctoral work involving physiology and neuroscience, and research as an original member of the Beckman Institute that produced a medical engineering marvel and the discovery of a unique capability in the animal kingdom.

Feng joined the Institute a few months before it officially opened in the spring of 1989 and was a founding member of the Neuronal Pattern Analysis group at Beckman, the predecessor to his current NeuroTech group. He is one of the world's leading researchers in the neural bases of sound communication, a fact that led to his involvement in two seemingly disparate but major groundbreaking research efforts. One was that engineering marvel, an intelligent hearing aid that works in noisy environments, and the other the discovery that a Chinese frog could communicate using ultrasound, the first time an amphibian had been shown to have that capability.

But those two breakthroughs in seemingly different arenas—the hearing aid involved biomedical engineering and the frog discovery biology, including field studies of the creatures in their remote habitat in rural China—are related. Feng's early research into the neural bases of communication in frogs played a role in designing the Intelligent Hearing Aid, a device which received national attention and was later licensed by a large hearing technology company.

And after that project was done, a now yearly journey to China to study a unique frog species, called *Odorrana tormota*, produced another accomplishment that resulted in worldwide attention. Feng and his collaborators found that the males of the species communicated using ultrasound as well as audible frequencies, something scientists had thought only certain species such as bats and dolphins could do. They followed that discovery by learning that, unlike most frogs, the females also vocalize to communicate with and attract males and that *Odorrana tormota* have a nearly limitless vocal repertoire. They also are able to produce a variety of calls and distinguish calls of individual males with a precision that rivals animals like dolphins and even humans.

When asked to choose which of these two research feats was most satisfying to him, Feng answered like a proud parent.

"I got equal pleasure in both accomplishments, in the technology development as well as the pursuit of science," he answered.

Feng's journey from electrical engineering to neurobiology in the 1970s was unusual for its time but not as circuitous as it may seem. As part of his master's degree from Miami, Feng was required to build biomedical devices and he kept veering more toward biology while earning a Ph.D. at Cornell that had him qualify for a doctorate in both electrical engineering and neurobiology.

"While at Miami, I was exposed to extensive use of electronic gadgets in medical practices and the understanding that the human body really relies on a lot of electrical signaling for the functioning of the heart and the brain, in particular, and other parts of the body," Feng said. "There I found my background in electrical engineering to be very handy."

Feng later joined the University of Illinois as a member of what is now called the Department of Molecular and Integrative Physiology, from which he retired earlier this year. When he first came to Beckman more than two decades ago, Feng believed his days of inventing and designing gadgets were over.

"In the beginning I didn't think I would venture back to the engineering side," Feng said. "I thought for awhile that an engineering feat was not going to be something I would accomplish."

But as often happens at Beckman, good things happen to those who collaborate. So he was well-prepared for the Intelligent Hearing Aid project when he and Beckman colleagues Bruce Wheeler and Charissa Lansing led a team that brought it to life in 1992.

Feng had served on a Long-Range Strategic Planning Committee at the National Institutes of Health on hearing and deafness disorders, and learned about problems people were having with the performance of their hearing aids, especially when it came to understanding speech in noisy environments, also known as the cocktail party problem.

"As an engineer trained in biomedical engineering and knowing the state of the art of electronics, I just could not believe there was a deficiency in the performance of an electronic gadget like that," Feng said. "I remember speaking to Bruce and he could not believe it either. He said 'no way; we can build any gadget.'

"Then we met with Charissa Lansing from Speech and Hearing Science and basically she confirmed that it is a serious problem because people will always tell you, 'yeah the hearing aid has helped me to hear but it doesn't help me to understand.' That really was the trigger for the Intelligent Hearing Aid project."

A visit with then Beckman Institute Director Jiri Jonas helped get the project rolling and within three years year they had a hearing aid prototype, using an algorithm inspired by Feng's work on the ability of frogs to localize and distinguish sounds in a noisy environment. The biomimetic, or biologically-inspired, signal-processing algorithms and two directional microphones were used in the hearing aid to extract the desired signals from a noisy environment. Feng liked the interdisciplinary nature of the project, both in the science and the team members.

"That was truly satisfying because that showed the power of teamwork too," Feng said. "That also shows the Beckman model is really the right model to pursue this kind of science and technology development because clearly we have shown that teamwork gets the job done. The Beckman organizational structure allowed this thing to flourish.

"Then to solve an engineering problem using a biological principle is just doubly sweet," he added with a laugh.

HUMAN-COMPUTER INTELLIGENT INTERACTION OVERVIEW

Computer technology has become so interwoven into the fabric of 21st Century life that its influence isn't always known and advances in applications like electronic devices are often taken for granted. Recent research highlights in the Human-Computer Intelligent Interaction (HCII) research theme testify to that pervasive influence, including studies such as how cell phones distract pedestrians and the role brain volume plays in video game success.

But projects within HCII involve more than just the immediate human-computer interactions obvious all around us in the forms of laptops and digital cameras. They also involve studies of the effects of social interaction on cognitive function, and investigations of the visual, both how humans process the world around them and how computers can learn to recognize objects in images through newly-developed algorithms.

The main mission of the Human-Computer Intelligent Interaction research theme is to enhance those interactions through research and technology development in three main groups: Artificial Intelligence, Human Perception and Performance, and Image Formation and Processing. Co-chairs for HCII are Tom Huang and Dan Morrow, who was chosen in 2010 to replace Art Kramer, who was named Beckman Institute Director in May.

The projects within HCII are as diverse as any of Beckman's four research themes. They are as far-reaching as developing sensors for underwater vehicles based on an adaptation fish use to sense water flow **(Doug Jones)**, to studying the effects on cognition of factors like the impact physical goals can have on our mental states **(Edward McAuley)**.

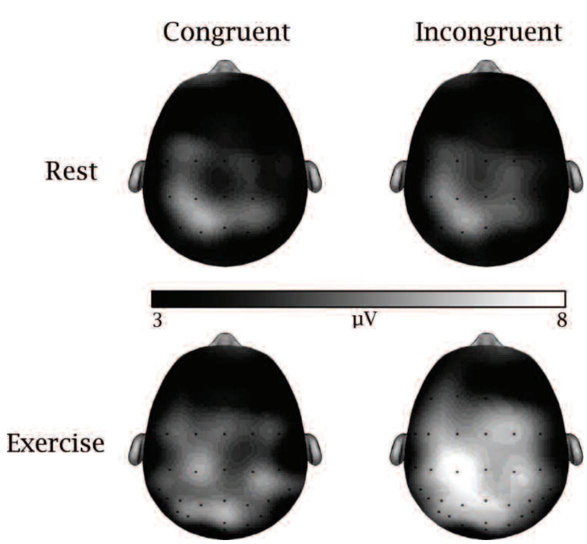
Then, of course, there is the advanced technology found within HCII. In 2010, a humanoid robot called an iCub was added to researcher **Steve Levinson**'s Language Acquisition and Robotics Laboratory, making it the only research group in America to be awarded one of the highly advanced robots. The iCub, which costs around $300,000, was awarded to the lab for research into language acquisition and other aspects of human learning free of charge for 99 years. It is designed in both size and capabilities to simulate the way a human toddler learns about their world.

Perhaps no computer technology is more omnipresent than cell phones, and HCII faculty members like Kramer have pioneered research into the effect these ubiquitous devices have on our lives. Kramer led studies looking at the ways in which cell phone usage distracted drivers. A new research line looking at the effects of cell phones and other electronic devices on pedestrians produced its first paper this past year.

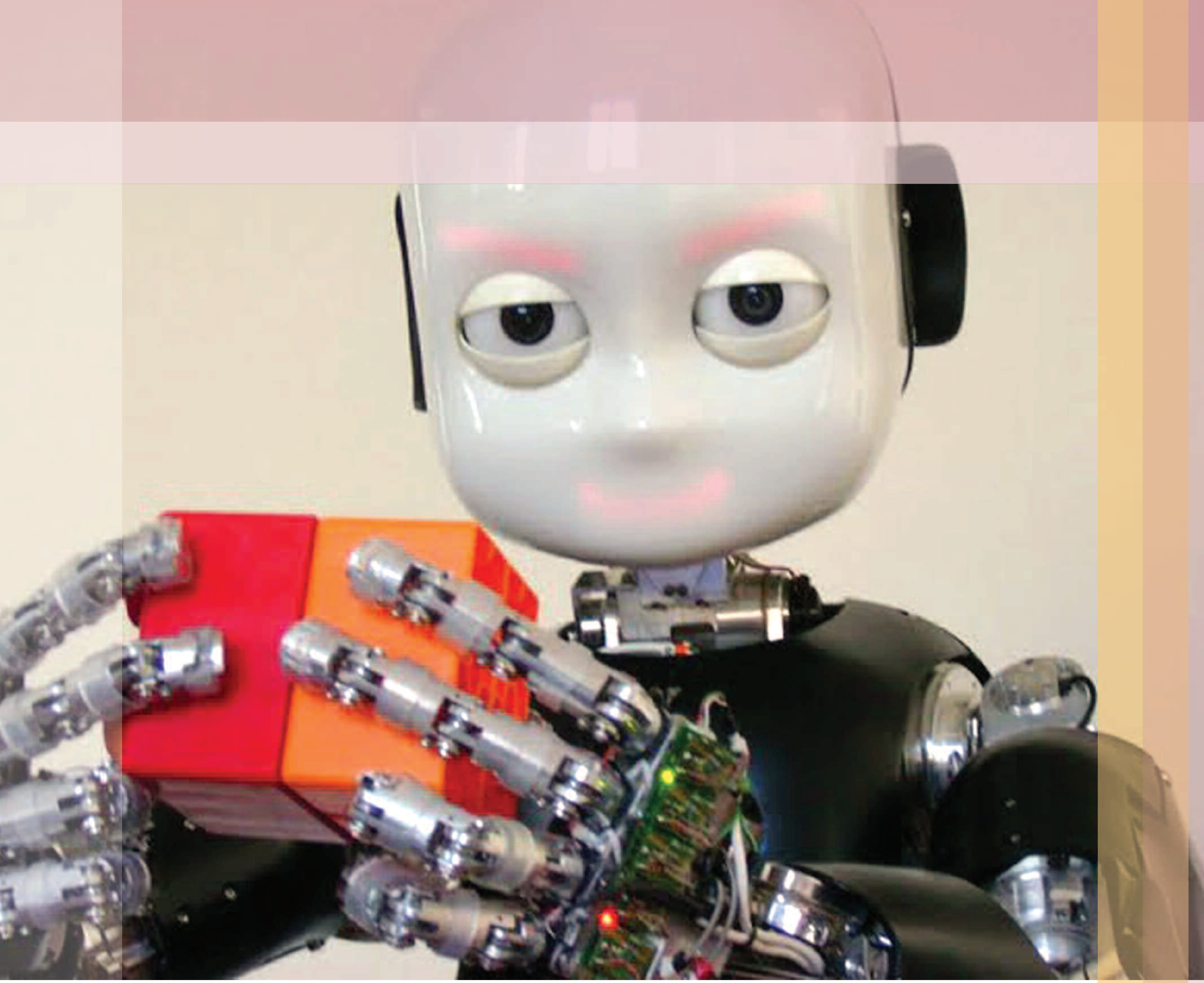
As with cell phones, much of the research taking place in HCII has a direct impact on people's lives. **Jont Allen** is working to improve hearing aid technology while **Deana McDonagh**'s efforts involving students with disabilities in her industrial design classes has led to innovative designs for people with disabilities. HCII researchers like McAuley and **Charles Hillman** are studying the cognitive benefits of exercise while **Elizabeth Stine-Morrow** looks at the beneficial effects that team problem-solving can have for older adults.

Researchers from HCII were also part of the popular entertainment world in 2010. **Dan Simons** co-authored a popular psychology book called *The Invisible Gorilla* based on his work involving attention, memory, and visual perception that drew praise from reviewers in the *New York Times* and numerous other publications. **Pierre Moulin**'s contribution to popular culture is truly invisible, as he develops software that imprints digital fingerprints in movies for piracy prevention.

The influence of HCII researchers is felt far beyond the Beckman Institute. Three HCII faculty members,



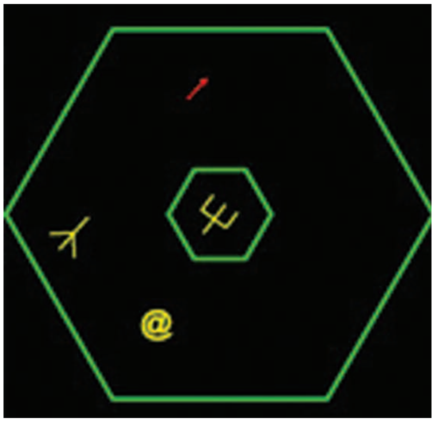
The image at right is from Charles Hillman's research that studies the cognitive benefits of exercise.



Narendra Ahuja, Jiawei Han, and Huang, received the HP Labs Innovation Research Award in 2009. In addition, Huang and **Mark Hasegawa-Johnson** led a team of researchers from NEC Labs America and the Beckman Institute that was ranked first in two international evaluations of algorithms for solving challenging visual recognition tasks: TRECVID (Video Event Detection), and PASCAL visual object classification.

The variety of projects within the Human-Computer Intelligent Interaction research theme are advancing research and technology in areas as diverse as human brain function and cognition, computer vision and processing, and how it is humans learn to navigate the world.

The iCub joined Stephen Levinson's Language Acquisition and Robotics Laboratory in February, 2010. Levinson's lab has the only iCub in the United States and North America and is the only research group using one to study language acquisition.



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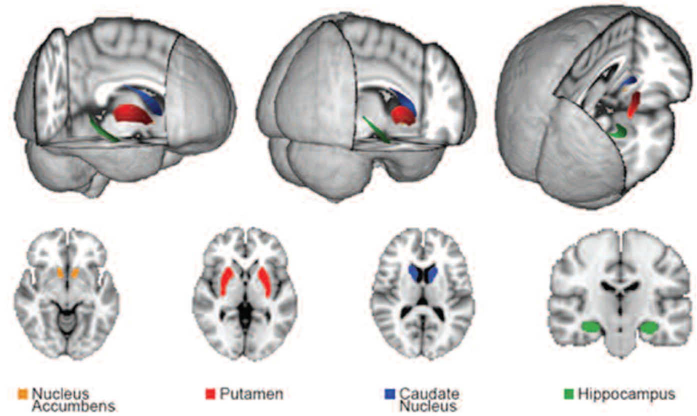


Left: Video game Space Fortress, developed at the University of Illinois, requires players to try to destroy a fortress without losing their own ship to one of several potential hazards. The game can be manipulated to test various aspects of cognition.

Above: MRI scans reveal the brain structures analyzed in the gaming study: nucleus accumbens (orange), putamen (red), caudate nucleus (blue), and hippocampus (green). *Photo courtesy Cerebral Cortex. Rights-protected image. Contact Oxford University Press.*

Brain Volume Predictive of Video Game Success

Video gamers may think hand-eye coordination is the key to scoring points but the volume of a particular part of their brains may be the best barometer of success. **Art Kramer** of the Human Perception and Performance group was a co-principal investigator of a multi-institutional research project that discovered that the volume of particular parts of the striatum were predictive of performance and learning rates on a video game called Space Fortress. The game was developed at the University of Illinois and the functional Magnetic Resonance Imaging measurements of the subject's brains were done at Beckman's Biomedical Imaging Center. The researchers looked at the volume of brain structure in three different parts of the striatum in test subjects divided into two groups of game players trained on two versions of Space Fortress. The results showed that those subjects with larger brain volume in the part of the striatum associated with rewards did better in the early part of the training period, while those with larger volume in areas associated with learning new skills did better throughout the training period. Kirk Erickson, a former graduate student of Kramer's who is now at the University of Pittsburgh, said the results provide insight into more than how the brain works when learning to play a video game. "This study tells us a lot about how the brain works when it is trying to learn a complex task," Erickson said. "We can use information about the brain to predict who is going to learn certain tasks at a more rapid rate."

Body Movements Affect Cognition

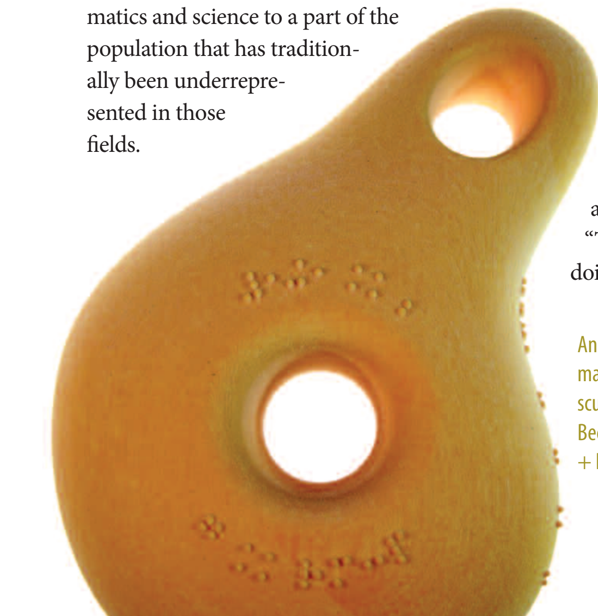
Alejandro Lleras of the Human Perception and Performance group has shown in previous research that directing the eye movements of test subjects affected their cognitive processes when it came to problem-solving—challenging the idea that cognitive function always controls eye movements. In 2009 Lleras and his former graduate student Laura Thomas reported that the concept also applies to body movement through their study showing that directing test subjects to swing their arms helped them solve complex problems. It was the first research to demonstrate how a person moves can affect their ability to solve a problem. The experiment featured subjects trying to solve a problem, with the problem-solving sessions separated by 20 seconds of exercise that featured one group of subjects swinging their arms forward and backward and another group doing arm stretches. The subjects doing the arm-swinging were activating a part of their brain that unconsciously required them to think about that type of motion while problem-solving. The results demonstrated that directed movements can guide a high level cognitive processing task like problem-solving without the person being aware of it.

PHOTO BY L. BRIAN STAUFFER

Beckman faculty member Alejandro Lleras led research that demonstrated that physical movements, such as eye movements or arm swinging, can aid in problem solving.

Creating Tools for the Visually Impaired to Learn Math

The work of Human Perception and Performance group member **Deana McDonagh** introducing students with disabilities to the field of industrial design has led to a career path change for at least one of those students and a potentially life-changing creation for children with visual impairments. Sheila Schneider's experience as a student in McDonagh's Disability + Relevant Design class inspired her to become the first legally blind student to major in sculpture at the University of Illinois's School of Art and Design where McDonagh is a faculty member. As part of a project directed by McDonagh, Schneider is creating small sculptures imprinted with mathematical and scientific symbols in Braille. The aim of the project is to help the 12 million children with visual impairments learn mathematics by giving them a hands-on experience with the sculptures. The sculptures follow McDonagh's theory of empathic design, which takes the users's needs into account during the design process. The process began with Schneider sculpting balsa foam cube models that were turned into 3-D computer images for modeling bronze sculptures that will be used by teachers of visually impaired students in the classroom to determine their effectiveness, as well as user factors such as where to place the symbols. Since most math instruction for the visually impaired is currently done with abacuses, the sculptures could become a unique new tool to introduce mathematics and science to a part of the population that has traditionally been underrepresented in those fields.



Digital Fingerprinting of Movies

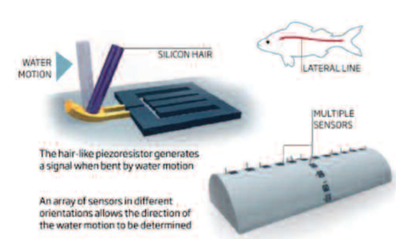
As you watch a crime scene investigator in a movie look for evidence, know that the movie itself is providing a clue toward crime prevention. Most movies today include an on-screen yet invisible anti-piracy digital fingerprint that stamps the individual theater showing the motion picture—a technology that is being advanced by Beckman Institute researcher **Pierre Moulin's** research into the forensics of video and images. Moulin, a member of the Image Formation and Processing group at Beckman, is a leader in decoding those clues through his research into information hiding and extraction in images and video. Moulin describes a digital fingerprint as "an invisible pattern superimposed onto the image in the case of image fingerprinting, or an inaudible pattern in the case of audio." He said that once a pirated DVD is obtained, then the question becomes one of how to extract the digital fingerprint from it. Moulin has developed applications for extracting digital fingerprints that need to be both invisible and detectable. Moulin's digital fingerprinting methods are based on mathematical theories and algorithms and are currently in use worldwide. Hiding information such as digital fingerprints in a movie and extracting that information when the need arises is the key focus of work in information forensics. "It is a field that is quite multidisciplinary because it addresses issues that pertain to content of images and video and how you present them efficiently, and also to coding techniques and information theory," Moulin said. "There are several fields that are essential to doing this kind of work."

An example of a small sculpture that is imprinted with mathematical and scientific symbols in Braille. The sculpture was created by Sheila Schneider, a student in Beckman faculty member Deana McDonagh's Disability + Relevant Design class.

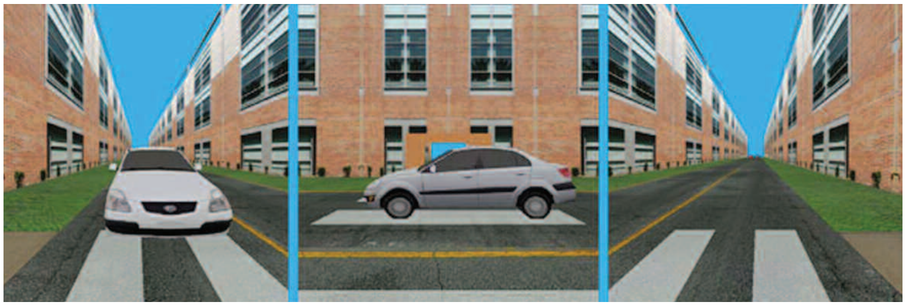
Pierre Moulin, a member of Beckman's Image Formation and Processing group, is a leader in "digital fingerprinting" methods.

Creating an Underwater Sensor Inspired by Fish

Using biomimetics, or nature-inspired, technology, **Doug Jones** from the Image Formation and Processing Group collaborated with former Beckman researcher Chang Liu from Northwestern to create a pressure sensor that could be used for navigation and detection in underwater vehicles. The pressure sensor created by Jones and Liu uses artificial neuromasts patterned after the lateral-line, hair-like sensors composed of receptor cells called neuromasts that run along the bodies of fish. Fish use neuromasts to sense flow field around them, detecting pressure changes and movement of water, which allows them to sense depth and current direction. It is a capability that could come in handy for underwater vehicles operating in murky waters with low visibility. The sensor array created by Jones and Liu uses a piezoresistor composed of lateral-lined, boron-treated silicon "hairs" that generate signals when affected by the movement of water. The resistance of the hairs change in response to the water movement, and the force of the water can then be calculated. The technology could be used for underwater robots or robot submarines to help them detect potentially hazardous objects when low visibility adversely affects cameras or the object is too close for sonar to be effective.



The image above describes research by Beckman faculty member Doug Jones and his collaborators.



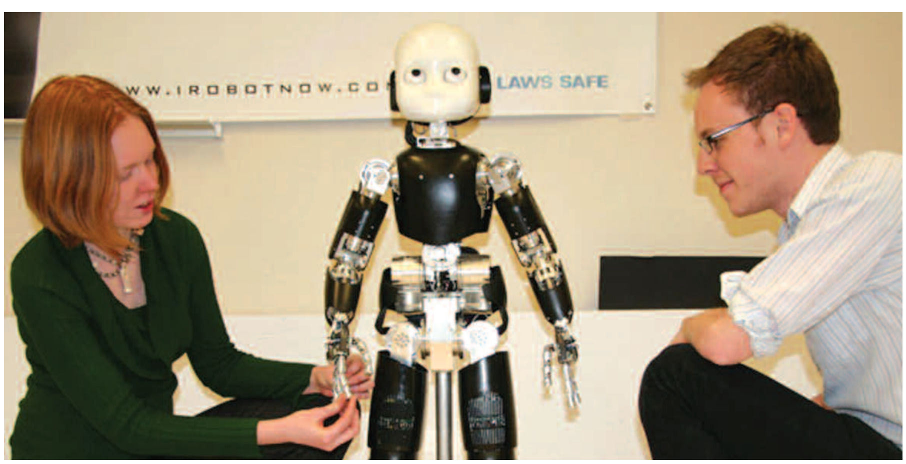
Mark Neider (above) and Art Kramer from the Human Perception and Performance group explore the topic of pedestrian distraction while using cell phones or listening to music.

Pedestrians Distracted by Cell Phones

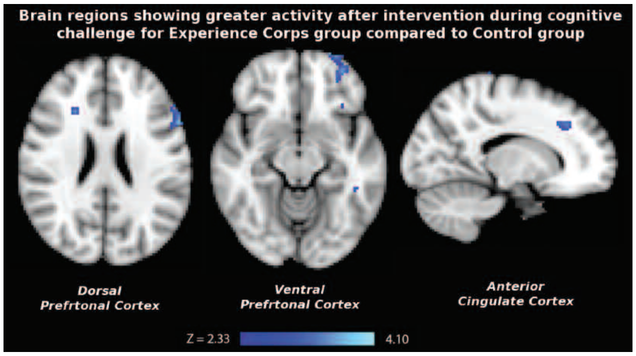
As past Beckman Institute research showed cell phone use distracts drivers, a new research line is showing the same hazardous effect for pedestrians. Using a modified treadmill in the CAVE™ virtual reality environment at Beckman's Illinois Simulator Laboratory, researchers **Art Kramer** and **Mark Neider** from the Human Perception and Performance group reported on the results of test subjects engaging in the dual tasks of talking on a cell phone or listening to music on an iPod while they tried to cross a virtual reality street. The researchers found that talking on a cell phone was in fact a distraction while trying to cross the street but that listening to an iPod was not. The experiments did not result in any of the test subjects colliding with a virtual car or being distracted while listening to music, but the study was the first in an ongoing research line, so future results should add more information on those issues. Regardless, the researchers said, these initial results show that trying to perform two tasks, especially one as potentially hazardous as crossing a street, should be done with caution."That's why we began this, as a way to look at yet another automatic behavior that we assume is impenetrable," Kramer said. "But, with respect to distraction, it is not impenetrable because, when this behavior is in the context of the real world, you really do have to pay attention to what's going on. We are not, evidently, experts on paying attention to vehicles when we are crossing the street."

Rare iCub Humanoid Robot Joins Beckman

It was a more than year-long process of writing proposals, competing against top research labs from around the world, waiting for the humanoid robot prize to be awarded, and then finally shipped from Italy to the Beckman Institute. But with the arrival of the iCub in February of 2010, the Language Acquisition and Robotics Laboratory at Beckman led by Stephen Levinson was handed the keys to a rare research tool for investigating language acquisition, as well as other topics related to how humans learn to navigate their worlds. Levinson's lab was awarded the iCub, a highly advanced humanoid robot that is intentionally the same size as a human toddler, for 99 years by a European robot research consortium to study language acquisition and other issues related to human learning. The iCub's motor skills and sensors are so advanced that it responds to touch (key for acquiring language, such as when learning to differentiate between a hard object and a soft object), uses its articulated hands for dexterous manipulation, and uses its fully articulated head and eyes for detection and navigation in the world. All of these skills and sensory abilities are designed to mimic those of a human infant, so that researchers can gain insights into the ways language and other skills are acquired by a child: through interactions with the world around it, by learning about its own body movements and motor skills, and by absorbing knowledge from its "parent-teachers", in this case the lab members. The Levinson lab is the only research group in the western Hemisphere awarded an iCub, and it is the only lab in the world using one to study language acquisition.



Graduate students Lydia Majure and Logan Niehaus of the Language Acquisition and Robotics Laboratory are shown checking out the iCub.



The image at left was provided by Art Kramer and graduate student, Michelle Voss. It supports their research that shows social activities and volunteerism can provide cognitive benefits.

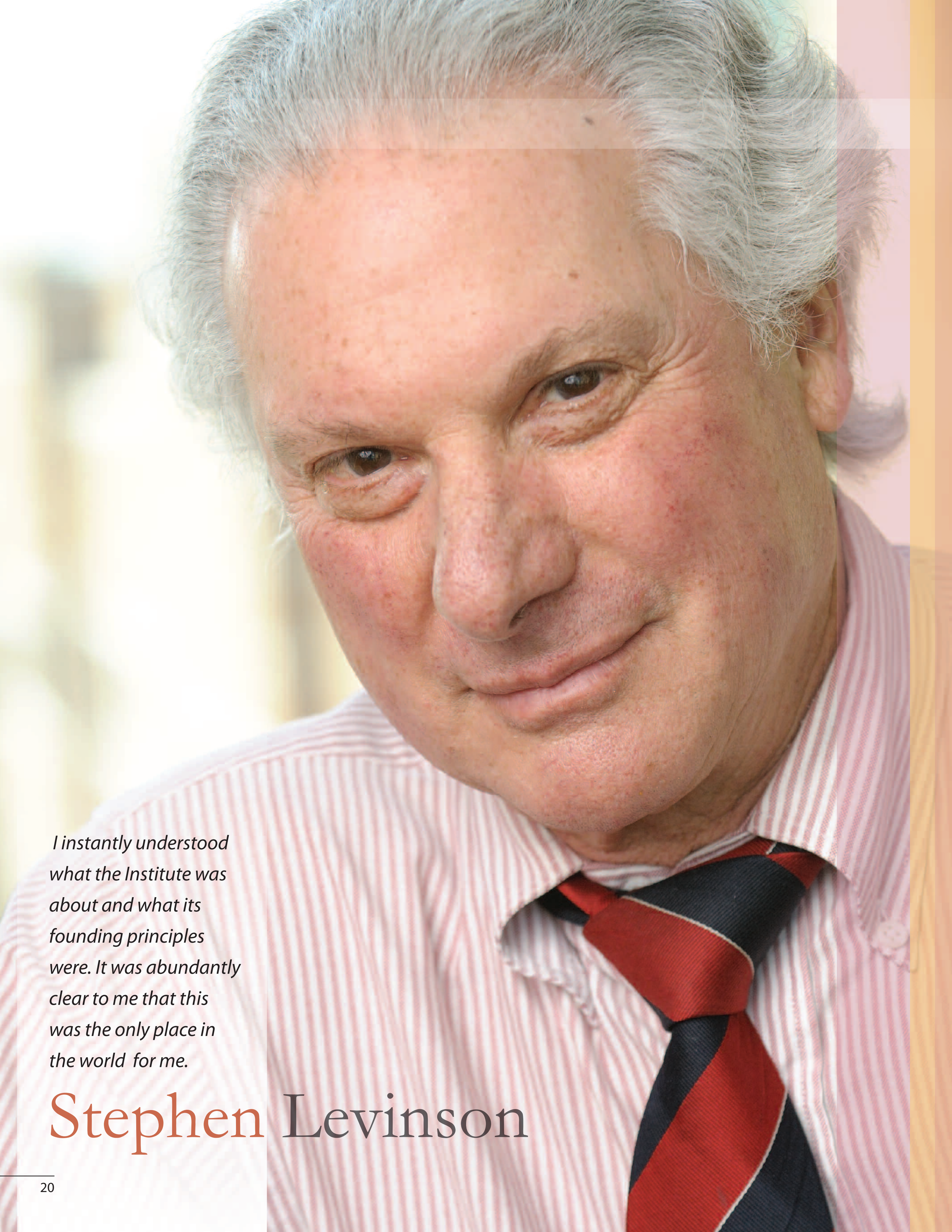
Social Activities and Volunteerism Can Improve Brain Function

Older adults who volunteer can not only help those they are trying to serve, but they can also gain important cognitive benefits for themselves. Beckman Institute Director **Art Kramer** and his graduate student **Michelle Voss** were part of a multi-university study that looked at whether the social service program Experience Corps could improve age-vulnerable executive functions and whether increased cognitive and physical activity could increase activity in brain regions for a high-risk group, in this case older females who were volunteers with the program. Using functional Magnetic Resonance Imaging, the researchers report they were able to demonstrate "intervention-specific short-term gains in executive function and in the activity of prefrontal cortical regions in older adults at elevated risk for cognitive impairment" in the test subjects. The Experience Corps volunteers, who were serving as tutors for public school children in Baltimore schools, had low education, low income, and other factors indicative of a risk for cognitive impairment in older adulthood. The researchers write that this study gives older adults hope for improving cognitive function through participation in volunteering and other social service activities: "These pilot results provide proof of concept for use-dependent brain plasticity in later life, and, that interventions designed to promote health and function through everyday activity may enhance plasticity in key regions that support executive function." The study is the first to test the effects of the program on brain and cognition. Experience Corps is a national program with the mission of engaging "people over 55 in meeting their communities' greatest challenges."

Edward McAuley, a member in the Human Perception and Performance group at the Beckman Institute.

Mastering Physical Activity also Plays Role in Reducing Disease-related Depression

While it is known that a person suffering from depression can benefit from exercise, an important corollary to that intervention technique, according to **Ed McAuley** of the Human Perception and Performance group, is that a belief in one's own ability, or self-efficacy, when it comes to exercise can also be instrumental in reducing depression. McAuley's research has previously shown that increased physical activity also increases self-efficacy and a sense of well-being. In 2009 he was lead author of a study involving subjects with diseases showing that physical activity also influenced their levels of depression and fatigue by increasing self-efficacy. By analyzing data from previously published studies involving breast cancer survivors and people diagnosed with multiple sclerosis, the researchers found a correlation between higher levels of physical activity and higher self-efficacy, as well as lower levels of depression and fatigue. When self-efficacy was controlled for, they discovered significantly reduced effects of physical activity on fatigue and depression. The results show that gaining a sense of mastering the physical activity can help to reduce depression and fatigue.



I instantly understood what the Institute was about and what its founding principles were. It was abundantly clear to me that this was the only place in the world for me.

Stephen Levinson

LEVINSON PLOTS HIS COURSE FOR SUCCESS

When he talks about his love for sailing, Stephen Levinson makes it seem like nothing else exists when his sailboat, the Sylphide, is cruising at top speed on an Atlantic Ocean summer's day and he's holding onto the rigging of the forward sail.

"One of my favorite things to do is when we're really sailing along and going as fast as the boat can possibly go, is to go up on the foredeck and hold onto the forestay and just look up at the shape of the headsail," Levinson said. "There is just something I can't describe. It's a feeling you get, to see the shape of the sail and to feel the force of the wind pulling the boat through the water, is priceless."

But those moments don't make up Levinson's entire summer break. Some of this Beckman Institute robotics researcher's most important work, in fact, is done in his seaside condominium in Mystic, Conn., and at conferences in the summer.

Levinson spends the academic year as a faculty member in the Beckman Institute's Artificial Intelligence group and at the Department of Electrical and Computer Engineering at the University of Illinois. But when Levinson tells colleagues and others that he spends his summers in Mystic sailing along the eastern seaboard, they often assume it is one long, leisurely holiday, or some kind of refuge from his professional life.

"The truth of the matter is that it certainly is a change of pace and it certainly is a change of venue but some of the most important things I've done since I've been at Illinois have been worked out during summers," Levinson said. "For example, my meeting with David Vernon was at a conference that took place in July. I spent the rest of the summer talking to him and working out with him how I should go about applying for the iCub."

The iCub is a highly advanced humanoid robot that is the gem of Levinson's Language Acquisition and Robotics Laboratory at Beckman. It was created (at a cost of about $300,000) by a European robotics consortium and given to Levinson's lab free for 99 years to study language acquisition in a way that has never been done before: having a robot learn language as a child would. The Levinson proposal for one of 10 iCubs won out over many larger research groups in a worldwide competition because of their focus on studying language acquisition. It also helped that Levinson spent the summer of 2007 preparing the proposal with the help of Vernon, then head of the RobotCub project that created the iCub.

The iCub is a robotic version of a human toddler with anthropomorphically correct body parts, articulated hands for manipulating objects, and sensors that provide sight, sound, and touch information to the robot's computing system.

"The thing about the iCub, if you compare it to the robots we built, this robot is fully humanoid and it has a much richer sensory motor periphery," Levinson said. "And the idea is that with much more information coming in from the outside world and with a much greater capability of manipulating the outside world, it opens up the opportunity to really head more toward natural language. We can explore things that we couldn't possibly have explored before."

Unlike other robots, the iCub won't be programmed to accomplish tasks but rather programmed to "learn" on its own, through interactions with the world, such things as the meaning of verbs—just as a human toddler learns language.

"I can honestly say that this is the most exciting event in my entire research career," Levinson said of the iCub acquisition. "Unqualified, I can say that it is. And I've been at it for awhile."

Awhile in Levinson's case means first getting hooked on research in his undergraduate days at Harvard, continuing through an engineering Ph.D. at the University of Rhode Island that also included an introduction to speech and hearing science, and into a 23-year stint at Bell Labs. Levinson describes Bell Labs as a paradise for researchers during the time he worked there, but his interest in using robotics to understand language, which first began there in the 1980s, had to be pursued on his own time.

In an event that proved to be fortuitous for Levinson and the field of language acquisition, the breakup of Bell's parent company, AT&T, forced him to look elsewhere. His boss at the time, Jim Flanagan, just happened to be on the first advisory committee for the new Beckman Institute.

"I said 'Jim, what the hell am I going to do' and he said 'well you ought to look into the University of Illinois; it's a great place,'" Levinson recalled. "I said 'I don't want to go there; I want to stay in the northeast.' And he said 'you really ought to go to the University of Illinois. They have built a palace out there.' What he was referring to was the Beckman Institute."

After some recruiting from a Beckman original, Tom Huang, Levinson came to Illinois for an interview.

"When I left the Beckman Institute I said this is the only place in the world I should possibly go," Levinson said. "I instantly understood what the Institute was about and what its founding principles were. It was abundantly clear to me that this was the only place in the world for me."

Levinson said his transition from industry to university professor and researcher has "gone pretty much according to plan but there was a lot of serendipity." The most serendipitous moment was his meeting with Vernon.

"He said 'you really ought to apply to our institute for an iCub.' That was out of the blue; that wasn't even on my radar screen," Levinson said. "I had no idea that the RobotCub consortium existed and had no idea that the iCub had been designed. That was really huge because we were outgrowing the robots that we had built and all of a sudden this opportunity came along out of nowhere. You could say that luck favors the prepared mind but that was really something that was not according to plan. It's really opened up new horizons. It's like a rebirth of the whole project."

INTEGRATIVE IMAGING OVERVIEW

The Integrative Imaging (IntIm) research theme was created in 2009 to take advantage of the people, ideas, and resources at the Beckman Institute in the realm of imaging modalities and research. In a scientific world that increasingly depends on the visual, imaging instruments and techniques enhance the ability to do good science by giving researchers new and better visualization tools. In addition, efforts in IntIm for the advancement of imaging technologies leads to improved applications in real world settings such as cancer clinics. As the first new research theme at Beckman in 15 years, Integrative Imaging has already become an important part of the Institute's research mission because of the role that imaging plays in conducting science in the 21st Century.

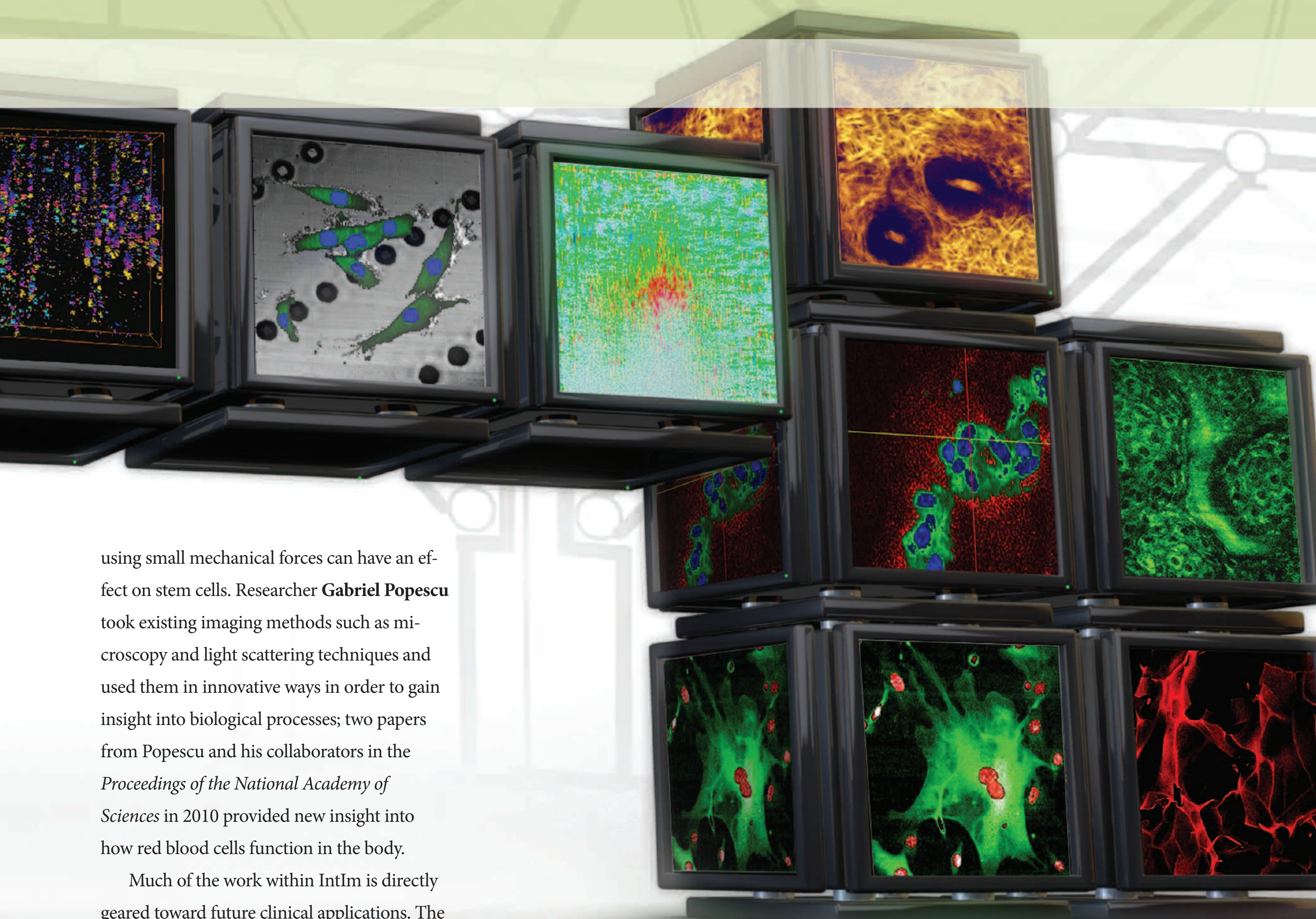
The Integrative Imaging research theme includes research work in topics that directly apply to advancing imaging methods, such as working on ways to improve ultrasound and magnetic resonance imaging techniques, while creating novel uses for methods like computed tomography (CT), and optical imaging.

Researchers from fields as varied as materials science, kinesiology, and neuroscience are involved in the IntIm research theme, with work focused around two main groups: the Bioacoustics Research Laboratory (BRL) and the Bioimaging Science and Technology group (BST).

Stephen Boppart and **Zhi-Pei Liang,** Co-chairs for Integrative Imaging, write that the theme's mission is to "foster the interdisciplinary discovery of fundamental principles in imaging science, new enabling technologies for the next generation of imaging instruments, and novel techniques for basic and translational research." IntIm includes members who use imaging technology for research and other scientific purposes and others who are involved in the design, engineering, and optimization of imaging instruments and methods, and some who are engaged in both efforts.

Recent research highlights from IntIm include Stephen Boppart's use of an optical coherence tomography (OCT) system for assessing tumor margins in resected breast tissue in real-time during operating room procedures. This past year, Boppart's system was validated during a hospital study. Boppart and his collaborators also developed a noninvasive contrast agent for use with OCT, MRI and other imaging systems that employs magnetic nanoparticles.

IntIm researcher **Ning Wang** also works at the smallest scales in projects that potentially have big applications in the world of medicine. Wang reported in 2009 on how



This image was used as cover art for the 11/09 issue of the *Journal of Biophotonics*. It accompanied an article titled "Imaging engineered tissues using structural and functional optical coherence tomography."
Credit: Alex Jerez, Beckman Institute Visualization Laboratory

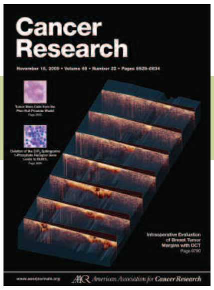
using small mechanical forces can have an effect on stem cells. Researcher **Gabriel Popescu** took existing imaging methods such as microscopy and light scattering techniques and used them in innovative ways in order to gain insight into biological processes; two papers from Popescu and his collaborators in the *Proceedings of the National Academy of Sciences* in 2010 provided new insight into how red blood cells function in the body.

Much of the work within IntIm is directly geared toward future clinical applications. The work of **Rohit Bhargava** combines chemical information and computation toward creating a non-laboratory system for medical personnel information on how biological structures like cell tissue change over time, particularly as it would apply to cancer evaluation methods.

The Bioacoustics Research Laboratory (BRL) is headed by **William O'Brien,** who is a leader in advancing ultrasound techniques for biomedical and research purposes. O'Brien led a successful effort this past year to add a high resolution ultrasound system to Beckman's Biomedical Imaging Center. The new addition is already being used by campus researchers, including O'Brien and fellow BRL member **Michael Oelze** in their breast cancer assessment research investigations.

Researchers in IntIm also work to advance the technology, often in projects that have basic science research value. **Scott Carney** applies theory to the development of algorithms in collaborations with fellow IntIm members like Bhargava and Boppart. **Brad Sutton** works on advances in the engineering side of imaging technologies, collaborating in projects like research into memory. Liang is a leader in advancing imaging processing and pattern recognition, and in improving magnetic resonance imaging methods. **Michael Insana,** leader of the Bioimaging Science and Technology group, develops instrumentation and methods for ultrasound imaging of soft tissue microstructure, elasticity and blood flow, especially toward applications in cancer research and clinical use.

Together, these researchers, as well as the methods and instruments they use, provide a comprehensive resource for imaging research that stands out as a leader in this growing and essential field.

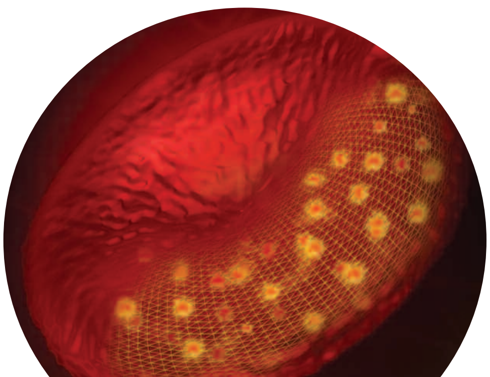


Optical System Proves Value as Breast Cancer Imaging Tool

After many years of development, a light-based technology for imaging subsurface biological tissue was successfully demonstrated in a clinical setting, providing a potential solution for the often agonizing time that patients spend waiting for lab results. Integrative Imaging Co-chair **Stephen Boppart** has been developing the imaging system—which uses optical coherence tomography (OCT) to provide high-resolution, micron-scale images—for more than seven years. Boppart put his system to the test through a collaborative study involving his laboratory and Carle Foundation Hospital in Urbana. The study included 37 breast cancer patients and used an OCT imaging system as an intraoperative (within the operating room during the procedure) real-time diagnostic tool for assessing tumor margins in resected breast tissue. The results showed that, when correlated with post-surgical findings of pathologists, the accuracy of the results from the OCT system was validated by the histology data. The results clearly showed that the system is an effective, real-time imaging tool for the critical task of assessing breast cancer margins in the operating room during lumpectomy procedures. "Histology, with its resolution and staining, is really what is used to make the final diagnosis," Boppart said. "However, histology has limits in terms of how much it can sample, how long it takes, and how much it costs." The advantages of the OCT system, as the study's co-authors write in the paper reporting their findings, are that it "provides surgeons the ability to assess margin status in real-time, complementing current gross visual examination, potentially reducing the number of positive/close margins discovered post-operatively, and thereby reducing the need for additional surgical procedures."

Popescu's Lab Shines Light on Red Blood Cell Structure, Function

Gabriel Popescu and his Quantitative Light Imaging (QLI) laboratory at the Beckman Institute are providing new insights into the function and structure of red blood cells (RBCs), the vital carriers of oxygen to the body's tissues. In two papers published this year in the *Proceedings of the National Academy of Sciences,* Popescu and his collaborators showed how essential deformability, or the ability to change shape, was to red blood cells performing their job of cellular oxygen transport in the body. Their lab makes innovative use of imaging methods such as light scattering techniques, interferometry (bringing two waves together), and microscopy to study light-tissue interactions. Using a technique developed by Popescu called diffraction phase microscopy they were able to not only observe but also measure, for the first time ever, the nanoscale membrane fluctuations of RBCs that allow them to move through the body. Red blood cells must change shape in order to fit through capillaries half their size that transport them through the body. Popescu, his students, and their multi-university collaborators reported in their January *PNAS* article that the remarkable deformability of red blood cells is maintained by energy consumption via ATP transport and that the ability of red blood cells to squeeze through narrow capillaries in the microvasculature is governed by the continuous remodeling of the cell's supporting spectrin protein network. They later reported on measuring the mechanics of RBCs during morphological changes. The diffraction phase microscopy method used in the research does not damage RBCs, so it could be used to evaluate the effectiveness of drugs developed for blood cell morphology diseases. The method also has potential for screening stored blood or for blood diseases.



This image was featured on the cover of the journal, *PNAS* (01/26/10). It accompanied red blood cell research by Gabriel Popescu and his Quantitative Light Imaging Laboratory. *Image created by Alex Jerez of the Beckman Institute's Visualization Laboratory.*

Developing "Electronic Nose" and "Artificial Tongue" Biosensors

Kenneth Suslick's research involving the development of innovative biosensors has produced an "artificial tongue" that can sense subtle differences in both artificial and natural sweeteners and an "electronic nose" that can distinguish different flavors of coffee. The biosensors are based on colorimetric technology that can turn the chemical properties of substances like sweeteners or coffee into a visual image for simple, fast, and accurate detection and evaluation purposes. Other technologies for differentiating sweeteners and coffee have had problems distinguishing between varieties that are similar. Both the artificial tongue and electronic nose are based on colorimetric sensor technology that uses chemical interactions to produce a color change for visualization and to render digital data. In the case of the artificial tongue, the method uses a business-card size sensor that is dipped into a sample; the interaction of the sweetener and a derivative of boric acid in the sensor results in pH changes that are detected and used to identify the source of the sweetness. The electronic nose features a printed array of different nanoporous pigments that strongly interact with chemicals. The coffee sensor the lab developed produced unique molecular "fingerprints" of the coffee aromas of 10 brands tested, demonstrating an ability to accurately discriminate between the closely related mixtures of compounds found in coffee to a degree that is not possible with other electronic analyzers. Vapors from each brand were forced over the sensor arrays, causing color changes in the nanoporous pigments due to the strong interactions between the compound's molecules and the sensor's pigments. The electronic nose was able to accurately identify different coffee aromas to a high degree of specificity and accuracy, a difficult problem since roasted coffee beans contain more than 1,000 chemical compounds. The lab has already produced a prototype of a handheld device that gives readouts of the data

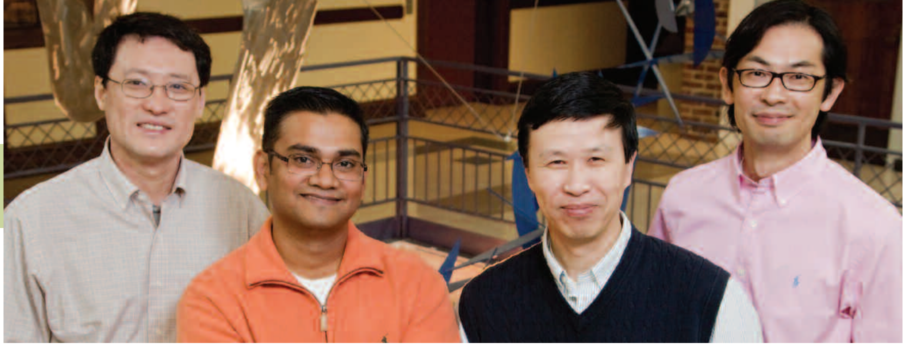


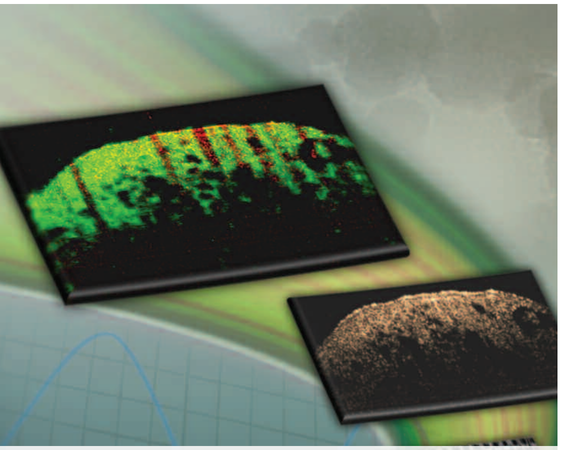
PHOTO BY L. BRIAN STAUFFER

The team that discovered that small mechanical forces have a big impact on embryonic stem cells was led by, from left, Fei Wang, cell and developmental biology; Farhan Chowdhury, doctoral student in mechanical science and engineering: Ning Wang, Beckman faculty and mechanical science and engineering; and Tetsuya Tanaka, animal sciences.

from the sensor. The work also has potential applications for industrial and research laboratories where the electronic nose technology could be used in a small device for the detection of toxic chemicals.

Magnetic Nanoparticles that Move

Stephen Boppart and his collaborators reported in the *Proceedings of the National Academy of Sciences* in 2010 on a project that uses magnetism and nanoparticle contrast agents inside the body to create a noninvasive contrast agent for imaging. The method uses magnetism to move nanoparticles inside the body in order to target tumor cells and other tissue with a high degree of specificity not seen with other contrast agents. The technique enables micron scale tissue detection and manipulation; in this project it was applied to a preclinical mammary tumor model. "What is novel about this whole approach and this work is that we're using external magnetic forces to move nanoparticles within tissue, to modulate them," Boppart said. "Most other particles will localize somewhere and typically sit there. They may provide a signal change, but they don't physically move. No other particle is dynamic like this, which is a unique way to generate contrast." The magnetic nanoparticles can be used with magnetic resonance imaging (MRI) as well as OCT and, potentially, other imaging technologies, enabling biomechanical tissue measurements, contrast, and therapy through hyperthermia. "I believe this represents an entirely new class of imaging agents that we can use to tell more about the tissue, for diagnostic purposes and for therapeutic techniques," Boppart said.



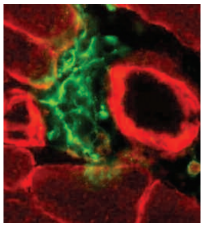
Magnetomotive dynamics from targeted iron-oxide nanoparticles are used to provide contrast for *in vivo* optical molecular imaging of tumors in a pre-clinical model of human breast cancer tissue. *Image courtesy of researcher Stephen Boppart, and Alex Jerez and Zach Johnson of the Beckman Institute's Visualization Laboratory.*

Small Mechanical Forces Big Factor in Cellular Activity

Small mechanical forces can induce extremely fast signaling in the cellular world, and may play a larger role in cellular function than current thinking on the subject allows, according to research by **Ning Wang** of the Integrative Imaging research theme. "The big issue right now in the field of mechanotransduction is whether the genes in the nucleus can be directly activated by forces applied to the cell surface," Wang told *The Scientist* magazine. His research is directly addressing that issue. Mechanical signals involving cellular activity, or biomechanical signals, move much faster than chemical signals in the body; the role of biomechanics in the body's biological responses is an emerging area of study in part because of the importance of those responses in processes such as tissue regeneration. To test the kinds of roles biomechanics plays in cellular activity, one of Wang's research projects looked at how applying a small mechanical force affected the embryonic stem cells of mice. Wang used magnetic beads four microns in diameter and moved them using an oscillating magnetic field to measure the effects of the mechanical force on the cells. Since stem cells become stiffer as they differentiate, the experiment tested the softness and stiffness of the cells at an embryonic stage and after they had differentiated. Using the beads to apply a mechanical force, Wang and his collaborators found that the embryonic stem cells were much softer (a quality that determines the degree to which it attaches and spreads on a surface) and more sensitive to forces than the more advanced cells. The results, Wang said, suggest that "small forces may indeed play critical roles in inducing strong biological responses in embryonic stem cells, and in shaping embryos during their early development." The results not only have import for adding to our understanding of the role of biomechanics in cellular processes but could in the future lead to applications in areas such as regenerative medicine.

Studying the Body's Mechanisms for Responding to Strain

Studying ways to counter the loss of skeletal muscle caused by disease and aging is a mission of the Molecular Muscle Physiology Laboratory led by **Marni Boppart.** Exercise therapy and molecular-based interventions are two approaches to this problem that Boppart investigates by studying the cellular mechanisms responsible for musculoskeletal remodeling and growth in response to exercise and mechanical strain. Boppart has a research focus on integrin—receptors that mediate and promote interactions between cells and their environment by acting as cellular sensors and signaling molecules. Boppart focuses on integrin because it protects against skeletal muscle injury, using both *in vitro* and *in vivo* experiments to determine the potential role of the different integrin subtypes and isoforms in diseases such as muscular dystrophy, sarcopenia, insulin resistance, and protection from cancer cachexia. Her work has shown an expanded role for the $\alpha7\beta1$ integrin receptor in muscle remodeling by demonstrating that it is a prerequisite for the appearance of mesenchymal stem cells (MSCs), a stem cell population currently used in clinical trials for the treatment of a variety of neuromuscular diseases. In the past year, work in Boppart's lab has shown that this integrin receptor is found in several locations in skeletal muscle, including around blood vessels following a single bout of exercise, and that these cells contribute to the de novo formation of muscle fibers, which ultimately increases force generation. Currently work in the lab is trying to determine whether MSCs alone or MSCs in conjunction with exercise therapy can enhance muscle growth and function in aged skeletal muscle and, in collaboration with Stephen Boppart, is tracking bone marrow-derived stem cells using both optical and immunohistochemistry techniques.



This figure, provided by the Molecular Muscle Physiology group, led by Prof. Marni Boppart, shows mesenchymal stem cells (green flourescence) are found in several locations in skeletal muscle, including around blood vessels following exercise.

The scientific aspects are interesting and very satisfying intellectually, but the real payoff is the fact that you can truly help people.

Rohit Bhargava

BHARGAVA'S WAY: AN INTERDISCIPLINARY APPROACH TO FIGHTING DISEASE

Rohit Bhargava took a long and winding road to becoming an interdisciplinary, translational researcher: advanced degrees in chemical engineering and polymer science leading to on-the-job training in a completely different area, biomedicine, at the National Institutes of Health. Now, as a leading researcher in the development of advanced imaging techniques, Bhargava is mentoring a Beckman Fellow who's taking a much straighter route to doing interdisciplinary research with potential biomedical applications.

Shortly after the first-ever position of Carle Foundation Hospital/Beckman Institute Fellow was created, Bhargava encouraged a young postdoctoral researcher from England, Michael Walsh, to apply for it. Walsh was selected for the coveted post and is now working with Bhargava doing interdisciplinary research that combines engineering and biology toward developing imaging techniques that take clinical cancer detection and evaluation methods to a new level.

At NIH Bhargava said he had to forge links between his research and potential applications of that work in clinics and hospitals. As a Beckman researcher, Bhargava said the path from research lab to clinic is much more direct and efficient.

"At NIH I went to people who were practicing clinicians and sat down with them and asked them 'what's important, how do things function in healthcare?' In Beckman, we have built it into training our emerging scientists," Bhargava said. "I think that is absolutely the future of biomedical research. A place like Beckman, which combines multiple disciplines on the research side, and an outlet like Carle which allows us to translate those research developments to the clinic, coming together."

As a key member of the Integrative Imaging research theme at Beckman, Bhargava has leveraged his multidisciplinary background in chemical engineering, polymer science, and biomedical sciences into a leading role in research that integrates chemistry and advanced computational methods into imaging modalities for medical and research applications.

While his Ph.D. from Case Western was in Macromolecular Science and Engineering, Bhargava's research work at NIH involved biomedical issues, including a landmark study of prostate tissue analysis with spectroscopic imaging. His degrees did not prepare Bhargava for the application, or biomedical side, of the topics he was working on at NIH.

"Everything was a huge learning curve: the way medicine operates and the issues facing clinicians and physicians," Bhargava said. "We had no idea how they work and what kind of tough questions are there in their lives. Anytime you are trying to develop technology that will assist a certain constituency, you have to know what's important.

"When I went to NIH I had no idea that only males had prostate glands. I had never heard of prostate cancer because it was pretty much non-existent when I was growing up in India because India and Japan have the two lowest prostate cancer rates in the world."

Bhargava's current research, including clinically-oriented projects funded by NIH, is forging a new path in advancing bioimaging instrument development by integrating chemical information and computation into imaging methods. It is a real-time non-laboratory approach that gives the user, such as technicians at a clinic, information on how biological structures like cell tissue change over time. The method has exciting potential for evaluating cancerous and non-cancerous cells, with Bhargava's research focusing on prostate cancer evaluation methods that also have possibilities for use in breast and colon tissue analysis.

Bhargava said a grant reviewer for the National Cancer Institute, an agency funding one of his projects, wrote this about their proposal: "this grant is outstanding because it addresses the Holy Grail of cancer today." That Holy Grail is a cancer detection method that tells physicians which cancers will become life-threatening and which won't with more precise certainty than current methods offer. The American Cancer society says that nearly 200,000 men were diagnosed with prostate cancer in 2009 and that 27,000 men died from the disease, even though Bhargava said more than 90 percent of those diagnosed receive treatment.

Bhargava said that current prostate diagnosis methods provide a correct diagnosis 50 percent of the time for moderate, confined disease. Creating an automated technology with chemical imaging techniques and powerful software for quickly extracting information from large datasets could provide more accurate diagnoses for prostate cancer (by giving information on both cell structure and chemistry) and help prevent unneeded surgery.

"The idea there is to demonstrate with this new technology that we can outperform current tests and figure out who can be treated and who should not be treated under our current system," Bhargava said.

Bhargava said that for every 100 men treated for prostate cancer only five lives are saved.

"Which means for every life saved you've treated 20 people and roughly one out of those 20 had no benefit, they still died," he said. "Out of the survivors, 20 percent suffer incontinence and impotence even two years after surgery. So one person still died, and you have four people whose lives are very adversely affected. So is this really the right way to administer healthcare?

"But if we could at the point of detection say that there is no hope in treating this person because it's not going to work, and there is no need to treat these people because nothing will happen to them then that will really solve our entire prostate cancer epidemic. It will become a much more manageable disease. Breast cancer is moving toward the same paradigm, where we are detecting cancer earlier and earlier. We're extending this method to breast tissue as well."

The possibility that his work could someday help thousands, if not millions, of people is Bhargava's main motivation.

"The scientific aspects are interesting and very satisfying intellectually, but the real payoff is the fact that you can truly help people," Bhargava said. "At the end of the day that's all what we are all about. If it benefits somebody in such a direct and personal way, I think that's very, very important."

MOLECULAR AND ELECTRONIC NANOSTRUCTURES OVERVIEW

Imagine the experience of doing science at the scale of molecules, of manipulating and understanding structures so small that the most powerful microscopes of 30 years ago weren't able to visualize them. That is what researchers in the Beckman Institute's Molecular and Electronic Nanostructures (M&ENS) research theme do every day in research lines that encompass everything from computer simulations of the smallest workings of cells to creating electronics composed of carbon nanotubes.

Exploring both the makeup and the function of natural and man-made structures at the nanoscale is the main focus of the Molecular and Electronic Nanostructures research theme. Researchers working in M&ENS have the broad mission of understanding chemical and physical processes and structures at the nanometer scale, as well as advancing the development of nanoscale applications, including creating software for basic science and translational research projects.

There are five research groups within the Molecular and Electronic Nanostructures research theme. The 3-D Micro- and Nanosystems group develops strategies for assembling and studying three-dimensional systems at the micro- and nanoscales. Research in the Autonomous Materials Systems group is centered on the design of autonomic multifunctional materials systems. Members of the Computational Multiscale Nanosystems group use computational methodologies that involve multiple physics domains and multiple scales in time and space toward the design of nanosystems. The Nanoelectronics and Nanomaterials group develops and uses experimental and simulation tools to explore biological, nanoelectronic and materials systems at scales down to the atomistic level. The Theoretical and Computational Biophysics group seeks to understand biological structure and function through the use of computational methods such as dynamic simulations.

This past year's research highlights demonstrated once again the breadth of topics covered within M&ENS, as well as their relevancy to the current science. Developing novel technologies and techniques, M&ENS researchers demonstrated everything from technologies with potential biomedical and electronics applications (**John Rogers**, LEDs, silicon-on-silk electronics) to direct write assembly methods for nanoscale structures (**Jennifer Lewis,** printed origami, **Paul Braun** and **Jeff Moore**, writing 3-D channels within a porous matrix, and **William King**, nanolithography for complex nanostructures).

Breakthroughs in nanoscale biological research were once again a highlight for this research theme as new insights into biological processes were shown by **Martin Gruebele** (visualizing live protein dynamics), **Klaus Schulten** (atomistic scale computer simulations of ribosome interactions), and **Yi Lu** (tailor-made, synthetic proteins).

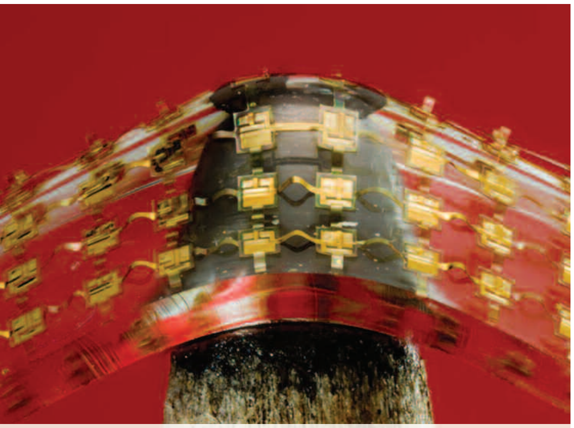
Turning the science into usable applications such as biosensors or self-healing coatings is an important part of the mission of M&ENS research. Lu developed an easy-to-use dipstick test that, unlike other methods, requires no instrumentation or laboratory work and that meets EPA guidelines for lead detection. Researchers such as **Nancy Sottos**, **Scott White, Jeff Moore** and **Paul Braun** have led the development of self-healing materials for use in coatings for bridges and other structures. This past year this team also made progress toward extending self-healing to microelectronic devices. Researchers like **Joe Lyding** of the Nanoelectronics and Nanomaterials group perform experiments that test the viability of new technologies such as using graphene in electronics.

Researchers in the Molecular and Electronic Nanostructures research theme were also involved in new findings on the theoretical side, with **Steve Granick** helping to change thinking regarding Brownian motion and its role in the movements of a liquid as its diffuses through another material. Granick showed that Brownian motion can best be described with greater extremes than the traditional bell-shaped curve model.

Developing and using powerful computational tools is a pillar of research within M&ENS and those tools helped fuel advances in areas such as mirco- and nanoelectromechanical systems (**Narayana Aluru** and **Ioannis Chasiotis**) biophysics (**Klaus Schulten**), and biomechanics (**Iwona Jasiuk**) this past year.

Taken together, the computational and visualization tools used at Beckman by M&ENS researchers, along with their theoretical advances, experimental approaches, and vision for research at the nanoscale make this theme as leading edge today as when it was formed 16 years ago.

This image appeared on the cover of *Advanced Functional Materials* (Vol. 20, Issue 11, June 9, 2010). The image, created by Beckman's Visualization Laboratory, illustrates the first microcapsule system for the restoration of conductivity in mechanically damaged electronic devices in which the repairing agent is not conductive until its release. Paper authors are Susan Odom, Mary Caruso, Aaron Finke, Alex Prokup, Joshua Ritchey, John Leonard, Scott White, Nancy Sottos, and Jeff Moore.



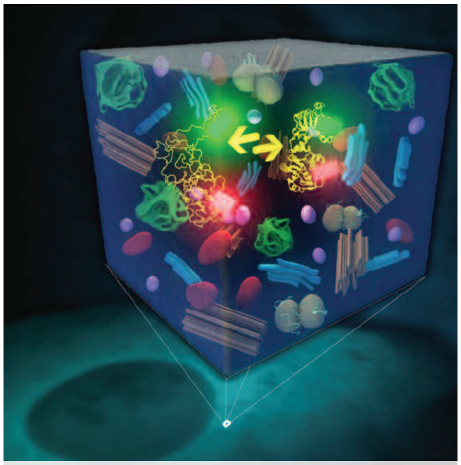
Macro photography of a pencil tip deforming flexible circuits developed by Professor John Rogers. The silicon interconnects, seen arching up from the surface, are designed to provide slack as the clear rubbery PDMS sheet below is stretched and deformed. The interconnect at top center can be seen pulled fully taut from being stretched over the pencil tip.
Image created by Chas Conway of Beckman's Visualization Laboratory.

Stretching the Possibilities for Electronics

The innovations that **John Rogers** brings to the areas of semiconductor and electronics research are so redefining that he was profiled by *Science* magazine in 2010 as a "pioneering researcher" who could "change the way we light our homes, treat diseases, and power the planet." Rogers lived up to that description with two papers this past year, one reporting on a new method for fashioning ultrathin, ultra-small, inorganic light-emitting diodes (LEDs) and another describing the development of silicon-on-silk electronics. Both technologies have potential biomedical applications: the flexible LEDs could be used as wearable health monitors, while the biodegradable silicon-on-silk technology conforms to biological tissue, making it useful in devices for monitoring and treating disorders like arrhythmia and epilepsy. The ultrathin LEDs offer some of the capabilities of organic LEDs such as brightness and long life, while providing scalability and the ease of processing of inorganic LEDs. They were created using an epitaxial growth technique for sizes as much as 100 times smaller than usual methods. The research team also created printing processes to assemble the devices into large arrays on stiff, flexible, and stretchable substrates that were then interconnected by thin-film processing. The method, Rogers says, allows them to "create general lighting and high-resolution display systems that otherwise could not be built with the conventional ways that inorganic LEDs are made, manipulated and assembled." In addition to biomedical applications, the novel technique could be used in solid-state lighting systems and instrument panels. The silicon-on-silk technology works, Rogers and his collaborators write, by integrating "single crystalline silicon electronics, where the silicon is in the form of nanomembranes, onto water soluble and biocompatible silk substrates." The technology is biocompatible, flexible, and mostly resorbable in the body, making it ideal for a number of biomedical applications such as heart monitors or brain interfaces like implanted monitors or for use with prosthetics.

Electrospinning for Self-healing Coatings

Paul Braun of the 3-D Micro and Nanosystems group reported on a new method for creating encapsulated self-healing materials using an electrospun coaxial healing agent. Electrospinning—the process of producing micro- to nanoscale polymer filaments using electrostatic force—was used in the project to create a self-healing coating system that offers several advantages for functionality in polymer coatings. Using polysiloxane-based bead-on-string healing agents and an acrylate matrix, the method is described this way by Braun and co-author Jeong-Ho Park in a report in *Advanced Materials:* "Self-healing polymer coatings are formed by electrospinning bead-on-string healing agent filled capsules onto a substrate followed by infilling of a polymer matrix. Upon damage to the self-healing coating, liquid healing agents are released from the ruptured beads passivating the damaged region." The researchers write that there are several advantages to this method, including that it uses physical force rather than chemical reactions to form the core/sheath structure, making it, they write, "suitable for processing a broader variety of materials for self-healing." Braun told *Nanowerk* that the one-step coaxial electrospinning encapsulation method "offers a number of unique opportunities. Perhaps most significantly, the location and concentration of the healing component can be spatially varied; this is in contrast to a capsule-based system, where the capsules are mixed into the matrix precursors before it is applied to the substrate." The authors also write of the method's potential for applications: "electrospinning is both a high throughput and selective area technique. Thus, the self-healing functionality can be selectively added to large area substrates in a continuous process under rather mild conditions."



Martin Gruebele and his colleagues have developed a system for moving observation of protein folding from *in vitro* to *in vivo.*

Visualizing Protein Folding in a Live Cell for the First Time

Martin Gruebele of the Nanoelectronics and Nanomaterials group and his collaborators developed a new technique for studying protein dynamics *in vivo*, visualizing for the first time the critical biological process of protein folding in a live cell. The method works by using laser pulses to create fast upward and downward temperature jumps in the cell sample, followed by stabilization of the cell temperature and its aqueous medium at the final value. Then an inverted fluorescence microscope is used to observe and record what happens inside the cell. Researchers have used temperature jumps before to study kinetics of chemical reactions in test tubes; fluorescence microscopy permits them to see inside cells, but not study their kinetics and dynamics. Gruebele and his collaborators have, by combining these two approaches, created a new method—which they call Fast Relaxation Imaging—that gives scientists an intimate view of living cells as they function. The researchers write in the journal *Nature Methods* that in order to "reveal the full functionality of proteins and other biomolecules, they must be studied in the living cell." Gruebele said the technique provided unprecedented views of folding and unfolding of proteins in real time. "This is the first experiment that allows us to observe the dynamics of a protein folding in a live cell," he said. "Now we have the capability of looking at how fast biological processes occur as a function of time."

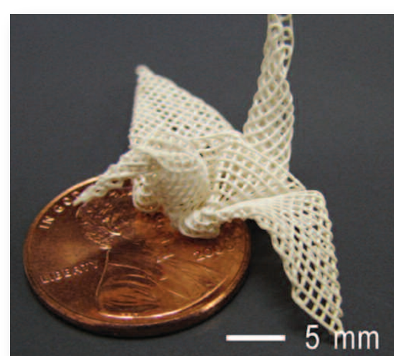
Image from the cover of the *Biophysical Journal* (10/09).
Created for the Theoretical and Computational Biophysics group by Alex Jerez and Zach Johnson of Beckman's Visualization Laboratory.
Inset: Beckman researcher Klaus Schulten (center) and graduate student Leonardo Trabuco, left, and postdoctoral researcher James Gumbart, with model of a ribosome.

Molecular Dynamics Provides New Insights into the Ribosome

Klaus Schulten has been a pioneer in bringing computational methods to the study of nature and the Theoretical and Computational Biophysics (TCB) group he has headed at Beckman for more than 20 years has been a leader in developing dynamic molecular scale computer simulations of biological processes and systems. This past year, Schulten and fellow TCB group members Leonardo Trabuco and James Gumbart reported on two new studies that used a method called molecular dynamics flexible fitting (MDFF) to render unprecedented visual insights into the interactions between the ribosome and two of its most important partners in carrying out its translational duties within proteins. MDFF combines data from X-ray crystallography and cryo-electronmicroscopy, allowing the researchers to use the data to create simulations of atomic-scale models of ribosome-protein complexes and then track the behavior of millions of virtual atoms that simulate the processes involved in the interactions. In one study they detected the precise maneuvering between the ribosome and an elongation factor (EF-Tu) essential for the successful assembly of proteins. The second study gave insight into the interaction with a membrane protein called SecY that sometimes latches onto the ribosome and steers a newly forming protein toward its final destination.

Printed Origami Developed for Small, Complex Structures

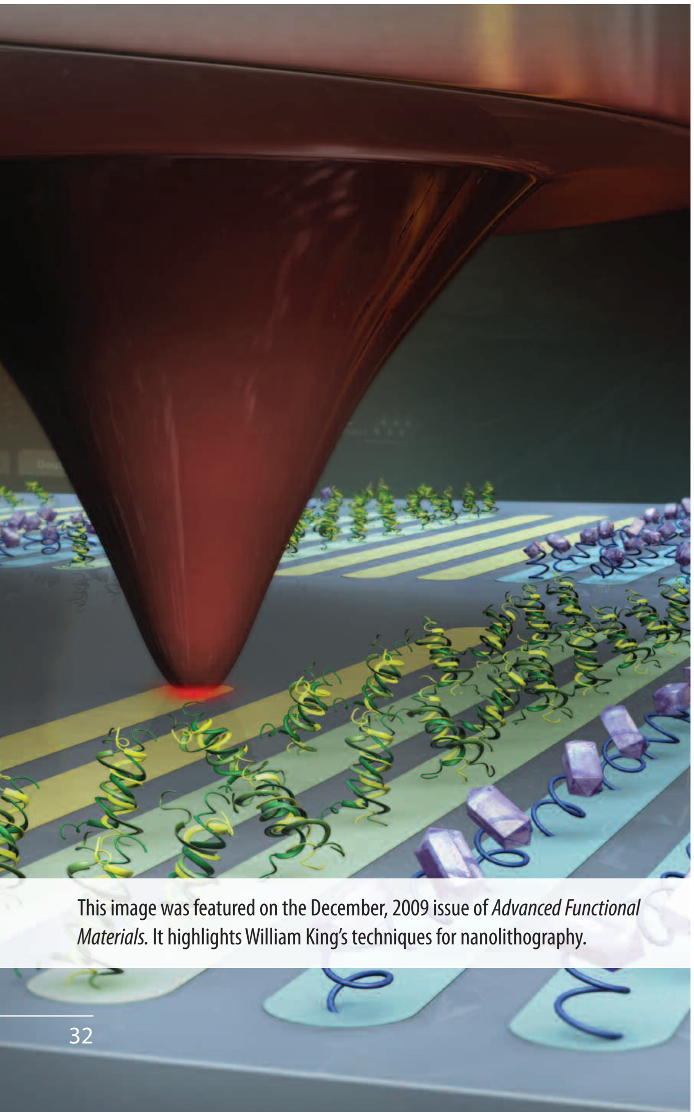
Jennifer Lewis led a team that developed a new method for constructing complex three-dimensional structures for biocompatible devices using an old folk art, origami, as inspiration. Lewis has been a leader in developing direct write techniques for fabricating small, intricate shapes of metal and ceramics with applications in electronics and biomedical devices. The "origami" technique differs in that instead of assembling a structure layer by layer using inks containing the desired material, large flat sheets of a material—in this case titanium scaffolds for tissue engineering—were printed and then rolled into a spiral or folded into shapes, as is done in creating origami art. The research team imitated an origami technique called wet-folding by using a mixture of fast-drying and slow-drying solvents in the ink that would dry the sheets but leave them flexible enough for folding through multiple steps. By bringing together printing and origami, the team was able to create structures with greater complexity and with a greater variety of patterns than other methods.



The penny-sized titanium bird began as a printed sheet of titanium hydride ink.
Image courtesy of Jennifer Lewis.

Techniques for Nanolithography, Direct Writing Composites of Nanoparticles and Polymers

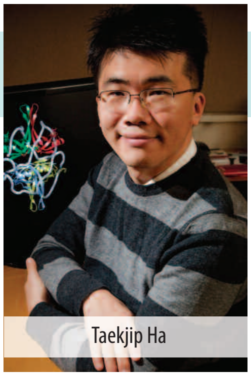
William King of the 3-D Micro- and Nanosystems group has been a pioneer in using atomic force microscopy (AFM) and thermal properties to create novel nanoscale tools and methods, including what has been dubbed a nano-soldering iron with amazing capabilities. This past year King reported on the development of a new technique for direct-writing composites of nanoparticles and polymers, and on a thermochemical method for nanolithography. King and collaborator Zhenting Dai developed a nanoscale thermal processing tool in the form of an atomic force microscope with a heated silicon tip that can be used like a small scale soldering iron. King used the tool for thermochemical nanolithography (TCNL), a patterning technique that allows for the manipulation, design, and manufacture of complex nanostructures for potential applications such as protein detection chips and nanoelectronic devices. TCNL has advantages for patterning at scales below 100 nanometers due to its writing speed (one millimeter per second) and because of its ability to create specific, high-resolution patterns that are stable and therefore suitable for storage and future use. King also used AFM in the development of a technique for direct-writing of composites of nanoparticles and polymers. Working with collaborators at the Naval Research Laboratory, King employed the heated probe of an atomic force microscope to deposit nanoparticle polymer composites containing magnetic, semiconductor, metal, and optically active nanoparticles on multiple surfaces with great precision. The method of thermally controlled deposition is a stable process for dispersion of the nanoparticles in the polymer and overcomes limitations found with other approaches to fabricating nanostructures from nanoparticles or nanoparticle composites. This method's advantages include the ability to direct write aligned rows of less than 10 nanometers wide, narrower than any other similar technique, and, King and his collaborators wrote in their paper in *Nano Letters* on the work, the ability to deposit "a wide range of nanoparticle types on multiple substrates with no solution processing and no sources of cross-contamination." This robust technique, they add, "enables direct access to the exceptional properties of nanocomposites that promise significant advances in nanoelectronics, data storage, biosensors, mechanics, and optical imaging applications."



This image was featured on the December, 2009 issue of *Advanced Functional Materials.* It highlights William King's techniques for nanolithography.

Capsules for Self-healing for Electronics

Researchers in the Beckman Institute's Autonomous Materials Systems (AMS) group helped establish the field of self-healing materials for polymers nearly a decade ago in research that has led to applications such as coatings on large scale structures like bridges. Now, members of the AMS group are demonstrating in two separate research lines that self-healing can also work for a critical small scale application: restoring lost conductivity in electronics. One project involves a twin-microcapsule method for autonomous repair of electronics while the other uses carbon nanotubes to restore a damaged circuit. Lead author of the paper on the twin-microcapsule method is postdoctoral researcher Susan Odom, with faculty members Jeff Moore, Nancy Sottos and Scott White of the AMS group as co-authors. Writing in *Advanced Functional Materials* the researchers report that the method is "the first microcapsule system for the restoration of conductivity in mechanically damaged electronic devices in which the repairing agent is not conductive until its release." Self-healing begins when the shells of the twin microcapsules rupture in response to damage and the non-conductive component precursor materials are released as a liquid from the core, forming a conductive solid charge-transfer salt that restores conductivity to the electronic device. In the other research line, carbon nanotubes (CNTs) were used to restore lost conductivity in electronics. Led by faculty member Jeff Moore and lead paper author Mary Caruso of the AMS group and faculty member Paul Braun of the 3-D Micro and Nanosystems group, the researchers were able to demonstrate restoration of conductivity between two electric probes separated by about 100 micrometers. They used microcapsules with robust walls containing unfunctionalized single-walled CNTs suspended in an organic solvent and tested the method by rupturing the microcapsules using vigorous stirring. The CNTs were released upon the microcapsules rupturing and migrated toward the probes tips, forming a bridge that completed the circuit and current was restored.



Taekjip Ha

PHOTO BY L. BRIAN STAUFFER

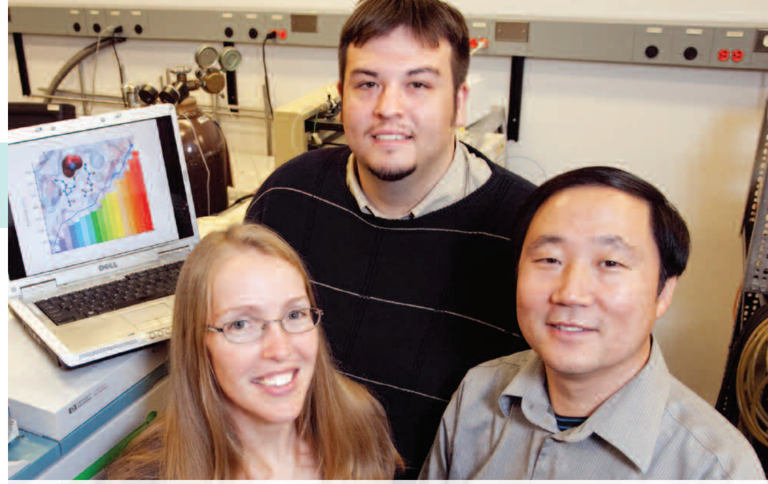


PHOTO BY L. BRIAN STAUFFER

Beckman faculty member, Yi Lu (right), and his students Tiffany Hopper and Nick Marshall have mimicked nature in their development of tailor-made proteins.

DNA-binding Protein Critical to DNA Repair

Taekjip Ha was part of a multi-university research project that discovered that a single-stranded DNA-binding protein known as SSB is a dynamic player in the repair and replication of single stands of DNA by other proteins. The researchers found that not only is SSB dynamic—rather than mostly static as previously thought—but their study is also the first one to report on a protein migrating randomly backward and forward on single-stranded DNA. Ha, who studies the physical mechanisms of biological molecules and systems and develops research techniques such as a method called fluorescence resonance energy transfer (FRET) that was used in this study, said gaining knowledge about SSB is important because it is critical to the repair, recombination, and replication of DNA strands.

Long Polymer Chains Dance the Conga

Steve Granick led a collaboration showing that actin, a molecule that forms filaments critical to cell structure and that plays a role in cellular signaling and transport, behaves much differently than what was previously thought. Granick and his collaborators found that these filaments form long chains that move like a conga line, rather than the snakelike movement that had been used to describe their actions in forming the matrix needed for cell structure. In order to study the "conga line" the researchers used a new method for observation, tagging individual links in the molecular chain with a fluorescent dye and tracking their motion as they would individual dancers in a conga line. What they found was the filaments moved not as though they were in a cylinder as previously thought but more freely and sometimes more tangled up through the empty spaces of the matrix.

Steve Granick

PHOTO BY L. BRIAN STAUFFER

Writing 3-D Channels within a Porous Matrix

Paul Braun of the 3-D Micro- and Nanosystems group and **Jeff Moore** of the Autonomous Materials Systems group reported on a new method for fabricating three-dimensional microfluidic channels within a porous matrix. Using a laser for two-photon patterning, the researchers were able to direct write a hydrophilic (capable of hydrogen bonding) pathway in a 3-D porous matrix to form microfluidic channels in an otherwise hydrophobic host. Along with lead author Jyh-Tsung Lee and Matthew George, Braun and Moore wrote about the implications of their method in the *Journal of the American Chemical Society:* "Surfaces with switchable hydrophilicity are of considerable interest because of their potential applications in, for example, sensors, drug delivery, microfluidics, and colloidal assembly." This novel method for fabricating 3-D microfluidic channels, they write, provides the ability "to locally switch the interior surface of a porous solid from a hydrophobic state to a hydrophilic state", allowing these structures to be selectively infilled with "water and/or hydrophobic oil with a minimum feature size of only a few micrometers. We envision that this approach may enable the fabrication of complex microfluidic structures that cannot be formed via current technologies."

Synthetic Proteins to Study Nature

Yi Lu of the 3-D Micro- and Nanosystems group brings chemistry and biology together in research lines that are providing insights into biological systems and leading to applications like biosensors. In 2009, Lu contributed to two papers for *Nature* that reported on his development of synthetic proteins that help illuminate the critical biological process of oxidation-reduction reactions and the structure and function of the native protein nitric-oxide reductase. In one project, Lu and his collaborators created a nature-based, tailor-made protein to gain understanding of oxidation-reduction reactions (redox for short) processes that are, as Lu and his collaborators write in *Nature,* "at the heart of numerous functions in chemistry and biology, from long-range electron transfer in photosynthesis and respiration to catalysis in industrial and fuel cell research." These redox processes are performed by a limited number of redox-active agents that require a particular potential. How these potentials are fine tuned by nature has not been well understood until this research demonstrated two interactions, hydrophobicity and hydrogen bonding, are capable of fine-tuning the reduction potential of a particular class of copper-containing proteins called cupredoxins, redox-active copper proteins that are critical to important processes such as photosynthesis and cell signaling. Lu was also corresponding author for the paper on a synthetic protein that mimics the structure and function of a metalloprotein (proteins containing metal atoms or clusters which are involved in a wide range of important biological processes) called nitric-oxide reductase. Lu and his co-authors write that the creation of synthetic proteins such as the one they fashioned as a model for nitric-oxide reductase is important because protein design "provides a rigorous test of our knowledge about proteins and allows the creation of novel enzymes for biotechnological applications." Reproduction of the metal-containing metalloproteins has been difficult but, Lu and his collaborators write, the successful design of a structural and functional metalloprotein greatly advances the field of protein design and our understanding of enzymes.

It's great to be an engineer, but I was missing a connection to humans, and I got that through biomechanics and biomedical applications.

Iwona Jasiuk

JASIUK APPLIES MECHANICAL ENGINEERING PRINCIPLES TO BIOLOGY

Just two years after moving with her family from Poland to America, Iwona Jasiuk rekindled an old flame as a way of getting to know her adopted country. As an undergraduate at the University of Illinois at Chicago, Jasiuk decided to join the fencing team. It was a sport she had greatly enjoyed while growing up in Poland and now in college it appealed to her on several levels.

"It was a great, great way to meet people and travel in America," Jasiuk said. "It's called physical chess. I really liked it for that reason, but also it gave me the opportunity to meet very many interesting people."

Jasiuk did indeed travel the land for area and national competitions and kept fencing until time requirements at her first faculty position at Michigan State intervened. She still has the uniform and thinks about returning to the sport, but these days Jasiuk's schedule is fuller than ever as a top researcher in the area of micromechanics, especially as it applies to the topic of bone.

Jasiuk received her Ph.D. in Theoretical and Applied Mechanics from Northwestern and eventually joined the University of Illinois, coming to campus in 2006 in large part because of the possibility of interdisciplinary research collaborations at the Beckman Institute.

Jasiuk's background had been in the area of mechanics of man-made materials but in the past decade she became drawn to issues affecting people in a more direct way, working on a number of projects involving biology such as bone tissue regeneration. She has increasingly pursued a research direction involving the applications of mechanics in biology, especially in the four years since she joined Beckman's 3-D Micro and Nanosystems group.

"It's great to be an engineer, but I was missing a connection to humans, and I got that through biomechanics and biomedical applications," Jasiuk said.

Jasiuk's research, which relies heavily on advanced computer modeling, involves both characterization of materials and the mechanical forces that affect them, as well as the development of technologies such as scaffolds for the regrowth of bone damaged through fracture or disease.

In one project she and her collaborators are developing a synthetic scaffold around which natural tissue will grow, with Jasiuk's contribution looking at how mechanical stimuli can help promote growth. In order to do her work, Jasiuk says it is important to understand bone at different scales.

"By understanding bone at different scales we can design scaffolds that mimic bone," she said. "One project involves the characterization of bone at different scales, from nanoscale to macroscale. And that's important to know, to assess the quality of bone."

Eventually, Jasiuk would like to see her research translate to practical applications such as in a clinical setting. In order to do that, she says, her work is focusing more and more on using non-invasive techniques for the characterization of bone.

"The (previous work) has been invasive but if one wants to use it in a clinical setting, this is not realistic," she said. "There has to be an easier, quicker way to diagnose the state of bone."

So Jasiuk is collaborating with Beckman colleagues to non-invasively characterize bone through Raman microscopy and ultrasound techniques that complement her own methods.

"It's the combination of all these inputs, invasive, non-invasive, and computational modeling that will hopefully lead to more accurate predictions of bone quality," Jasiuk said. "The research is pretty fundamental but it has many important applications. In bone regeneration, we can use these techniques to assess the quality of regenerated bone and compare it with a normal tissue and that should be done at more than one level to ensure quality.

"Any project in orthopedics should have a very good understanding of bone. Another topic is intervention, looking at how medications influence bone or affect bone disease, or even how a diet or another disease not related to bone, like diabetes or obesity, may affect bone. For all of these one needs to have an understanding of what healthy bone is like. Then you can see what has changed."

Jasiuk said so many opportunities are out there for research collaborations that there are almost too many to choose from. She is interested in or has upcoming collaborations involving bio-inspired materials, multi-scale study of the brain for better mechanics models of the brain, and various applications in orthopedics.

"I'm curious about so many things. The last four years I have gotten into many areas that I was thinking about and now I'm thinking about many new areas," she said. "I would like to get more of an understanding of biological materials at the cellular level because that can provide more input on the biological aspect of materials.

"In bone remodeling I'm looking at cellular activity, how mechanical loads can affect cells and how cells can translate it to regeneration of bone. Such models just using mechanics would not be complete. I need to bring in cellular inputs, whether it is for bone remodeling or tissue engineering."

And she has no better place to do that kind of interdisciplinary research than at the Beckman Institute.

"It's so natural here," Jasiuk said. "There is a general trend to become more interdisciplinary and Beckman is a great example of how it can be done."

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2009 – June 30, 2010

BIOLOGICAL INTELLIGENCE FACULTY

(name followed by home department)

Cognitive Neuroscience
Diane M. Beck, *Psychology*
Neal J. Cohen, *Psychology*
Florin Dolcos, *Psychology*
Monica Fabiani, *Psychology*
Kara D. Federmeier, *Psychology*
Susan M. Garnsey, *Psychology*
Brian D. Gonsalves, *Psychology*
Gabriele Gratton, *Psychology*
Christopher M. Grindrod, *Speech and Hearing Science*
Wendy Heller, *Psychology*
Torrey M. Loucks, *Speech and Hearing Science*
Gregory A. Miller, *Psychology*
Richard S. Powers, *English*
Sharon Y. Tettegah, *Curriculum and Instruction*

Cognitive Science
Aaron S. Benjamin, *Psychology*
J.K. Bock, *Psychology*
William F. Brewer, *Psychology*
Kiel Christianson, *Educational Psychology*
Jennifer S. Cole, *Linguistics*
Gary S. Dell, *Psychology*
Cynthia L. Fisher, *Psychology*
Jose Mestre, *Educational Psychology*
Michelle Perry, *Educational Psychology*
Brian H. Ross, *Psychology*
Chilin Shih, *East Asian Languages and Cultures*
Annie Tremblay, *French*
Jonathan Waskan, *Philosophy*
Duane G. Watson, *Psychology*

NeuroTech
Thomas J. Anastasio, *Molecular and Integrative Physiology*
Stephanie S. Ceman, *Cell and Developmental Biology*
David F. Clayton, *Cell and Developmental Biology*
Charles (Lee) Cox, *Molecular and Integrative Physiology*
Albert S. Feng, *Molecular and Integrative Physiology*
Roberto Galvez, *Psychology*
Martha L. Gillette, *Cell and Developmental Biology*
William T. Greenough, *Psychology*
Janice M. Juraska, *Psychology*
David P. Kuehn, *Speech and Hearing Science*
Mark E. Nelson, *Molecular and Integrative Physiology*
Justin S. Rhodes, *Psychology*
Gene E. Robinson, *Entomology*
Edward J. Roy, *Psychology*
Taher Saif, *Mechanical Science and Engineering*
Jonathan V. Sweedler, *Chemistry*

BIOINTEL SELECTED HONORS AND AWARDS

Aaron Benjamin
- Hohenboken Award for Excellence in Undergraduate Teaching, 2009

Kiel Christianson
- Review panel member for Interagency Language Roundtable and Center for the Advanced Study of Language; ad-hoc reviewer for National Science Foundation, 2008
- Participating investigator in NIH Training Grant (Language Processing: A Training Program T32-HD055272), led by Kathryn Bock (Psychology)

Jennifer Cole
- Member, *ex officio,* Executive Council, Association for Laboratory Phonology, 2009-2014
- Elected Member-at-large, American Association for the Advancement of Science, Section Z (Linguistics), 2010-2014
- General Editor, *Laboratory Phonology,* 2009-2014

Gary Dell
- Fellow, American Association for the Advancement of Science (AAAS), 2010

Kara Federmeier
- Young Investigator Award, Cognitive Neuroscience Society (CNS), 2010
- James S. McDonnell Scholar Award, 2010

Cynthia Fisher
- Fellow, Association for Psychological Science (APS), 2010

Wendy Heller
- Fellow, Association for Psychological Science (APS), 2009

Richard Powers
- American Academy of Arts and Letters (AAAL), 2010

Brian Ross
- Chair of Governing Board, Psychonomic Society, Jan 2010-Dec 2010

BIOINTEL SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Biological Intelligence research theme were inventors on the following two patent applications (1.4% of the 139 patent applications filed by the campus) and three patents issued (4.3% of the 69 patents issued to campus) during FY2010 (Beckman Institute faculty members are listed in bold):

Albert Feng, Michael Lockwood, **Douglas Jones**, Carolyn J. Bilger (Legal Representative), **Charissa Lansing**, **William O'Brien**, **Bruce Wheeler**, and Robert Bilger: "Systems and Methods For Interference-Suppression With Directional Sensing Patterns," Patent issued August 18, 2009, Patent Number 7,577,266.

Monica Fabiani, Edward (Ed) Maclin, **Gabriele Gratton**, and Kathy Low: "Non-Invasive Optical Imaging for Measuring Pulse and Arterial Elasticity in the Brain," Patent filed October 29, 2009, Application Number 61/256,024.

Douglas Jones, Michael Lockwood, Robert C. Bilger, Carolyn T. Bilger (Legal Representative), **Albert Feng**, **Charissa Lansing**, **William O'Brien**, **Bruce Wheeler**, Mark Elledge, and Chen Liu: "Interference Suppression Techniques," Patent issued November 3, 2009, Patent Number 7,613,309.

James Ross, Edgar Brown, Swaminathan Rajaraman, Mark Allen, and **Bruce Wheeler**: "Apparatus and Methods for High Throughput Network Electrophysiology and Cellular Analysis," Patent filed November 10, 2009, Application Number 12/615,778.

Erik Larsen, **Albert Feng**, and **Douglas Jones**: "Room Volume and Room Dimension Estimation," Patent issued March 30, 2010, Patent Number 7,688,678.

BIOINTEL GRANTS AWARDED *($1,328,240)*

Kathryn Bock, NSF, "Number Cognition to Number Grammar," July 1, 2009-June 30, 2013, $469,810.

Jennifer Cole and **Mark Hasegawa-Johnson**, NSF, "RI-Collaborative Research: Landmark-based Robust Speech Recognition Using Prosody-guided Models of Speech Variability," August 10, 2009-May 31, 2010, $6,600.

Monica Fabiani, **Gabriele Gratton**, **Arthur Kramer**, and **Brad Sutton**, NIH, "Brain and Behavioral Correlates of Fitness, Cerebrovascular Health and Aging," September 30, 2009-September 29, 2011, $774,515.

Ivan Jeanne Weiler and **William Greenough**, Hoffmann-La Roche, Ltd., "ERK Activation in Human Leucocyte," October 16, 2009-December 31, 2010, $72,706.

Ivan Jeanne Weiler and **William Greenough**, Hoffmann-La Roche, Ltd., "ERK Activation in Human Leucocyte," October 16, 2009-December 31, 2010, $4,609 (Supplement).

BIOINTEL SELECTED PUBLICATIONS

Becic, E.; **Dell, G. S.**; **Bock, K.**; **Garnsey, S. M.**; Kubose, T.; **Kramer, A. F.**, Driving impairs talking. *Psychonomic Bulletin & Review* **2010,** 17, 15-21.

Beck, D. M.; Kastner, S., Top-down and bottom-up mechanisms in biasing competition in the human brain. *Vision Research* **2009,** 49, (10), 1154-1165.

Chu, L. Q.; Masyuko, R.; **Sweedler, J. V.**; Bohn, P. W., Base-induced delignification of miscanthus x giganteus studied by three-dimensional confocal raman imaging. *Bioresource Technology* **2010,** 101, (13), 4919-4925.

Clayton, D. F.; Balakrishnan, C. N.; London, S. E., Integrating Genomes, Brain and Behavior in the Study of Songbirds. *Current Biology* **2009,** 19, (18), R865-R873.

Engels, A. S.; **Heller, W.**; Spielberg, J. M.; Warren, S. L.; **Sutton, B. P.**; Banich, M. T.; **Miller, G. A.**, Co-occurring anxiety influences patterns of brain asymmetry in depression. *Cognitive, Affective, and Behavioral Neuroscience* **2010,** 10, 141-156.

Erickson, K. I.; Boot, W. R.; Basak, C.; Neider, M. B.; Prakash, R. S.; Voss, M. W.; Graybiel, A. M.; **Simons, D. J.; Fabiani, M.**; **Gratton, G.**; **Kramer, A. F.**, Striatal volume predicts level of video game skill acquisition. *Cerebral Cortex* **2010,** doi:10.1093/cercor/bhp293

Federmeier, K. D.; Laszlo, S., Time for Meaning: Electrophysiology Provides Insights into the Dynamics of Representation and Processing in Semantic Memory. In *Psychology of Learning and Motivation: Advances in Research and Theory,* **2009**; Vol. 51, pp 1-44.

Feng, A. S., Neural mechanisms of target ranging in FM bats: Physiological evidence from bats and frogs. *Journal of Comparative Physiology* **2010,** Epub 05/15/2010.

Fisher, C.; Gertner, Y.; Scott, R.; Yuan, S., Syntactic bootstrapping. *Wiley Interdisciplinary Reviews: Cognitive Science* **2010,** 1, 143-149.

Gratton, G.; **Fabiani, M.**, Fast optical imaging of human brain function. *Frontiers in Human Neuroscience* **2010,** 4:52. doi:10.3389/fnhum.2010.00052.

Gupta, R.; Duff, M. C.; Denburg, N. L.; **Cohen, N. J.**; Bechara, A.; Tranel, D., Declarative memory is critical for sustained advantageous complex decision-making. *Neuropsychologia* **2009,** 47, (7), 1686-1693.

Hasegawa-Johnson, M.; **Cole, J.**; Chen, K.; Partha, L.; Juneja, A.; Yoon, T.; Borys, S.; Zhuang, X., Prosodic Hierarchy as an organizing framework for the sources of context in phone-based and articulatory-feature-based speech recognition. In *Linguistic Patterns of Spontaneous Speech, Special Issue of Langauge and Linguistics*, Tseng, S., Ed. Academia Sinica: Taipei, Taiwan, **2009**; pp 101-128.

Helfer, J. L.; Goodlett, C. R.; **Greenough, W. T.**; Klintsova, A. Y., The effects of exercise on adolescent hippocampal neurogenesis in a rat model of binge alcohol exposure during the brain growth spurt. *Brain Research* **2009,** 1294, 1-11.

Johnson, Z. V.; Revis, A. A.; Burdick, M. A.; **Rhodes, J. S.**, A similar pattern of neuronal Fos activation in 10 brain regions following exposure to reward- or aversion-associated contextual cues in mice. *Physiology & Behavior* **2010,** 99, (3), 412-418.

Jones, D. L.; Ratham, R., Blind location and separation of callers in a natural chorus using a microphone array. *Journal of the Acoustical Society of America* **2009,** 126, (2), 895-910.

Mathewson, K. E.; **Fabiani, M.**; **Gratton, G.**; **Beck, D. M.**; **Lleras, A.**, Rescuing stimuli from invisibility: Inducing a momentary release from visual masking with pre-target entrainment. *Cognition* **2010,** 115, (1), 186-191.

Mestre, J. P.; **Ross, B. H.**; Brookes, D. T.; Smith, A. D.; Nokes, T. J., How Cognitive Science Can Promote Conceptual Understanding in Science Classrooms. In *Fostering Scientific Habits of Mind: Pedagogical Knowledge and Best Practices in Science Education*, Saleh, I. M.; Khine, M. S., Eds. Sense Publishers: Rotterdam, The Netherlands, **2009**; Vol. 3, pp 145-171.

Mo, Y.; **Cole, J.**; **Hasegawa-Johnson, M.**, Prosodic effects on vowel production: Evidence from formant structure, *Proceedings of Interspeech 2009*, Brighton, UK, **2009**.

Nelson, M. E., Smart Sensing Strategies: Insights from a Biologically Active Sensing System. Proceedings of the 5th International Workshop on Advanced Smart Materials and Smart Structures Technology, Boston, MA, **2009**.

Rothganger, F. H.; **Anastasio, T. J.**, Using input minimization to train a cerebellar model to simulate regulation of smooth pursuit. *Biological Cybernetics* **2009,** 101, (5-6), 339-359.

Silton, R. L.; **Heller, W.**; Towers, D. N.; Engels, A. S.; Spielberg, J. M.; Edgar, J. C.; Sass, S. M.; Stewart, J. L.; **Sutton, B. P.**; Banich, M. T.; **Miller, G. A.**, The time course of activity in dorsolateral prefrontal cortex and anterior cingulate cortex during top-down attentional control. *Neuroimage* **2010,** 50, (3), 1292-1302.

Spalek, K.; **Bock, K.**; Schriefers, H., A purple giraffe is faster than a purple elephant: Inconsistent phonology affects determiner selection in English. *Cognition* **2010,** 114, (1), 123-128.

Warker, J. A.; Xu, Y.; **Dell, G. S.**; **Fisher, C.**, Speech errors reflect the phonotactic constraints in recently spoken syllables, but not in recently heard syllables. *Cognition* **2009,** 112, (1), 81-96.

Warren, W. C.; **Clayton, D. F.**; Ellegren, H.; Arnold, A. P.; Hillier, L. W.; Künstner, A.; Searle, S.; White, S.; Vilella, A. J.; Fairley, S.; Heger, A.; Kong, L.; Ponting, C. P.; Jarvis, E. D.; Mello, C. V.; Minx, P.; Lovell, P.; Velho, T. A.; Ferris, M.; Balakrishnan, C. N.; Sinha, S.; Blatti, C.; London, S. E.; Li, Y.; Lin, Y. C.; George, J.; Sweedler, J.; Southey, B.; Gunaratne, P.; Watson, M.; Nam, K.; Backström, N.; Smeds, L.; Nabholz, B.; Itoh, Y.; Whitney, O.; Pfenning, A. R.; Howard, J.; Völker, M.; Skinner, B. M.; Griffin, D. K.; Ye, L.; McLaren, W. M.; Flicek, P.; Quesada, V.; Velasco, G.; Lopez-Otin, C.; Puente, X.; Olender, T.; Lancet, D.; Smit, A. F.; Hubley, R.; Konkel, M. K.; Walker, J. A.; Batzer, M. A.; Gu, W.; Pollock, D. D.; Chen, L.; Cheng, Z.; Eichler, E. E.; Stapley, J.; Slate, J.; Ekblom, R.; Birkhead, T.; Burke, T.; Burt, D.; Scharff, C.; Adam, I.; Richard, H.; Sultan, M.; Soldatov, A.; Lehrach, H.; Edwards, S. V.; Yang, S. P.; L, i. X.; Graves, T.; Fulton, L.; Nelson, J.; Chinwalla, A.; Hou, S.; Mardis, E. R.; Wilson, R. K., The Genome of a Songbird. *Nature* **2010,** 464, 757–762.

Woroch, B.; **Gonsalves, B. D.**, Event-related potential correlates of item and source memory strength. *Brain Research* **2010,** 1317, 180-191.

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2009 – June 30, 2010

HCII FACULTY

(name followed by home department)

Artificial Intelligence

Narendra Ahuja, *Electrical and Computer Engineering*
Jont Allen, *Electrical and Computer Engineering*
Eyal Amir, *Computer Science*
Timothy W. Bretl, *Aerospace Engineering*
Todd P. Coleman, *Electrical and Computer Engineering*
Gerald F. Dejong, *Computer Science*
Roxanna Girju, *Linguistics*
Mark A. Hasegawa-Johnson, *Electrical and Computer Engineering*
Seth A. Hutchinson, *Electrical and Computer Engineering*
Steven M. Lavalle, *Computer Science*
Stephen E. Levinson, *Electrical and Computer Engineering*
Silvina A. Montrul, *Spanish, Italian, and Portugese*
Dan Roth, *Computer Science*
Ryan K. Shosted, *Linguistics*

Human Perception and Performance

Matthew Dye, *Speech and Hearing Science*
Wai-Tat Fu, *Human Factors Division*
Charles H. Hillman, *Kinesiology and Community Health*
Derek W. Hoiem, *Computer Science*
Fatima T. Husain, *Speech and Hearing Science*
David E. Irwin, *Psychology*
Alex Kirlik, *Human Factors Division*
Arthur F. Kramer, *Psychology*
Charissa Lansing, *Speech and Hearing Science*
Alejandro Lleras, *Psychology*
Edward McAuley, *Kinesiology and Community Health*
Jason S. McCarley, *Human Factors Division*
Deana C. McDonagh, *Industrial Design*
Daniel G. Morrow, *Human Factors Division*
Daniel J. Simons, *Psychology*
Jacob J. Sosnoff, *Kinesiology and Community Health*
Elizabeth A L Stine-Morrow, *Educational Psychology*
Ranxiao Wang, *Psychology*

Image Formation and Processing

Brian P. Bailey, *Computer Science*
Yoram Bresler, *Electrical and Computer Engineering*
Minh N. Do, *Electrical and Computer Engineering*
George K. Francis, *Mathematics*
Jiawei Han, *Computer Science*
Thomas S. Huang, *Electrical and Computer Engineering*
Douglas L. Jones, *Electrical and Computer Engineering*
Yi Ma, *Electrical and Computer Engineering*
Pierre Moulin, *Electrical and Computer Engineering*
Klara Nahrstedt, *Computer Science*

HCII SELECTED HONORS AND AWARDS

Narendra Ahuja
- Open Innovation Research Award, Hewlett-Packard, 2008 and 2009

Todd Coleman
- Co-recipient, College of Engineering's Grainger Award in Emerging Technologies, 2008
- DARPA ISAT study group selection, 2009
- Fellow, Center for Advanced Study, UIUC

Roxana Girju
- Excellent evaluation for the tutorial "Semantic Relation Extraction and its Applications," European Summer School in Logic, Language, and Information (ESSLLI) 2008

Mark Hasegawa-Johnson
- Associate Editor, IEEE Transactions on Audio Speech and Language, 2006-2009
- Workshops Chair, HLT/NAACL, June 2009
- Associate Editor, Journal of the Acoustical Society of America, 2009-present
- Associate Editor, Laboratory Phonology, 2009-present
- General Chair, Speech Prosody 2010, May 11-14 2010

Dan Roth
- Fellow, Association for the Advancement of Artificial Intelligence (AAAI), 2009
- Ryan K. Shosted, Linguistics
- Arnold O. Beckman Award, 2009 and 2010

Thomas Huang
- Open Innovation Research Award, Hewlett-Packard, 2009
- Star Challenge (A*STAR) Grand Finals, Illinois team placed 3rd, 2009

Fatima Husain
- Chosen to attend the UC-Davis ERP Bootcamp, from July 20-29, 2009

Alex Kirlik
- Editorial Board Member, IEEE Transactions on Systems, Man, and Cybernetics (2009 -)

Alejandro Lleras, Psychology
- Department of Psychology Head Award for outstanding service, 2009
- Helen Corley Petit Scholar, 2010-2011 (for outstanding record as assistant professor in the College of Liberal Arts & Sciences)

Yi Ma
- Keynote Speaker, Workshop on Local and Non-Local Approximation in Image Processing, 2009
- Plenary Speaker, Picture Coding Symposium, 2009

Edward McAuley
- Appointed Chair, Psychosocial Risk and Disease Prevention Study Section, National Institutes of Health, 2009
- Invited to participate on the NIH Distinguished Editorial Panels, the group responsible for evaluating critiques of ARRA Challenge Grants and assigning final impact evaluations, 2009
- Distinguished Lecturer, Institute for Health Research and Policy, University of Illinois-Chicago, 2010

Deana C McDonagh
- Fellow, World Demographic Association
- Fellow, Design Research Society
- Fellow, Royal Society of Arts

Pierre Moulin
- IEEE Signal Processing Board of Governors, 2005-2008
- Founding Editor-in-Chief, *IEEE Transactions on Information Forensics and Security*, 2005-2008
- Top 10% paper award, IEEE Multimedia Workshop, 2009
- 3rd Best Paper award, SPIE conference on Watermarking and Media Forensics, 2009

Daniel J Simons
- Graduate Student Organization Award for excellence in graduate instruction and mentoring, University of Illinois, 2008

Elizabeth Al Stine-Morrow
- President, Division 20 (Adult Development and Aging) of the American Psychological Association

HCII INVENTION DISCLOSURES

Faculty members from the Human-Computer Intelligent Interaction research theme were inventors on six invention disclosures (3.4% of the 178 invention disclosures filed by campus) during FY2010.

HCII SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Human-Computer Intelligent Interaction research theme were inventors on the following four patents issued (5.8% of the 69 patents issued to campus) during FY2010 (Beckman Institute faculty members are listed in bold):

Albert Feng, Michael Lockwood, **Douglas Jones**, Carolyn J. Bilger (Legal Representative), **Charissa Lansing**, **William O'Brien**, **Bruce Wheeler**, and Robert Bilger: "Systems and Methods For Interference-Suppression With Directional Sensing Patterns," Patent issued August 18, 2009, Patent Number 7,577,266.

Douglas Jones, Michael Lockwood, Robert C. Bilger, Carolyn T. Bilger (Legal Representative), **Albert Feng**, **Charissa Lansing**, **William O'Brien**, **Bruce Wheeler**, Mark Elledge, and Chen Liu: "Interference Suppression Techniques," Patent issued November 3, 2009, Patent Number 7,613,309.

Erik Larsen, **Albert Feng**, and **Douglas Jones**: "Room Volume and Room Dimension Estimation," Patent issued March 30, 2010, Patent Number 7,688,678.

Ashvin K. George and **Yoram Bresler**: "Fast Hierarchical Tomography Methods and Apparatus," Patent issued June 1, 2010, Patent Number 7,729,526.

HCII GRANTS AWARDED *($5,567,492)*

Timothy Bretl, NSF, "Eager: Control Systems, Mechanical Symmetry, and the Origins of Language," August, 15, 2009-July 31, 2010, $45,000.

Timothy Bretl and **Seth Hutchinson**, NSF, "CPS: Small: Mathematical, Computational, and Perceptual Foundations for Interactive Cyber-Physical Systems," September 1, 2009-August 31, 2012, $525,000.

Douglas Jones, **Todd Coleman**, **Monica Fabiani**, and Robert Wickesberg, NSF, "IGERT: Neuroengineering-A Unified Educational Program for Systems Engineering and Neuroscience," August 1, 2009-July 31, 2014, $2,992,413.

Stephen Levinson, Sandia National Laboratories, "Mathematical Models of Neocortical Circuits," August 16, 2009-August 15, 2010, $53,231.

Daniel Morrow and **Elizabeth Stine-Morrow**, NIH, "Medtable: An EMR Strategy to Promote Patient Medication Understanding and Use," April 7, 2010-February 28, 2011, $1,877,848.

Richard Sproat, **Mark Hasegawa-Johnson**, **Chilin Shih**, **Kathryn Bock**, and **Brian Ross**, NSF, "DHB: An Interdisciplinary Study of the Dynamics of Second Language Fluency," May 4, 2010-January 31, 2011, $24,000.

Stephen Levinson, DOD-Naval Research Lab, "The Role of Sensorimotor Function, Associative Memory and Reinforcement Learning in Automatic Acquisition of Spoken Language by an Autonomous Robot," June 1, 2010-June 15, 2011, $50,000.

HCII SELECTED PUBLICATIONS

Coleman, T. P.; Yanike, M.; Suzuku, W.; Brown, E. N., A mixed-filter algorithm for dynamically tracking learning from multiple behavioral and neurophysiological measures. In *Neuronal Variability and Its Functional Significance*, Ding, M.; Glanzman, D., Eds. Oxford University Press: **2010**.

Erickson, K. I.; Prakash, R. S.; Voss, M. W.; Chaddock, L.; Hu, L.; Morris, K. S.; White, S. M.; Wojcicki, T. R.; **McAuley, E.**; **Kramer, A. F.**, Aerobic Fitness is Associated With Hippocampal Volume in Elderly Humans. *Hippocampus* **2009,** 19, (10), 1030-1039.

Gao, C.; Hua, H.; **Ahuja, N.**, A hemispherical imaging camera. *Computer Vision and Image Understanding* **2010,** 114, (2), 168-178.

Gilbert, J. l.; Steelman-Allen, K. S.; **Lansing, C. R.**; **McCarley, J. S.**; **Kramer, A. F.**, Effect of overheard conversations on bystander productivity. *Human Factors and Ergonomics Society* **2009,** 53, (8), 1314-1318.

Huang, T. S.; **Hasegawa-Johnson, M. A.**; Chu, S. M.; Zeng, Z. H.; Tang, H., Sensitive Talking Heads. *IEEE Signal Processing Magazine* **2009,** 26, (4), 67-72.

Husain, F. T.; Patkin, D. J.; Thai-Van, H.; Braun, A. R.; Horwitz, B., Distinguishing the processing of gestures from signs in deaf individuals: An fMRI study. *Brain Research* **2009,** 1276, 140-150.

Jones, D. L.; Ratham, R., Blind location and separation of callers in a natural chorus using a microphone array. *Journal of the Acoustical Society of America* **2009,** 126, (2), 895-910.

Jourdas, J. F.; **Moulin, P.**, High-Rate Random-Like Spherical Fingerprinting Codes With Linear Decoding Complexity. *IEEE Transactions on Information Forensics and Security* **2009,** 4, (4), 768-780.

Li, F.; **Allen, J. B.**, Additivity law of frequency integration for consonant identification in white noise. *Journal of Acoustical Society of America* **2009,** 126, (1), 347-353.

Ma, Y.; Miller, J. C.; Crandall, H.; Larsen, E. T.; Dunn, D. M.; Weiss, R. B.; Subramanian, M.; Weis, J. H.; Zachary, J. F.; Teuscher, C.; Weis, J. J., Interval-Specific Congenic Lines Reveal Quantitative Trait Loci with Penetrant Lyme Arthritis Phenotypes on Chromosomes 5, 11, and 12. *Infection and Immunity* **2009,** 77, (8), 3302-3311.

McDonagh, D., Empathic Design: Disability + Relevant Design. *Journal of Nanjing University of Science and Technology (Natural Science)* **2009,** 33, 24-29.

Morrow, D. G.; Fischer, U. M., Communication in socio-technical systems. In *Oxford Handbook of Cognitive Engineering* Lee, J. D.; Kirlik, A., Eds. Oxford University Press: New York, NY, **2010**.

Ning, H. Z.; Xu, W.; Zhou, Y.; Gong, Y. H.; **Huang, T. S.**, A General Framework to Detect Unsafe System States From Multisensor Data Stream. *IEEE Transactions on Intelligent Transportation Systems* **2010,** 11, (1), 4-15.

Noh, S.; Gao, X.; **Stine-Morrow, E.**, The Effects of Resource Allocation and Fluid Ability on Text Memory Change through Later Adulthood. *Gerontologist* **2009,** 49, 349-350.

Sarmiento, A.; Murrieta-Cid, R.; **Hutchinson, S.**, An Efficient Motion Strategy to Compute Expected-Time Locally Optimal Continuous Search Paths in Known Environments. *Advanced Robotics* **2009,** 23, (12-13), 1533-1560.

Stivers, T.; Enfield, N. J.; Brown, P.; Englert, C.; Hayashi, M.; Heinemann, T.; Hoymann, G.; Rossano, F.; de Ruiter, J. P.; Yoon, K. E.; **Levinson, S. C.**, Universals and cultural variation in turn-taking in conversation. *Proceedings of the National Academy of Sciences of the United States of America* **2009,** 106, (26), 10587-10592.

Thomas, L. E.; **Lleras, A.**, Swinging into thought: Directed movement guides insight in problem solving. *Psychonomic Bulletin & Review* **2009,** 16, (4), 719-723.

Vidoni, E. D.; **McCarley, J. S.**; Edwards, J. D.; Boyd, L. A., Manual and oculomotor performance develop contemporaneously but independently during continuous tracking. *Experimental Brain Research* **2009,** 195, (4), 611-620.

Wan, X. I.; Ambinder, M. S.; **Simons, D. J.**, Change blindness. In *The Oxford Companion to Consciousness* Bayne, T.; Cleeremans, A.; Wilken, P., Eds. Oxford University Press: Oxford, UK, **2009**; pp 130-133.

White, S. M.; Klamm, E. L.; **McAuley, E.**, Leading a physically active lifestyle: Effective individual behavior change strategies. *American College of Sports Medicine Health & Fitness Journal* **2010,** 14, 8-15.

Xu, D.; Yan, S. C.; Lin, S.; **Huang, T. S.**; Chang, S. F., Enhancing Bilinear Subspace Learning by Element Rearrangement. *IEEE Transactions on Pattern Analysis and Machine Intelligence* **2009,** 31, (10), 1913-1920.

Yoon, S. Y.; Pierce, L.; Huensch, A.; Juul, E.; Perkins, S.; **Sproat, R.**; **Hasegawa-Johnson, M.**, Construction of a rated speech corpus of L2 learners' speech. *CA-LICO Journal* **2009,** 26, (3), 662-673.

Yu, T. L.; Luo, J. B.; **Ahuja, N.**, Search strategies for shape regularized active contour. *Computer Vision and Image Understanding* **2009,** 113, (10), 1053-1063.

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2009 – June 30, 2010

INTEGRATIVE IMAGING FACULTY

(name followed by home department)

Bioacoustics Research Laboratory
William D. O'Brien, *Electrical and Computer Engineering*
Michael L. Oelze, *Bioengineering*
Douglas Simpson, *Statistics*

Bioimaging Science and Technology
Rohit Bhargava, *Bioengineering*
Stephen Boppart, *Electrical and Computer Engineering*
Marni Boppart, *Kinesiology and Community Health*
Scott Carney, *Electrical and Computer Engineering*
Michael Insana, *Bioengineering*
Jianming Jin, *Electrical and Computer Engineering*
John A. Katzenellenbogen, *Chemistry*
Zhi-Pei Liang, *Electrical and Computer Engineering*
Ling J. Meng, Nuclear, *Plasma, and Radiological Engineering*
William C. Olivero, *Surgery*
Gabriel Popescu, *Electrical and Computer Engineering*
Martin Starzewski, *Mechanical Science and Engineering*
Kenneth S. Suslick, *Chemistry*
Brad Sutton, *Bioengineering*
Kimani Toussaint, *Mechanical Science and Engineering*
Amy J. Wagoner Johnson, *Mechanical Science and Engineering*
Michelle Wang, *Statistics*
Ning Wang, *Mechanical Science and Engineering*
John Wang, *Surgery*
Yingxiao Wang, *Bioengineering*
Kenneth L. Watkin, *Speech and Hearing Science*
Sheng Zhong, *Bionengineering*

INTIM SELECTED HONORS AND AWARDS

Zhi-Pei Liang

- Fellow, International Society for Magnetic Resonance in Medicine (ISMRM), 2010
- President-elect, IEEE Engineering in Medicine and Biology Society (EMBS), 2009

Kenneth Suslick

- 3ème Cycle Lectureship, Switzerland, 2010
- Fellow, Materials Research Society, 2010
- Acoustical Society of America Mentorship Award, 2009

Michael Oelze, Bioengineering
Senior Member, IEEE, 2009

INTIM INVENTION DISCLOSURES

Faculty members from the Integrative Imaging research theme were inventors on 19 invention disclosures (10.7% of the 178 invention disclosures filed by campus) during FY2010.

INTIM SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Integrative Imaging research theme were inventors on the following seven patent applications (5.0% of the 139 patent applications filed by the campus) and ten patents issued (14.5% of the 69 patents issued to campus) during FY2010 (Beckman Institute faculty members are listed in bold):

Gabriel Popescu and Zhuo Wang: "Jones Phase Microscopy of Transparent Samples," Patent filed July 24, 2009, Application Number 12/460,808.

Albert Feng, Michael Lockwood, **Douglas Jones**, Carolyn J. Bilger (Legal Representative), **Charissa Lansing**, **William O'Brien**, **Bruce Wheeler**, and Robert Bilger: "Systems and Methods For Interference-Suppression With Directional Sensing Patterns," Patent issued August 18, 2009, Patent Number 7,577,266.

Kenneth Suslick, Sung Lim, Jonathan Kemling, Christopher Musto, and Liang Feng: "Colorimetric Sensor Arrays Based on Nanoporous Pigments," Patent filed September 2, 2009, Application Number 12/552,899.

Daniel Marks and **Stephen Boppart**: "Distinguishing Non-Resonant Four-Wave-Mixing Noise in Coherent Stokes and Anti-Stokes Raman Scattering," Patent issued September 8, 2009, Patent Number 7,586,618.

Haohua Tu and **Stephen Boppart**: "Optical Frequency Up-Conversion of Femtosecond Pulses into the Visible and Ultraviolet," Patent filed September 16, 2009, Application Number 61/276,774.

Kevin F. King, Dan Xu, and **Zhi-Pei Liang**: "Hybrid K-T Method of Dynamic Imaging with Improved Spatiotemporal Resolution," Patent issued September 22, 2009, Patent Number 7,592,809.

Tyler Ralston, Daniel Marks, **Paul Carney**, and **Stephen Boppart**: "Interferometric Synthetic Aperture Microscopy," Patent issued October 13, 2009, Patent Number 7,602,501.

Stephen Boppart and Alexander Wei: "Multi-Functional Plasmon-Resonant Contrast Agents for Optical Coherence," Patent issued October 27, 2009, Patent Number 7,610,074.

Douglas Jones, Michael Lockwood, Robert C. Bilger, Carolyn T. Bilger (Legal Representative), **Albert Feng**, **Charissa Lansing**, **William O'Brien**, **Bruce Wheeler**, Mark Elledge, and Chen Liu: "Interference Suppression Techniques," Patent issued November 3, 2009, Patent Number 7,613,309.

Stephen Boppart and Woong Gyu Jung: "Apparatus for Biomedical Imaging," Patent filed November 18, 2009, Application Number 61/262,429.

Stephen Boppart and Daniel Marks: "Nonlinear Interferometric Vibrational Imaging," Patent issued November 24, 2009, Patent Number 7,623,908.

Michael Insana, Marko Orescanin, and Kathleen Toohey: "Techniques to Evaluate Mechanical Properties of a Biologic Material," Patent filed December 1, 2009, Application Number 12/592,717.

Daniel Marks, Brynmor Davis, **Stephen Boppart**, and **Paul Carney**: "Partially Coherent Illumination for Inverse Scattering Full-Field Interferometric Synthetic Aperture Microscopy," Patent issued January 5, 2010, Patent Number 7,643,155.

Brad Sutton: "Method for Dynamic Motion Guided Functional Magnetic Resonance Imaging," Patent filed February 1, 2010, Application Number 12/697,617.

Jin Kwak, **Rohit Bhargava**, and Saurabh Sinha: "Multimodal Microscopy for Automated Histologic Analysis of Prostate Cancer," Patent filed April 20, 2010, Application Number 61/326,151.

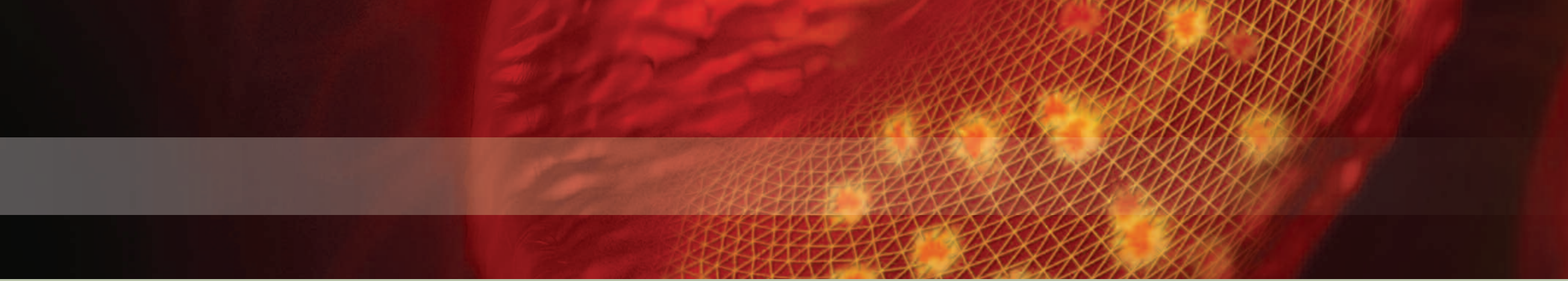
Dan Xu, Kevin F. King, and **Zhi-Pei Liang**: "System and Method for Designing Improved RF Pulse Profiles," Patent issued April 27, 2010, Patent Number 7,705,594.

Stephen Boppart and Chenyang Xu: "Contrast Enhanced Spectroscopic Optical Coherence Tomography," Patent issued May 25, 2010, Patent Number 7,725,169.

INTIM GRANTS AWARDED *($6,752,962)*

Brad Sutton and **David Kuehn**, NIH, "MRI Analyses of the Velopharyngeal Mechanism among Different Adult Populations," June 5, 2009-May 31, 2012, $276,442.

Marni Boppart, **Stephen Boppart**, and Bradford Schwartz, Ellison Medical Foundation, "Utilization of Alpha7 Integrin-Derived Stem Cells as Therapy for the Alleviation of Scarcopenia," August 16, 2009-August 15, 2013, $400,000.



Stephen Boppart, NIH, "Nonlinear Interferometric Vibrational Imaging of Cancer," August 18, 2009-July 31, 2011, $577,528.

Stephen Boppart and **Marni Boppart**, NSF, "3-D Optical Tracking of Bone-Marrow Derived Skin Stem Cells," August 15, 2009-July 31, 2012, $306,000.

Stephen Boppart, Sharon Donovan, **Lawrence Schook**, Charles Werth, and **Scott White**, NSF, "MRI: Acquisition of a Molecular Imaging Instrument for Dynamic Materials and Biological Systems," September 1, 2009-August 31, 2012, $1,770,910.

Stephen Boppart and **Kenneth Suslick**, NIH, "Targeted Microspheres for Contrast Enhancement in Optical Coherence Tomography," July 15, 2009-June 30, 2013, $1,293,533.

William O'Brien, **Stephen Boppart**, **Michael Insana**, **Michael Oelze**, Kenneth Wilund, **Marni Boppart**, **Martha Gillette**, John Erdman, and **Iwona Jasiuk**, NIH, "High- Resolution In Vivo Ultrasound Imaging using VisualSonics Vevo 2100 System," September 1, 2009-August 31, 2010, $479,498.

Gabriel Popescu, NIH, "Label Free Imaging of Blood Smears and Tissue Biopsies," April 8, 2010-March 31, 2012, $321,721.

Brad Sutton and **Brian Gonsalves**, UTD, "Cognitive Neuroscience of Aging and Culture," July 1, 2009-June 30, 2010, $116,865.

Brad Sutton, Wen-Mei Hwu, and **Zhi-Pei Liang**, NIH, "Accelerating Advanced MRI Reconstructions on GPUs," June 1, 2010-May 31, 2012, $405,470.

Rohit Bhargava and **Minh Do**, NSF, "Novel Acquisition and Computation in Vibrational Spectroscopic Imaging," June 15, 2010-May 31, 2013, $400,000.

Brad Sutton and **Arthur Kramer**, NIH, "Controlling Sensitivity Bias in Functional MRI Studies Due to Field Inhomogenity," July 1, 2010-June 30, 20102, $404,995.

INTIM SELECTED PUBLICATIONS

Ahmad, A.; Adie, S. G.; Wang, M.; **Boppart, S. A.**, Sonification of optical coherence tomography data and images. *Optics Express* **2010,** 18, (10), 9934-9944.

Bhargava, R.; Perlman, R. S.; Fernandez, D. C.; Levin , I. W.; Bartick, E. G., Non-invasive detection of superimposed latent fingerprints and inter-ridge trace evidence by infrared spectroscopic imaging. *Analytical and Bioanalytical Chemistry* **2009,** 394, (8), 2069–2075.

Chowdary, P. D.; Benalcazar, W. A.; Jiang, Z.; Marks, D. M.; **Boppart, S. A.**; **Gruebele, M.**, High Speed Nonlinear Interferometric Vibrational Analysis of Lipids by Spectral Decomposition. *Analytical Chemistry* **2010,** 82, (9), 3812-3818.

Davis, B. J.; **Carney, P. S.**; **Bhargava, R.**, Theory of Midinfrared Absorption Microspectroscopy: I. Homogeneous Samples. *Analytical Chemistry* **2010,** 82, (9), 3474-3486.

Ding, H. F.; Nguyen, F.; **Boppart, S. A.**; **Popescu, G.**, Optical properties of tissues quantified by Fourier-transform light scattering. *Optics Letters* **2009,** 34, (9), 1372-1374.

Fortunato, M. E.; Rostam-Abadi, M.; **Suslick, K. S.**, Nanostructured Carbons Prepared by Ultrasonic Spray Pyrolysis. *Chemistry of Materials* **2010,** 22, (5), 1610-1612.

Heo, S.; Prakash, R. S.; Voss, M. W.; Erickson, K. I.; Ouyang, C.; **Sutton, B. P.**; **Kramer, A. F.**, Resting hippocampal blood flow, spatial memory and aging. *Brain Research* **2010,** 1315, 119-127.

Hruska, D. P.; **Oelze, M. L.**, Improved Parameter Estimates Based on the Homodyned K Distribution. *IEEE Transactions on Ultrasonics Ferroelectrics and Frequency Control* **2009,** 56, (11), 2471-2481.

Kalyanam, S.; Yapp, R. D.; **Insana, M. F.**, Poro-Viscoelastic Behavior of Gelatin Hydrogels Under Compression-Implications for Bioelasticity Imaging. *Journal of Biomechanical Engineering-Transactions of the Asme* **2009,** 131, (8).

Karampinos, D. C.; King, K. F.; **Sutton, B. P.**; **Georgiadis, J. G.**, Myofiber Ellipticity as an Explanation for Transverse Asymmetry of Skeletal Muscle Diffusion MRI In Vivo Signal. *Annals of Biomedical Engineering* **2009,** 37, (12), 2532-2546.

Karampinos, D. C.; Van, A. T.; **Olivero, W. C.**; **Georgiadis, J. G.**; **Sutton, B. P.**, High-Resolution Diffusion Tensor Imaging of the Human Pons With a Reduced Field-of-View, Multishot, Variable-Density, Spiral Acquisition at 3 T. *Magnetic Resonance in Medicine* **2009,** 62, (4), 1007-1016.

Li, J.; **Ostoja-Starzewski, M.**, Fractal solids, product measures and fractional wave equations. *Proceedings of the Royal Society a-Mathematical Physical and Engineering Sciences* **2009,** 465, (2108), 2521-2536.

Liang, X.; Orescanin, M.; Toohey, K. S.; **Insana, M. F.**; **Boppart, S. A.**, Acoustomotive optical coherence elastography for measuring material mechanical properties. *Optics Letters* **2009,** 34, (19), 2894-2896.

Ostoja-Starzewski, M., A derivation of the Maxwell-Cattaneo equation from the free energy and dissipation potentials. *International Journal of Engineering Science* **2009,** 47, (7-8), 807-810.

Park, Y.; Diez-Silva, M.; Fu, D.; **Popescu, G.**; Choi, W.; Barman, I.; Suresh, S.; Feld, M. S., Static and dynamic light scattering of healthy and malaria-parasite invaded red blood cells. *Journal of Biomedical Optics* **2010,** 15, (2).

Poellmann, M. J.; Harrell, P. A.; **King, W. P.**; **Wagoner Johnson, A. J.**, Geometric microenvironment directs cell morphology on topographically patterned hydrogel substrates. *Acta Biomaterialia*, **2010,** on-line.

Ralston, T. S.; Charvat, G. L.; Adie, S. G.; Davis, B. J.; **Carney, P. S.**; **Boppart, S. A.**, Interferometric synthetic aperture microscopy: Microscopic laser radar. *Optics and Photonics News* **2010,** 21, 32-38.

Sakoglu, U.; Pearlson, G. D.; Keihl, K. A.; **Wang, Y. M.**; Michael, A. M.; Calhoun, V. D., A Method for Evaluating Dynamics Functional Network Connectivity and Task-Modulation: Application to Schizophrenia. *Magnetic Resonance Materials in Physics, Biology, and Medicine* **2010,** 10.1007/s10334-010-0197-8.

Santin, M. D.; King, D. A.; Foiret, J.; Haak, A.; **O'Brien, W. D.**; Bridal, S. L., Encapsulated contrast microbubble radial oscillation associated with postexcitation pressure peaks. *Journal of the Acoustical Society of America* **2010,** 127, (2), 1156-1164.

Siriani, D. F.; Choquette, K. D.; **Carney, P. S.**, Stochastic coupled mode theory for partially coherent laser arrays. *Journal of the Optical Society of America A-Optics Image Science and Vision* **2010,** 27, (3), 501-508.

Wang, Z.; **Popescu, G.**, Quantitative phase imaging with broadband fields. *Applied Physics Letters* **2010,** 96, (5).

Xu, H. X.; **Suslick, K. S.**, Molecular Emission and Temperature Measurements from Single-Bubble Sonoluminescence. *Physical Review Letters* **2010,** 104, 244301.

Zysk, A. M.; Schoonover, R. W.; **Carney, P. S.**; Anastasio, M. A., Transport of intensity and spectrum for partially coherent felds. *Optics Letters* **2010,** 35, (13), 2239-2241

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2009 – June 30, 2010

M&ENS Faculty

(name followed by home department)

3D Micro- and Nanosystems
Rashid Bashir, *Electrical and Computer Engineering*
Paul V. Braun, *Materials Science and Engineering*
Nicholas X. Fang, *Mechanical Science and Engineering*
Steve Granick, *Materials Science and Engineering*
Iwona M. Jasiuk, *Mechanical Science and Engineering*
Paul J. Kenis, *Chemical and Biomolecular Engineering*
William P. King, *Mechanical Science and Engineering*
Deborah E. Leckband, *Chemistry*
Yi Lu, *Chemistry*
John A. Rogers, *Materials Science and Engineering*
Mark A. Shannon, *Mechanical Science and Engineering*
Stephen G. Sligar, *Biochemistry*
Pierre Wiltzius, *Materials Science and Engineering*

Autonomous Materials Systems
Ioannis Chasiotis, *Aerospace Engineering*
Philippe H. Geubelle, *Aerospace Engineering*
Jennifer A. Lewis, *Materials Science and Engineering*
Jeffrey S. Moore, *Chemistry*
Nancy R. Sottos, *Materials Science and Engineering*
Scott R. White, *Aerospace Engineering*

Computational Multiscale Nanosystems
Narayana R. Aluru, *Mechanical Science and Engineering*
Andreas Cangellaris, *Electrical and Computer and Engineering*
John G. Georgiadis, *Mechanical Science and Engineering*
Eric Jakobsson, *Molecular and Integrative Physiology*
Harley T. Johnson, *Mechanical Science and Engineering*
Olgica Milenkovic, *Electrical and Computer Engineering*
Christopher V. Rao, *Chemical and Biomolecular Engineering*
Umberto Ravaioli, *Electrical and Computer Engineering*

Nanoelectronics and Nanomaterials
Ilesanmi Adesida, *Electrical and Computer Engineering*
Aleksei Aksimentiev, *Physics*
Alexey Bezryadin, *Physics*
Matthew Gilbert, *Electrical and Computer Engineering*
Gregory Girolami, *Chemistry*
Martin Gruebele, *Chemistry*
Jean-Pierre Leburton, *Electrical and Computer Engineering*
Xiuling Li, *Electrical and Computer Engineering*
Joseph W. Lyding, *Electrical and Computer Engineering*
Nancy Makri, *Chemistry*
Margery Osborne. *Curriculum and Instruction*
Eric Pop, *Electrical and Computer Engineering*
Angus Rockett, *Materials Science and Engineering*
Moonsub Shim, *Materials Science and Engineering*
Gregory L. Timp, *Electrical and Computer Engineering*
Min-Feng Yu, *Mechanical Science and Engineering*

Theoretical and Computational Biophysics
Laxmikant V. Kale, *Computer Science*
Zan Luthey-Schulten, *Chemistry*
Klaus J. Schulten, *Physics*
John Stack, *Physics*
Emadeddin Tajkhorshid, *Biochemistry*

M&ENS SELECTED HONORS AND AWARDS

Alek Aksimentiev
- Career Award, National Science Foundation (NSF), 2010
- Beckman Fellowship, Center for Advanced Study (UIUC), 2009-2010

Paul Braun
- Friedrich Wihelm Bessel Research Award, Humboldt Foundation, 2010

Ioannis Chasiotis
- Xerox Award for Faculty Research, 2010
- Presidential Early Career Award, National Science Foundation (NSF), 2009
- Willett Faculty Scholar of Engineering, 2009

Nicholas Fang
- Faculty Early Career Development (CAREER) Award, National Science Foundation (NSF), 2009
- John G. Bollinger Outstanding Young Manufacturing Engineer Award, Society of Manufacturing Engineers (SME), 2009

Martin Gruebele
- American Academy of Arts and Sciences, 2010

Harley Johnson
- Thomas J.R. Hughes Young Investigator Award, American Society of Mechanical Engineers (ASME), 2010

William King
- Bergles-Rohsenow Young Investigator Award in Heat Transfer, American Society of Mechanical Engineers (ASME), 2009

Deborah Leckband
- Fellow, American Chemical Society (ACS), 2009

Yi Lu
- Illinois Sustainable Technology Center (ISTC) Research Fellow Award, 2009
- Special Creativity Extension Award, National Science Foundation (NSF), 2009

Eric Pop
- Young Investigator Research Award, U.S. Air Force, 2009
- Faculty Early Career Development (CAREER) Award, National Science Foundation (NSF), 2010
- Young Investigators Award, Office of Naval Research (ONR), 2010

John Rogers
- Fellow, IEEE, 2010
- MacArthur Fellow, John D. and Catherine T. MacArthur Foundation, 2009

M&ENS SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Molecular and Electronic Nanostructures research theme were inventors on the following 21 patent applications (15.1% of the 139 patent applications filed by the campus) and 17 patents issued (24.6% of the 69 patents issued to campus) during FY2010 (Beckman Institute faculty members are listed in bold):

John Rogers, Dahl-Young Khang, and Etienne Menard: "Stretchable Semiconductor Elements and Stretchable Electrical Circuits," Patent issued July 7, 2009, Patent Number 7,557,367.

Alfred Baca, **John Rogers,** Heung Cho Ko, Michael Motala, Ralph Nuzzo, Sang II Park, Chang Jae Yu, Jongseung Yoon, Matthew Meitl, Mark Stoykovich, and Jong-Hyun Ahn: "Optical Systems Fabricated by Printing-Based Assembly," Patent filed July 9, 2009, Application Number 12/522,582.

Yi Lu, Abhijit Mishra, Mehmet Veysel Yigit, and **Gerard Wong**: "Amphiphilic Substances and Functionalized lipid Vesicles Including the Same," Patent filed July 16, 2009, Application Number 12/523,443.

Jonathan Engel, Jack Chen, and **Chang Liu**: "Artificial Lateral Line Sensor," Patent filed July 23, 2009, Application Number 12/508,229.

Jeffrey Moore, Joseph Rule, **Scott White**, **Nancy Sottos**, and Eric Brown: "Wax Particles for Protection of Activators, and Multifunctional Autonomically Healing Composite Materials," Patent issued July 28, 2009, Patent Number 7,566,747.

Michael Keller, **Nancy Sottos**, and **Scott White**: "Self-Healing Elastomer System," Patent issued August 4, 2009, Patent Number 7,569,625.

Stephen Sligar and Timothy Baybert: "Membrane Scaffold Proteins and Tethered Membrane Proteins," Patent issued August 18, 2009, Patent Number 7,575,763.

Scott White, **Nancy Sottos**, Jericho Moll, Benjamin Blaiszik, and Brett Beiermann: "Interfacial Functionalization for Self-Healing Composites," Patent filed August 18, 2009, Application Number 12/543,206.

Ioannis Chasiotis and Mohammad Naraghi: "Stress Micro Mechanical Test Cell, Device, System and Methods," Patent filed August 19, 2009, Application Number 12/527,776.

William King, Kevin Kjoller, Jonathan Felts, and Craig Prater: "Microcantilever with Reduced Second Harmonic while in Contact with a Surface and Nano Scale Infrared Spectrometer," Patent filed September 11, 2009, Application Number 12/558,150.

Stephen Sligar, Timothy Bayburt, Mary Schuler, Natanya Civjan, Ylena Grinkova, Ilia Denisov, and Stephen Grimme: "Membrane Scaffold Proteins," Patent issued September 22, 2009, Patent Number 7,592,008.

Ralph Nuzzo, Etienne Menard, Zhengtao Zhu, Yugang Sun, Keon Jae Lee, Matthew Meitl, **John Rogers**, and Dahl-Young Khang: "Methods and Devices for Fabricating and Assembling Printable Semiconductor Elements," Patent filed September 22, 2009, Application Number 12/564,566.

Paul Braun, Xindi Yu, and Hui Zhang: "Porous Battery Electrode for a Rechargeable Battery and Method of Making the Electrode," Patent filed October 7, 2009, Application Number 12/575,197.

Xiuling Li, **Nicholas Fang**, Winston Chern, Ik Su Chun, Keng Hao Hsu, and Placid Ferreira: "Method of Forming an Array of High Aspect Ratio Semiconductor Nanostructures," Patent filed October 21, 2009, Application Number 61/253,700.

Paul Braun, Soo Hyoun Cho, **Scott White**, **Nancy Sottos**, and H. Magnus Andersson: "Self-Healing Polymers," Patent issued November 3, 2009, Patent Number 7,612,152.

Yi Lu and Juewen Liu: "Nucleic Acid Biosensors," Patent issued November 3, 2009, Patent Number 7,612,185.

Ralph Nuzzo, **John Rogers**, Etienne Menard, Keon Jae Lee, Dahl-Young Khang, Yugang Sun, Matthew Meitl, and Zhengtao Zhu: "Methods and Devices for Fabricating and Assembling Printable Semiconductor Elements," Patent issued November 24, 2009, Patent Number 7,622,367.

James Morrissey, Vincent Pureza, and **Stephen Sligar**: "Tissue Factor Compositions and Methods," Patent issued November 24, 2009, Patent Number 7,622,437.

Gregory Timp, Utkur Mirsaidov, **Aleksei Aksimentiev**, Jeffrey Comer, and Winston Timp: "Polynucleotide Sequencing by Solid-State Nanopassages," Patent filed December 18, 2009, Application Number 61/287,974.

Paul Kenis, Adrzej Wieckowski, and Eric Choban: "Membraneless Electrochemical Cell and Microfluidic Device without PH Constraint," Patent issued December 22, 2009, Patent Number 7,635,530.

John Rogers: "Nanoscale, Electrified Liquid Jets for High Resolution Printing of Charge," Patent filed January 8, 2010, Application Number 61/293,258.

Chang Liu, Jonathan Engel, and Jack Chen: "Artificial Lateral Line," Patent issued January 12, 2010, Patent Number 7,644,624.

Jang-Ung Park, Placid Ferreira, **John Rogers**, and Deepkishore Mukhopadhyay: "High Resolution Electrohydrodynamic Jet Printing for Manufacturing Systems," Patent filed January 15, 2010, Application Number 12/669,287.

Larry Markoski, **Jeffrey Moore**, and **Joseph Lyding**: "Electrochemical Cells Comprising Laminar Flow Induced Dynamic Conducting Interfaces, Electronic Devices Comprising Such Cells, and Methods Employing Same," Patent issued January 26, 2010, Patent Number 7,651,797.

Stephanie Potisek, **Scott White**, Douglas Davis, **Jeffrey Moore**, and **Nancy Sottos**: "Self-Assessing Mechanochromic Materials," Patent filed January 26, 2010, Application Number 12/693,801.

Yi Lu and Juewen Liu: "Nucleic Acid Based Fluorescent Sensor for Mercury Detection," Patent filed February 9, 2010, Application Number 12/672,833.

Stephen Sligar and Timothy Baybert: "Membrane Scaffold Proteins and Embedded Membrane Proteins," Patent issued February 16, 2010, Patent Number 7,662,410.

John Rogers, David Kaplan, Fiorenzo Omenetto, Dae-Hyeong Kim, and Jason Amsden: "Dissolvable Films of Silk Fibroin for Ultrathin, Conformal Bio-Integrated Electronics," Patent filed March 17, 2010, Application Number 61/314,739.

Andrew Cox, **Nicholas Fang**, and Chunguang Xia: "Three-Dimensional Microfabricated Bioreactors with Embedded Capillary Network," Patent filed March 23, 2010, Application Number 12/679,497.

Stephen Sligar and Timothy Baybert: "Membrane Scaffold Proteins," Patent issued (Continuation) April 6, 2010, Patent Number 7,691,414.

Scott White, Mary Caruso, David Delafuente, **Nancy Sottos**, **Jeffrey Moore**, Jason Kamphaus, and Benjamin Blaiszik: "Solvent-Promoted Self-Healing Materials," Patent filed April 23, 2010, Application Number 12/739,537.

John Rogers, Seokwoo Jeon, and Jangung Park; "Methods and Devices for Fabrication Three Dimensional Nanoscale Structures," Patent issued April 27, 2010, Patent Number 7,704,684.

Ralph Nuzzo, **John Rogers**, Nathan Mack, **Matthew Stewart**, Viktor Malyarchuk, and Jimin Yao: "Multispectral Plasmonic Crystal Sensors," Patent issued April 27, 2010, Patent Number 7,705,280.

James Henderson, Gerald Wilson, Christopher Britt, Benjamin Blaiszik, **Nancy Sottos**, **Scott White**, **Jeffrey Moore**, and Mary Caruso: "Systems for Self-Healing Composite Materials," Patent Filed April 29, 2010, Application Number 12/769,904.

John Rogers, Ralph Nuzzo, Hoon-Sik Kim, Eric Brueckner, Sang II Park, and Rak Kim: "Printed Assemblies of Inorganic Light-Emitting Diodes for Deformable and Semitransparent Displays," Patent filed May 12, 2010, Application Number 12/778,588.

Paul Braun, Soo Hyoun Cho, and **Scott White**: "Self-Healing Coating System," Patent issued May 25, 2010, Patent Number 7,723,405.

Yi Lu and Yu Xiang: "Personal Glucose Meters for Detection and Quantification of a Broad Range of Analytes," Patent filed May 26, 2010, Application Number 61/348,615.

Joshua Ritchey, **Nancy Sottos**, Mary Caruso, **Scott White**, Odom Susan, Michael Thackeray, **Jeffrey Moore**, Aaron Jackson, Khalil Amine, Benjamin Blaiszik, **Paul Braun**, Aaron Finke, and Marta Baginska: "Method and Apparatus for Automatic Repair and Restoration of Electrical Conductivity," Patent filed June 18, 2010, Application Number 61/356,356.

M&ENS INVENTION DISCLOSURES

Faculty members from the Molecular and Electronic Nanostructures research theme were inventors on 30 invention disclosures (16.9% of the 178 invention disclosures filed by campus) during FY2010.

M&ENS

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

M&ENS SELECTED GRANTS AWARDED

($3,914,000)

Deborah Leckband and **Paul Braun**, NSF, "Mechanism and Dynamics of Protein Interactions with Polymer Brushes," October 1, 2008-September 30, 2011, $8,060.

Scott White, DOD, "2nd International Conference on Self-Healing Materials," June 1, 2009-November 30, 2009, $70,000.

Susan Odom (Postdoctoral Researcher with AMS), NSF, "Microencapsulated Molecular Regenerators for Lithium Ion Batteries," September 1, 2009-August 31, 2011, $200,000.

Klaus Schulten, Lilly Research Laboratories, "Computational Biology of the Cell-The Next Decade," September 1, 2009-December 31, 2009, $3,000.

Scott White, **Nancy Sottos**, and **Philippe Geubelle**, ONR Subaward through Texas A&M, "Synthesis, Characterization and Modeling of Functionally Graded Multifunctional Hybrid Composites for Extreme Environments," September 15, 2009-September 14, 2014, $1,500,000.

Klaus Schulten, **Laxmikant Kale**, **Zaida Luthey-Schulten**, **Emadeddin Tajkhorshid**, and **Aleksei Aksimentiev**, NIH, "Resource for Macromolecular Modeling," September 25, 2009-July 31, 2010, $291,158.

Jeffrey Moore, American Chemical Society, "Associate Editor of the American Chemical Society," January 1, 2010-December 31, 2011, $147,288.

Klaus Schulten, Antony Crofts, **Stephen Sligar**, Paul Selvin, **Taekjip Ha**, and **Emadeddin Tajkhorshid**, NIH, "Petascale Molecular Dynamics Data Processing System," April 1, 2010-March 31, 2011, $488,504.

Jeffrey Moore, **Paul Braun**, and **Nancy Sottos**, US Army RDECOM Acquisition Center, "Mechanochemically-Active Polymer Composites-HSAP," May 10, 2010-August 31, 2010, $6,000.

Scott White, **Jeffrey Moore**, and **Nancy Sottos**, AFOSR, "Regeneration and Remodeling of Composite Materials," June 1, 2010-May 31, 2015, $1,200,000.

M&ENS SELECTED PUBLICATIONS

Agarwal, N.; **Aluru, N. R.**, A domain adaptive stochastic collocation approach for analysis of MEMS under uncertainties. *Journal of Computational Physics* **2009,** 228, (20), 7662-7688.

Aksimentiev, A.; Brunner, R. J.; Cruz-Chu, E. R.; Comer, J.; **Schulten, K.**, Modeling Transport Through Synthetic Nanopores. *IEEE Nanotechnology Magazine* **2009,** pp 21-28.

Aragon, A. M.; Duarte, C. A.; **Geubelle, P. H.**, Generalized finite element enrichment functions for discontinuous gradient fields. *International Journal for Numerical Methods in Engineering* **2010,** 82, (2), 242-268.

Arpin, K. A.; Mihi, A.; **Johnson, H. T.**; Baca, A. J.; **Rogers, J. A.**; **Lewis, J. A.**; **Braun, P. V.**, Multidimensional Architectures for Functional Optical Devices. *Advanced Materials* **2010,** 22, (10), 1084-1101.

Beiermann, B. A.; Keller, M. W.; **Sottos, N. R.**, Self-healing flexible laminates for resealing of puncture damage. *Smart Materials & Structures* **2009,** 18, (8), doi: 10.1088/0964-1726/18/8/085001.

Blaiszik, B. J.; Kramer, S. L. B.; Olugebefola, S. C.; **Moore, J. S.**; **Sottos, N. R.**; **White, S. R.**, Self-Healing Polymers and Composites. *Annual Review of Materials Research* **2010,** 40, 179-211.

Brassart, L.; Inglis, H. M.; Delannay, L.; Doghri, I.; **Geubelle, P. H.**, An extended Mori-Tanaka homogenization scheme for finite strain modeling of debonding in particle-reinforced elastomers. *Computational Materials Science* **2009,** 45, (3), 611-616.

Cannon, A. H.; **King, W. P.**, Microstructured metal molds fabricated via investment casting. *Journal of Micromechanics and Microengineering* **2010,** 20, (2), doi: 10.1088/0960-1317/20/2/025025.

Caruso, M. M.; Davis, D. A.; Shen, Q.; Odom, S. A.; **Sottos, N. R.**; **White, S. R.**; **Moore, J. S.**, Mechanically-Induced Chemical Changes in Polymeric Materials. *Chemical Reviews* **2009,** 109, (11), 5755-5798.

Caruso, M. M.; Schelkopf, S. R.; Jackson, A. C.; Landry, A. M.; **Braun, P. V.**; **Moore, J. S.**, Microcapsules containing suspensions of carbon nanotubes. *Journal of Materials Chemistry* **2009,** 19, (34), 6093-6096.

Chen, K.; Roberts, E.; **Luthey-Schulten, Z.**, Horizontal gene transfer of zinc and non-zinc forms of bacterial ribosomal protein S4. *BMC Evolutionary Biology* **2009,** 9.

Chiu, S. W.; Scott, H. L.; **Jakobsson, E.**, A Coarse-Grained Model Based on Morse Potential for Water and n-Alkanes. *Journal of Chemical Theory and Computation* **2010,** 6, (3), 851-863.

Daly, S. R.; **Girolami, G. S.**, Synthesis, Characterization, and Structures of Divalent Europium and Ytterbium N,N-Dimethylaminodiboranates. *Inorganic Chemistry* **2010,** 49, (10), 4578-4585.

Enkavi, G.; **Tajkhorshid, E.**, Simulation of Spontaneous Substrate Binding Revealing the Binding Pathway and Mechanism and Initial Conformational Response of GlpT. *Biochemistry* **2010,** 49, (6), 1105-1114.

George, M. C.; Nelson, E. C.; **Rogers, J. A.**; **Braun, P. V.**, Direct Fabrication of 3D Periodic Inorganic Microstructures using Conformal Phase Masks. *Angewandte Chemie-International Edition* **2009,** 48, (1), 144-148.

Gruebele, M., How to mark off paths on the protein energy landscape. *Proceedings of the National Academy of Sciences of the United States of America* **2009,** 106, (45), 18879-18880.

Hossain, M. Z.; Medhekar, N. V.; Shenoy, V. B.; **Johnson, H. T.**, Enhanced quantum confinement due to nonuniform composition in alloy quantum dots. *Nanotechnology* **2010,** 21, (9), doi: 10.1088/0957-4484/21/9/095401.

Jonnalagadda, K. N.; **Chasiotis, I.**, Strength and Fracture Resistance of Amorphous Diamond-Like Carbon Films for MEMS. *Journal of Nanomaterials* **2009,** Article ID 204281, 1-8.

Jonnalagadda, K. N.; **Chasiotis, I.;** Yagnamurthy, S.; Lambros, J.; Pulskamp, J.; Polcawich, R.; Dubey, M., Experimental Investigation of Strain Rate Dependence of Nanocrystalline Pt Films. *Experimental Mechanics* **2010,** 50, (1), 25-35.

Jonnalagadda, K. N.; Karanjgaokar, N.; **Chasiotis, I.**; Chee, J.; Peroulis, D., Strain Rate Sensitivity of Nanocrystalline Au Films at Room Temperature. *Acta Materialia* **2010,** 58, 4674-4684.

Kollia, V.; **Cangellaris, A. C.**, A Domain Decomposition Approach for Efficient Electromagnetic Analysis of the Power Distribution Network of Packaged Electronic Systems. *IEEE Transactions on Electromagnetic Compatibility* **2010,** 52, (2), 320-331.

Landis, E. C.; Klein, K. L.; Liao, A.; **Pop, E.**; Hensley, D. K.; Melechko, A. V.; Hamers, R. J., Covalent Functionalization and Electron-Transfer Properties of Vertically Aligned Carbon Nanofibers: The Importance of Edge-Plane Sites. *Chemistry of Materials* **2010,** 22, (7), 2357-2366.

Liu, F.; **Gruebele, M.**, Mapping an Aggregation Nucleus One Protein at a Time. *Journal of Physical Chemistry Letters* **2010,** 1, (1), 16-19.

Luan, B. Q.; **Aksimentiev, A.**, Electric and electrophoretic inversion of the DNA charge in multivalent electrolytes. *Soft Matter* **2010,** 6, (2), 243-246.

Lyding, J. W., Carbon Nanotubes: A simple approach to superlattices. *Nature Nanotechnology* **2009,** 4, (9), 545-546.

Martin, P. N.; Aksamija, Z.; **Pop, E.**; **Ravaioli, U.**, Reduced Thermal Conductivity in Nanoengineered Rough Ge and GaAs Nanowires. *Nano Letters* **2010,** 10, (4), 1120-1124.

Melnikov, D. V.; **Leburton, J. P.**, Few-electron Quantum Dot Spintronics. In *Frontiers in Nanoscience and Nanotechnology*, Narlikar, V.; Fu, Y., Eds. Oxford University Press: UK, **2009**; Vol. 3, pp 47-89.

Rogers, J. A.; Someya, T.; Huang, Y. G., Materials and Mechanics for Stretchable Electronics. *Science* **2010,** 327, (5973), 1603-1607.

Seidelt, B.; Innis, C. A.; Wilson, D. N.; Gartmann, M.; Armache, J. P.; Villa, E.; Trabuco, L. G.; Becker, T.; Mielke, T.; **Schulten, K.**; Steitz, T. A.; Beckmann, R., Structural Insight into Nascent Polypeptide Chain-Mediated Translational Stalling. *Science* **2009,** 326, (5958), 1412-1415.

Shih, A. Y.; **Sligar, S. G.**; **Schulten, K.**, Maturation of high-density lipoproteins. *Journal of the Royal Society Interface* **2009,** 6, (39), 863-871.

Tran, P.; Kandula, S. S. V.; **Geubelle, P. H.**; **Sottos, N. R.**, Dynamic Delamination of Patterned Thin Films: A Numerical Study. *International Journal of Fracture* **2010,** 162, 77-90.

White, S. R.; **Geubelle, P. H.**, Self-Healing Materials Get ready for repair-and-go. *Nature Nanotechnology* **2010,** 5, (4), 247-248.

Xu, Y.; Mi, X. B.; **Aluru, N. R.**, Detection of defective DNA in carbon nanotubes by combined molecular dynamics/tight-binding technique. *Applied Physics Letters* **2009,** 95, (11), doi:10.1063/1.3231922.

Yeom, J.; **Shannon, M. A.**, Detachment Lithography of Photosensitive Polymers: A Route to Fabricating Three-Dimensional Structures. *Advanced Functional Materials* **2010,** 20, (2), 289-295.

BECKMAN IN THE NEWS

The Beckman Institute contributes scientific discoveries and technology development to the world, and that work was reported in peer-reviewed journals and recognized in national and local media in 2009 and 2010. But the contributions of Beckman researchers went beyond those traditional forums this past year. Institute researchers were called on for their scientific expertise by national media, wrote works of popular non-fiction and fiction, and were recognized by the President.

Dan Simons of the Human Perception and Performance group co-authored a popular psychological science book about everyday illusions humans have when it comes to aspects of cognition like memory and attention. The book, *The Invisible Gorilla,* by Simons and longtime collaborator Chris Chabris, took its title from a famous psychology experiment the two did involving students passing a basketball back and forth while a person in a gorilla suit walked through the scene. The book received praise from reviewers in the *New York Times* and *Psychology Today* for its insights into human behavior and writing style.

Beckman faculty member **Richard Powers** from the Department of English won the 2006 National Book of the Year Award for Fiction for his novel *The Echo Maker.* In 2009 Powers published his 10th novel, *Generosity: An Enhancement.* Powers's work often has a scientific backdrop and his latest novel is no different. In it, he explores the world of personal genomics through the story of a college student from Algeria with a tragic past.

Other Beckman researchers contribute to the public discourse in their fields in national and international media. Beckman Institute Director **Art Kramer** co-authored an article for *Scientific American* on the links between physical activity and mental acuity. Kramer, a leading researcher in the areas of cognitive aging and the effects of exercise on our mental states, and his co-authors write that "if you do not work out, your muscles get flaccid. What most people don't realize, however, is that your brain also stays in better shape when you exercise."

The recognition given Beckman researchers was evidenced in many ways this past year. Beckman researcher **Ioannis Chasiotis** was honored by President Barack Obama at the White House in 2009 with a Presidential Early Career Award for Scientists and Engineers, the highest honor given by the United States government to young professionals at the beginning of their independent research careers. In addition, two other Beckman faculty members received prestigious honors. Powers was elected to the American Academy of Arts and Letters, while **Martin Gruebele** was named to the American Academy of Arts and Sciences.

The national media also focused on Institute researchers. **John Rogers** of the 3-D Micro- and Nanosystems group was the subject of a profile in the prestigious journal *Science* in 2010, while Beckman researchers like Yi Ma, Kramer, and Simons were called upon by major media this past year for their expertise in stories about technology, politics, health, and finance.

The Institute's role in the community of Champaign-Urbana was brought to life this past year with a feature story in the local newspaper, the *News-Gazette,* on Beckman's 20th Anniversary Celebration and two decades of interdisciplinary research. The feature story and photos highlighted the people and research that have made Beckman what University of Illinois officials have called the "crown jewel" of research facilities on campus. Also, a local magazine, *Community Concierge,* featured the Beckman Institute building as an iconic symbol of 21st Century architecture in the area, and had a feature story on the work of researcher Elizabeth Stine-Morrow and her cognitive aging studies.

The Beckman Institute has always been known as a place where traditional academic boundaries are broken down for the larger goal of doing good science. It's also a place where researchers often transcend their field of work.

BIOMEDICAL IMAGING CENTER

The Biomedical Imaging Center (BIC) is one of the country's major magnetic resonance facilities thanks to its instrumentation and faculty and staff resources. It is a valuable resource for conducting research and developing magnetic resonance imaging (MRI). BIC serves a wide variety of researchers and projects and develops new, leading-edge MRI equipment and techniques that meet the challenges of researchers's imaginations. The MRI team also combines magnetic resonance imaging with other imaging methods such as optical imaging, eye-tracking, EEG, and transcranial magnetic stimulation.

Biomedical Imaging Center 2010

A new era of exciting growth has accompanied the Biomedical Imaging Center's move this past year from its south campus location into the Institute. Even as its machines were being installed in the basement of the Institute and its staff and mock magnets were being situated on the first floor, the Biomedical Imaging Center (BIC) was adding to its repertoire of magnetic resonance imaging machines and to its other capabilities. In 2009, a new whole-body 3T MRI scanner called the MAGNETOM Trio joined BIC's 14T (600) MHz Varian NMR system and 3T Allegra headscanner. The additional 3T scanner will accommodate more MR engineering development work as well as diverse human, animal, and other applications. But the expansion didn't end with one new magnet. Researchers from a growing number of fields are using or planning to use the magnets in the future. In addition, BIC's imaging capabilities broadened in 2010 when a new high resolution ultrasound system was acquired. A Visualsonics Vevo 2100 High Frequency Ultrasound Imaging System was added to BIC's array of imaging instruments thanks to a grant from the National Institutes of Health. William O'Brien of Beckman's Bioacoustics Research Laboratory (BRL) was principal investigator on the application to acquire the Vevo 2100. The Vevo 2100 gives researchers the ability to use ultrasound at frequencies up to about 55 MHz, a capability that provides high resolution for imaging samples such as tumors in animal models. Campus researchers are

The image above provides an inside view of the MAGNETOM Trio Whole-body 3T MRI Scanner.

Biomedical Imaging Center Systems:

- **600 MHz Varian NMR System**
  Used for micro-imaging and spectroscopic measurements, such as high resolution imaging of very small samples, including biological tissue, as well as liquid and non-living samples.
- **Siemens MAGNETOM Allegra 3T MRI Headscanner**
  Primarily used for cognitive studies; also includes capabilities for animal scanning, including scans for clinical work.
- **Siemens MAGNETOM Trio Whole-body 3T MRI Scanner**
  A workhorse for many cognitive and human clinical research studies, as well as being used in animal studies, clinical care scans for animal patients, and imaging many other types of samples.
- **3T Allegra Mock Magnet and 3T Trio Mock Magnet**
  Used to prepare human research subjects for experiments in the actual magnets, as well as for tours and other educational outreach programs to explain how magnetic resonance imaging works.
- **High-resolution Ultrasound**
  A Visualsonics High-resolution Ultrasound Vevo 2100 High Frequency Ultrasound Imaging System was added to the BIC lineup in 2010. The Vevo 2100 is designed for imaging smaller animals at high frequencies (up to around 55 megahertz), providing really high resolutions that permit researchers to study topics such as disease states in animal models.
- **Siemens MicroPET/SPECT/CT**
  A molecular imaging instrument (microPET/SPECT/CT) used for imaging dynamic biological and material systems will be installed by the end of the year. The MicroPET/SPECT/CT is used for molecular imaging research in the areas of pre-clinical medical research in cancer and neuroscience; nanomedicine; nanoparticle biodistribution and physiological integration; stem cell tracking and functional integration; nutritional metabolomics; non-destructive evaluation and functional characterization of materials; and microbial and molecular dynamics in environmental media.

already using the Vevo 2100, including O'Brien and BRL colleague Michael Oelze in their breast cancer assessment project.

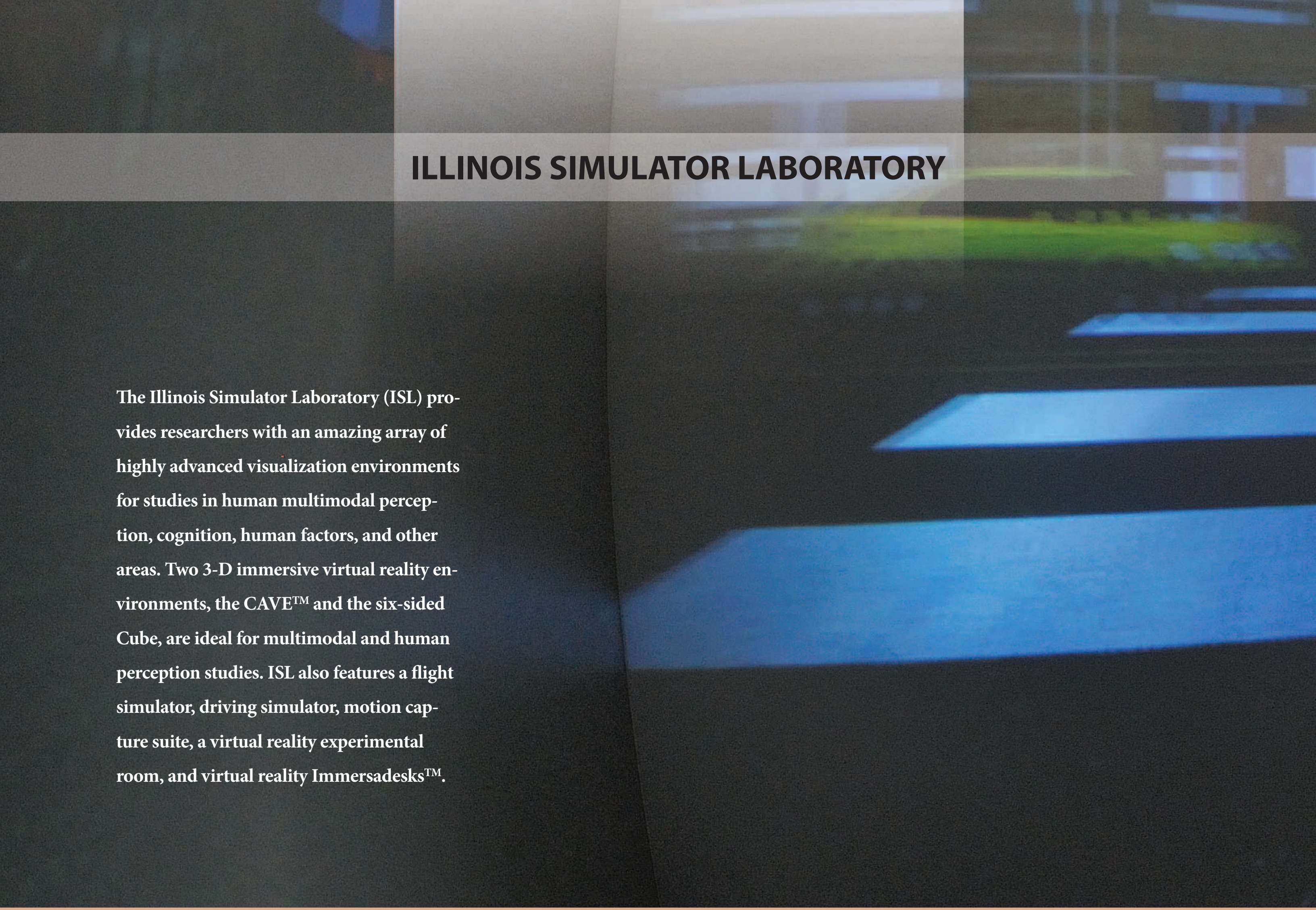
The Center will also be adding a Micro-PET/SPECT/CT machine for dynamic molecular imaging this fall thanks in part to a Major Research Instrumentation Program grant from the National Science Foundation. The Micro-PET/SPECT/CT will be useful for researchers in a number of areas, particularly those involved with pre-clinical medical research such as Beckman's Stephen Boppart, who has a focus on cancer research and who led the effort to secure the machine.

The diversity of studies taking place at BIC testifies to the power of its instruments. Current research projects include, for example, investigating the effects of physical activity intervention on the childhood brain and cognition; studying the pig hippocampus as a model for the human brain; evaluating the impact of emotional stimuli on cognition; performing thermal mapping of the brain; and clinical work with small animals.

BIC Associate Director Tracey Wszalek said the facility has grown significantly in the past year. "Now that we're located at Beckman, we are starting to attract users from disciplines that perhaps weren't traditionally involved in doing imaging," Wszalek said. And those users as well as visitors have been impressed with BIC's capabilities. "Clearly, from interactions with visitors of late, this is a unique facility which gives many different disciplines the opportunity to pursue imaging studies," Wszalek said. "It's a state-of-the-art, beautiful lab."

Change at BIC in 2010 also came in the form of a new administrator. Greg Miller was chosen to replace Art Kramer as Biomedical Imaging Center Director in May of 2010.

Nancy Dodge, medical radiography coordinator at the Biomedical Imaging Center, works on images collected from the MAGNETOM Trio Whole-body 3T MRI Scanner.



ILLINOIS SIMULATOR LABORATORY

The Illinois Simulator Laboratory (ISL) provides researchers with an amazing array of highly advanced visualization environments for studies in human multimodal perception, cognition, human factors, and other areas. Two 3-D immersive virtual reality environments, the CAVE™ and the six-sided Cube, are ideal for multimodal and human perception studies. ISL also features a flight simulator, driving simulator, motion capture suite, a virtual reality experimental room, and virtual reality Immersadesks™.

Illinois Simulator Laboratory

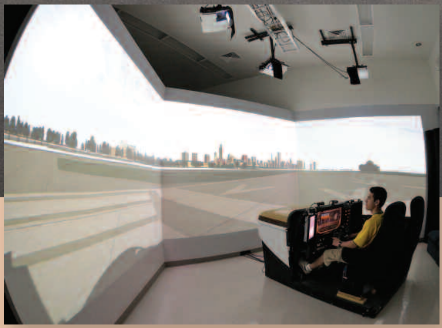
Now comfortably settled in its new home on south campus, the Beckman Institute's world-renowned advanced visualization facility, the Illinois Simulator Laboratory (ISL), is pulsating with activity. After completing the move from Beckman's main building to the former Biomedical Imaging Center building this past year, ISL is now fully operational with experiments running in every space. ISL Director Hank Kaczmarski said the lab's new home gives them the space and versatility to do visualization research in ways that weren't possible before. "The exciting thing is we have been able to expand beyond one researcher using one environment," Kaczmarski said. "Now it's much broader. If the biggest problem we have over the next year is scheduling all these diverse projects, that's a good problem to have. We have stable space and a good understanding of how to modify without affecting other labs in the building." In the past year, ISL has expanded to run experiments as diverse as testing virtual reality surgery to studying why novice wheelchair users have higher rates of upper shoulder and carpal tunnel injuries in the motion capture suite. Grants from NASA and the FAA are funding studies of the next generation of air traffic control systems in the flight simulator (now outfitted with eye-tracking capabilities), while the CAVE™ is being used for studies of pedestrians, including adults, older adults, children, and those in wheelchairs. ISL's two Immersadesks™ are being employed in a study of how operators, such as those controlling a drone aircraft, can collaborate when they are at separate, often distant locations. The Cube is playing host to an innovative study funded by the National Science Foundation and the Department of Homeland Security investigating whether sound can be visualized in order to extract information more efficiently, while the driving simulator continues to be home to studies of human attention and other forms of cognitive behavior.

Illinois Simulator Laboratory Capabilities:

- **The Cube**
  The Cube is a world-renowned, six-sided virtual reality chamber that provides a completely immersive environment. Used extensively by researchers in the area of perceptual psychology, the Cube is driven by a continuously upgraded cluster of personal computers using an ISL-developed application called Syzygy.

- **The CAVE™**
  The CAVE is a four-sided immersive reality environment operated by the ISL. First constructed in 1995, the CAVE continues to function as a prototyping facility for the Cube and as a research environment in its own right. Several Immersadesks™ (horizontal and vertical stereo video large screen display devices) are located in discrete lab spaces in the new facility, connected to specialized graphics computers, enabling users to quickly develop, test, and remotely demonstrate new applications and modalities of human-computer interaction.

A child participates in a street crossing task in the CAVE™.



The Illinois Simulator Laboratory's Flight Simulator is used for research recently funded by NASA and the FAA.

- **Flight Simulator**
  Based on a Frasca 142 simulator cockpit, the ISL flight simulator has been continuously updated to meet aviation human factors researchers's requirements with state-of-the-art displays and other technologies. Featuring both a large-screen environment and LCD cockpit displays, the flight simulator has easily expandable graphics-cluster technology and an advanced six-camera eye tracking system. Currently, an FAA-funded effort is under way by human factors researchers to study the next generation of air traffic control systems.

- **Driving Simulator**
  Used extensively by perceptual psychologists examining the way drivers interact with both their environment and the increasingly complex nature of their automobiles, the driving simulator uses a General Motors Saturn automobile that surrounds test subject drivers with eight projected moving images. These images, and a fully integrated eye-tracking system, allow researchers to gather data on how humans interact with the automobile.

- **Motion Capture Suite**
  Used by kinesiologists for the analysis of human motion, the Motion Capture Suite features a Motion Analysis ten camera motion capture system, force-feedback plates, video outputs, and gigabit networking that allows researchers to store data for later analysis or to connect with other visualization environments for real-time collaborative research.

- **CANVAS and the Traveling CANVAS (Collaborative Advanced Navigation Virtual Art Studio)**
  CANVAS is a room-sized immersive 3-D environment with origins in CAVE™ technology. It is a scalable, reconfigurable display technology that facilitates the creation and display of immersive art works. It is collaborative because it can be connected to an array of geographically dispersed immersive virtual spaces, has advanced navigation to allow viewers in different locations to interact with virtual art, and allows for the creation and presentation of virtual art that exists not in two- or three-dimensional spaces, such a painting or sculpture, but in the multi-dimensional world of virtual images. The CANVAS is currently set up in its own gallery space at the Krannert Art Museum, with a recent show expanding on the new Beckman Imaging Initiative, highlighting the artistry of nature at the microscopic scale.

IMAGING TECHNOLOGY GROUP

A variety of items printed using the Visualization Laboratory's color 3-D printer.

The ability to visualize science has become essential to doing research in many fields and it is an integral means of sharing their work for researchers in virtually every discipline. That is why the facilities and capabilities of the Beckman Institute's Imaging Technology Group (ITG) have become such a valuable resource for campus researchers. The combined capabilities of the ITG's two groups, the Microscopy Suite and the Visualization Imaging Laboratory, are truly extraordinary for a university facility.

Microscopy Suite

The Microscopy Suite gives researchers comprehensive microscopy capabilities at amazingly small scales with incredible resolutions. Its four main modes of imaging are scanned probe microscopy, light microscopy, electron microscopy, and computed tomography (CT). The Suite's nano-CT instrument, for example, has better resolution (50 nanometers) than any other comparable instrument outside of a synchrotron (30 nm).

Even with those capabilities, the staff of the Microscopy Suite used some creative engineering this past year to add another instrument for researchers: a light microscope that can perform Raman spectroscopy at three critical wavelengths. Taking the body of a fluorescence-capable inverted microscope, they fashioned a microspectroscopy workstation with the ability to capture spectra from ultraviolet, visible, and infrared light, as well as Raman, or vibrational, spectra at excitation wavelengths of 532, 647, and 785 nm. It was an innovation Beckman faculty member Joe Lyding's STM group took advantage of.

"That means people can tell what chemical species they're seeing not only to the element but to the level of combinations of elements—to molecules—including shifts due to different chemical bonds," said Microscopy Suite manager Scott Robinson. "You can also get information about whether you have, for example, a single atomic layer of graphene. So the Lyding group can focus on a surface they've laid graphene down on and use Raman spectroscopy to confirm that it's there."

Robinson said the development of the microspectroscopy workstation was simply a matter of responding to the needs of the Microscopy Suite users.

"What it represents is us responding to our user's requests, building these instruments, and then making the instruments more and more sophisticated," he said.

Visualization Laboratory

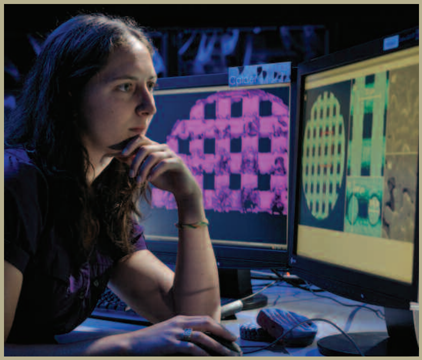
The Visualization Laboratory is a premier facility for a variety of scientific imaging needs and projects, including image analysis, animation and video production, 2-D and 3-D object scanning and printing, and publication graphics, to name a few.

Available to all students, staff, and faculty at the University of Illinois, the Visualization Laboratory's fourth floor location in the Beckman Institute includes highly advanced equipment such as an ultra high-speed camera, a full-color 3-D printer, and new computer workstations that can power the most demanding of visualization tasks.

Visualization Laboratory manager Darren Stevenson said that the workstations for image processing and analysis have been upgraded in the past year to the point where they can easily handle large image volumes and other tasks that require formidable processing power.

"It is as much current computer technology as you can put in a single workstation," Stevenson said of the workstations. "The next step up is a supercomputer."

The Visualization Laboratory not only provides hardware to faculty and student researchers but also training in using the advanced equipment. Stevenson said that the lab's relationship is a symbiotic one that benefits both researcher and the lab. As evidence of the success of that relationship, the Visualization Laboratory has produced, along with its users, 20 cover images for various scientific journals in the past year.



Samantha Polak, bioengineering Ph.D. student, works with artificial bone implant scaffold images in the Visualization Laboratory. Polak works with Beckman faculty member Amy Wagoner-Johnson on this line of research.

Microscopy Suite Capabilities:

- **Micro- and Nano-computed Tomography**
  The four Micro and Nano-CT instruments permit the collection of 3-D x-ray datasets of materials, biomaterials, and biological samples with resolutions ranging from 5 microns to 50 nanometers, with 'hard' or 'soft' x-rays, and with a variety of choices for magnification/field of view.
- **Light Microscopy**
  Suite users may choose from laser scanning confocal microscopes with standard and multi-photon imaging capabilities; an inverted fluorescence microscope with the ability to create seamless mosaics of images in x, y, and z; a highly sophisticated upright microscope with fluorescence and differential contrast interference (DIC) imaging, as well as comprehensive stereology and nerve-tracing software packages; and a stereozoom dissecting microscope with color-corrected imaging, in addition to other light microscopes and light-scattering particle sizers.
- **Scanned Probe Microscopy**
  Atomic force microscopy (AFM), with its multitude of permutations; scanning tunneling microscopy (STM); and near-field scanning optical microscopy (NSOM) are available. There is even a specialized STM holder that fits into the TEM.
- **Electron Microscopy**
  The environmental scanning electron microscope (ESEM), with a field-emission electron gun and many other options, is an essential component of the Bugscope project, which has run continuously for more than 11 years. The transmission electron microscope (TEM), for which the Suite has made a number of specialized holders, operates at accelerating voltages of up to 200 kV.
- **Fluorescence Correlation Spectroscopy**
  Useful to researchers in biology, biomaterials, and materials, the fluorescence correlation spectroscopy (FCS) system can, for example, permit the observation of a single weakly fluorescent protein as it enters a cell.
- **Sample Preparation Equipment**
  A variety of sample preparation equipment is available to Microscopy Suite users. The dual-metal evaporator is another example of an instrument that was designed and fabricated in response to requests from numerous researchers.

Visualization Laboratory Capabilities:

- **Image Analysis**
  The ability to obtain qualitative and quantitative information from 2-D and 3-D image sets, including object detection, feature extraction and measurements, cell counting, and various other benefits gained from viewing microscopic imagery.
- **Scientific Visualization**
  Visualization capabilities include imaging, modeling, and simulating data in a visual format, presented in various digital media formats: 2-D image, 3-D image, video, and animation, for both analysis and presentation.
- **3-D Modeling**
  This allows for geometric modeling in three-dimensional space, using parameters based both on actual and simulated x-y-z directionals.
- **Animation and Video Production**
  Offers ability to produce moving image sequences, created as communication resources for scientific presentation and for understanding of research findings.
- **Color 3-D Printing**
  Capabilities include plaster-based, multi-color object creation from three-dimensional geometry and surface data that are created in order to give scale, proportion, and tactile understandings of research materials and static processes.
- **Ultra High Speed Video Capture and Analysis**
  Offering both qualitative and quantitative visual motion capture and analysis of dynamic processes, which occur at rates of speed undetectable by human vision or traditional video capture speeds.
- **Macro Photography and Macro Video**
  Offering high-magnification photography and video to capture research objects and scientific processes, for analysis and presentation purposes.
- **3-D Object Scanning**
  Offering multi-point laser detection to create three-dimensional surface geometry of real-world objects; also used for object measurement and three-dimensional modeling.
- **Research Presentation**
  Assistance with graphics and illustrations created in order to better understand and communicate ideas and results.

Current Beckman Institute Fellows

2010 Fellows

S. Derin Babacan

Derin joined the Beckman Institute from Northwestern University where he completed his Ph.D. work in Electrical Engineering in December 2009. His research interests are focused on problems in image processing, computer vision, and compressive sensing. He is interested in investigating novel Bayesian modeling and inference procedures that effectively utilize complex signal and degradation models that are consistent with the nature of imaging instruments and subjects. These novel methods could potentially advance the state-of-the-art in many imaging applications.

Simon Fischer-Baum

Simon will earn his Ph.D. in Cognitive Science from Johns Hopkins University in the fall of 2010. He is currently a William Orr Dingwall Foundation Neurolinguistic Fellow at Johns Hopkins. His research seeks to identify domain-independent principles of cognitive processing, specifically regarding how serial order is represented and processed. This line of research could have implications for many aspects of biological intelligence, including more high-level cognitive processes like language and problem solving, and more peripheral processes like perception and motor control.

Malini Ranganathan

Malini is slated to earn a Ph.D. in the Energy and Resources Group at the University of California at Berkeley by the summer of 2010. Her dissertation research explores the political ecology of water in the city of Bangalore in India, specifically focusing on the implications of market-oriented reforms for equity at the peri-urban interface. At Beckman, she will continue to investigate the specific social and environmental vulnerabilities—particularly related to water infrastructure—of populations living in fringe areas of developing cities. She aims to substantiate the claim that greater resilience to water-related environmental hazards in peri-urban Manila or Bangalore can, in part, be explained by the existence of neighborhood associations, their relationships with the state, and the wider social and political networks in which they operate.

Ilia Solov'yov

Ilia received a Ph.D. in Physics from Frankfurt University in Germany in 2008 and a Candidate of Science degree in Theoretical Physics from the Ioffe Physical-Technical Institute in St. Petersburg, Russia, in 2009. His current research interests cover a broad range of questions on the structure and dynamics of nanosystems and biomolecules. Specifically his research explores animal magnetoreception in creatures, including migratory birds. This work could eventually lead to solutions in protecting airports from birds.

Jonathan Viventi

Jonathan earned a Ph.D. in Bioengineering from the University of Pennsylvania, working with Dr. Brian Litt. His research focuses on developing technology for a new generation of implantable medical devices that are flexible and can conform to the shapes of organs and biological structures. At the Beckman Institute he specifically plans to focus on developing flexible sheets of high-resolution multiplexed electrodes that can map and disrupt the abnormal regions of the brain that give rise to epileptic seizures and map and ablate cardiac arrhythmias on the epicardial surface of the heart.

2009 Fellows

Jeremy Brooks

Jeremy earned his Ph.D. in Ecology from the University of California, Davis, in 2008. He came to the Beckman Institute from Loyola University where he served as an instructor. His research work seeks to understand the individual characteristics and contextual factors that influence attitudes and behaviors related to a variety of environmental issues including climate change.

Nanshu Lu

Nanshu joined the Beckman Institute from Harvard University, where she earned a Ph.D. in the School of Engineering and Applied Science. Her research interest has focused on the mechanics and materials for the integration of hard and soft materials. As a Beckman Fellow, she seeks to develop smart, flexible electronic devices by integrating soft active matters into current flex circuit configurations.

David Mayerich

David completed his Ph.D. in Computer Science from Texas A&M University. While there he helped develop a prototype microscope capable of quickly imaging large three-dimensional tissue samples. His current research goals are to advance methods for reconstruction and visualization of biomedical data in order to provide an unprecedented understanding of anatomy at the sub-cellular level. He plans to focus on creating sub-cellular anatomical models of tissue as well as better ways to process and visualize datasets provided by new microscope techniques.

Nathan Parks

Nathan completed his Ph.D. in the area of Cognitive and Brain Science at the Georgia Institute of Technology. His research plan concentrates on examining the neural mechanisms of attention, competition, and short-term plasticity within the human visual system. He will use a variety of noninvasive neuro-physiological measures and psychophysical techniques in his investigations.

Edward Wlotko

Eddie earned a Ph.D. from the Brain and Cognition Division of the Department of Psychology at the University of Illinois at Urbana-Champaign. His research explores how the two hemispheres of the brain each serve language functions that are necessary for comprehension. At the Beckman Institute, he uses the event-related optical signal (EROS) system to explore the individual and joint contributions of the cerebral hemispheres to language comprehension, and how those contributions change over the lifespan.

2008 Fellows

Jacob Eisenstein

Jacob earned a Ph.D. in Computer Science at the Massachusetts Institute of Technology. His research focuses on non-verbal modalities such as gestures that supplement speech. At the Beckman Institute Jacob works on computational statistical models of the relationship between gesture, speech, and discourse with the goal of improving natural language understanding.

Agustín Mihi

Agustin received his Ph.D. in Physics from the University of Seville. His research, which focused

For a few select young scientists, the dream of pursuing their research goals unfettered by the responsibilities of teaching or working in industry becomes a reality at the Beckman Institute. Postdoctoral researchers from across the country and the world have taken part in the Beckman Institute Fellows Program since 1992 and gone on to careers in academia, government, and business. The Beckman Fellows Program nurtures independent research in a stimulating and supportive interdisciplinary environment that allows young scientists to advance their research during a period that bridges the time between earning a Ph.D. and beginning a professional career. The Beckman Institute Fellows are selected based on evidence of professional promise, capacity for independent work, outstanding achievement, and interdisciplinary work research interests that correspond to one or more of the Beckman Institute's research themes. Applications for the Beckman Institute Fellows program are accepted during the Fall semester and the announcement of the selected Fellows is made in late February/early March of the Spring semester. Fellows may begin working at the Beckman Institute as early as July of the calendar year they are selected and no later than December 31 of that same year.

on increasing the light harvested in Dye Sensitized Solar Cells by coupling Photonic Crystals, was carried out at the Institute of Materials Science of Seville (Spain). At the Beckman Institute, Agustín is deepening the understanding of the effect of optical design on the efficiency of photoelectrochemical processes and extending the application of these concepts to other types of photonic structures.

Amy Shih

Amy completed her Ph.D. in Biophysics and Computational Biology at the University of Illinois at Urbana-Champaign. Her research interests are focused on biophysical characterizations of the structure and function of health-relevant biomolecules. As a Beckman Institute Fellow she uses advanced computational modeling to study HDLs and cytochrome P450s.

Joel Voss

Joel received his Ph.D. in Neuroscience from Northwestern University. He joined the Beckman Institute after spending a year as a postdoctoral researcher at Northwestern University. His research examines the operation of explicit and implicit expressions of memory. He currently studies the biological basis for the distinction between conscious and nonconscious expressions of memory, as well as the role that volition plays in memory processes that evolve over time, such as with navigation of novel environments.

Carle Foundation Hospital/Beckman Institute Fellow

Michael Walsh

Michael received his Ph.D. in Biological Sciences from Lancaster University in the United Kingdom. As the first-ever Carle Foundation Hospital/Beckman Institute Fellow, his research focuses on advancing non-invasive cancer detection methods. His goals include finding ways to use imaging to automate the examination and classification of tissue in order to overcome many of the limitations that exist in current pathology methodologies. Such automation could eventually reduce the time-consuming nature of diagnosis and it could also eliminate operator bias that can lead to misdiagnosis.

Postdoctoral Fellows Program Alumni

2007

Derek Hoiem, Ph.D., Carnegie Mellon University
Zhi Jiang, Ph.D., Purdue University
Séverine Lepage, Ph.D., University of Liège, Belgium
Jongseung Yoon, Ph.D., Massachusetts Institute for Technology

2006

Joseph B. Geddes III, Ph.D., Pennsylvania State University
Yael Gertner, Ph.D., University of Pennsylvania
Ming Hsu, Ph.D., California Institute of Technology
Mark Neider, Ph.D., Stony Brook University
Stephanie Rinne, Ph.D., University of Illinois
Sarah Brown-Schmidt, Ph.D., University of Rochester
Dirk Bernhardt-Walther, Ph.D., California Institute of Technology

2005

Chandramalika Basak, Ph.D., Syracuse University
Emma Falk, Ph.D., Helsinki University
Silvio Savarese, Ph.D., CalTech
Zhihong Zeng, Ph.D, Chinese Academy of Sciences

2004

Byron McCaughey, Ph.D., Tulane University
Michelle Meade, Ph.D., Washington University, St. Louis
Timothy Nokes, Ph.D., University of Illinois, Chicago
Maxim Raginsky, Ph.D., Northwestern University

2003

Joshua Ballard, Ph.D., University of Colorado
Richard Godijn, Ph.D., Vrije Universiteit, Amersterdam
Mathews Jacob, Ph.D., Swiss Federal Institute of Technology
Ryan Kershner, Ph.D., Massachusetts Institute of Technology

2002

Tyler Bruns, Ph.D., University of Illinois
Stan Colcombe, Ph.D., University of Illinois
Diego Diaz, Ph.D., Cornell University
Sarah Grison, Ph.D., University of Wales
Cristina Iani, Ph.D., University of Bologna

2001

Michael Bevan, Ph.D., Carnegie Mellon University
Donald Cannon, Ph.D., Penn State University
Christina Grozinger, Ph.D., Harvard University
Jesse Spencer-Smith, Ph.D., Indiana University

2000

John Paul Minda, Ph.D., SUNY, Buffalo
Slava Rotkin, Ph.D., Ioffe Institute, Russia
Ilya Zharov, Ph.D., University of Colorado

1999

Dale Barr, Ph.D., University of Chicago
Hong Hua, Ph.D., Beijing Institute of Technology
Jason McCarley, Ph.D., University of Louisville
Lolita Rotkina, Ph.D., Ioffe Physico-Technical Institute

1998

Michal Balberg, Ph.D., Hebrew University of Jerusalem
Gregory DiGirolamo, Ph.D., University of Oregon

1997

Brendan Frey, Ph.D., University of Toronto
Tammy Ivanco, Ph.D., McMaster University

1996

Srinivas Akella, Ph.D., Carnegie Mellon University
Jose Jimenez, Ph.D., Columbia University
Chen Liu, Ph.D., Techinion-Israel Institute of Technology

1995

Prahlad Gupta, Ph.D., Carnegie Mellon University
Gregory Zelinsky, Ph.D., Brown University

1994

Barbara Church, Ph.D., Harvard University
Narayan Srinivasa, Ph.D., University of Florida

1993

Andreas Herz, Ph.D., Heidelberg University
Rejeev Sharman, Ph.D., University of Maryland

1992

Andrew Nobel, Ph.D., University of North Carolina
Efrat Shimshoni, Ph.D., Weizmann Institute of Science

The Beckman Graduate Fellows Program offers unique research opportunities for some of the top graduate students at the University of Illinois. The program is supported by funding from the Arnold and Mabel Beckman Foundation and gives U. of I. graduate students at the M.A., M.S., or Ph.D. level the opportunity to pursue interdisciplinary research at the Institute. Research projects must involve at least one Beckman faculty member as well as a second U. of I. faculty member. Preference is given to those proposals that are interdisciplinary and involve the active participation of two Beckman faculty members from two different groups.

THE 2010 BECKMAN INSTITUTE GRADUATE FELLOWS

Wylie Ahmed
Wylie is a Ph.D. candidate in Mechanical Engineering whose research involves cell mechanics and high resolution imaging techniques. His research project focuses on the connection between mechanical tension in neuronal axons and synaptic plasticity, with the goal of understanding the mechanism(s) underlying that connection and neurotransmission. Wylie is collaborating with Beckman faculty members Taher Saif and Jonathan Sweedler in this project, which seeks to contribute foundational work to the emerging field of neuromechanics.

Chao Ma
After earning bachelor's and master's degrees in Electrical Engineering at Tsinghua University (Beijing, China), Chao is now working on his Ph.D. in Electrical and Computer Engineering. His research efforts with Beckman faculty members Zhi-Pei Liang and Brad Sutton have led to work on a mobile nuclear magnetic resonance (NMR) system with full spectroscopy capability. The goal of this interdisciplinary research project is to develop, for the first time, a mobile NMR spectroscopic system with full spectroscopy capability that will enable new applications, such as on-site detection of toxic materials and detection of bacteria and biomarkers for point-of-care diagnosis, that are not possible with conventional NMR systems.

Jihye Seong
Jihye is a native of Korea who earned a master's degree in pharmaceutical science and is working on her Ph.D. in Neuroscience at Illinois. Working with Beckman faculty members Yingxiao Wang and Ning Wang, Jihye's research focuses on the effects of mechanical stimulation on cellular function. Her project will seek to understand how mechanical force is converted into biochemical signals—a process known as mechanotransduction—toward a systematic understanding of cellular function, especially as it relates to the development of diseases such as cancer.

Wladimir Benalcazar
Wladimir has been a research associate in Beckman faculty member Stephen Boppart's Biophotonics Imaging Laboratory while working toward a Ph.D. in Electrical Engineering. In addition to working with Boppart, Wladimir has collaborations with Beckman faculty members Scott Carney, Martin Gruebele, and Yingxiao Wang toward development of a nonlinear microscopy technique for the spatial-spectral inspection of biological specimens. The microscope uses endogenous vibrational contrast to provide high chemical selectivity without the use of exogenous markers, a biochemical imaging technique Wladimir will use for a systematic study of tumor development.

Mallory Stites
A graduate of Truman State University in Missouri, Mallory is working on a Ph.D. in Cognitive Psychology at Illinois. Mallory investigates the basic neurological and behavioral processes involved in reading comprehension, especially as it applies to how the brain handles misspellings. In collaborations with Beckman faculty members Kiel Christianson (eye-tracking) and Kara Federmeier (event-related brain potentials), Mallory will use these measurement techniques to understand the processes involved in reading errors, testing the effects of letter transpositions across morpheme boundaries. Mallory plans to expand her research to continue a collaboration with Beckman faculty member Liz Stine-Morrow to study how misspellings affect reading behavior in older adults.

NEW FACULTY

Twelve new faculty members joined the Beckman Institute this past year, bringing with them exciting research lines and new areas of exploration. Roberto Galvez is a full-time member of the NeuroTech group and faculty member in the Department of Psychology who brings his work in understanding how a certain part of the brain stores and retrieves information. New part-time faculty members have also joined Beckman from the departments of Bioengineering (Sheng Zhong), Physics (John Stack), Materials Science and Engineering (Angus Rockett), and Chemistry (Gregory Girolami). The diversity of researchers who joined Beckman this past year is also demonstrated through the variety of home departments of new affiliate faculty members: Taher Saif and Kimani Toussaint (Mechanical Science and Engineering), David P. Kuehn and Matthew Dye (Speech and Hearing Science), and Geography (Ashwini Chhatre and Thomas Bassett).

FULL-TIME FACULTY

Biological Intelligence

Roberto Galvez from the Department of Psychology joined the Beckman Institute as a full-time faculty member of the NeuroTech group in the Biological Intelligence research theme. Galvez earned a Ph.D. in Neuroscience from the University of Illinois. His research topics include long-term storage of associative memory and molecular correlates of experience-induced neocortical plasticity.

PART-TIME FACULTY

Integrative Imaging

Sheng Zhong is an Assistant Professor of Bioengineering, Statistics, Computer Science, Computational Science and Engineering, and Biophysics at Illinois who joined the Bioimaging Science and Technology group at Beckman. His research uses systems biology approaches to study cellular differentiation and evolution.

Molecular and Electronic Nanostructures

John Stack is a member of the Theoretical and Computational Biophysics group at Beckman and a Professor of Physics at Illinois. His research interests lie in studies of lattice field theory and in understanding of confinement and other non-perturbative phenomena in quantum chromodynamics and high energy theory.

Angus Rockett joined the Beckman Institute as a faculty member in the Nanoelectronics and Nanomaterials group. Rockett is a Professor in the University of Illinois Department of Materials Science and Engineering. His research focuses on topics such as photovoltaics, or solar cells, radiation detectors, and thin films.

Gregory Girolami is a new faculty member in the Nanoelectronics and Nanomaterials group. Girolami is a Professor in the Department of Chemistry at the University of Illinois. His research focuses on the synthesis, properties, and reactivity of new inorganic, organomettallic, and solid state species.

AFFILIATE FACULTY

Biological Intelligence

Taher Saif, the Gutgsell Professor in the Department of Mechanical Science and Engineering, has joined the NeuroTech group at Beckman. He earned a Ph.D. in Theoretical and Applied Mechanics from Cornell. Saif's research interests include the mechanics of microelectromechanical systems (MEMS), bio-MEMS, fracture mechanics, and submicron materials behavior.

David P. Kuehn joined the NeuroTech group at Beckman. Kuehn is a professor in the departments of Bioengineering and Speech and Hearing Science at the University of Illinois. His research interests include speech anatomy and physiology and cleft palate, with a specific emphasis on the anatomy and physiology of the velopharyngeal region.

Human-Computer Intelligent Interaction

Matthew Dye joined the Beckman Institute as a faculty member in the Human Perception and Performance group. Dye is a Professor in the University of Illinois Department of Speech and Hearing Science. His research areas include cross-modal plasticity and deafness, with a focus on the effects of altered sensory experience on the development of visual cognition skills.

Integrative Imaging

Kimani Toussaint is faculty member in the Bioimaging Science and Technology (BST) group of the Integrative Imaging (IntIm) research theme. Toussaint is an Assistant Professor in the Department of Mechanical Science and Engineering at Illinois whose research focus is in the area of optics.

Social Dimensions of Environmental Policy

Ashwini Chhatre is a faculty member in the Department of Geography and at the Center for Global Studies at the University of Illinois. He studies the intersection of democratic politics and environment and development, with a more recent focus on climate change vulnerability and adaptation.

Thomas Bassett comes to Beckman as a Professor in the Department of Geography at the University of Illinois. Bassett's research areas include Africa and Third World development, with a focus on topics such as African agrarian systems, political ecology, agricultural development, and socio-cultural change.

THE IMPACT OF GIVING

There are many words and phrases that have come to be associated with the Beckman Institute over its 21-year history: interdisciplinary research, neuroscience, nanotechnology, and advanced science are a few. But one word, generosity, best describes why Beckman exists as a world class research institute. Generosity is what led Arnold and Mabel Beckman to donate $40M in 1985 to build an interdisciplinary research center at his alma mater, the University of Illinois, and generosity through the donations of individuals and organizations help continue the work taking place at the Beckman Institute.

Donors to the Beckman Institute can make a direct impact through the funding of scholarships and gifts to specific groups and areas of study that will nurture both current and future research and the people—faculty, students, and staff—who make Beckman a world-class research facility.

"The Beckman Institute fundraising priorities are closely aligned with this reality," said Beckman's Director of Development, Tim Montague. "Our top priorities are raising support for students (undergrad and grad), postdocs, and faculty. Private support provides essential resources to recruit and retain top science and engineering talent in an extremely competitive landscape."

Impact of Scholarships and Fellowships

The Beckman Institute Fellows programs were created to give young scientists in the postdoctoral and graduate programs and faculty from other universities in the senior program greater opportunities to do innovative research. The Arnold and Mabel Beckman Foundation provides funding for the three programs.

Michael Walsh was chosen in 2008 as the first ever Carle Foundation Hospital-Beckman Institute Fellow. The Carle-Beckman Fellows program was created with funding from Carle Foundation Hospital to give recent Ph.D.s with a research focus on the engineering of biological materials an opportunity to advance work in the molecular imaging of cancer. Walsh said that the program has given him the ability to launch an independent research career and develop his skills as a postdoctoral researcher.

"The fellowship program is a fantastic opportunity to work in an interdisciplinary environment and work with exceptional scientists from a broad variety of backgrounds," Walsh said. "The research allowance has also given me the freedom to develop new avenues of research and to present my progress at a number of international conferences."

Chen Liu came to Beckman in 1995 to work on the Intelligent Hearing Aid project as a postdoctoral researcher. He was taking advantage of a one-time opportunity to be part of that groundbreaking project that used biologically-inspired principles to create a hearing aid that worked in noisy environments. The project got its initial funding from Beckman, followed by a grant from a hearing aid company, and Liu ended up becoming a Beckman Postdoctoral Fellow. The funding behind the story of this successful project testifies to the myriad ways giving—whether from a foundation, business, or individual—can impact both researchers and research.

"It was an unforgettable three years for me," said Liu, who is now the principal staff research scientist with the Human Interaction Research Lab at Motorola Labs in Schaumburg, Illinois. "It was one of the most intense growing periods in my research life.

"One thing about the Beckman Institute is the freedom, especially for a Beckman Fellow. You don't need to worry about funding; you're free to do whatever you want. It's really a rare, precious opportunity for a young scientist."

Creating new scholarship opportunities is also an important focus of development efforts at Beckman. In the fall of 2010 the Beckman Institute will be awarding the Erik Haferkamp Memorial Scholarship to a promising undergraduate student to perform research in neuroscience. The scholarship was made possible

by friends and family members of Erik Haferkamp, an undergraduate whose life was enriched by his experience in the laboratory of Beckman researcher Justin Rhodes.

The Erik Haferkamp Memorial Scholarship will support two undergraduate research assistants in the summer of 2011 in the area of neuroscience, with future plans to support one full-time student per summer. Rhodes said Haferkamp was a valued member of his lab for more than three years, as he went from undergraduate student to lab technician.

"He proved to be an outstanding student and dedicated a large amount of his time in the lab from 2007 up until his death in 2010," Rhodes said. "Erik quickly became competent at many of the technical procedures in the lab. He also made substantial contributions collecting data for a paper currently in the late stages of the review process examining the effects of exercise on the growth of new nerve cells in the brain.

"For his technical and intellectual contributions, Erik is a co-author on a paper recently accepted in *Behavioral Brain Research* on exercise-induced neurogenesis. Thus, Erik was a key member of the Rhodes lab and is terribly missed."

Impact of Endowed Chairs/Professorships

Creating endowed chairs/professorships is also a goal of development efforts at the Beckman Institute. An endowed chair represents the highest honor the University of Illinois can confer on prominent faculty members. These endowed chairs are used to help attract and retain brilliant scholars, and enable the most gifted faculty members to reach their full potential. Several Beckman researchers have been honored with endowed chairs in their home departments and can testify to their impact.

Tom Huang is Co-chair of the Human-Computer Intelligent Interaction research theme at Beckman and is the William L. Everitt Professor of Electrical Engineering in the Department of Electrical and Computer Engineering (ECE).

"In our profession, there is nothing more rewarding than the recognition by one's peers and to get a named professorship is one such indication," Huang said. "In my case, I am particularly honored, because the Professorship is named after Dean Everitt, who for a long period of time was head of ECE and then Dean of Engineering at Illinois. He was my hero and role model."

Nancy Sottos is Co-chair of the Molecular and Electronic Nanostructures research theme at Beckman and the Donald B. Willett Professor of Engineering at Illinois.

"Having a chaired professorship is a wonderful honor," Sottos said. "Most importantly, it provides flexible funds to use for research and seeding new projects. I also think chaired professorships are critical for retention of the best faculty."

Jean-Pierre Leburton is the Gregory Stillman Professor of Electrical and Computer Engineering in ECE and a full-time faculty member in the Nanoelectronics and Nanomaterials group at Beckman. He said that endowed chairs do help retain outstanding faculty by honoring their work and by providing needed support.

"This is recognition in the department and there are just a few of them," Leburton said. "It comes with some financial support, which is always very nice. It allows you to attend conferences and gives you more freedom. It helps research because it provides support."

And the chair shows how the work of a professor or researcher can live on through the generosity of those they affected.

"People know they owe their careers to Stillman, to his teaching, his mentoring and leading them in research," Leburton added. "He was a highly-respected leader in his field. I am very grateful that I was recognized in his name."

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(July 1, 2009 – June 30, 2010)

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Dr. Andrew Webb

$500-$999

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Mr. H. Christopher and Mrs. Maritza Maceo Zaenger

$250-$499

Dr. Van Allen and Mrs. Donna Jalane Anderson
Mr. William A. Chittenden III and Mrs. Jill L. Chittenden
Robin Edmonds
Mr. Bernard W. and Mrs. Robin L. Gray
Ms. Claire Marie Huber
Dr. Arthur F. and Dr. Laurie F. Kramer
Dr. Meng Tao
Mr. John Zasadzinski

$100-$249

Dr. Kangguo Cheng
Ms. Becky E. Cleavenger
Mr. Alan and Mrs. Gail Cohen
Mr. Nigel John Grinter
Ms. Nanette Hedden
Dr. Xiaoai Jiang
Mr. Kenneth Kopecky
Kim Lucas
Dr. John S. Popovics
Dr. Justin S. and Mrs. Nancy Rhodes
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Mr. Thomas P. Sampogna
Dr. Peter William and Mrs. Sylvia Louise Sauer
Ms. Varsha Shivakumar
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As might be expected from a cutting-edge interdisciplinary research facility, public and educational outreach efforts at the Beckman Institute are many and take a variety of forms. From art exhibits highlighting the visualization of nature through scientific images to educational programs that train students in new ways to do research, Beckman is reaching out in a number of traditional and unique ways to inform people and enhance the larger community.

One way to reach people on a personal level is through art. A unique art exhibition curated by Hank Kaczmarski, Director of Beckman's Illinois Simulator Laboratory, brought nature to life at the University of Illinois's Krannert Art Museum this past year. Titled "Imag(in)ing Life: Nature in her genius had imitated art," the exhibition featured images of nature as rendered by science, from historical pieces like a reproduction of the first-ever X-ray to images created by Beckman researchers and staff using highly-advanced visualization technologies. Beckman labs of researchers Gabriel Popescu and Klaus Schulten contributed works, as did Darren Stevenson and Zach Johnson of the Institute's Visualization Laboratory. The exhibit was sponsored by Krannert Art Museum's Intermedia gallery in collaboration with Beckman.

The Institute is also supportive of many educational programs and plays host to speaker series and seminars, including the annual Director's Seminar Series at Beckman, an annual nanobiophotonics summer school, and a speaker series on the social dimensions of environmental policy.

An important new training program funded by the National Science Foundation was located at the University of Illinois this past year, thanks to an effort led by researchers from the Beckman Institute. An interdisciplinary training program grant, known as an IGERT, was awarded to the campus to train future researchers in how to collaborate in interdisciplinary neuroengineering projects. Beckman researchers Doug Jones, Todd Coleman, and Monica Fabiani spearheaded the effort, and a three semester training program began in the fall of 2009 to teach neuroscience and engineering students how to collaborate in neuroengineering projects.

Speaker series are one way to spread the news of research at Beckman and Illinois. The Director's Seminar Series at Beckman have been a way to spotlight research and researchers at the Institute through an hour-long noontime presentation. A strategic initiative at the Institute, the Social Dimensions of Environmental Policy (SDEP), seeks to improve the management of earth's environment through research on social and policy dimensions of sustainability. This past year, the SDEP played host to a speaker series at Beckman featuring some of the world's top scientists and thinkers on topics involving the complex relationships between human societies and the environment, and issues such as climate change.

One way to reach people with the news of Beckman research is through open house events. Beckman's Illinois Simulator Laboratory held an open house in March of 2010 to celebrate the rebirth of its facility after moving from the Institute to the south campus building formerly occupied by the Biomedical Imaging Center. The biennial Beckman Institute Open House will be held in March of 2011. The last Open House featured more than 30 exhibits for the thousands of visitors at the two-day event held in conjunction with Engineering Open House on the University of Illinois campus. Exhibits included brain-computer interfaces, robots learning grammar, and 3-D computer simulations.

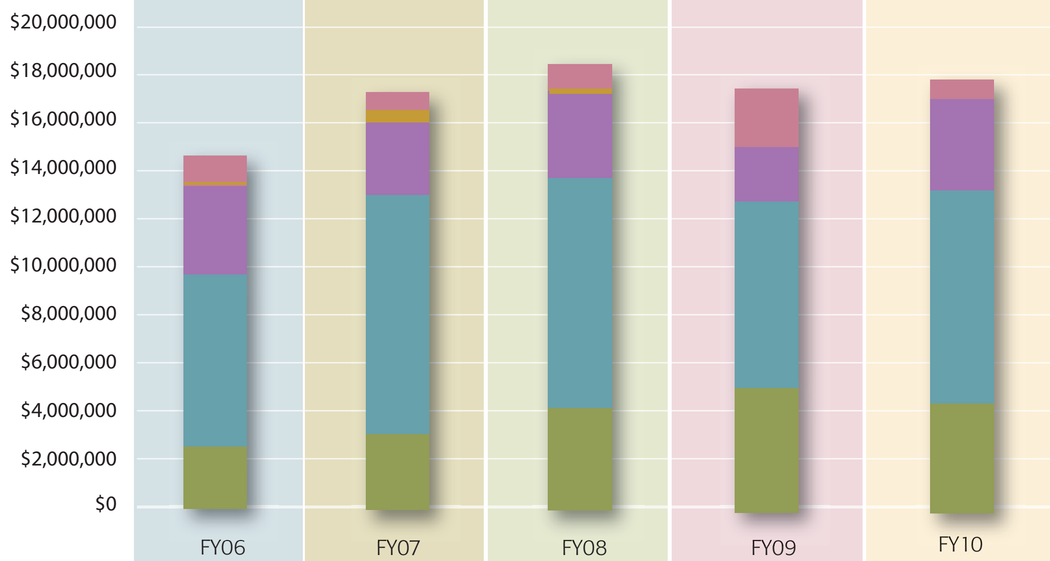
Beckman's educational outreach program Bugscope, operated by the Imaging Technology Group's Microscopy Suite, is still going strong after celebrating its 10-year anniversary in 2009. Bugscope gives remote control of an electron microscope via the Internet to students from around the world, reaching more than 250 classrooms since it was started in March of 1999 with a grant from the National Science Foundation (NSF).

The Beckman Institute is more than a campus research facility. It is part of larger communities and these programs testify to the fact that an important mission at the Institute is to share the work that goes on at Beckman with others and contribute in beneficial ways to those communities.

BECKMAN INSTITUTE Outreach

BECKMAN INSTITUTE Funding 2009-2010

Research Expenditures by Funding Source[1]



	FY06	FY07	FY08	FY09	FY10
DOD	$ 2,603,956	$ 3,172,803	$ 4,217,584	$ 5,238,196	$ 4,358,155
NIH	$ 7,144,039	$ 9,889,110	$ 9,444,099	$ 7,518,406	$ 9,072,558
NSF	$ 3,760,526	$ 3,004,266	$ 3,596,633	$ 2,310,613	$ 3,403,358
IBHE	$ 156,333	$ 512,229	$ 223,626	$ (1,674)	$ -
Other	$ 1,087,590	$ 1,008,914	$ 1,151,309	$ 2,578,214	$ 1,075,980
Total	$ 14,752,443	$ 17,587,322	$ 18,633,251	$ 17,643,755	$ 17,910,050

Research Awards by Funding Source[2]

	FY06	FY07	FY08	FY09	FY10
DOD	$ 191,000	$ 11,012,039	$ 7,030,763	$ 2,115,780	$ 2,831,689
NIH	$ 20,527,604	$ 7,450,733	$ 15,036,128	$ 5,234,846	$ 7,488,077
NSF	$ 1,818,340	$ 2,349,181	$ 4,628,500	$ 1,693,264	$ 6,747,793
Other	$ 685,903	$ 5,262,943	$ 1,917,393	$ 666,790	$ 683,834
Total	$ 23,222,847	$ 26,074,896	$ 28,612,784	$ 9,710,680	$ 17,751,393

DOD Department of Defense
NIH National Institutes of Health
NSF National Science Foundation
IBHE Illinois Board of Higher Education (grant match funds)

[1] In addition to those sources itemized in the chart, funding for the Beckman Institute is received from the following sources:
a) The state of Illinois to the University of Illinois and allocated through individual departments: Faculty Salaries
b) The state of Illinois to the Beckman Institute: Administration, Operating Expenses
c) The Arnold and Mabel Beckman Foundation: Beckman Institute Fellows Program, Beckman Institute Graduate Fellows Program, Beckman Institute Equipment Competition, Seed Proposals, and Sponsorships (e.g., symposia, lectures, etc.)

[2] The Beckman Institute primarily processes interdisciplinary research grants that have multiple faculty investigators from multiple departments. Total funding for multi-year awards is reported in the fiscal year of the award notice.

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Beckman Institute Annual Report Credits
Project Manager: Sue Johnson, Director of Communications
Writers: Steve McGaughey and Sue Johnson
Design: Pat Mayer, Urbana, IL
Photography: Unless otherwise noted, photography by Thompson-McClellan and the Beckman Institute Communications Office.

Beckman Institute

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