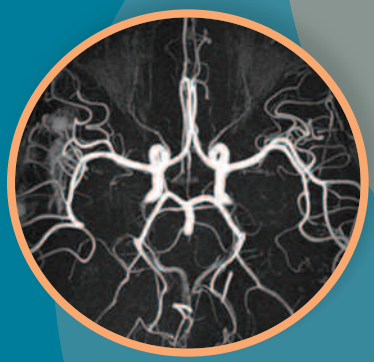
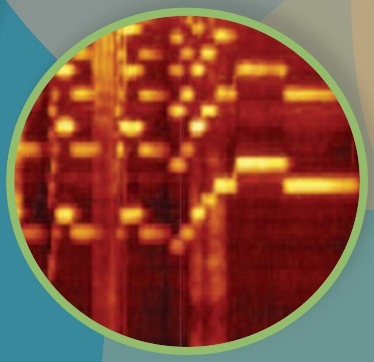
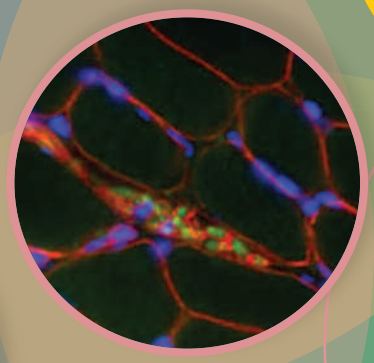
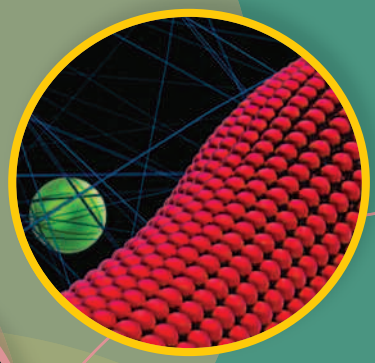
Annual Report **2010-2011**



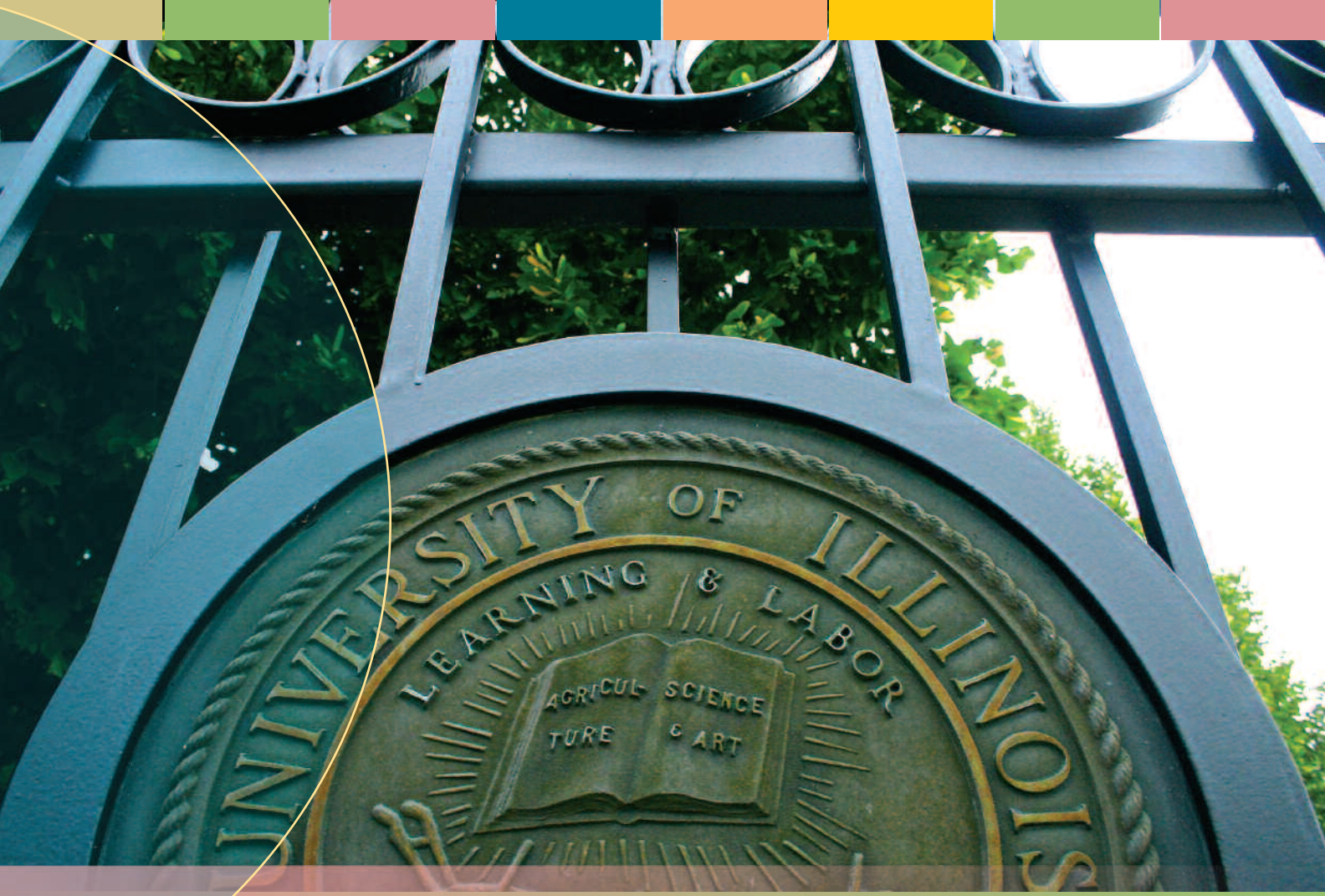






Beckman Institute

FOR ADVANCED SCIENCE AND TECHNOLOGY



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 4)
- Human-Computer Intelligent Interaction (page 12)
- Integrative Imaging (page 20)
- Molecular and Electronic Nanostructures (page 28)

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

- HABITS
- Imaging
- Social Dimensions of Environmental Policy

More than 1,000 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, cutting edge 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:

- 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.

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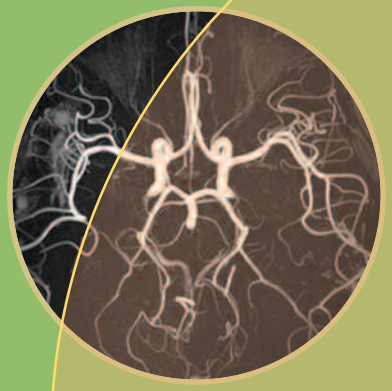
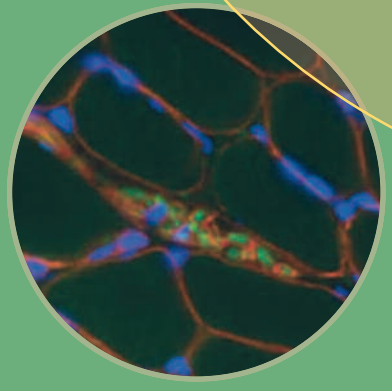
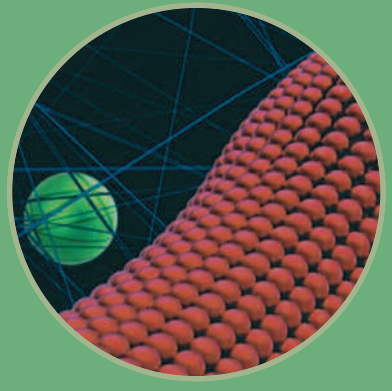






From the Director

Last May I went on a journey with several of my neuroscience colleagues that took us "outdoors and out of reach." For one week we traveled along the San Juan river in southern Utah. We were completely offline … no laptops, no cell phones, no email, and really, no connection to the outside world. Our trip was chronicled by *New York Times* reporter and book author, Matt Richtel.

The trip was something different for all of us who are constantly connected to our phones, computers, and other devices. It was challenging to be suddenly disconnected, but refreshing at the same time. It is a journey I won't soon forget. I see some parallels with this trip and being the Director of the Beckman Institute.

I have been a long-time faculty member of the Institute and I have been very connected to the Institute since it opened in 1989. However, in my new role as Director, I had to step back and look at things with fresh eyes. I had to disconnect from my role as a research theme co-chair and faculty member and then re-engage as the Director of the Institute. A whole new world opened up to me, and while there have been challenges, it has also been a very rewarding experience.

It is no secret that the biggest challenge we have faced at the University of Illinois and the Beckman Institute are the deep budget cuts we have endured because of the State of Illinois' financial crisis. Careful planning and prudent budgeting has saved us from major disruptions, but in order to build upon our world-class reputation, we are continuing to look for funding opportunities from the public and private sectors. This will be an ongoing effort that I hope will yield new research opportunities with corporations and funding agencies beyond those with whom we are currently working. Indeed, this is one reason that we are currently searching for an Associate Director for Research, someone who can help faculty research teams make new funding contacts and craft successful program, project and center grants.

Since taking on the Directorship at the Beckman Institute I have also continued my research. This was very important to me and I feel it helps keep me connected with the 'faculty side of life.' Our world-class faculty are the lifeblood of the Institute and they continue to excel in their fields. Grant funding was stable this year and research by our faculty and their collaborators is being published in top scientific journals including *Science, Nature, PNAS, Advanced Materials,* and many, many more.

So even though the upcoming year might not provide another opportunity to raft and kayak down a challenging river (sometimes without a boat ….), I am very much looking forward to the journey I am traveling, with all of my colleagues, staff, and students, at the best interdisciplinary research institute in the world.

Best Regards,

Art Kramer
Director

Art Kramer

"The Beckman Institute has been a well recognized leader in interdisciplinary research in the physical, life and behavioral sciences, and engineering over the past two decades and I look forward to continuing to work with our talented faculty, staff and students to further enhance our research portfolio and develop important novel and exciting lines of interdisciplinary research."

The Biological Intelligence (BioIntel) research theme is comprehensive in scope, as researchers seek to understand the brain, cognition, and behavior from the molecular and cellular levels to higher expressions of intelligence like memory and attention. BioIntel research groups (and their areas of study) are: Cognitive Science (higher mental processes, such as language, memory, information processing, and learning), Cognitive Neuroscience (the relationships between brain physiology and structure and cognitive functions like memory, emotion, and attention), and NeuroTech (brain organization and function, including how information is coded and processed by neural systems and the molecular and cellular origins of brain plasticity and neurological disorders). Many of these areas saw advances this past year, including in several research lines involving brain function, as well as language, cognitive aging, neural mechanisms, and disorders.

Control over Your Learning Environment Enhances Memory

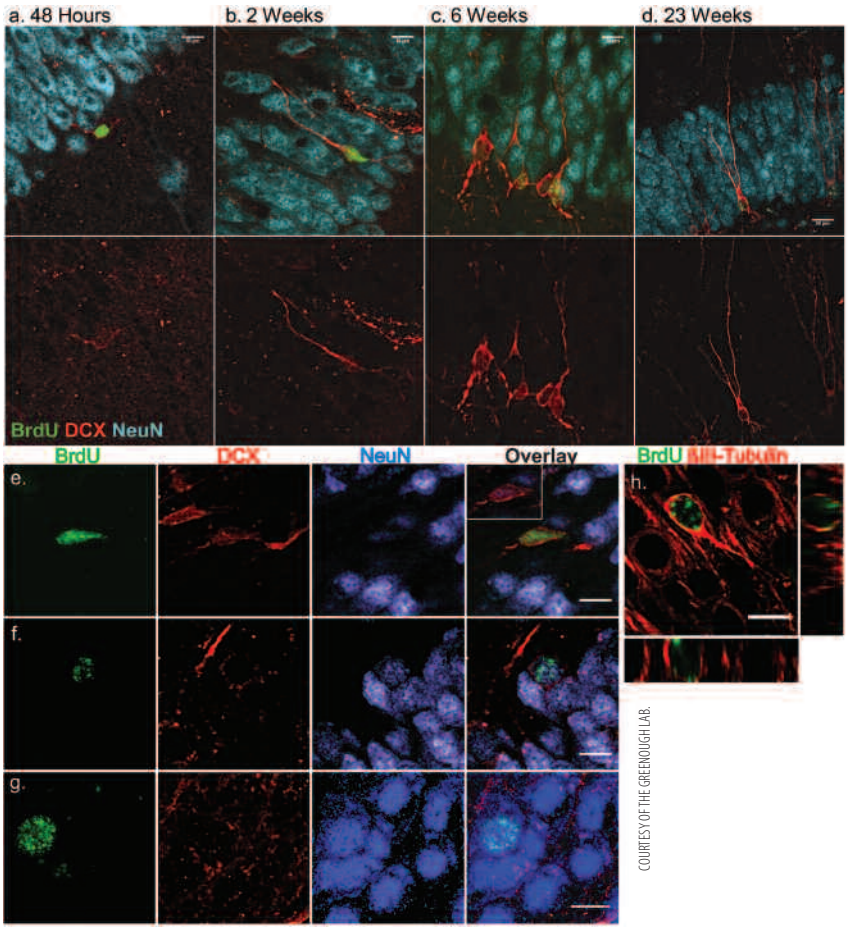
Having active control over how you learn new information greatly improves your ability to remember that information, according to research from **Neal Cohen** of the Cognitive Neuroscience group. Cohen's research on memory has shown that multiple, separate memory systems in the brain, especially one system that includes the hippocampus, are responsible for much of everyday memory. Cohen and Beckman colleagues **Kara Federmeier** and **Brian Gonsalves,** and postdoctoral researcher **Joel Voss** collaborated on a study looking at several brain regions, including the hippocampus, to understand exploratory behaviors that play an important role in learning. As described in *Nature Neuroscience,* they had test subjects memorize objects and their exact locations on a computer screen, either through an active method (using a mouse to control their viewing of the objects) or a passive method (viewing a replay of the previous "active" test subject's viewing choices) and used functional magnetic resonance imaging (fMRI) to study the subjects' brain activity. They also used a group of amnesia patients with hippocampal damage to zero in on which particular brain regions were involved in the learning process. The results showed that the active learners were much better in the task performance and had greater hippocampal activity than the passive learners, and that other brain structures were more engaged during active control of viewing the objects. The importance of the hippocampus and connections between different brain systems was demonstrated, as well as the importance of having active control over learning. The researchers wrote that "our behavioral, neuropsychological and neuroimaging data indicate that volitional control benefits memory performance and is linked to a brain network that is centered on the hippocampus" and that the data indicates that "it is the interplay between multiple cortical areas and the hippocampus that produces optimized learning with volitional control. We propose that volitional control is advantageous for learning."

PHOTO BY L. BRIAN STAUFFER. MONTAGE BY JOEL VOSS.

Neal Cohen and postdoctoral researcher Joel Voss found that people who have some control over their learning environment do better at remembering what they learned than those who don't.

Exercise-induced Neurogenesis

A growing body of research within the Biological Intelligence research theme has shown that exercise plays a beneficial role in the formation of new brain cells, or neurogenesis, across the lifespan. Some studies have even shown that exercise is a factor in mediating or even preventing cognitive decline in older adults. The laboratories of **Justin Rhodes** and **William Greenough** each reported on studies of exercise-induced neurogenesis this past year, providing new insights into the impor-



COURTESY OF THE GREENOUGH LAB.

Confocal micrographs demonstrating the sequence of neuron maturation. This Greenough lab image appeared in the June 21, 2011, issue of PNAS with the paper *Maturation time of new granule cells in the dentate gyrus of adult macaque monkeys exceeds six months.*

tant role that exercise plays in this process, especially in areas of the brain such as the hippocampus that are critical for learning and memory. In one study the Greenough lab looked at how brain anatomy changes as a result of regular exercise training at a level that would be recommended for middle-aged people interested in improving fitness. Using a primate model they found that exercise increased vascular volume and was associated with faster learning times. Their findings, as reported in *Neuroscience*, "indicate that the level of exercise associated with improved fitness in middle-aged humans is sufficient to increase both the rate of learning and blood flow to the cerebral cortex, at least during the period of regular exercise." The research was begun by lead author I.J. Rhyu when he was a visiting scientist in the NeuroTech Group with Greenough, his collaborator and co-author on the study. In another study, the Greenough Lab found that maturation of new neurons in the hippocampus requires six months for non-human primates and likely more for humans, suggesting a reconsideration of theories that indicated anti-depressant drugs affected hippocampal neurogenesis. The Rhodes Lab reported that some strains of mice respond to exercise by growing large numbers of new nerve cells in the hippocampus, while other strains exhibited much less of a response to exercise-induced neurogenesis. The findings, Rhodes and his collaborators wrote, are part of research that has implications for medical and treatment intervention. "Adult neurogenesis represents a natural model for understanding how to grow and incorporate new nerve cells into pre-existing circuits in the brain. Finding molecules or biological pathways that increase neurogenesis has broad potential for regenerative medicine." The mouse strains provide a method for doing that. "Because the strains represent defined and reproducible genetic backgrounds, it may be possible to find the genes that enhance growth of new nervous tissue in the brains of the predisposed strains," Rhodes said. In another study reported in *Neuroscience,* Rhodes and his collaborators found that "acute bouts of aerobic exercise increase the expression of three different proteins known to play an important role in learning and memory in the hippocampus" including a particular protein, Arc, that is "thought to play an important role in synaptic plasticity but had never before been shown to be induced from aerobic physical activity itself without any cognitive demands."

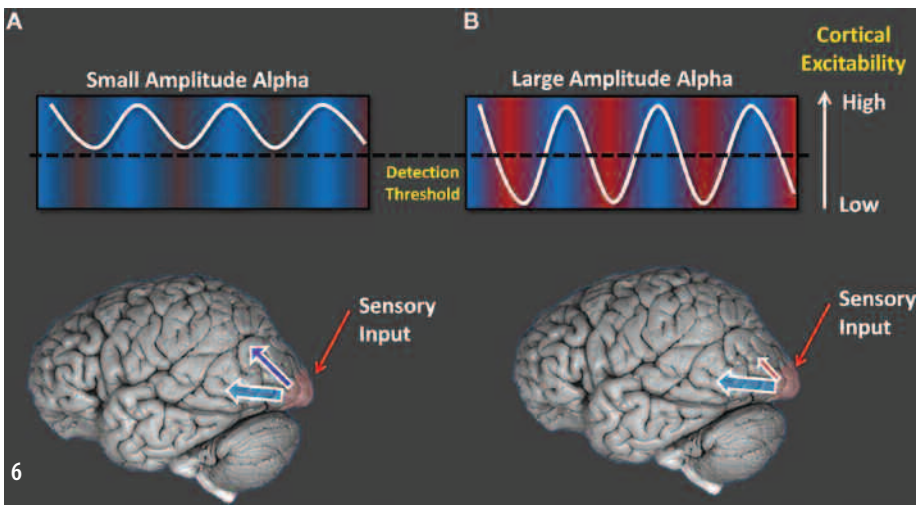
Older Adults Rely on Different Pathways and Processes for Language Comprehension

Kara Federmeier of the Cognitive Neuroscience group and Beckman Fellow **Eddie Wlotko** reported in an overview paper on the insights that electrophysiological studies have provided into how the brain mechanisms of language comprehension change with age. The research line is part of an overall theme in Biological Intelligence that studies cognitive aging because, as Federmeier and Wlotko wrote in the paper, "psychological facets of normal aging are likely to become more consequential as life expectancy continues to increase in the developed world and as medicine offers more solutions to the physical problems of aging. It is clear that research on cognitive aging is an imperative so that intellectual functioning can be correspondingly prolonged." By studying language comprehension processing in older adults, they found the aging brain flexibly adapts to age-related declines. Electrophysiological studies of language comprehension, they report, show that "the organization and structure of semantic knowledge is similar across age, but when integrating meaning across words to form message-level representations, older adults show both quantitative and qualitative changes in processing." Even with these changes, older adults "do build meanings from sentences, so the brain must compensate

for the change in timing by adjusting resources and strategies." Some of these adjustments, they write, "may be seen in the differences in controlled processing or a switch to a less predictive mode of comprehension for older adults. All of these changes are modulated by individual differences, highlighting the importance of understanding what types of abilities, strategies, or brain states may protect against some of the declines in comprehension seen in old age." Wlotko said that the overall theme of the paper "is that the brain can flexibly adapt, using multiple neural pathways, to make use of available resources (that are diminished or changed with age) to achieve similar comprehension outcomes."

Pulsed out of Awareness

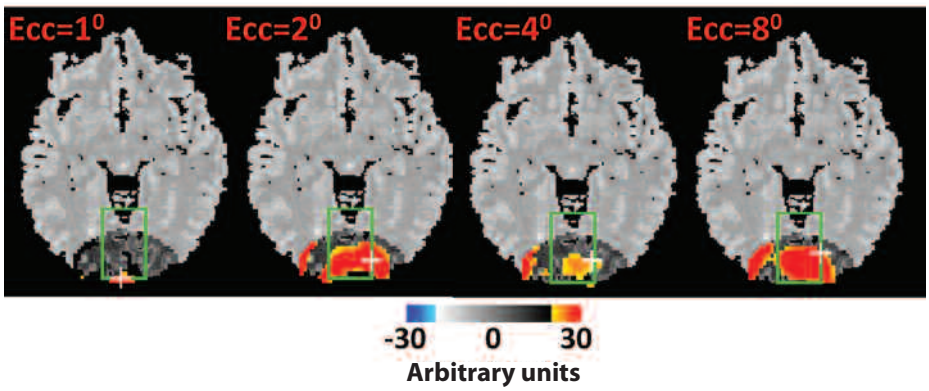
Beckman Institute researchers have turned their discovery of a pulsed inhibition mechanism in the brain into a new theory for the role of alpha oscillations involving attentional selection and control. Beckman Institute Fellow **Kyle Mathewson** discovered the mechanism while working in the lab of researchers **Monica Fabiani** and **Gabriele Gratton**; they joined with Beckman colleagues **Diane Beck** and **Alejandro Lleras** to show that, one, the mechanism operated in the human visual system, to "sample" the world in waves or frames rather than continuously, and two, that these frames could be entrained to rhythmic stimuli in the environment. The researchers wrote a review paper on their work published in 2011 in the journal *Frontiers in Perception Science* that summarized their previous work and laid out their theory that alpha oscillations modulate sensory input in the visual system and play a role in attentional selection and control in the brain. "Alpha represents," they wrote, "a pulsed-inhibition of ongoing neural activity. The phase of the ongoing electroencephalography can influence evoked activity and subsequent processing, and we propose that alpha exerts its inhibitory role through alternating microstates of inhibition and excitation." Alpha neural oscillatory mechanisms play a critical role in cognitive functions such as learning and memory, and in the visual system where the researchers found that the pulsed inhibition mechanism explained how people often fail to perceive stimuli from the environment that at other times would be readily detectable. In the recent paper, titled *Pulsed Out of Awareness: EEG Alpha oscillations represent a pulsed inhibition of ongoing cortical processing,* they write that these alpha oscillations play a role in cognitive control and attention, that they act as synchronized pulse-inhibitors of neural processing, and that the brain uses them to "time microstates of excitation and/or inhibition so as to be optimally ready to process or inhibit incoming information." They add that may be "part of a general temporal tuning mechanism, by which our brain can exploit regularities in the environment to optimize processing."



This schematic was published in the May 2011 issue of *Frontiers in Psychology*. Research by Beckman scientists is indicating that our visual experience may at least sometimes be coming through in waves.

Understanding Stuttering in the Adult Brain

Torrey Loucks is a member of the Cognitive Neuroscience group and a researcher in the Stuttering Research Project, which seeks to identify a biomarker for persistent stuttering in children through different structural and functional MRI approaches. In adults with chronic stuttering, a region of the brain called the anterior corpus callosum is larger and has a higher density of white matter. Loucks and his collaborators reported a new study in 2011 that focused on the corpus callosum (CC), which is responsible for most interhemispheric transfer of information between the left and right cerebral hemispheres of the brain. Their findings suggest that neuroanatomical differences are part of the biological basis for persistent developmental stuttering, which affects about one percent of the adult population and about four times as many males as females. Past research has shown anatomical differences in the brains of adults who stutter (AWS) and normally fluent adults (NFA), including that AWS have atypical brain symmetry and distributions of gray and white matter tissue across the cerebral hemispheres. In their paper, *Corpus callosum differences associated with persistent stuttering in adults,* the researchers studied 11 male AWS and 12 male NFA between 20- and 35-years-old, using the headscanner magnetic resonance imaging magnet at Beckman's Biomedical Imaging Center. They report that "structural differences in the CC may be associated with the atypical functional brain organization in AWS and may be a factor in the performance of AWS on tasks" and that the "overall pattern of brain differences suggest increased right



This figure from researchers Monica Fabiani and Gabriele Gratton shows latency of event-related optical signal (EROS) activity. Researchers are hoping that advances in EROS will "lead to a new level of analysis of human brain function."

hemisphere participation in speech production with particular decreases in functional and anatomical anomalies in the left hemisphere of AWS compared to NFA." Their study of the corpus callosum showed the rostrum and anterior midbody of the CC were larger in AWS than NFA, that the overall callosa area was larger in AWS than NFA, and that the results "potentially reflect anatomical changes associated with differences in the hemispheric distribution of language processes that have been reported previously in AWS."

Fast Optical Imaging of Human Brain Function

Gabriele Gratton and **Monica Fabiani** have been taking advantage of a neuroimaging method for capturing event-related optical signals (EROS) they developed that records "fast optical" signals in the brain. Their EROS system uses near-infrared light to identify and measure changes in the light scattering and absorption properties of neurons, providing information on rapid brain events down to the millisecond timescale. This past year, the researchers reviewed the method's impact on research and explained its advantages for brain imaging in a paper for *Frontiers in Human Neuroscience.* They discussed the method's challenges (such as the difficulty in using light to penetrate through tissues like skull and skin), the advancements in overcoming the obstacles (using diffusive optical imaging for greater penetration, and signal averaging for reducing background signal noise) and the rewards (recording rapid — to within 100 milliseconds — interactions between different elements of complex neuronal networks, as well as spatial resolution at sub-centimeter scale of fast brain activity). Fabiani and Gratton also addressed controversies and reviewed supporting studies and data for EROS, as well as noting advantages such as the method being complementary to other neuroimaging methods. "Taken together," they wrote, "the work published so far provides a strong support for the idea that fast optical signals (EROS) can be detected from surface recording, providing a tool for studying rapid changes in brain activity." They conclude that, while "EROS is still in its infancy" the many advances in methodology will result in higher signal-to-noise ratio and "significant improvement in the quality of the data, including higher spatial and temporal resolution. … Hopefully these advancements will lead to a new level of analysis of human brain function."

Conversation Fillers Facilitate Memory for Discourse

Duane Watson from the Cognitive Science group studies the cognitive processes that underlie language production and comprehension, with a focus on understanding how speakers use stress, pitch, and intonational boundaries to convey information to a listener. In his paper *The disfluent discourse: Effects of filled pauses on recall* that appeared in *The Journal of Memory and Language,* Watson looked at the mechanisms by which conversation fillers such as "uh" and "um" can affect memory for discourse. Previous research has shown that fillers can benefit online comprehension of simple materials; this study attempted to see if there are beneficial effects of fillers on discourse, on situations involving later memory, and it sought to examine the mechanisms that might be involved. The study, which had participants listen to and attempt to recall recorded passages adapted from *Alice's Adventures in Wonderland,* found that the effect of fillers on memory had to do with attention. "Because fillers originate in the language production system," Watson reported, "they may lead listeners to attend more to what the speaker is producing, which can facilitate comprehension and recall of a discourse relative to a fluent version." The experiments showed that fillers facilitated later recall of complex discourses. The results, as reported in the paper, "are most consistent with an attentional orienting account in which fillers direct attention to the speech stream but do not always result in specific predictions about the nature of upcoming material. These results also generalize past experimental findings on fillers to the level of the discourse and to later recall, demonstrating that fillers can facilitate recall even of complex discourses."

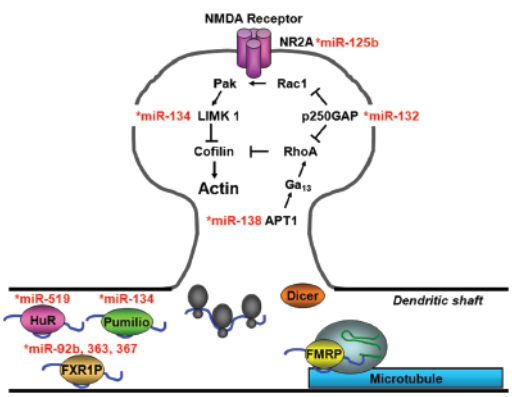
Line Drawings Represent Natural Scenes Just as Well as Photographs

From the earliest works of cave dwellers to the artistic endeavors of today's children, humans have used line drawings to represent their world, and now research from **Diane Beck** of the Cognitive Neuroscience group and her collaborators has shown that simple line drawings can capture the essence of a natural scene for viewers just as well as a photograph. Beck, whose research investigates how humans categorize natural scenes, and her research partners used line drawings in a study because of the role they have played in how humans represent

the world around them. "One reason why humans may be so fast at processing natural scenes is that our visual system evolved to efficiently encode statistical regularities in our environment," they wrote in their paper on the study. "However, we can nevertheless recognize and categorize line drawings of natural scenes despite their having very different statistical properties from photographs. Indeed, the fact that early artists as well as young children represent their world with line drawings suggests that such depictions capture the essence of our natural world." The researchers used functional Magnetic Resonance Imaging (fMRI) to look at activity in visual areas of the brain in test subjects who viewed photographs and line drawings of six natural scenes. "Despite the marked difference in scene statistics," they wrote, "we were able to decode scene category from fMRI data for line drawings just as well as from activity for color photographs" and that, remarkably, "error patterns for decoding from line drawings were very similar to those from color photographs. These data suggest that, in these regions, the information used to distinguish scene category is similar for line drawings and photographs." The results confirmed their hypothesis that the scene structure preserved in line drawings is important for categorization and that global structure, which they define as contours that separate large but relatively homogenous regions of the image, plays a more prominent role than local structure (captured in short contours). They concluded that "that global scene structure, which is preserved in line drawings, plays an integral part in representing scene categories."

Fragile X Research

The Fragile X mental retardation protein (FMRP) plays a critical role in nervous system development, while Fragile X syndrome (FXS) is the most common cause of inherited mental impairment and a single gene cause of autism. Research involving Fragile X has long been a key element of work in the laboratory of **William Greenough**, including their investigations of synaptic plasticity, while **Stephanie Ceman** has frequently collaborated with fellow NeuroTech group member Greenough and others in her efforts to understand FMRP, Fragile X, and related topics at the cellular and molecular levels. Ceman and her collaborators discovered that an RNA binding protein closely related to FMRP, called FXR1P, is regulated by microRNAs (miRNAs), which are gene regulatory molecules. FXR1P plays an important role in normal muscle development and has been implicated in cardiac and muscular disorders, including certain forms of muscular dystrophy. Their findings suggest that FXR1P is regulated by miRNAs whereas FMRP is not. FXR1P is the first RNA binding protein that has been shown to exhibit this form of regulation. So while the study was prompted by the desire to better understand Fragile X Syndrome, the discovery may actually turn out to have more relevance for understanding how miRNA dysregulation contributes to muscle-related diseases. The Greenough Lab used a Fragile X mouse model to look at synaptic plasticity. Their efforts included a review paper by researcher **Ivan Jeanne Weiler**, *The Molecular Basis of Fragile X Syndrome,* and work from **Der-I Kao** showing that in the absence of the FMRP protein, mRNA is no longer accurately transported and docked within single cells. In a paper published in association with **Jonathan Sweedler**, a possible basis for the failure of synapse maturation in FX was suggested when it was discovered that neuropeptide release from synapses is impaired in FX knockout mice; these neuropeptides may be necessary for molecular maturation of the synapse.



Beckman researchers discovered that an RNA binding protein FXR1P that is key for normal muscle function is regulated by microRNAs. This is the first RNA binding protein that has been demonstrated to be regulated my microRNAs.

Understanding how Memory Works through Imaging of the Brain

Brian Gonsalves uses brain imaging techniques to study the neurological basis of human memory, with a focus on how memory is organized and implemented in the brain and the processes and brain regions that make memory possible. In one study, Gonsalves and graduate student **Carol Baym** focused on misinformation and the neural mechanisms underlying that kind of memory failure. Using functional Magnetic Resonance Imaging (fMRI), they had participants look at photos of a common activity and later, sentences describing the photos, including some descriptions that conflicted with the photo. The results, they reported, "showed reliable creation of false memories, in that participants reported information that had been presented in the verbal misinformation but not in the photographs." They found that differences in neural activity during the original encoding of the photographs were predictive of subsequent true memory, false memory, and forgetting. The fMRI results also showed that brain region activity indicated that false memories were not simply caused by a failure to encode the original event and that differences in encoding may contribute to later susceptibility to misinformation. "The results of the present study suggest that strong encoding of the

general contextual frame of an event, combined with weaker encoding of the particular details that turn out later to be important — such as the identity or specific features of objects present during the event — are optimal conditions for the formation of false memories." In a paper he co-authored with Beckman Fellow **Joel Voss,** Gonsalves reported on distinct neural substrates revealed by priming and recognition, which are behavioral expressions tied to memory. They wrote in the journal *Frontiers in Human Neuroscience* that priming, a response used to measure implicit memory, and recognition, considered an explicit expression of memory, have been thought to result from the operation of two distinct memory systems. Their experimental results showed that how long test subjects studied an object had opposite effects on their recognition performances, suggesting different neural substrates for the different kinds of memory. They found that study duration "had opposite effects on priming and recognition, and on the engagement of implicit versus explicit memory systems. These findings call into question single-process accounts of priming and recognition, and substantiate previous behavioral, neuropsychological, and neuroimaging dissociations between implicit and explicit memory. … The duration for which objects were studied had opposite behavioral effects on subsequent priming and recognition, and revealed distinct electrophysiological responses associated with each kind of memory."

Decoding the Elements of Communication

Jennifer Cole studies how people communicate using elements of speech such as the tone of one's voice. Researchers like Cole have found that it is often the pauses, voice inflections, and tones in speech that communicate meaning. Prosody describes speech elements like intonation and the vocal rhythms produced when we speak; pauses and the use of "umms" and "ahhs" in speech are called disfluencies. This past year her research produced two papers on how listeners perceive the prosodic patterns of speech, and how they associate prosody with meaning in spoken discourse. In one paper, Cole and Beckman colleague **Mark Hasegawa-Johnson** looked at the perception of prosodic prominence (the strength of a spoken word relative to the words surrounding it in the utterance) in spontaneous speech, using untrained listeners who did an online task transcription of prosody. They found that the untrained listeners "reliably perceive prosodic prominence in spontaneous speech" and that "prominence perception is both signal-driven (influenced by acoustic factors) and expectation driven (influenced by word frequency and repetition)." They add that there is a parallel between these two notions of prominence when it comes to attention, writing that "prominence ratings produced in the task of online prosody transcription reflect the relative attention the listener commits to processing each word in its given discourse context. This notion of prominence perception that relates to attentional resources in speech processing successfully links the speaker and the listener in the communication of prosody." In another paper Cole reported on the role of syntactic structure in guiding prosody perception with ordinary listeners and everyday speech. In everyday speech, listeners assign structure to prosodic phrasing in order to understand meaning. Cole tested the relationship between syntactic and prosodic phrase structures to investigate the production and perception of spontaneous speech and found that "speakers encode syntactic structure in their production of prosody in spontaneous, conversational speech" and concluded that "listeners are guided in their perception of prosody by acoustic cues and syntactic context, and that the effect of syntactic context appears to be partly independent of the effect due to final vowel duration, the primary acoustic cue to prosodic phrase boundaries."

Software for Emulating Aphasia

Gary Dell collaborated with members of the Department of Computer Science at the University of Illinois in a project that promotes empathy for sufferers of aphasia — defined as the total or partial loss of the ability to use or understand language — by creating software that emulates the disorder. Dell, a member of the Cognitive Science group, focuses on how people produce and understand sentences, developing computational models of these processes. The goal of the researchers in creating a system that emulates aphasia is to promote empathy for people who have aphasia, especially in their loved ones and in those who work with them. Aphasia is an acquired communication disorder, and one, the researchers wrote, that forces those who suffer from it to "constantly struggle against a world that does not understand them. This lack of empathy and understanding negatively impacts their quality of life." The problem, they write, is not so much one of a loss cognitive functioning because "their impairment relates to receptive and expressive language, not to thinking processes. We introduce a novel system and model, Aphasia Characteristics Emulation Software (ACES), enabling users (e.g., caregivers, speech therapists and family) to experience, firsthand, the communication-distorting effects of aphasia." Results from a pilot study showed very positive reactions to the system. "By allowing neurologically typical individuals to 'walk in another's shoes,' we aim to increase patience, awareness and understanding," they wrote. "Results from an evaluation of 64 participants indicate that ACES provides a rich experience that increases understanding and empathy for aphasia."

BIOLOGICAL INTELLIGENCE

To the public he became famous as a psychology case study with a two-letter name: HM. To neuroscience researchers, the unique nature of his memory impairment filled hundreds of pages of journal articles. To Neal Cohen HM was also a friend who, in most of the thousands of moments they interacted, met him anew each time.

Before he was a faculty member at the University of Illinois, Cohen was a postdoctoral researcher at MIT who, he said, "had the good fortune to study HM.

"I used to drive two hours, pick him up, drive him back to MIT, where he would stay for two weeks. It was an extraordinary experience. People all over the world know of him but he himself never knew that he was the patient HM and he never learned who we were. It is remarkable to think how much he taught us about memory and the brain."

What made HM, whose real name was Henry Molaison and who died in 2008, such a remarkable case study and eventually world famous, was a memory impairment that prevented him from committing even very recent events to his long-term memory. He was studied extensively during his lifetime and his brain is now the subject of research at the University of California at San Diego, where Cohen earned his Ph.D. in neuroscience.

Cohen knew HM as more than a research subject.

"It wasn't so much in the experiments as it was the off time, the time in the car, driving along and you realized that if we stop talking for awhile he will have no idea who I am and why we are in this car," Cohen said. "Think about what a frightening experience it would be to have no idea why you are going down the highway with this strange person. You had this responsibility; he was such a trusting soul that you had to take care of him and make sure other people didn't take advantage of him."

Today, Cohen is one of the world's leading researchers in the area of memory, with a focus on amnesia as a path toward understanding memory systems. A Professor of Psychology and member of Beckman's Cognitive Neuroscience group, Cohen's Amnesia Research Laboratory at the Institute has been making contributions to our understanding of how memory works for more than two decades.

Cohen's approach has been to look at damaged abilities of people with amnesia in order to understand how memory functions normally. His research has shown that multiple, separate memory systems in the brain, particularly in the hippocampus, are responsible for most of our ability to employ working memory and form longer term memories.

Cohen says the subjects in his lab have made the same kinds of contributions over the years that HM did. He said one in particular was noteworthy for the way she was able to adapt by using memory aids such as lists and other devices that helped her to lead a fairly normal life with a family and a job.

Investigating and promoting interventions such as exercise, memory aids, and learning to use other parts of the brain to improve memory function have become a greater part of Cohen's work over the years. He said amnesiacs such as the one he described help provide insights that could be used to help others with memory deficits.

"It was remarkable to spend time with her," Cohen said. "It's not just about the laboratory doing our specialized tests. It's about getting a sense of how it impacts real life, what the role of different kinds of memory is in real life. The more we get to know about that, the more it is possible for us to help people take advantage of the things they could do so as to not be bogged down by the things they couldn't."

Cohen said traditional thinking was that damage to the hippocampus as was found with HM and with the amnesia patients in his lab caused only long-term memory deficits.

"Everyone thought the hippocampus was not involved in anything related to short-term memory, working memory, and our recent work shows that's not the case, that as long as it's about relational memory, the relating together of elements, it doesn't matter how short the delay is," Cohen said. "The hippocampus is critical for binding the elements of experience together, even in the present."

When it comes to theory, Cohen said there is a direct line from his Ph.D. and MIT research to his current perspective.

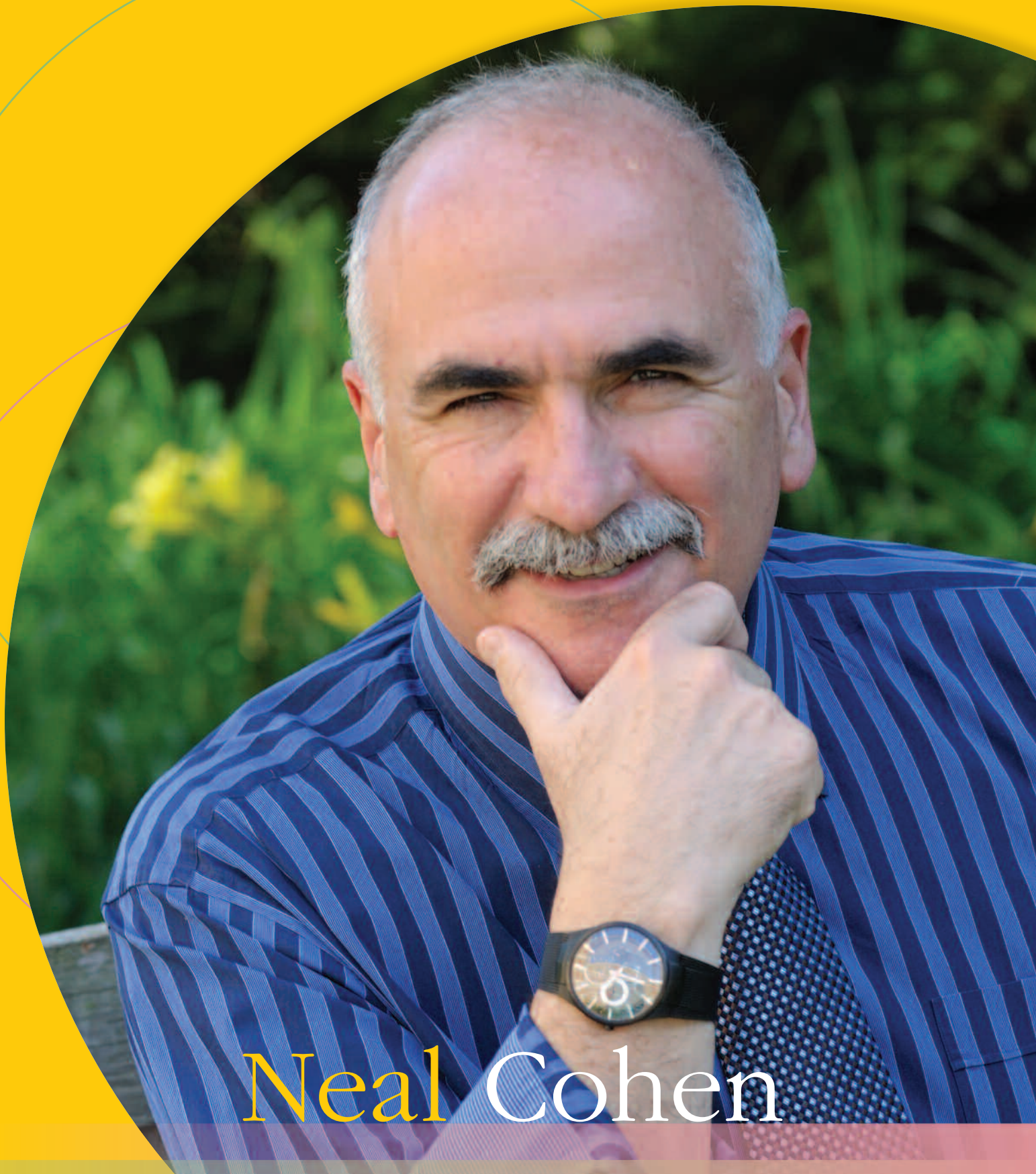
"The initial big picture stuff that continues to this day is the idea that we are about identifying and characterizing the multiple memory systems of the brain," he said. "The particular memory system we spend most of our time on is the one that's centered in the hippocampus and has to do with relational memory. These days one of our points of interest is that the hippocampus doesn't do it alone; it's about the interaction of the hippocampus with other systems and in particular, the pre-frontal cortex."

A native of the Queens, New York, Cohen is the first person in his family to go to college. An early interest in artificial intelligence gave way to a fascination with the real thing.

"It just stuck me as obvious that a much more challenging problem is how the brain actually does it, how biology actually does it," he said.

Cohen joined Beckman in 1990, shortly after it opened and is a fervent exponent of the interdisciplinary approach.

"We continue to push the margins of that," he said. "It was a fantastic draw for me and the entire cognitive neuroscience community. It's about how people interact. No one comes to Illinois for the mountain-climbing or the surfing. They come here because there is a community in which you can build something and Beckman is a linchpin for that."



Neal Cohen

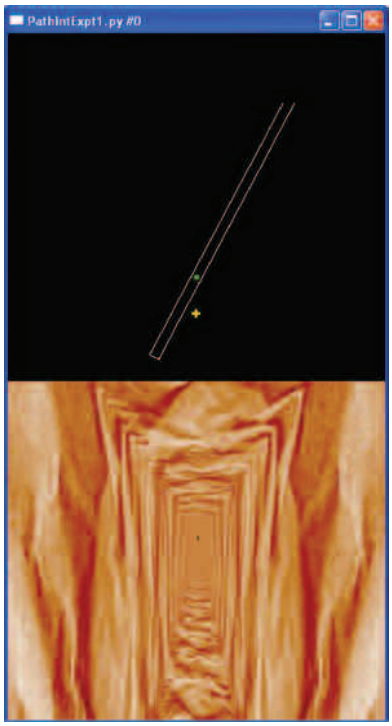
"It's not just about the laboratory doing our specialized tests. It's about getting a sense of how it impacts real life, what the role of different kinds of memory is in real life."

HUMAN-COMPUTER INTELLIGENT INTERACTION

The Human-Computer Intelligent Interaction (HCII) research theme has a mission that both utilizes and develops advanced technology, while also pursuing a greater understanding of the human side of the man-machine interface. HCII accomplishes its goals of enhancing human-computer interactions, technology optimization, and understanding cognitive processes and behavior through research in three main groups: Artificial Intelligence, Human Perception and Performance, and Image Formation and Processing. HCII includes research areas as diverse as computer vision and processing, human brain function and cognition, robotics, and speech and hearing science. This past year, HCII researchers advanced technology and added to our knowledge in a wide variety of areas.

Having Choices Doesn't Aid Human Navigation

Ranxiao (Frances) Wang uses the Cube, a six-sided, 3-D immersive virtual reality environment in Beckman's Illinois Simulator Laboratory (ISL), to study human spatial cognition and visual perception. In one of her research lines Wang investigates the mechanisms involved in human navigation of our three-dimensional world, with a recent study focusing on how it is people calculate where they are (known as path integration) by tracking their movements over time in virtual hallways. In a paper published in *Journal of Vision* titled *The effect of active selection in human path integration,* Wang and co-authors James Crowell of the ISL and Xiaoang Wan reported on some surprising new findings about path integration, which they describe as the ability to integrate self-motion information in order to estimate one's current position and orientation relative to the path's origin. In the study, all of the test subjects received the same perceptual and motor information but one group's subjects were allowed to voluntarily select their path (known as active selection) in attempting to return to their origin. Wang said the results showed that active selection (including decisions such as which way to go, and how far to walk), rather than passively following other people's choices does not improve their path integration performance. "That is," she said, "those who can choose their own routes are no better in keeping their sense of direction than those who have no choices, which is against people's general belief. Previous research has shown that humans are generally much worse in path integration than many animals such as desert ants and rats, and some researchers proposed that this poor performance was due to using passive tasks where people cannot control their paths. Our findings suggest that's not true because control/choice of one's path does not help people's navigation performance."



This image from Ranxiao (Frances) Wang's research illustrates the virtual maze that is used in a study that examines human navigation.

Do Athletes Excel at Everyday Tasks?

Are college varsity athletes better at physically and mentally challenging everyday tasks such as crossing a busy street? The expected and correct answer is yes, but the reason behind the athlete's success was unexpected: their advantage came from superior information processing power rather than athletic superiority. Using a modified treadmill set in the CAVE™, a 3-D immersive virtual reality environment in Beckman's Illinois Simulator Laboratory, Beckman Institute Director **Art Kramer**, along with his research group members **Laura Chaddock**, **Mark Neider**, **Michelle Voss**, and **John Gaspar**, created a study that tested 36 male and female college students. Half of the test subjects were varsity athletes from a variety of sports and half were healthy students from academic departments; they were asked to walk across a virtual street while dodging virtual cars within 30 seconds. The researchers found that the athletes did much better — meaning they weren't hit by a virtual car — than the non-athletes, but their success didn't depend on speed or other physical abilities; rather it was related to their ability to mentally gather information (such as checking more often for cars) and process it more rapidly. The study used a computer-based test of simple reaction time that also showed the athletes had faster processing speeds and that their shorter reaction times were associated with greater success in crossing the street. The researchers wrote in their paper for the

Mark Neider (pictured) and Art Kramer continued their research on pedestrian distraction and found that older adults took significantly longer to cross the street than their younger counterparts while engaged in activities such as talking on the phone.

IMAGE CREDIT: L. BRIAN STAUFFER.

Journal of the American College of Sports Medicine that the results "suggest that participation in athletics relates to superior street crossing multitask abilities and that athlete and non-athlete differences in processing speed may underlie this difference. We suggest that cognitive skills trained in sport may transfer to performance on everyday fast-paced multitasking abilities."

Multitasking a Danger for Older Pedestrians

Researchers **Art Kramer** and **Mark Neider** extended last year's work showing that talking on a cell phone while crossing a street was a distraction, with another study focusing on older adults and multitasking. As with their previous experiment, the researchers used a modified treadmill set inside the three wall screens of the 3-D virtual reality environment the CAVE™ and asked test subjects to avoid traffic while crossing a street and performing tasks within an allotted time. The experiment used 18 college age students and 18 adults aged 59 through 81 who either talked on a cell phone or listened to music. They found that the older adults took significantly longer than college students to cross the street, that greater caution on their part did not help their performance, and that the older adults showed significant impairment while engaged in the most challenging street crossing tasks and another task, especially when using a cell phone. "Combined with our previous work, the current findings suggest that while all pedestrians should exercise caution when attempting to cross a street while conversing on a cellphone, older adults should be particularly careful," Neider said.

Taking Brief Breaks Greatly Improves Focus

Alejandro Lleras has a research focus on people's awareness of visual information and how they use that information. In a study published in the journal *Cognition,* Lleras challenged traditional theories of "vigilance decrement" when it comes to focusing on a task for a long period of time. "For 40 or 50 years, most papers published on vigilance decrement treated attention as a limited resource that would get used up over time, and I

Alejandro Lleras challenged traditional theories with his research on task focus. His work shows that taking breaks can improve focus.

IMAGE CREDIT: L. BRIAN STAUFFER.

Ron Carbonari, programmer, is shown in the Illinois Simulator Laboratory's Cube. He is searching for anomalies in a large dataset. Inset is a graphical visualization of a large audio file.

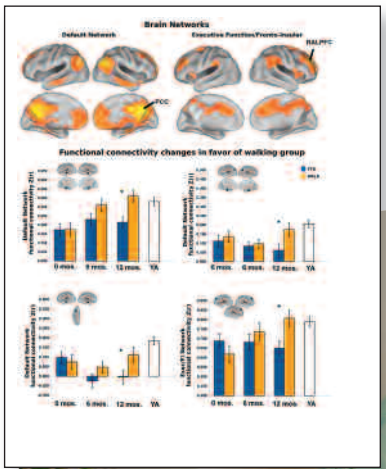
believe that to be wrong," Lleras said. "You start performing poorly on a task because you've stopped paying attention to it. But you are always paying attention to something. Attention is not the problem." The new study had 84 test subjects perform a repetitive computerized task for one hour under various conditions, with some taking breaks or being given other diversions. They found that those who took two brief breaks from the task remained focused during the entire hour. Staying focused for a long time, they showed, actually hampers performance. "We propose that deactivating and reactivating your goals allows you to stay focused," Lleras said. "From a practical standpoint, our research suggests that, when faced with long tasks (such as studying before a final exam or doing your taxes), it is best to impose brief breaks on yourself. Brief mental breaks will actually help you stay focused on your task."

Tools for Visualizing Sound

Analysts trying to examine audio data, such as those working in the area of homeland security, have a daunting task: the human mind is not as adept at processing audio signals as it is at processing visual signals. So Beckman researchers **Thomas Huang** from the Image Formation and Processing group and **Mark Hasegawa-Johnson** from the Artificial Intelligence group led a collaboration that developed new methods for creating graphical visualizations of large audio files. The visualizations allow the user to scan an audio recording at 200 times that of real-time, enabling them to discover unexpected events. Using an analogy to items sometimes hidden in video games by manufacturers, the researchers dubbed these unexpected events "easter eggs." Hasegawa-Johnson said the software is designed to free up the analyst by having the computer perform certain tasks, and render the data visually. "The idea is to let the computer do what computers are good at and have the humans do what humans are good at," he said. "So humans are good at inference, big picture, and anomaly detection. Computers are really good at processing hundreds of hours of data all at once and then compressing it into some format, into some image." The researchers have applied the technology to an audio book. "If you try to skim an audio book, if you try to speed it up by four times, you really can't understand what it's saying most times," Hasegawa-Johnson said. "But if you take the entire thing and plot it as a spectrogram you can actually plot it as some kind of signal summary of the entire three hours and get some information from one screen of data. From that one screen of data you can figure out what in the three hours you want to zoom into."

Message Clear for Older Adults Worried About Their Cognitive Health: Exercise, Exercise, Exercise

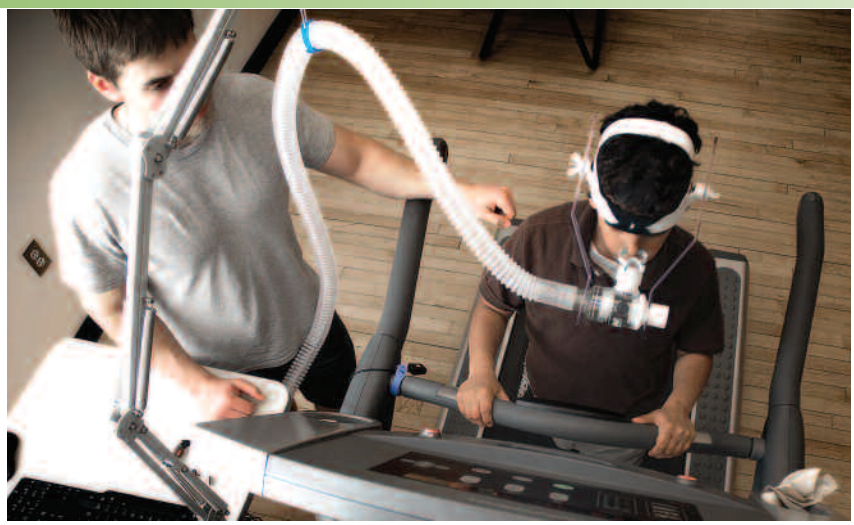
Two new studies on cognitive aging and interventions published this year confirm a growing body of evidence showing that even moderate exercise can boost brain function for older adults, including the one function that is most often affected as we age, memory. In one study, Beckman Institute researchers **Ed McAuley, Art Kramer,** and doctoral student **Michelle Voss** tested adults aged 59 to 80 who had previously led a sedentary lifestyle in groups that began programs of either moderate walking, or toning, or stretching exercises. After one year the subjects who walked showed significant improvement in brain function, particularly in a brain network that is dominant when people are engaged with the outside world and that is involved in dysfunction in the aging brain. Functional magnetic resonance imaging of the subjects showed improved connectivity in brain circuits, which leads to better performance on executive control tasks that decline with age. The researchers write that the study "provides the first evidence for exercise-induced functional plasticity in large-scale brain systems in the aging brain, using functional connectivity techniques, and offers new insight into the role of aerobic fitness in attenuating age-related brain dysfunction." In another study in which Kramer collaborated with Kirk Erickson, formerly of his research group, researchers focused on older adults who had experienced atrophy in the hippocampus, the brain structure most critical to memory function. They found through a randomized controlled trial with 120 older adults that this shrinkage, which leads to impaired memory and increased risk for dementia, can be modified and even reversed in late adulthood. "Aerobic exercise training," they write, "increases the size of the anterior hippocampus, leading to improvements in spatial memory" and that exercise training increased hippocampal volume, effectively reversing age-related loss in volume. They add that these findings "indicate that aerobic exercise training is effective at reversing hippocampal volume loss in late adulthood, which is accompanied by improved memory function."



Online Media Users Unknowingly Provide Information

Users of online media such as blogs, forums, and social networking sites, may be giving away more information than they realize, according to research by **Wai-Tat Fu** of the Human Perception and Performance group. Fu's research, which involves a wide range of interactive behavior, looked at how ideas propagate in online social media and how users explicitly share information within their social networks. A 2010 paper, *Semantic imitation in social tagging,* by Fu and his collaborators reported that ideas can also propagate implicitly, even when people are not explicitly sharing information. They wrote that their semantic imitation model of social tagging and exploratory search "assumes that social tags evoke a spontaneous tag-based topic inference process that primes the semantic interpretation of resource contents during exploratory search, and the semantic priming of existing tags in turn influences future tag choices." Their experimental results confirmed this, showing that merely seeing how other people index information is sufficient to influence how a person will interpret and index information. The researchers used cognitive science-based theories of human text comprehension and concept formation to show, as Fu writes, that "this form of implicit propagation of ideas can be characterized as a semantic imitation process, which is shown to be useful in explaining the tendency for people to imitate the semantic interpretation of information by others. The results not only have theoretical implication to information and idea propagation in social networks, but also practical implication to technological designs that facilitate knowledge sharing and expertise development in networked communities."

The research of Art Kramer and Michelle Voss shows that even moderate exercise can improve brain function for older adults.



A child takes part in an exercise test at Charles Hillman's Neurocognitive Kinesiology Laboratory.

Exercise Intervention Increases Brain Volume, Improves Cognition in Preadolescents

Charles Hillman of the Human Perception and Performance group began a program called *FITKids* as both an intervention program for preadolescent children and as a platform for studying the effects of exercise on cognition in that age group. This past year, Hillman, **Art Kramer,** and lead author **Laura Chaddock** reported on the first study ever of the association between childhood aerobic fitness and basal ganglia structure and function in their paper, *Basal ganglia volume is associated with aerobic fitness in preadolescent children,* published in *Developmental Neuroscience.* Noting that research has shown that higher aerobic fitness levels are associated with greater hippocampal volumes, superior performance on tasks of attentional and interference control, and elevated event-related brain potential indices of executive function, the researchers focused their study on higher-fit and lower-fit 9- and 10-year-old children. They wanted to see if they exhibited differential volumes of other subcortical brain regions, specifically the basal ganglia involved in attentional control. They looked at both the dorsal and ventral striatum, and at task performance using functional magnetic resonance imaging. The reseachers found that higher-fit children showed greater volumes of the dorsal striatum and, as they write, the results "support the claim that the dorsal striatum is involved in cognitive control and response resolution and that these cognitive processes vary as a function of aerobic fitness." They conclude that the findings "suggest that increased childhood aerobic fitness is associated with greater dorsal striatal volumes and that this is related to enhanced cognitive control. Because children are becoming increasingly overweight, unhealthy and unfit, understanding the neurocognitive benefits of an active lifestyle during childhood has important public health and educational implications."

The Invisible Gorilla and Real-world Implications of Inattentional Blindness

Daniel Simons of the Human Perception and Performance group and collaborator Christopher Chabris have been studying the topic of inattentional blindness (what they describe as the failure to see visible and otherwise salient events when one is paying attention to something else) for more than a decade, and this past year their work led to a popular psychology book that made the best-seller lists and another paper on the research. Their book, *The Invisible Gorilla,* came out in 2010 and in 2011 the paperback edition reached the top 25 of the *New York Times* nonfiction best-seller list. The book opens with the story of Boston police officer Kenny Conley, who was convicted of perjury and obstruction of justice for denying that he witnessed the beating of an undercover office — who had been mistaken for a suspect — by fellow policemen, while Conley was pursuing the actual suspect. In a paper for the open access journal *i-Perception,* Simons and Chabris reported on a study using similar, real-world conditions: student test subjects chased a researcher for three minutes, during which they ran past a staged fight the subjects had not been told about. The "fight" and "chase" were staged to resemble the conditions in the Boston case, with yelling, punching, and kicking, and one experiment set during the day and one at night as happened in the actual incident; some subjects were also asked to count the number of times the runner touched his head in order to focus their attention on a task. At night, only about one-third of the subjects noticed the fight, while during the day more than 40 percent missed it. "We can't say with certainty that Conley didn't see the fight," Simons said. "But the study shows that even under less demanding conditions than he must have experienced, it's possible to miss something as obvious as a fight."

The Invisible Gorilla, authored by Beckman researcher Dan Simons and Christopher Chabris, reached the Top 25 of the *New York Times* nonfiction best-seller list.

Predicting Video Game Aptitude

Researchers report that they can predict "with unprecedented accuracy" how well a person will learn on a complex task such as a strategic video game simply by analyzing activity in a specific region of the brain. The findings offer detailed insights into brain structures that facilitate learning, and may lead to the development of training strategies tailored to individual strengths and weaknesses. The research analyzed background activity in the basal ganglia, a group of brain structures known to be important for procedural learning, coordinated movement, and feelings of reward. "There are many, many studies, hundreds perhaps, in which psychometricians, people who do the quantitative analysis of learning, try to predict from SATs, GREs, MCATS or other tests how well you're going to succeed at something," said Beckman Institute Director **Art Kramer,** who led the research which also included Beckman faculty **Monica Fabiani**, **Gabriele Gratton**, **Dan Simons**, **Brad Sutton**, **Michelle Wang**, and lead author **Loan Vo**. These methods, along with studies that look at the relative size of specific brain structures, have had some success predicting learning, Kramer said, "but never to this degree in a task that is so complex." After having their brains imaged, participants spent 20 hours learning to play Space Fortress, a video game developed at the University of Illinois in which players try to destroy a fortress without losing their own ship to one of several potential hazards. None of the subjects had much experience with video games prior to the study but after 20 hours of training and practice, all the players' scores went up significantly. Some did much better than others, however, a difference that can be predicted to a large degree by analyzing activity in parts of the basal ganglia. "We predict up to three times as much of the variance (in learning) as you would using performance measures," Kramer said. "Our data suggest that some persistent physiological and or neuroanatomical difference is actually the predictor of learning."

Researcher Jont Allen (center) meets with students in the Beckman Institute Café. His group focuses on problems of human speech perception.

Quantifying Speech Loss

Hearing impairment is different for each individual and for an individual's left and right ears, according to research findings from **Jont Allen's** Human Speech Recognition group. Allen's work focuses on problems of human speech perception, including topics such as speech processing for hearing aid applications. One line of research aimed at advancing hearing aid technology called "Quantifying Speech Loss in the Hearing Impaired Ear" has been measuring consonant identification for normal and hearing impaired ears. Ears with normal hearing rarely make errors when it comes to consonant identification, even at a signal-to-noise ratio (SNR) of minus 10 decibels, while Allen's research has shown hearing-impaired ears show confusion error rates for particular consonants. One of the biggest problems facing hearing aid manufacturers and those who use the devices is their inability to distinguish between speech and background noise, a speech recognition task the normal ear performs easily. Allen's research found huge errors for even mild noise among hearing impaired subjects, including in different ears, and was able to quantify the amount of hearing loss in each ear when it came to consonants such as "s" as in Sue and "z" as in zoo. Allen writes that "data such as this will play an important role in furthering our understanding of speech loss by hearing impaired listeners, and hopefully will someday allow us to make much better hearing aids."

Combining Theory and Mathematics for Greater Content Security

Pierre Moulin's research focus on the growing area of information forensics and security is undergirded by a theory he helped develop on information theory of watermarking and data hiding. His work also illustrates the principle of translating theory into real-world applications. Protecting digital content is increasingly a concern for manufacturers, especially in the entertainment field, and Moulin's work has led to methods and algorithms for hiding "digital fingerprints" in audio and video content that are used worldwide in those products. One recent effort by Moulin and students from his research group included matching video or audio content reliably and quickly to a media database, thereby overcoming editing and filtering operations. Another effort involved using a mathematical model for media security in order to gain a precise description of the number of users a fingerprinting system can accommodate for a given fingerprint code-length, and to gain a given number of those who might be trying to compromise the content. Moulin also explored information-theoretic performance limits for compressive sensing, a method which is frequently used for efficient acquisition of sparse signals, toward optimal signal processing.

If J.K. Rowling wrote a tale of a young girl who became fascinated with the unseen, almost magical powers of the human mind, and who then went on to divine new knowledge about these powers, the Harry Potter author could be writing about educational psychology researcher Elizabeth Stine-Morrow. The hidden neural mechanisms and cognitive processes that give rise to human consciousness have intrigued Stine-Morrow since she was a teenager back in New Orleans, and today that fascination continues to inform her work focusing on learning across the lifespan.

"I was one of those kids who got a subscription to *Psychology Today* and really loved psychology," said Stine-Morrow, a member of Beckman's Human Perception and Performance group and a professor in the Department of Educational Psychology.

"And I loved the movie *Freud*," she added with a laugh. "What captivated me about that in high school was the idea that there were things going on inside that would be manifested in behavior in subtle ways that you wouldn't expect. I never was that interested in clinical psychology but I was interested in the causes of behavior that are not always obvious."

Stine-Morrow, who heads the Adult Learning Laboratory at Beckman, is working to make them more obvious through her research built around two complementary lines: self-regulated learning, and a project called Senior Odyssey of the Mind that she created and has nurtured over the past seven years into a multimillion dollar grant-funded line of study and intervention program.

Senior Odyssey of the Mind has been a foundation for much of Stine-Morrow's work the past few years. Based on the educational program for students called Odyssey of the Mind, Stine-Morrow's creation serves as a platform for studies of the effects of performing challenging mental tasks and social engagement on the cognitive abilities of older adults. Participants engage in a creative team problem-solving tournament every year and may even advance to the Odyssey of the Mind national event — a competition where they have performed well in the past.

Stine-Morrow got the idea after her sons participated in Odyssey of the Mind, and that is not the only example of her creative approach to research. A fan of the wildly popular Harry Potter book series, Stine-Morrow used a notion from it in a well-received paper called the *Dumbledore hypothesis of cognitive aging*. She used this quote from the headmaster Dumbledore in the paper because it has special relevance in illustrating her work researching and promoting healthy aging cognitive: "It is our choices … that show what we truly are, far more than our abilities."

Stine-Morrow's work is part of a growing body of evidence researchers have reported on regarding the beneficial cognitive effects older adults can experience when they choose to be physically and mentally active. Senior Odyssey has proven itself as a community-based cognitive intervention program for older adults and now Stine-Morrow and others, including many of the participants, want to see it continue once the experimental portion of the study is done.

While the popular culture references and atmosphere at a Senior Odyssey of the Mind tournament are fun, the research projects and peer-reviewed papers are undergirded by Stine-Morrow's serious work involving years of experimental results. She and her collaborators have produced new findings involving neuroscience topics like fluid ability (the capacity to quickly detect patterns and manipulate and transform information), reading strategies people employ as they age, and assessments of working memory in older adults.

Those factors are also being studied in Senior Odyssey of the Mind. Stine-Morrow said they measure aspects of cognition such as attentional engagement and experiential engagement "so we can look at how these things interact.

"The idea is how these sorts of different engagement influence cognition and how does cognition in turn influence engagement."

Stine-Morrow said that her research lines of self-regulated learning and Senior Odyssey "are about the same thing: how engagement of different sorts affects cognitive outcomes.

"I really see close linkages between what we are doing with the reading project and Senior Odyssey," she added. "They both have to do with how well you regulate your environment and activities and engage experience to create a healthy lifestyle.

"What's gratifying to me about all this is the opportunity to consider the idea that engaging experience is important for long-term cognitive vitality and then testing it in a way that's meaningful for seniors."

The three types of engagement she sees as intertwined are activity engagement (behavioral, as with the Odyssey project), attentional engagement (such as how people allocate reading time), and experiential engagement (which she describes as the disposition to be interested and comfortable with novelty).

"In the Odyssey project we have all of these things represented," Stine-Morrow said. "What we want to find out is how these three forms of engagement interact with each other. Ultimately this is going to be the key to understanding the difference between training and education."

Stine-Morrow got her undergraduate degree at Loyola University in New Orleans, where she found a home in the psychology department and in her future field.

"I literally got a key to the whole department and had the run of the place," she said. "I would sometimes stay there all night with other students and work.

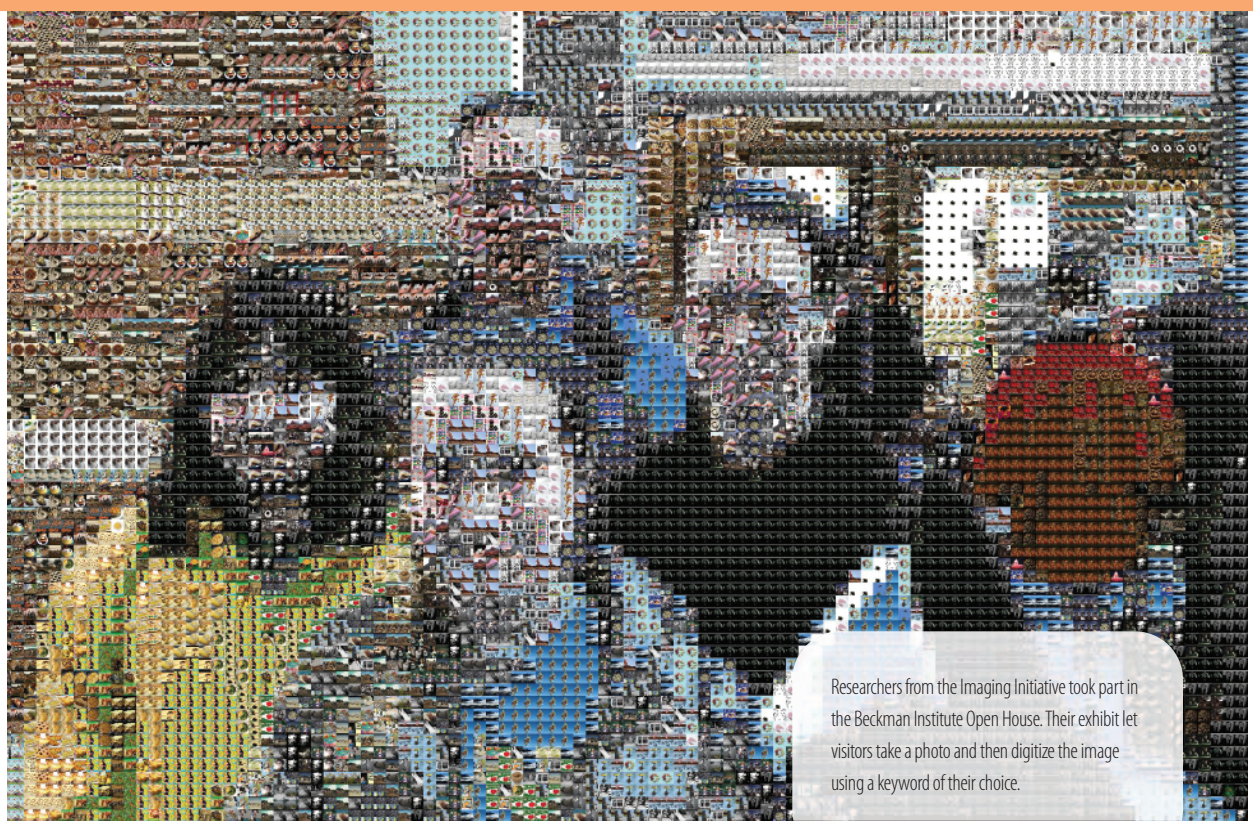
"What intrigued me about psych was that to understand behavior, you had to look at it from different points of view: biology, experience, the social context. It seemed like it was a field where you could use the scientific approach to address really, really important questions. It was an area I was just drawn to; it all was so fascinating."

Elizabeth Stine-Morrow

"It seemed like (psychology) was a field where you could use the scientific approach to address really, really important questions. It was an area I was just drawn to; it all was so fascinating."

INTEGRATIVE IMAGING

The Integrative Imaging (IntIm) research theme brings together people and technologies to create advances in imaging science that have real-world impacts in both research and clinical settings. Researchers in Integrative Imaging's two groups, the Bioacoustics Research Laboratory (BRL) and the Bioimaging Science and Technology group (BST), include those who are working to design and engineer new imaging instruments and methods and optimize current techniques, those for whom imaging is an integral part of doing scientific research, and some who are engaged in both efforts. They are improving methods such as ultrasound and magnetic resonance imaging, creating new methods based on technologies like computed tomography and optical imaging, and applying the instruments and techniques for important biomedical purposes like fast, detailed cancer screening, for screening of toxins or explosives, and for basic research involving the life sciences. Work in IntIm this past year saw advances in all of these areas.

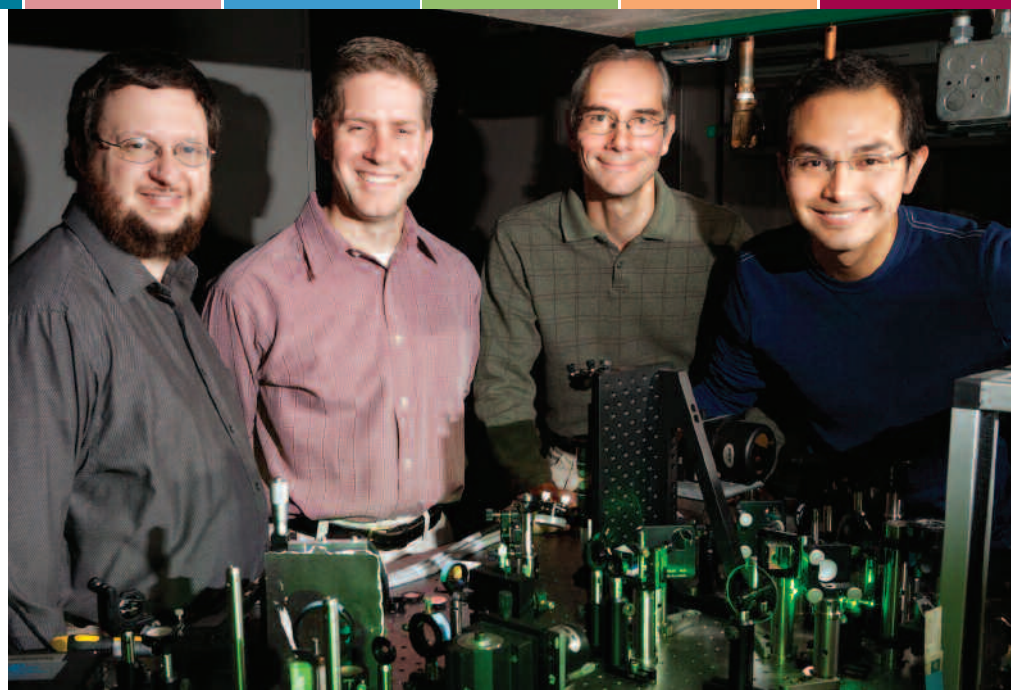


Researchers from the Imaging Initiative took part in the Beckman Institute Open House. Their exhibit let visitors take a photo and then digitize the image using a keyword of their choice.

Using nanoLAMPs to Illuminate Biomedicine

Rohit Bhargava has shined a light in an area of biomedical research that had previously been murky: measuring multiple molecules simultaneously with a high degree of accuracy and reliability. Bhargava developed a new class of molecular probes called nanoLAMPs (Nano-Layered Metal-dielectric Particles) that, unlike most probes used in biomedicine or research, don't require dyes or fluorescence. The method uses laser light to excite reporter molecules embedded in a multi-shell structure that is linked to, and acquires signals from, a target molecule. The nanoLAMPs can produce reliable, quantitative measurements from a single molecule or from hundreds of molecules, and from multiple species. The particles used are designed to be stable and won't decay over time; different metals and even dyes can be used in them. "It's an incredibly flexible platform," Bhargava said. "It allows you to image any molecular species, presents many routes to fabrication, and you can put in any dye you like, any reporter, use most any metal you like." The new method takes an existing spectroscopic technique called surface-enhanced Raman scattering (SERS) and uses nano-layered metal-dielectric particles that light up when exposed to laser light. The unique concentric, multi-shell structure allows for fine tuning the electric field surrounding a molecule, relying on the electromagnetic effect for enhancement and eliminating the need for a chemical effect. "We have an almost unlimited ability with this design to put in any molecule and use it as a marker," Bhargava said. "We don't need it to be a dye or fluorescent molecule, but just need to change the molecular structure of the reporter. This method, in principle, will allow us to image hundreds of molecular species quantitatively from a single molecule up to any limit."

PHOTO BY L. BRIAN STAUFFER.



A team of Beckman Institute researchers developed an imaging technique that uses laser light to identify cancer cells. From left, Eric Chaney, a research scientist; Stephen Boppart, a professor of electrical and computer engineering, of bioengineering and of medicine; Martin Gruebele, a professor of chemistry and of physics; and Wladamir Benalcazar, a graduate fellow at the Beckman Institute.

Microscopy at the Cellular Level Reveals Tumor Boundaries Quickly and Accurately

A research team led by **Stephen Boppart** developed a new microscopy technique that could transform one of the most difficult aspects of healthcare — the often stressful wait for laboratory results — for both medical personnel and patients. Called nonlinear interferometric vibrational imaging (NIVI), the method delivers molecular scale images of tissue that are color-coded, easy-to-read, and highly accurate for clinicians and doctors — and does it within five minutes, eliminating long lab wait times for patients. The technique's value was demonstrated on fresh, unstained rat breast-cancer cells and tissues, with the images revealing clear boundaries of tumors with a confidence rate of more than 99 percent. Also joining Boppart in the effort were Beckman faculty member **Martin Gruebele** and Bioimaging Science and Technology group research staff member **Eric Chaney** and graduate student **Wladimir Benalcazar.** The development of a real-time tool for rapid tissue characterization and diagnosis of cancer at the molecular scale — permitting a finer distinction of the boundaries between tumor cells and normal cells — enables earlier detection and eliminates time-consuming lab work. As the researchers wrote in their paper featured on the cover of *Cancer Research,* the advantage of early detection offered by NIVI is compelling: "The survival rate of less than 25% for late-stage diagnosis of metastatic breast cancer improves to better than 90% for diagnosis of an early-stage localized tumor." They added that stained histopathology remains the gold standard for disease diagnosis, but the NIVI method fills a need for "rapid quantitative analysis of histologic sections, resected tissue specimens, or *in situ* tissue. By optimizing optical sources and beam delivery, this technique can potentially enable real-time point-of-care optical molecular imaging and diagnosis." The NIVI method combines the information content of Raman spectroscopy with the high throughput of CARS microscopy to offer speed and quantification advantages those methods don't possess when used separately. NIVI uses two beams of light that take advantage of the uniqueness of an individual molecule's vibrational state of energy to make assessments and construct images. By using the precise optical frequency, the tissue molecules are excited, enhancing the resonance of their vibrations and the signals that are used to construct the color-coded (blue for normal cells, red for cancer) image. The researchers conclude that a "unique combination of quantitative accuracy and spectral acquisition speed makes NIVI a very promising tool for rapid tissue characterization and diagnosis," and that it has the potential to be a "real-time quantitative and objective complement to standard histology and immunohistochemistry."

PHOTO COURTESY KENNETH SUSLICK.

This handheld reader analyzes the color changes in the sensor array to quickly monitor the environment for explosive chemicals.

Electronic Sensor for Shoe Bombs

A hard-to-detect chemical explosive used by convicted "shoe bomber" Richard Reid and in other bombing attempts may now be easier to detect thanks to a sensor developed by **Kenneth Suslick** of the Bioimaging Science and Technology group. Suslick applied "opto-electronic nose" technology in the form of a colorimetric sensor he developed toward the detection of a powerful explosive, Triacetone triperoxide (TATP). Used in Reid's attempted detonation of a shoe bomb on an American Airlines flight in 2001, TATP is easy to make using commonly found ingredients but hard to detect, even with current methods that require expensive instrumentation and time-consuming lab work. The colorimetric sensor array can quantitatively detect even low levels of TATP vapor; a prototype of a handheld device incorporating the technology was also developed to provide a portable, quick, and low-cost device that could easily be adapted for screening purposes. The sensor provides visualization (through color change) of the pattern of

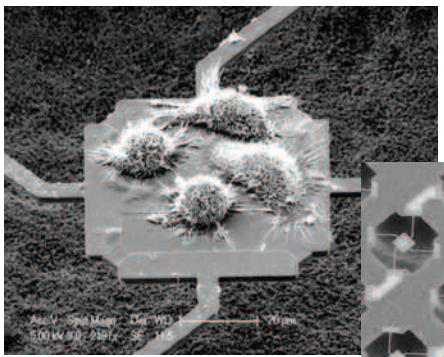
the complex mixture of chemicals present in an odor or vapor. In the paper reporting the technology, Suslick writes that it is "capable of sensitive and semi-quantitative detection of the vapor phase of the primary explosive TATP with limits of detection below 0.02% of its saturation vapor pressure. The printed array is highly selective for TATP, is unaffected by changes in humidity or by the presence of many common potential interferents, and can differentiate TATP from other chemical oxidants." The printed array used is smaller than a postage stamp and is stable and reproducible. The handheld prototype incorporating the sensor uses inexpensive white LED illumination and a small digital camera, making Suslick, said, the "whole process portable, sensitive, fast and inexpensive."

New Sensor Technology Answers Old Question about how Mass Affects Growth Rate in Cells

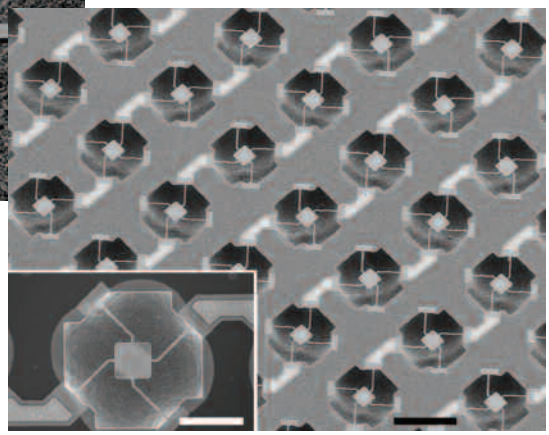
Rashid Bashir led a team that merged microscale engineering and cell biology to create a sensor that answers the important question of how cell mass affects the rate of cell growth. Bashir and his team that included fellow Bioimaging Science and Technology group member **Gabriel Popescu** created an array of silicon-on-a-chip MEMS (micro-electro-mechanical systems) sensors that can directly measure the biophysical properties, mass, and growth rate of single adherent cells. Fifty microns wide and suspended on a scale, the microsensors were used to track the mass and cell divisions of individual colon cancer cells for the first time ever, showing that, instead of having a steady growth rate, the cells grew faster as they became heavier. The researchers explained the importance of the microsensors for biomedicine and other research purposes in their paper reporting the technology: "The characterization of physical properties of cells such as their mass and stiffness has been of great interest and can have profound implications in cell biology, tissue engineering, cancer, and disease research. For example, the direct dependence of cell growth rate on cell mass for individual adherent human cells can elucidate the mechanisms underlying cell cycle progression." Researchers can culture cells on the chip, collect data from numerous cells at once, and track cellular processes and changes in mass with a microscope. The MEMS sensors, they write, "expand our understanding on the adherent cell's growth profile in a least-invasive way. Moreover, the ability to optically monitor the cell while being able to measure their mass can open up a wide set of analysis … we believe that our measurement system can make a significant contribution to understanding various cellular processes, such as cell growth, apoptosis, cell differentiation, and cell proliferation."

Powerful Synchrotron Light Powers New Imaging Technique

Faculty member **Rohit Bhargava** and Carle/Beckman Fellow **Michael Walsh** were part of a multi-university collaboration that developed a new imaging technique called Infrared Environmental Imaging (IRENI) that provides molecular scale pictures of tissues with unrivaled resolution and speed. Using the facilities of the Synchrotron Radiation Center at the University of Madison-Wisconsin, the team used the incredible intensity of multiple beams of synchrotron light to illuminate tissue at the molecular scale, producing images that were 100 times less pixelated than those from conventional infrared. By using 12 beams of synchrotron light in the mid-infrared range, researchers could collect thousands of chemical fingerprints from biochemically important molecules simultaneously. "We did not realize until now the improvement in detail and quality that sampling at this pixel size would bring," Bhargava said. "The quality of the chemical images is now quite similar to that of optical microscopy and the approach presents exciting new possibilities." IRENI was tested on breast and prostate cancer tissue samples and revealed cellular features that were distinguished with incredible detail. "IRENI provides us a new opportunity to study tissues and provides lessons for the development of the next generation of IR imaging instruments," Walsh said.

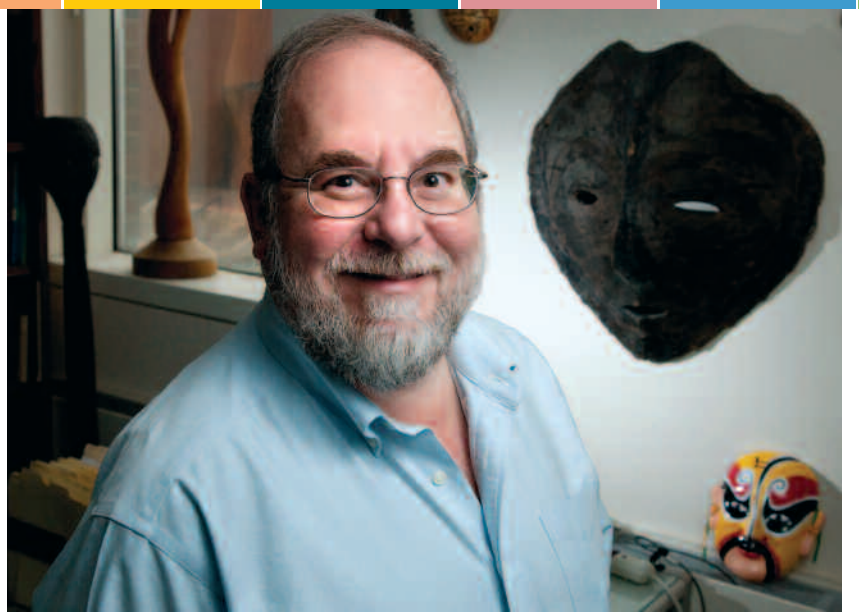


A scanning electron microscope image of cells growing on a microsensor. The researchers were able to measure the increase in mass as they watched a cell grow and divide into four cells.



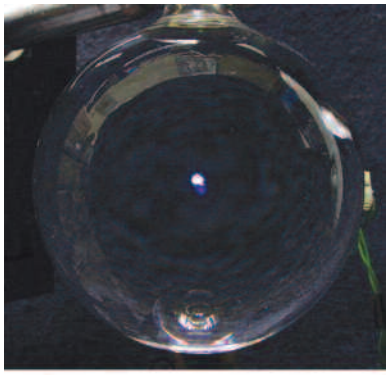
This image shows an array of microsensors made of suspended platforms (inset) that can measure cell mass like tiny scales.

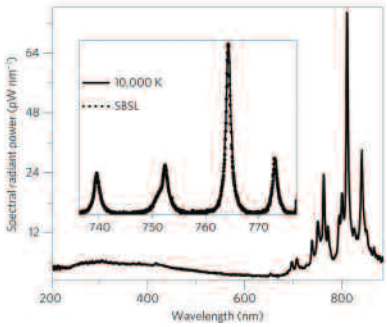
PHOTOS COURTESY RASHID BASHIR.



Kenneth Suslick, Beckman faculty member and Professor of Chemistry and Materials Science and Engineering.

Images below:
Top: Photograph of a rapidly translating sonoluminescing bubble at the velocity node of a spherical quartz resonator. The driver piezoceramic is partially visible at the bottom of the image, and the microphone is to the right. The entire apparatus is rigidly clamped at the narrow neck of the quartz flask (top of image). Bottom: A typical single-bubble sonoluminescence (SBSL) emission spectrum from a bubble driven with a relatively low acoustic driving pressure, Pa. The emission lines (700–900 nm) are due to electronic transitions between states within the 4p and 4s array of neutral Ar. Inset: A higher-resolution spectrum of SBSL Ar emission and a least-squares Lorentzian fit at a thermally equilibrated temperature of 10,000 K. Images description from *Nature Physics*, Vol 6, August 2010.



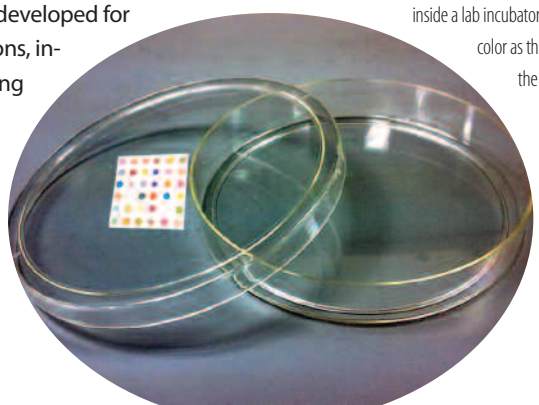


Bursting Bubbles Turn Gas into Plasma

Kenneth Suslick and his former student and current California Institute of Technology researcher **David Flannigan** quantified the effects of super-bright sonoluminescence, defined as the emission of light and very high temperatures that result from the implosion of bubbles caused by high-intensity ultrasound waves traveling through liquid. During sonoluminescence the gas inside the bubble sometimes becomes so hot that it ionizes into plasma — an event that wasn't well-understood until now. The researchers discovered super-bright sonoluminescence in 2005 when they created bubbles by sending ultrasound waves through sulfuric acid solutions. "The energies of the populated atomic levels suggested a plasma, but at that time there was no estimate of the density of the plasma, a crucial parameter to understanding the conditions created at the core of the collapsing bubble," Suslick said. They reported in 2010 on detailed analysis of the conditions of the region around the atoms inside the bubble as it collapses, as they experimentally determined the plasma electron density, temperature, and the extent of ionization, which is the amount of the gas that is converted to plasma. They found that that the degree of ionization increases along with the acoustic pressure and that the plasma properties strongly depend on the violence of the bubble implosion. The temperatures were intense — three times that of the sun's surface — but there was no evidence of fusion, which some have speculated happens during sonoluminescence. "It is evident from these results that the upper bounds of the conditions generated during bubble implosion have yet to be established," Suslick said. "The observable physical conditions suggest the limits of energy focusing during the bubble-forming and imploding process may approach conditions achievable only by much more expensive means."

Bacterial Sensors Provide New Method for Fast Diagnosis

A new automated sensor technology developed by **Kenneth Suslick** uses smell to rapidly detect deadly bacteria, a biomedical advancement that could save lives. Current diagnostic methods use blood cultures to detect blood-borne bacterial infections, a time-consuming process that can take two to three days of laboratory work and follow-up analysis. Suslick has been using "opto-electronic nose" technology in the form of colorimetric sensors he developed for different applications, including for detecting toxins and poisonous gases. This past year, he reported on using the sensor technology to detect bacteria through the smell emitted as a by-product of their metabolism. Within each species of bacteria and within different strains of each species there are a unique blend of gases, which Suslick's sensor was able to detect and identify using an



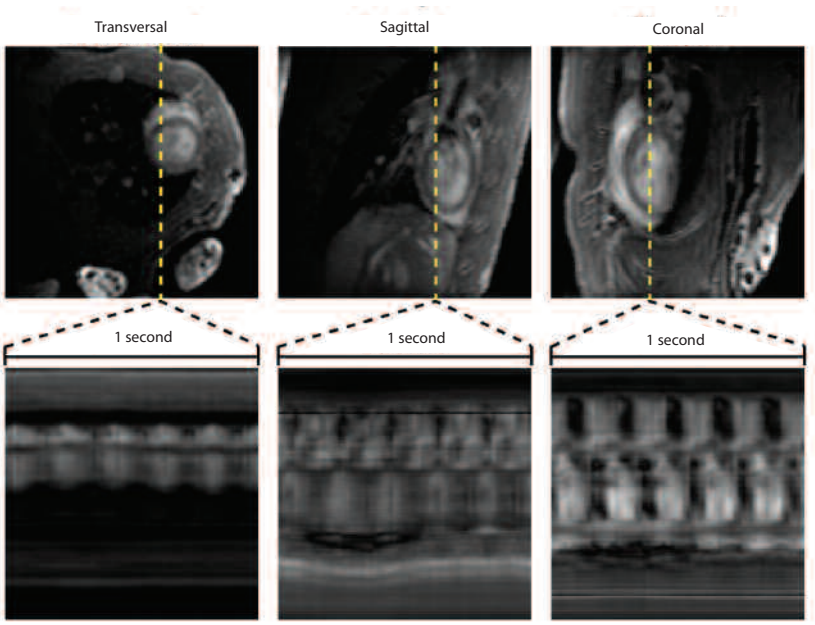
A colorimetric sensor array is placed in a Petri dish for culturing bacteria and scanned with an ordinary flatbed photo scanner kept inside a lab incubator. The dots change color as they react with gases the bacteria produce.

PHOTO BY K. S. SUSLICK.

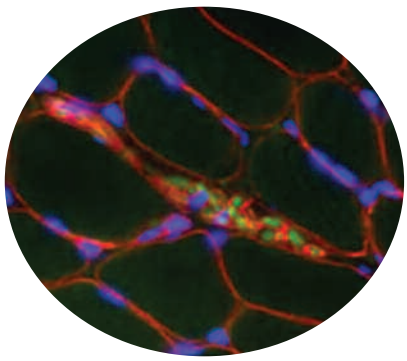
array of 36 cross-reactive pigment dots that changed color when they sensed airborne chemicals from blood samples on Petri dishes. The pattern of color changes in each dot was unique to each bacterium, allowing the researchers to identify within a few hours specific species and strains of bacteria, as well as antibiotic resistance. The researchers reported that they could identify 10 of the most common disease-causing bacteria with 98.8 percent accuracy. "We don't have an upper limit," Suslick said of the technology's ability to detect a greater variety of bacterial infections. "We haven't yet found any bacteria that we can't detect and distinguish from other bacteria. We picked out a sampling of human pathogenic bacteria as a starting point."

Method Developed for Fast, 3-D Imaging of a Beating Heart

Zhi-Pei Liang's research goals are to develop fast, efficient magnetic resonance imaging methods and smart computational algorithms for applications, including image processing and pattern recognition. This past year the Liang Research Group, including members **Justin Haldar, Bo Zhao, Anthony Christodoulou** and **Liang,** developed a novel magnetic resonance imaging method that can perform fast, three-dimensional imaging of a beating heart with high temporal resolution. Their method is based on a novel sparse sampling scheme for signal acquisition and reconstruction that enables high-quality image formation from highly under-sampled data. They reported on the innovation in 2010, writing that myocardial perfusion imaging (which illustrates heart muscle function) is "an important and challenging application of cardiovascular MRI" and that "sparse sampling is emerging as an effective tool to further accelerate MRI." Their new image reconstruction method allows the use of partial separability and sparsity constraints jointly, which enables high-resolution reconstruction from sparsely sampled data. They obtained images of a beating heart from a rat at unprecedented spatiotemporal resolution. They write that the method could have important implications for the diagnosis of cardiovascular diseases, including early detection of coronary artery disease and for acute heart transplant rejection. A paper reporting a part of the work received a 2010 IEEE-ISBI Best Paper Award.



Through a collaboration with Dr. Chien Ho's group at Carnegie Mellon University, Zhi-Pei Liang and his students, Justin Haldar, Bo Zhao, and Anthony Christodoulou, have obtained images from the beating heart of a rat at unprecedented spatiotemporal resolution. Their method can have important implications for diagnosis of cardiovascular diseases, including early detection of coronary artery disease and acute heart transplant rejection.



This image from Marni Boppart's laboratory shows that pericytes (green fluorescence) are found in the interstitial connective tissue of α7 integrin transgenic skeletal muscle following a single bout of exercise. Over the last year, the Boppart lab has demonstrated that these cells indirectly and directly contribute to the *de novo* formation of muscle fibers which ultimately increase force generation.

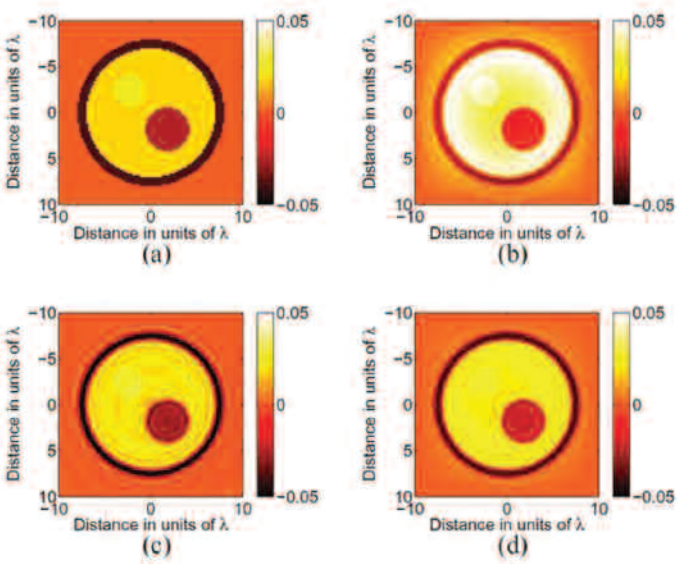
Understanding How the Body Responds to Exercise and Strain

Marni Boppart's research focus is on the molecular and cellular mechanisms responsible for musculoskeletal remodeling and growth in response to exercise and mechanical strain. Much of the work in the Molecular Muscle Physiology Laboratory she heads at Beckman revolves around the important topic of exercise. 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 because they protect against skeletal muscle injury. This past year, Boppart demonstrated an expanded role for the α7β1 integrin receptor by showing that it is a prerequisite for the appearance of RGS-positive pericytes, stem cells with direct potential for combating muscle atrophy that are found in the interstitial connective tissue of α7β1 integrin transgenic skeletal muscle after just one bout of exercise. Boppart has shown that the α7β1 integrin receptor in muscle remodeling is a prerequisite for the appearance of mesenchymal stem cells (MSCs), and this year made progress in showing that these cells contribute directly and indirectly to the *de novo* forma-

tion of muscle fibers, which ultimately increases force generation. Boppart also continued her collaboration with fellow Bioimaging Science and Technology group member Stephen Boppart that tracks bone marrow-derived stem cells in skeletal muscle and skin, using both optical and immunohistochemistry techniques. This past year, they were able to optically identify and track *in vivo* a specific cell type in the skin migrating from the bone marrow as dendritic cells.

Ultrasound Advance Allows for Imaging Breast Density

Michael Oelze's research involving quantitative ultrasound imaging methods seeks to improve biomedical imaging. Current biomedical imaging techniques are effective for detecting abnormalities due to their high sensitivity, but are often ineffective when it comes to actually diagnosing lesions because of poor specificity. In 2010 Oelze and his collaborators reported on the development of a new technique to address this issue, writing that "an 'overdiagnosis' crisis has emerged where the detection of so many abnormalities leads to many more biopsies being performed resulting in a negative finding." The technique they developed, called the multiple-frequency distorted Born iterative method (MF-DBIM) algorithm, is for imaging density variations and permits reconstruction of images of the breast with quantitative ultrasound that provides information on breast density not possible with other methods. The MF-DBIM approach consists of inverting the wave equation by solving for a single function that depends on both sound speed and density variations at multiple frequencies. They report that it outperformed other methods in reconstructions of targets from data.

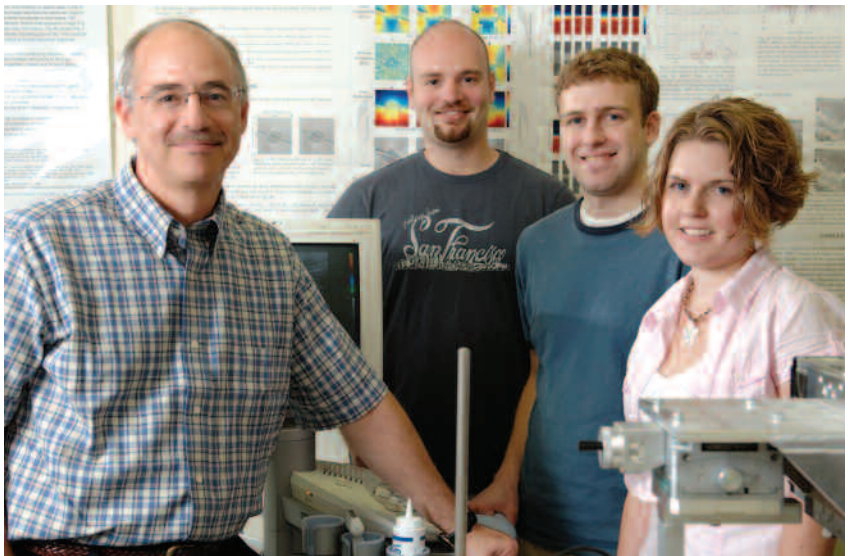


This figure from Michael Oelze's research group shows an example of a density image reconstruction of a phantom.

Project Offers Method for Rigorously Analyzing Ultrasound Instruments

Michael Insana's lab partnered with faculty at the University of California at Santa Barbara in a National Institutes of Health-funded project to comprehensively analyze sonographic instruments with the same rigor as radiology imaging instruments. Ultrasound diagnostics offer little risk to patients and recent advances in high-performance computing technologies make their use feasible for clinical diagnosis. Insana writes that the project is highly interdisciplinary because it "combines knowledge of human disease and imaging instrumentation with signal processing, statistical decision theory and knowledge of how the human eye-brain system is able to understand subtle features." They work with radiologists to find diagnostic features commonly used to diagnose disease; then express those features mathematically, and enhance diagnostic performance and data processing using statistical decision theory and optimal strategies for data processing. "We routinely find a 2-5-fold increase in visual detection efficiency for diagnosing breast cancer with little or no increase in instrumentation costs," Insana writes, adding that "ultrasound is a low-cost, low risk procedure, improving diagnostic performance has a major positive affect on healthcare."

Beckman faculty member, Mike Insana, is pictured with Marko Orescanin, David Mahr, and Rebecca Yap.



Gabriel Popescu believes there is a revolution going on in scientific research, one in which physicists and engineers are increasingly applying their talents to the worlds of biological and medical research. Popescu's unique contribution to that transformation, on the technology side, is the creation of innovative new light microscopy methods for quantitative measurements of cells, tissues, and their interactions.

"We're witnessing a new approach to biology and medicine in general, and that is to turn them into objective, quantitative science," Popescu said.

But perhaps just as important to the cause are the motivations behind Popescu's scientific research.

"I think pushing the boundaries is what got us to do research in the first place, the curiosity to go beyond what is known, beyond what has been done, to push our own limits," he said. "I think ultimately it comes down to that."

Popescu seems born to push the limits of science. He went to a math and physics high school and then studied physics at the University of Bucharest in his native Romania. The high school was located in a corner of the physics department, which just happened to be across the street from the country's national laser institute, where he eventually became a full-time scientist after completing a Master's in Physics.

Popescu said in all he spent 11 years on the campus, beginning at age 14 "when my high school physics teacher attracted me to science with her beautiful explanations of physical phenomena."

Popescu earned a Ph.D. in Optics at what was then the Center for Research and Education of Optics and Lasers at the University of Central Florida. He later was a postdoctoral researcher at MIT before coming to the University of Illinois and Beckman in 2007.

In just a few short years, the Quantitative Light Imaging Laboratory he directs at Beckman has created unique new imaging methods and used them to produce original insights into biological structures and functions. His lab, he says, has three major components: technology development, basic science, and clinical applications.

"They're interconnected," Popescu said. "And I think if you look at the history of experimental physics that has always been the case. For instance, during the scientific revolution, when the first microscope was invented, people started to apply it to many different areas. It also happened with the telescope, once Galileo turned toward the sky.

"But then at some point, you have a new challenge for the technology. That happens to us all the time. I want to see a particular motion in the cell and my instrument is just not good enough, so we need to come up with a new method. It's always that the methods push the science and then the science pushes back, demanding new methods."

And that dynamic is helping to advance biomedical technology and research thanks to Popescu and others like him.

"Applying physics and engineering methods to biology, I believe, will keep us interested for a long time," Popescu said. "In particular, optics is a great medium to do biological measurements because there is no contact, it's weightless, and it can be very fast and non-invasive."

Popescu is Assistant Professor in the Department of Electrical and Computer Engineering, while his lab boasts students from physics and three different engineering departments. But the driving focus of their work is in the biological realm, where their advances — which often result from combining different imaging techniques — have led to new real-time methods for imaging of cells and to groundbreaking research findings such as those involving red blood cells.

What sets these methods apart and makes them exciting tools for research and clinical applications is that they enable nanoscale measurements.

"Measuring a cell's thickness with an accuracy of a nanometer is equivalent to examining Mount Everest with a telescope from the International Space Station and establishing its height to within a few inches," Popescu said.

Again proving his point that technology pushes the science, Popescu and his group are very involved in research on the biological processes illuminated by their novel imaging methods that fall under a new field called quantitative phase imaging. Popescu wrote the first book on the subject, *Quantitative phase imaging of cells and tissues,* which was released this summer by McGraw-Hill.

One recently developed imaging method called SLIM (Spatial Light Interference Microscopy) combines phase contrast microscopy and holography to create a fast, extremely sensitive interferometric imaging technique for measuring nanoscale structures and cellular interactions.

A member of Beckman's Bioimaging Science and Technology group, Popescu is open to new ideas, novel methods, and even applications as unusual as when his group developed a method for using CD-ROMs for medical diagnostics. Popescu's hope is that one day people use CD-ROMs, a cheap, slightly modified CD player, and a droplet of blood for inexpensive diagnosis of diseases like malaria.

"If you look at the CD-ROM, you see that it is actually a confocal microscope," Popescu said. "Now, one big difference between the CD-ROM and the confocal is the price: there is about a thousand-fold difference. But, the optics are very similar in both."

Popescu said his collaborators in biology and medicine help make the research possible, as do the students in his research group, who have been integral to developing methods such as SLIM.

"The students are the heart of the lab and I'm very happy with their curiosity and dedication," Popescu said.

"I get applicants continuously," he added. "For me, of course, after looking at the GPA, background and so on, I look very carefully at how determined the student is. I know that made a difference in my career and I look for that in others. The desire to succeed and the curiosity that drives them are key."

Gabriel Popescu

"I THINK PUSHING THE BOUNDARIES IS WHAT GOT US TO DO RESEARCH IN THE FIRST PLACE, THE CURIOSITY TO GO BEYOND WHAT IS KNOWN, BEYOND WHAT HAS BEEN DONE, TO PUSH OUR OWN LIMITS."

The Molecular and Electronic Nanostructures (M&ENS) research theme brings together scientists from disciplines as diverse as physics and chemistry, as well as different units from biology and engineering, toward the goal of understanding and working with nanoscale structures. The five research groups comprising M&ENS are: 3-D Micro- and Nanosystems, Autonomous Materials Systems, Computational Multiscale Nanosystems, Theoretical and Computational Biophysics, and Nanoelectronics and Nanomaterials. Within these groups, M&ENS researchers develop and use computational tools for simulating biological processes and toward the design of nanosystems, create nanoelectronics for applications in biomedicine and consumer products, and design autonomic multifunctional materials systems. Their breakthrough technologies and discoveries this past year made news in journals and national media.

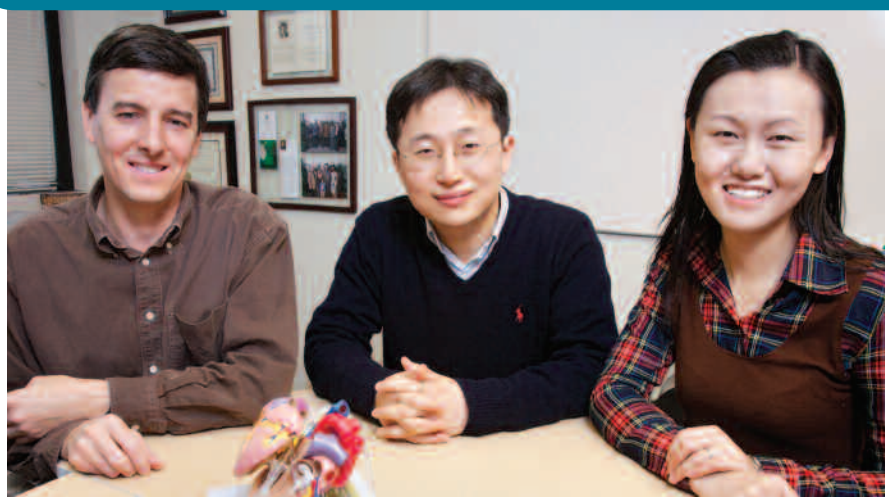


PHOTO BY L. BRIAN STAUFFER.

Beckman faculty member John Rogers, left, a professor of materials science and engineering, led a team of materials scientists, mechanical and electrical engineers, and physicians, including postdoctoral researchers Dae-Hyong Kim, center, and Nanshu Lu, to successfully integrate stretchable electronics technology with standard endocardial balloon catheters.

Creating New Electronics and Applications for Biomedicine

John Rogers continues to explore exciting new applications for the breakthrough technologies he has developed, as reported in *Nature Materials*, on two separate projects. Working with a team of physicians, materials scientists, and engineers, Rogers and his collaborators created a multifunctional, endocardial balloon catheter equipped with stretchable electronics that could be used for diagnosis and treatment of heart arrhythmias. Rogers and his collaborators developed implantable technology composed of inorganic LED semiconductors and photodetectors that is flexible and bio-compatible, making it ideal for biomedical applications such as health monitoring or in drug delivery. The LEDs (light-emitting diodes) use an established semiconductor, gallium arsenide (GaAs), and conventional metals to create flexible electronic circuits that work even when stretched repeatedly as much as 75 percent, and when immersed in biological fluids. The GaAs and metal diodes and detectors are stamped onto a flexible plastic film; interconnecting coiled metal wires are deposited onto the plastic, creating a mesh-like structure that is then encapsulated in a piece of rubber. The stretchable technology is compatible with biological tissue, allowing immersion in biofluids, and is conformable, which means it is implantable and could be used on curved surfaces such as a surgical glove. The endocardial catheter also incorporates stretchable electronics in the form of temperature, tactile, and EKG sensors that are integrated with balloon technology that has been used for many years in procedures such as angioplasty and stent placement. These flexible tubes are threaded through a vein or artery into the heart, where the balloon inflates and presses against tissue in order to perform the tasks of arrhythmia detection and killing small patches of cells that beat off-rhythm (ablation). The new technology, unlike current methods, is able to perform both of these tasks simultaneously, and without using rigid electronics. The sensors can measure electrical activity of the cardiac muscle, as well as temperature, blood flow, and pressure. The device's effectiveness was demonstrated using animal models, showing success in a project that Rogers said tested the limits of their stretchable electronics technology. "It demands all the features and capabilities that we've developed in stretchable electronics over the years in a pretty aggressive way," Rogers said. "It also really exercises the technology in an extreme, and useful, manner — we put everything on the soft surface of a rubber balloon and blow it up without any of the devices failing."

Writing a New Chapter for Carbon-based Electronics

Researchers from the Nanoelectronics and Nanomaterials group have created a practical method for direct writing of metal lines less than five nanometers (5 nm) wide. The technology is an important step in the fabrication of contacts to and interconnects between nanoscale device structures like carbon nanotubes and graphene that have great potential for applications in electronics. Beckman Institute faculty members **Joe Lyding,**

Gregory Girolami, and **Angus Rockett,** and lead author **Wei Ye** from Lyding's group reported in *ACS Nano* on their method for the patterning of metallic nanostructures on surfaces toward future fabrication of nanoelectronics and quantum devices. The researchers wrote that "Current top-down fabrication technologies used in industry involve conventional lithographic processes, which are approaching their fundamental size limits." Responding to the current challenges involving fabrication at scales smaller than 10 nm, they demonstrated the ability to write metal lines that are less than 5nm wide using electrons from the tip of a scanning electron microscope (STM) to break apart molecules and yield a metallic deposit. That technique is not new, but the advantage their method offers is low temperature chemical vapor deposition (CVD) without the high levels of carbon impurities of other methods. They wrote that to circumvent this issue, "we used a novel molecular precursor for the metallic ceramic hafnium diboride that was developed by Prof. Gregory Girolami's group for low temperature chemical vapor deposition (CVD) applications. Girolami's CVD precursor contains no carbon; only hafnium, boron and hydrogen. Electron beam induced deposition (EBID) by the STM cleanly drives out the hydrogen leaving a metallic HfB2 deposit, as confirmed by STM spectroscopy." They conclude by writing that "To our knowledge this is the first demonstration of sub-5 nm metallic nanostructures in an STM-EBID experiment, and it opens new opportunities for making deterministic molecular scale metallic contacts."

Computer Simulations Reveal Important Biological Processes for First Time

Klaus Schulten heads the Theoretical and Computational Biophysics group, which is a leader in developing and using molecular dynamics simulation software to create atomic scale computational models of biological structures and processes. This past year Schulten and his collaborators reported on discoveries that shed new light on two biological processes: a gating mechanism critical to the function of potassium and ion channels that power intelligence, and the interactions that enable the cell's protein-building machinery, the ribosome, to insert a growing protein into the cellular membrane. As reported in *Natural Structural and Molecular Biology*, Schulten and postdoctoral researcher James Gumbart joined with scientists at the University of Munich to illustrate a crucial stage of the process in which the newly forming protein traverses a path into its new home in the membrane. The Munich scientists used cryo-electron microscopy to create a snapshot of the insertion process; the Illinois researchers then created an atom-by-atom computational model of the system to create a simulation of more than three million atoms. Their analysis showed that regions of the membrane channel extend into the ribosome *exit* to assist the emerging protein into the channel. "This new work visualizes this process for the first time, giving researchers the first image of how nascent proteins actually get into membranes," Schulten said. "It's like going to Mars and being the first to look at Mars." In another study, the Illinois researchers discovered that growing proteins get inserted into the membrane by first getting pushed into the membrane channel by the ribosome, followed by the protein entering the membrane. The gating mechanism in sodium and ion channels

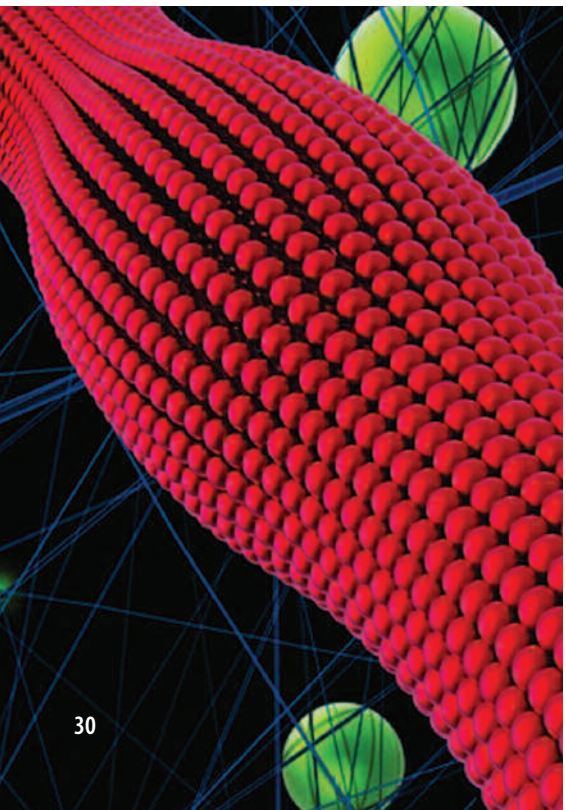
PHOTO BY L. BRIAN STAUFFER

Beckman faculty member Klaus Schulten, right, and postdoctoral researcher James Gumbart used cryo-EM images as well as detailed structural information about the ribosome and other molecules to construct an atom-by-atom model of the system that threads a growing protein into the cellular membrane.

was illuminated using molecular dynamics simulation software developed at TCB. Their large scale simulations created an atomistic model that, for the first time, gave detailed insight into the dynamics of how electrical signals from nerve cells function in sodium and ion channels. An important part of that process that empowers human intelligence and behavior involves a gating mechanism for generating and controlling the signals in those channels, a process that has confounded scientists for decades. Schulten and his collaborators were able to visualize and describe what is called a voltage gating charge that enables the process of nerve cell signaling in voltage-activated channels. They wrote that their simulations revealed that "the potential gradient is focused by the channel protein to a very narrow region such that its value is much larger than anticipated. The protein was also seen to arrange its charged amino acids sensing the gradient in an unusual helix, a so-called 3-10 helix, that aligns

A Granick research group schematic representation that single-particle fluorescence tracking shows surprisingly non-classical, non-Gaussian statistics combined with mundane Fickian displacement when colloidal beads diffuse not only on phospholipid tubes but also when they diffuse through networks of actin filaments.

IMAGE COURTESY OF RUI LU AND BO WANG.



charges perfectly while at the same time inducing a motion that opens and closes the channel." The researchers' computational findings about the gating current were validated by empirical observations.

Harnessing the Power of Janus Spheres

Steve Granick developed tiny latex colloids called Janus spheres that, when placed in saltwater, exhibit a hydrophobic effect that allows for self-assembly into useful structures. Named for the dual-natured Roman god Janus, the Janus sphere surfaces are hydrophobic (water repellent) on one hemisphere and hydrophilic (water attracting) on the other. This past year the Granick Research Group used the Janus spheres to create helical supermolecules that self-assemble into supramolecules with interesting functionalities, as reported in *Science,* and developed triblock Janus spheres that can be used to create smart materials, as reported in *Nature*. Janus spheres are simple colloidal balls (particles less than a few micrometers but larger than molecules) that, in a saltwater solution, form supermolecules that have the functionality of complex colloidal structures, such as those found in man-made materials like soap and in nature in the biological phospholipids that help make up cellular tissue. They can provide insight into molecular interactions for research purposes and have potential applications, such as in manufacturing non-allergenic soap, filters, or so-called smart materials like targeted drug delivery systems. The molecular interactions occur when the repelling effect is softened by the ions in salt water and their orientation changes, permitting the hydrophobic ends of the spheres to attract one another; this allows the spheres to form clusters and, with higher salt concentrations, kinetically self-assemble into chains with helical structures and then into larger clusters called supramolecules. The triblock Janus spheres have three stripes of reactivity, with a charged center band and hydrophobic poles that, in saltwater, are drawn together to form an intricate lattice that could potentially be used as filters. "This is a big step forward in showing how to make non-trivial, non-obvious structures from a very simple thing," Granick said. "People know a lot about how to do it with molecules — soaps for example — but scientists and engineers know very little about how to make it happen with particles. We can now make a whole new class of smart materials, which opens the door to new functionality that we couldn't imagine before."

Incorporating Self-healing to Create Longer Lasting, Safer Batteries

Scott White, Jeff Moore, and **Nancy Sottos** of the Autonomous Materials Systems (AMS) group are applying self-healing techniques to battery technology as part of an effort funded by the Department of Energy. Their goal is to make battery systems, especially those used in electrical vehicles, safer and longer lasting. Their work is part of a multi-institute effort funded by the Department of Energy called the Center for Electrical Energy Storage (CEES). White talked about the project during the annual meeting of the American Association for the Advancement of Science (AAAS). The CEES has a research focus on lithium-ion batteries, used in numerous electronic devices like the iPhone and laptops, and in battery systems for electric vehicles (EVs). Creating a battery system that could, for example, autonomically shut down malfunctioning battery cells in EVs could serve as a fail-safe mechanism on the road, while autonomic repair of damage in lithium-ion batteries could lead to greater reliability in electronic devices. The Beckman researchers have demonstrated conductivity restoration in systems through different methods, with a technique using liquid metal showing the most promise. The core of the egg-like liquid metal microcapsule is a liquid gallium-indium alloy with a poly-

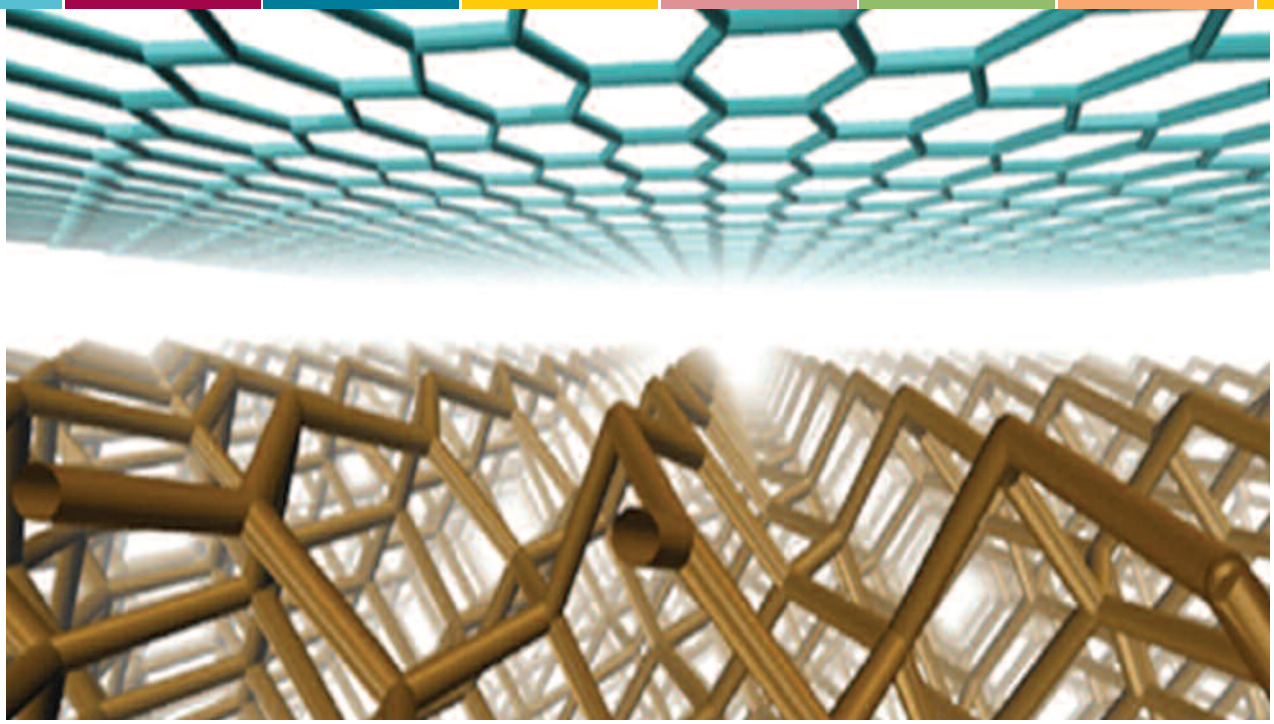


IMAGE COURTESY JOE LYDING.

A visualization of the nanoscale interaction between a semiconducting substrate (in gold) and graphene.

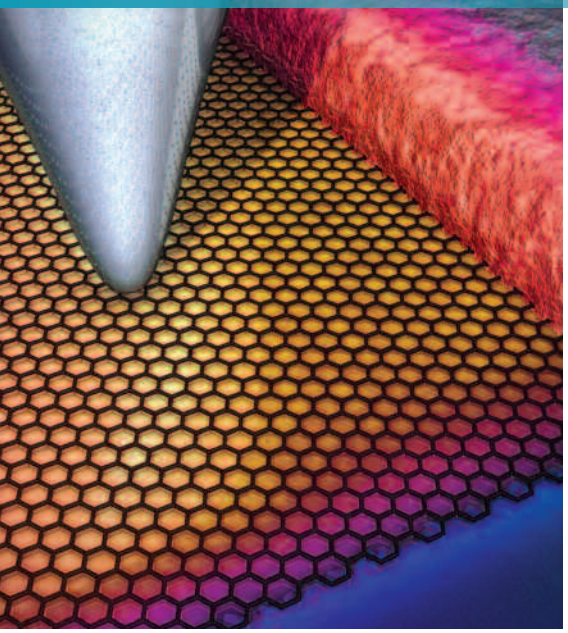
mer surface. White said the method has demonstrated conductivity restoration within 40 microseconds of capsule rupture. "It is immediate. We get 100 percent restoration of conductivity in a few microseconds," he said. White said most of the work in the research line is focused toward increasing the performance of energy storage devices so hybrid and electric vehicles will become a common sight on roadways, but he expects the technology to be applicable to other battery systems. "The DOE is particularly challenging the centers that they have set up to do the necessary science and innovation to allow electric vehicles to become a reality," he said. "The fundamental technology that we are developing works for lithium and will work for other battery systems as well. Batteries of the future are going to be ones that adapt to their environment and have some kind of higher-level function to them."

Taking Advantage of the Power of Graphene for Electronics

In separate projects, researchers **Joe Lyding** and **William King** are demonstrating practical methods for taking advantage of graphene — a single-atom layer of graphite with intriguing electronic and mechanical properties — for use in electronics instead of silicon or carbon nanotubes. King was part of a collaboration with Georgia Tech that used a thermochemical nanolithography technique he developed to create nanoscale circuitry, or nanowires, on graphene that changes the graphene from an insulating into a conducting material. Lyding led a collaboration that used a dry contact transfer (DCT) deposition method developed in his laboratory to deposit pieces of graphene on semiconducting substrates. Using DCT, they were able to deposit pristine, nanometer-sized graphene pieces *in situ* onto atomically flat UHV-cleaved Gallium arsenide and Indium arsenide semiconductor substrates with low amounts of extraneous contamination. The electronic semitransparency of the graphene pieces was observed when the UHV STM probe pushed the graphene 0.05nm closer to the surface, causing its electronic structure to mix with that of the surface. The researchers wrote in *Nanoletters* about graphene's potential applications: "Unlike carbon nanotubes, graphene can be patterned using standard e-beam lithographic techniques, making it an attractive prospect for use in semiconductor devices." King's method, as reported in *Science,* employs a technique he developed that uses the tip of an atomic force microscope to turn graphene oxide into reduced graphene oxide, which has the conducting property needed for creating functional nanocircuits. Using graphene as a semiconductor has advantages over silicon for uses in future electronics in terms of speed, energy use, and scaling possibilities. This new method is a breakthrough in showing a way to create graphene nanostructures in ways involving scalability and reproduction that make them feasible for manufacturing.

Cooling Effects Observed in Graphene Transistors

Eric Pop of the Nanoelectronics and Nanomaterials group and **William King** of the 3-D Micro- and Nanosystems group accomplished the first observation of thermoelectric effects at graphene contacts and found that graphene transistors have a nanoscale cooling effect that reduces their temperature. Graphene is viewed as an alternative to silicon in computer chips because that current technology has limitations in speed and size due to heat dissipation that results from electrons in the current colliding with the device material, known as resistive heating. Today's computers account for this effect with measures such as fans that consume much of a device's energy capacity. Using graphene could greatly reduce both the energy costs and size and improve the speed of electronics devices, but understanding



An atomic force microscope tip scans the surface of a graphene-metal contact to measure temperature with spatial resolution of about 10 nm and temperature resolution of about 250 mK. Color represents temperature data. Image by Alex Jerez, Beckman Institute Visualization Laboratory.

heat generation and distribution of a graphene device is essential to integrating it into future computer chips. Pop and King were able to advance that goal by using atomic force microscope tip technology King developed to make the first nanoscale temperature measurements of a working graphene transistor. They discovered that thermoelectric cooling effects can be stronger at graphene contacts than the effects of resistive heating, a phenomenon that lowered the temperature of the transistor. "In silicon and most materials, the electronic heating is much larger than the self-cooling," King said. "However, we found that in these graphene transistors, there are regions where the thermoelectric cooling can be larger than the resistive heating, which allows these devices to cool themselves. This self-cooling has not previously been seen for graphene devices." Pop said the discovery bodes well for future applications of graphene. "Graphene electronics are still in their infancy; however, our measurements and simulations project that thermoelectric effects will become enhanced as graphene transistor technology and contacts improve," he said also. The work was reported in *Nature Nanotechnology*.

Technology for Fast-charging Batteries with Good Storage Capacity

Paul Braun developed a system for charging batteries quickly and with long-lasting storage capacity, a unique combination of capabilities that makes the technology valuable for applications in consumer and medical electronic devices, lasers, and electric vehicles. Most thin films of the active material in a battery allow for quick charging and discharging but their low volume doesn't permit storage capacity. The system created by Braun's group offers both capabilities. The technology is based on using three-dimensional nanostructures of thin films for battery cathodes. Tiny spheres self-assemble into a uniform lattice — a process that eliminates the time and expense of other fabrication methods — and begins a process that leaves an open framework that is coated with a thin film of the active material, creating an electrode structure with good electrical conductivity. The technology can be used with both lithium-ion and nickel metal hydride rechargeable batteries, which typically don't perform well when charged and discharged quickly. "This system that we have gives you capacitor-like power with battery-like energy," Braun said. "Most capacitors store very little energy. They can release it very fast, but they can't hold much. Most batteries store a reasonably large amount of energy, but they can't provide or receive energy rapidly. This does both." This work was reported in *Nature Nanotechnology*.

Memory Advance Extends Mobile Battery Life

Eric Pop led a team that developed a form of ultra-low-power digital memory that is not only faster than similar, current memory technology but also uses 100 times less energy. Pop says his research is "focused on two fundamental bottlenecks in nanoelectronics: one is the memory problem and the other is the power problem." The ultra-low power memory his group developed as reported in *Science,* addresses both issues, creating an advance that could lead to much longer battery life for electronic devices. Their innovation centered on using phase change materials (PCM) instead of flash memory for higher-power memory, and carbon nanotubes instead of the standard metal wires to create nanoscale

Beckman faculty member Paul Braun, center, led the research group of graduate student Xindi Yu, left, and postdoctoral researcher Huigang Zhang that developed a three-dimensional nanostructure for battery cathodes that allows for dramatically faster charging and discharging without sacrificing energy storage capacity.

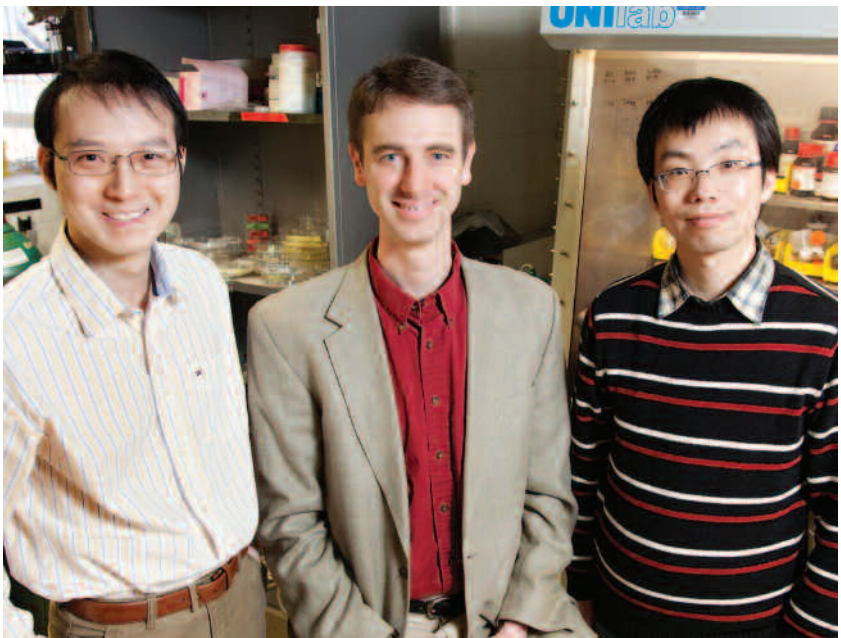
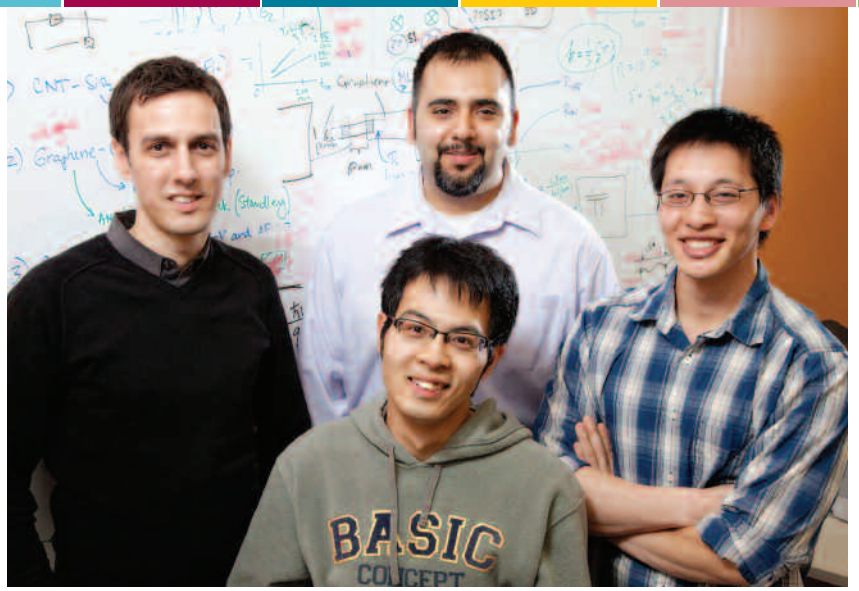


PHOTO BY L. BRIAN STAUFFER.

PHOTO BY L. BRIAN STAUFFER.



Led by Beckman Institute faculty member Eric Pop (electrical and computer engineering), left, a team of researchers have developed a form of ultra-low-power digital memory that is faster and uses 100 times less energy than similar available memory. Team members: back row, from middle, David Estrada and Albert Liao; front, Feng Xiong.

contacts. "Carbon nanotubes are the smallest known electronic conductors," Pop said. "They are better than any metal at delivering a little jolt of electricity to zap the PCM bit." The result was less power consumption and increased efficiency in the bits that were tested, which is just the beginning according to Pop. "Even though we've taken one technology and shown that it can be improved by a factor of 100, we have not yet reached what is physically possible," he said. "We have not even tested the limits yet. I think we could lower power by at least another factor of 10. I think anyone who is dealing with a lot of chargers and plugging things in every night can relate to wanting a cell phone or laptop whose batteries can last for weeks or months."

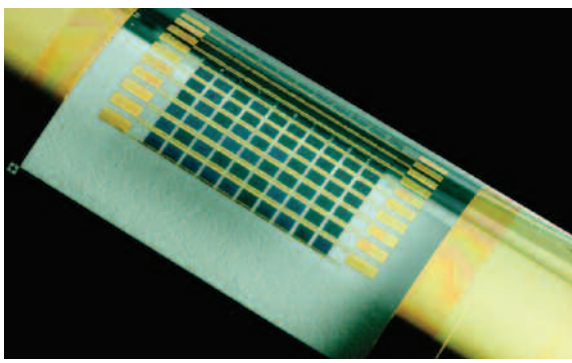
Nanoneedle a Unique Tool for Studying Nucleus of a Cell

Min-Feng Yu led a collaboration that included Beckman colleague **Ning Wang** which demonstrated that a tiny needle could be used to gain greater understanding of the properties and processes of a cell's nucleus. The researchers had previously developed a "nanoneedle" that could penetrate cellular membranes in order to deliver molecules into the cytoplasm or nucleus of a living cell. In 2010 they reported in the journal *Small* on using the nanoneedle to deliver quantum dots directly into a specific location in the nucleus of a living cell, allowing them to monitor the dots with a standard fluorescent microscope and gain information that has previously been difficult to obtain because of the difficulty in getting molecules into a cell, especially the nucleus. "This technique allows us to physically access the internal environment inside a cell," Yu said. The process works by coating a single nanotube with a thin layer of gold that creates a nanoscale electrode probe and then filling the nanoneedle with quantum dots, which are released with a small electrical charge. This method offers controllability unmatched by other techniques. "It's almost like a surgical tool that allows us to 'operate' inside the cell," Yu said.

Semiconductor Manufacturing Method Could Advance Solar Energy

John Rogers from the 3-D Micro- and Nanosystems group and **Xiuling Li** from the Nanoelectronics and Nanomaterials group created a semiconductor manufacturing method that could make the photovoltaic cells that power solar panels cheaper and easier to produce. Their method, as reported in *Nature,* makes use of compound semiconductors other than silicon, such as gallium arsenide, possible by greatly reducing the manufacturing costs. Gallium arsenide and its related compounds have much greater efficiency than the ubiquitous semiconductor found in almost all electronic devices, so Rogers and Li developed a way to replace silicon by creating a method for manufacturing thin films of gallium arsenide. Instead of the traditional deposition technique of single layers on a small wafer, they deposited multiple layers on a single wafer for a layered stack of gallium arsenide thin films that were then individually peeled off and transferred to another substrate such as glass or plastic that could be used for regrowth. "By doing this we can generate much more material more rapidly and more cost effectively," Rogers said. "We're creating bulk quantities of material, as opposed to just the thin single-layer manner in which it is typically grown." Writing about their work in the journal *Nature,* the researchers reported demonstrating three types of devices using the method: light sensors, high-speed transistors, and solar cells. The latter application fits the technology especially well because the process allows the layers to be laid out side-by-side on another substrate to produce a much larger surface area than the typical single-layer process. "For photovoltaics, you want large area coverage to catch as much sunlight as possible. In an extreme case we might grow enough layers to have 10 times the area of the conventional route," Rogers said. "You really multiply the area coverage, and by a similar multiplier you reduce the cost, while at the same time eliminating the consumption of the wafer."

PHOTO COURTESY JOHN ROGERS.



This image shows a flexible array of gallium arsenide solar cells. Gallium arsenide and other compound semiconductors are more efficient than the more commonly used silicon.

Joe Lyding says his laboratory at the Beckman Institute is similar in appearance to the basement in his family's home when he was 12. That's not a coincidence as it turns out, as a passion for inventiveness, engineering, and scientific discovery on the part of the Beckman Institute researcher imbued both locations. Even his current vocation as a professor of electrical and computer engineering at the University of Illinois has its origins in his youth, albeit with an unfortunate incident.

"I blew up my chemistry set so I decided to go into electronics," Lyding said. "I would go to the junkyard and drag old TVs home and take them apart. It was not very organized but I familiarized myself with them. My lab now looks a lot like my basement did then. There are kind of parts and stuff all over. I'm at home in that environment."

Home is an appropriate description because Lyding inherited his passion for science and discovery from his father.

"My father was a factory worker, but he was always curious about things," Lyding said. "He would bring home books from the library on astronomy and sit at the kitchen table and read passages out loud. He would also always have two or three hobbies going."

Along with his early interest in science, the younger Lyding was also an athlete and earned a track scholarship to Eastern Illinois University coming out of high school. However, when Northwestern University later offered an academic scholarship, Lyding accepted, eventually earning a Ph.D. in electrical engineering and starting on a path that would put him at the forefront of nanoscale technology research.

Lyding's career highlights include the creation of a new microscopy technology that made possible ultra-stable atomic scale analysis and manipulation of materials like silicon, and the discovery of a way to reduce degradation in silicon chips that has changed the manufacturing of everything from laptops to cell phones. The Lyding story also includes a couple of movie-worthy 'aha' moments.

Lyding's research lineage can be traced back to two-time Nobel Prize winner and inventor of the transistor John Bardeen, who lured the young Ph.D. to his lab at the University of Illinois in 1984. A faculty position (his first and only) in the Department of Electrical and Computer Engineering (ECE) was also secured for Lyding and the stage was set for his work with scanning tunneling microscopy (STM) technology, research in his current areas involving nanotechnology, and a position at the Beckman Institute when it opened in 1989.

Lyding's embrace of the new technology of scanning tunneling microscopy in 1985 was one of his "light bulb" moments — it came while listening to a talk by the inventor — and it paved the way for all of his successes over the years.

"It was like a light came on when I saw Gerd Binnig give this invited talk," Lyding said. "I was just thinking that this is such a neat instrument; all of the work I had been doing up until then we would measure a large object and make inferences about the atomic scale and here he was showing exactly what was happening at the atomic scale."

Lyding returned to Illinois and built an STM of his own using a campus machine shop.

"The old EE lab was basically a junkyard of old equipment so I was able to scrounge together the things I needed," Lyding said. "I went to a student shop in ECE and used the machines there. I did all the machining myself."

Lyding's feat meant Illinois was one of the few campuses in the country to have an STM, but he didn't stop there. In 1991 he built an ultra-high vacuum scanning tunneling microscope — providing a new level of highly stable atomic resolution — and has been refining the technology ever since in his third-floor lab at Beckman.

The STM technologies have enabled Lyding and his collaborators to explore and control at the atomic scale materials like silicon and processes such as nanoscale interactions and lithographic techniques that make current and future electronics possible. Lyding's research efforts have produced groundbreaking discoveries involving graphene and carbon nanotubes, materials that have processing speeds ten times faster or more than silicon and that could someday replace the ubiquitous semiconductor in devices.

Perhaps Lyding's most well-known discovery included a partnership with former Beckman researcher Karl Hess that focused on the chip degradation problems electronics manufacturers were facing as ever-smaller devices were packed with ever-growing computing power. In another aha moment, Lyding suggested replacing hydrogen with deuterium in chips during an informal talk, and Hess shot back, "That's it." A recent agreement with Samsung codified the technology that is now used in electronic devices worldwide.

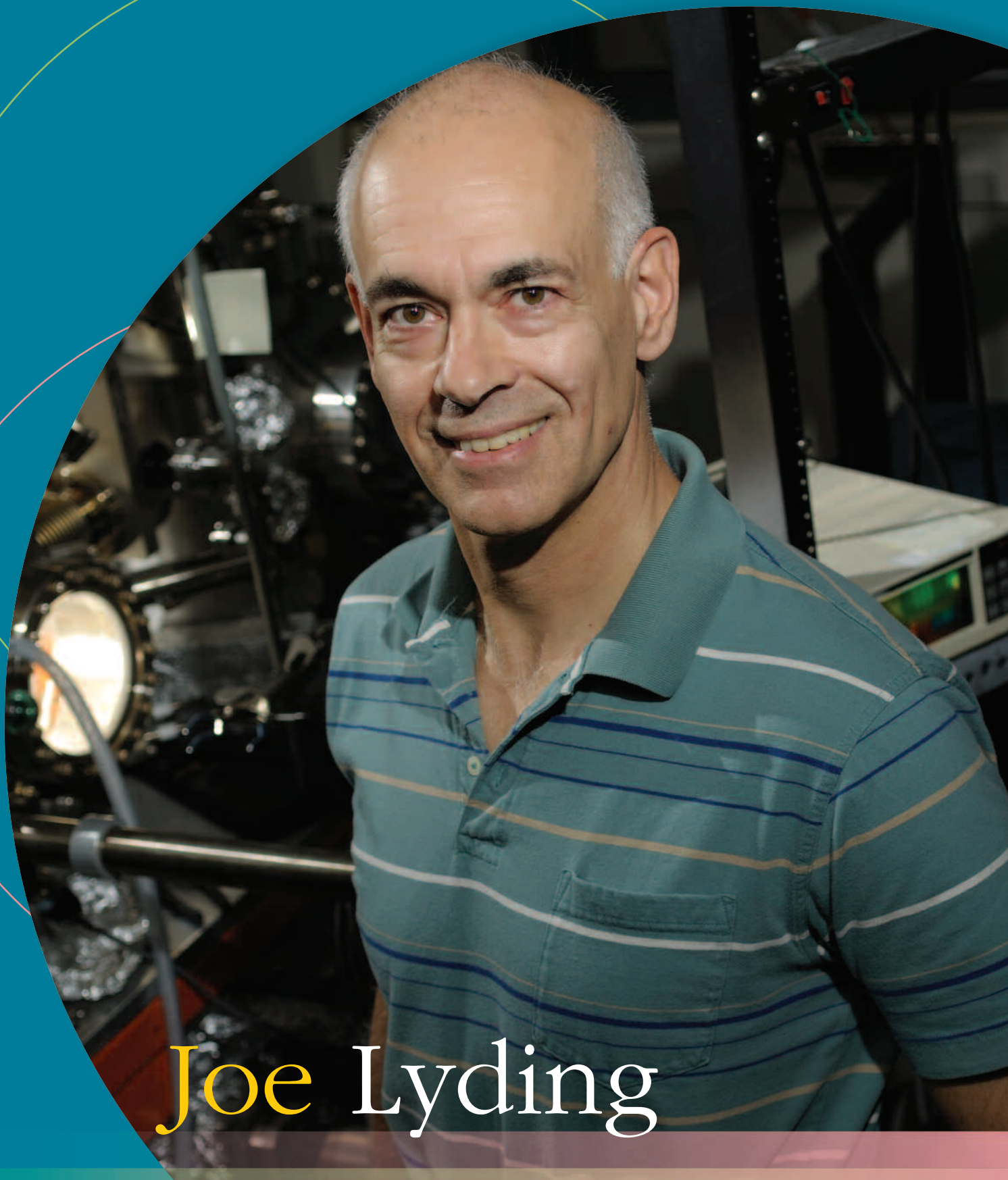
While he enjoyed the "junkyard" approach that resulted in that first STM, Lyding now appreciates the results that have come out of his Beckman lab.

"At Beckman we could get into the ultrahigh vacuum chambers we have now and could look at silicon, and lithography and deuterium," Lyding said. "All those things came as a result of coming up to Beckman."

Lyding also values the interdisciplinary approach and the commitment to translational research at the Institute.

"I've certainly benefitted from that environment," he said. "Being able to promote that and see my graduates go out and do great things has been inspiring. Also, the ability for me to look at things of future technological significance, exploring at the atomic level novel systems that are under consideration for future technologies, that's very, very important. I try to keep a close tie to technology. That has been the undertone of my research since coming to Beckman.

"The third thing is just having fun. This is really an enjoyable job and I couldn't imagine doing anything else."



Joe Lyding

"THE ABILITY FOR ME TO LOOK AT THINGS OF FUTURE TECHNOLOGICAL SIGNIFICANCE, EXPLORING AT THE ATOMIC LEVEL NOVEL SYSTEMS THAT ARE UNDER CONSIDERATION FOR FUTURE TECHNOLOGIES, THAT'S VERY, VERY IMPORTANT. "

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2010 – June 30, 2011

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*
Sarah Brown-Schmidt, *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*
Lee Cox, *Molecular and Integrative Physiology*
Albert S. Feng, *Molecular and Integrative Physiology*
Roberto Galvez, *Psychology*
Martha L. Gillette, *Cell and Developmental Biology*
Rhanor Gillette, *Molecular and Integrative Physiology*
William T. Greenough, *Psychology*
Janice M. Juraska, *Psychology*
Daniel Llano, *Medical Molecular Integrative Physiology*
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

Kara Federmeier
- James S. McDonnell Foundation Scholar Award (Understanding Human Cognition Initiative), Aug 2010

Cynthia Fisher
- Fellow, American Psychological Society, 2010

Wendy Heller
- Larine Y. Cowan Make a Difference Award

Jose Mestre
- Fellow, American Physical Society, 2010

Duane Watson
- Helen Corley Petit Scholar, UIUC, 2010-2011

Stephanie Ceman
- Arnold O. Beckman Award UIUC, 5/2011-5/2012

Roberto Galvez
Arnold O. Beckman Research Award, 2010

Jonathan Sweedler, *Chemistry*
- Viktor Mutt prize, International Regulatory Peptide Society, 2010
- Award for Outstanding Achievements in the Fields of Analytical Chemistry, Eastern Analytical Symposium, 2011

BIOINTEL INVENTION DISCLOSURES

Faculty members from the Biological Intelligence research theme were inventors on six invention disclosures (3.3% of the 182 invention disclosures filed by campus) during FY2011.

BIOINTEL SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Biological Intelligence research theme were inventors on the following patent issued (1.4% of the 69 patents issued to campus) during FY2011 (Beckman Institute BioIntel faculty members are listed in bold):

Albert Feng, Charissa Lansing, Robert Bilger, Bruce Wheeler, Herbert Bachler, and William O'Brien, "Intrabody Communication with Ultrasound," Patent issued May 17, 2011, Patent Number 7,945,064.

BIOINTEL GRANTS AWARDED ($6,707,546)

Beckman Institute faculty members are in bold. The awards represented are grants and contracts that have been received during fiscal year 2011.

Gabriele Gratton, Ed Maclin, and **Monica Fabiani**, NIH/ISS, "Opticortex: A Full-head Non-invasive Functional Optical Brain Imaging Device," 7/1/2010 – 6/30/2012, $116,688.

Gabriele Gratton, **Diane Beck**, **Stephen Boppart**, **Neal Cohen**, **Gary Dell**, and **Monica Fabiani**, NIH, "Diffusive Optical Tomography (DOT) at the Biomedical Imaging Center," 9/1/2010 – 8/31/2011, $600,000.

Monica Fabiani and Brian Gordon, Society for Psychophysiological Research, "Fellowship Training Award," 11/19/2010 – 11/18/2011, $1,600.

Ivan Jeanne Weiler and **William Greenough**, F. Hoffmann–La Roche Ltd., "ERK Activation in Human Leucocyte," 11/1/2010 – 6/30/2011, $20,759.

Charles "Lee" Cox and **William Greenough**, NIH, "Synaptic Phenotype, Development, and Plasticity in the Fragile X Mouse", 3/5/2010 – 11/30/2014, $2,024,880.

Neal Cohen and Joel Voss, NIH, "The Hippocampal System and Relational (Decarative) Memory," 7/1/2011 - 6/30/2016, $3,193,906.

Diane Beck and Dirk Bernhardt-Walther, NIH/Stanford University, CRCNS:fMRI Pattern Analysis of Neural Correlates of Natural Scene Categories," 8/1/2009 – 7/31/2012, $739,418.

Justin Rhodes, Biomodels, "Predict the validity of drinking in the dark model," 5/16/2011 – 5/15/2012, $10,295.

BIOINTEL SELECTED PUBLICATIONS

Amaya, K. R.; **Sweedler, J. V.; Clayton, D. F.**, Small molecule analysis and imaging of fatty acids in the zebra finch song system using time-of-flight-secondary ion mass spectrometry. *Journal of Neurochemistry* **2011**, 10.1111/j.1471-4159.2011.07274.x.

Baym, C. L.; **Gonsalves, B. D.**, Comparison of neural activity that leads to true memories, false memories, and forgetting: An fMRI study of the misinformation effect. *Cognitive Affective & Behavioral Neuroscience* **2010,** 10, (3), 339-348.

Becic, E.; **Dell, G. S.**; **Bock, K.**; **Garnsey, S. M.**; Kubose, T.; **Kramer, A. F.**, Driving impairs talking. *Psychonomic Bulletin & Review* **2010,** 17, (1), 15-21.

Benjamin, A. S., Representational Explanations of "Process" Dissociations in Recognition: The DRYAD Theory of Aging and Memory Judgments. *Psychological Review* **2010,** 117, (4), 1055-1079.

Bredemeier, K.; Spielberg, J. M.; Silton, R. L.; Berenbaum, H.; **Heller, W.; Miller, G. A.**, Screening for Depressive Disorders Using the Mood and Anxiety Symptoms Questionnaire Anhedonic Depression Scale: A Receiver-Operating Characteristic Analysis. *Psychological Assessment* **2010,** 22, (3), 702-710.

Brookes, D. T.; **Ross, B. H.; Mestre, J. P.**, Specificity, transfer, and the development of expertise. *Physical Review Special Topics-Physics Education Research* **2011,** 7, (1).

Chaddock, L.; Erickson, K. I.; Prakash, R. S.; Kim, J. S.; Voss, M. W.; VanPatter, M.; Pontifex, M. B.; Raine, L. B.; Konkel, A.; **Hillman, C. H.; Cohen, N. J.; Kramer, A. F.**, A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children. *Brain Research* **2010,** 1358, 172-183.

Chambers, K. E.; Onishi, K. H.; **Fisher, C.**, A vowel is a vowel: Generalizing newly-learned phonotactic constraints to new contexts. *Journal of Experimental Psychology-Learning Memory and Cognition* **2010,** 36, 821-828.

Cheever, A.; Blackwell, E.; **Ceman, S.**, Fragile X protein family member FXR1P is regulated by microRNAs. *Rna-a Publication of the Rna Society* **2010,** 16, (8), 1530-1539.

Clark, P. J.; Kohman, R. A.; Miller, D. S.; Bhattacharya, T. K.; Brzezinska, W. J.; **Rhodes, J. S.**, Genetic influences on exercise-induced adult hippocampal neurogenesis across 12 divergent mouse strains. *Genes Brain and Behavior* **2011,** 10, (3), 345-353.

Cole, J.; Mo, Y.; Baek, S., The role of syntactic structure in guiding prosody perception with ordinary listeners and everyday speech. *Language and Cognitive Processes* **2010,** 25, (7-9), 1141-1177.

Denkova, E.; Wong, G.; Dolcos, S.; Sung, K.; Wang, L. H.; Coupland, N.; **Dolcos, F.**, The Impact of Anxiety-Inducing Distraction on Cognitive Performance: A Combined Brain Imaging and Personality Investigation. *PLOS One* **2010,** 5, (11), e14150; doi:10.1371/journal.pone.0014150.

Federmeier, K. D.; Kutas, M.; Schul, R., Age-related and individual differences in the use of prediction during language comprehension. *Brain and Language* **2010,** 115, (3), 149-161.

Galvez, R.; Nicholson, D. A.; Disterhoft, J., Physiological and Anatomical Studies of Associative Learning: Convergence with Learning Studies of W. T. Greenough. *Developmental Psychobiology* **2011**.

Gonsalves, B. D.; **Cohen, N. J.**, Brain Imaging, Cognitive Processes, and Brain Networks. *Perspectives on Psychological Science* **2010,** 5, (6), 744-752.

Govindaiah, G.; Wang, T.; **Gillette, M. U.**; Crandall, S. R.; **Cox, C. L.**, Regulation of inhibitory synapses by presynaptic D4 dopamine receptors in thalamus. *Journal of Neurophysiology* **2010**, (104), 2757-2765.

Gratton, G.; Fabiani, M., Fast optical imaging of human brain function. *Frontiers in Human Neuroscience* **2010,** 4.

Isaacs, A. M.; **Watson, D. G.**, Accent detection is a slippery slope: Direction and rate of F0 change drives listeners' comprehension. *Language and Cognitive Processes* **2010,** 25, (7-9), 1178-1200.

Kuchinsky, S. E.; **Bock, K.**; **Irwin, D. E.**, Reversing the Hands of Time: Changing the Mapping From Seeing to Saying. *Journal of Experimental Psychology-Learning Memory and Cognition* **2011,** 37, (3), 748-756.

Llano, D. A.; Laforet, G.; Devanarayan, V., Derivation of a New ADAS-cog Composite Using Tree-based Multivariate Analysis Prediction of Conversion From Mild Cognitive Impairment to Alzheimer Disease. *Alzheimer Disease & Associated Disorders* **2011,** 25, (1), 73-84.

Loukina, A.; Kochanski, G.; Rosner, B.; Keane, E.; **Shih, C. L.**, Rhythm measures and dimensions of durational variation in speech. *Journal of the Acoustical Society of America* **2011,** 129, (5), 3258-3270.

Mathewson, K. E.; **Lleras, A.; Beck, D. M.; Fabiani, M.**; Ro, T.; **Gratton, G.**, Pulsed Out of Awareness: EEG Alpha oscillations represent a pulsed inhibition of ongoing cortical processing. *Frontiers in Perception Science* **2011,** 2, (99), 10.3389/fpsyg.2011.00099.

Nelson, M. E., Electrophysiological models of neural processing. *Wiley Interdisciplinary Reviews-Systems Biology and Medicine* **2011,** 3, (1), 74-92.

Pan, F.; Aldridge, G. M.; **Greenough, W. T.**; Gan, W. B., Dendritic spine instability and insensitivity to modulation by sensory experience in a mouse model of fragile X syndrome. *Proceedings of the National Academy of Sciences of the United States of America* **2010,** 107, (41), 17768-17773.

Qi, Z. H.; Jackson, S. R.; **Garnsey, S. M.**, The Left Hemisphere Knows More About Verbs Than the Right Hemisphere Does. *Psychophysiology* **2010,** 47, S78-S78.

Schwartz, M. F.; Kimberg, D. Y.; Walker, G. M.; Brecher, A.; Faseyitan, O. K.; **Dell, G. S.**; Mirman, D.; Coslett, H. B., Neuroanatomical dissociation for taxonomic and thematic knowledge in the human brain. *Proceedings of the National Academy of Sciences of the United States of America* **2011,** 108, (20), 8520-8524.

Smith, A. D.; **Mestre, J. P.**; **Ross, B. H.**, Eye-gaze patterns as students study worked-out examples in mechanics. *Physical Review Special Topics-Physics Education Research* **2010,** 6, (2).

Theyel, B. B.; **Llano, D. A.**; Issa, N. P.; Mallik, A. K.; Sherman, S. M., In vitro imaging using laser photostimulation with flavoprotein autofluorescence. *Nature Protocols* **2011,** 4, 502-508, http://www.ncbi.nlm.nih.gov/pubmed/21455186.

Voss, J. L.; **Gonsalves, B. D.**; **Federmeier, K. D.**; Tranel, D.; **Cohen, N. J.**, Hippocampal brain-network coordination during volitional exploratory behavior enhances learning. *Nature Neuroscience* **2011,** 14, (1), 115-U152.

Wang, D.; Govindaiah, G.; Liu, R.; De Arcangelis, V.; **Cox, C. L.**; Xiang, Y., Binding of Amyloid β peptide to β2 adrenergic receptor induces PKA dependent AMPA receptor hyperactivity. *FASEB Journal* **2010,** 24, 3511-3521.

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2010 – June 30, 2011

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*
Paris Smaragdis, *Computer Science*

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

Mark A Hasegawa-Johnson
Fellow, Acoustical Society of America, 2011

Fatima T Husain
Fellow, Center for Advanced Study, UIUC, 2011-2012

Edward McAuley
Named 2010-2011 Distinguised Scholar, Institute for Health Research and Policy, University of Illinois-Chicago

HCII INVENTION DISCLOSURES

Faculty members from the Human-Computer Intelligent Interaction research theme were inventors on six invention disclosures (3.3% of the 182 invention disclosures filed by campus) during FY2011.

HCII SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Human-Computer Intelligent Interaction research theme were inventors on the following four patent applications (2.4% of the 165 patent applications filed by the campus) and two patents issued (2.9% of the 69 patents issued to campus) during FY2011 (Beckman Institute HCII faculty members are listed in bold):

Allen Yang, **Yi Ma**, Andrew Wagner, and John Wright, "Recognition via High-Dimensional Data Classification," Patent filed July 30, 2010, Application Number 12/865,639.

Ha T. Nguyen and **Minh Do**, "Signal Processors, Signal Processing Methods, and Digital Filter Configuration Methods," Patent issued December 7, 2010, Patent Number 7,847,719.

Douglas Jones and Matthew Kleffner, "Method and Apparatus for Blind Signal Recovery in Noisy, Reverberant Environments," Patent filed December 9, 2010, Application Number 12/963,877.

Jont Allen and Feipeng Li, "System and Methods for Identifying Speech Sound Features," Patent filed December 29, 2010, Application Number 13/001,856.

Jont Allen and Feipeng Li, "Methods and Systems for Identifying Speech Sound Using Multi-Dimensional Analysis," Patent filed December 29, 2010, Application Number 13/001,886.

Albert Feng, **Charissa Lansing**, Robert Bilger, Bruce Wheeler, Herbert Bachler, and William O'Brien, "Intrabody Communication with Ultrasound," Patent issued May 17, 2011, Patent Number 7,945,064.

HCII GRANTS AWARDED ($5,036,199)

Mark Hasegawa-Johnson, NSF/Toyota, "RI Medium Collaborative Research: Explicit Articulatory Models of Spoken Language with Application to Automatic Speech Recognition," 7/1/2010 – 6/30/2012, $35,997.

Arthur Kramer and **Edward McAuley**, NIH, "Influence of Fitness on Cognitive Training on Brain and Cognition," 7/1/2010 – 6/30/2015, $2,805,889.

Elizabeth Stine-Morrow, Dan Morrow, Kiel Christianson, Joseph Robinson, and **WaiTat Fu,** NIH, "Age Differences in Resource Allocation during reading," 9/30/2010- 8/31/2011, $150,000.

Stephen Levinson, Sandia National Laboratories, "Computational Models of Neurals Dynamics," 1/1/2011 – 6/30/2011, $21,438.

Arthur Kramer, Neal Cohen, Kathleen Holden, Chandramallika Basak, and Michelle Voss, NIH, "Acting Out: Influence of an Acting Intervention on Cognition and Brain Function," 3/1/2011 – 2/28/2015, $1,634,637.

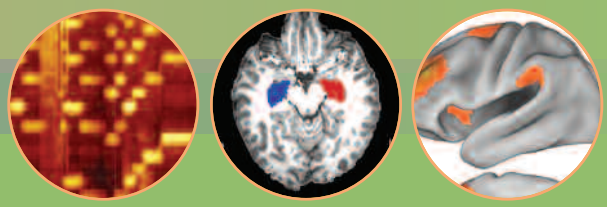
Mark Hasegawa-Johnson, **Roxanna Girju**, and Elabbas Benmamoun, QTAR, "Multi-dalect phrase-based speech recognition and machine translation for Qatari broadcast TV," 12/1/2010 – 11/30/2013, $352,088.

Stephen Levinson, Sandia National Labs, "Mathmatical models of neocortical circuits," 8/16/2009 – 8/15/2010, $8,358.

Stephen Levinson, Sandia National Labs, "Computational Models or Neurals Dynamics," 6/1/2011 – 12/31/2011, $27,792.

HCII SELECTED PUBLICATIONS

Ariga, A.; **Lleras, A.**, Brief and Rare Mental "Breaks" Keep You Focused: Deactivation and Reactivation of Task Goals Preempt Vigilance Decrements. *Cognition* **2011,** 118, (3), 439-443.



Brault, L.; Gilbert, J.; **Lansing, C.; McCarley, J. S.; Kramer, A. F.**, Bimodal Stimulus Presentation and Expanded Auditory Bandwidth Improve Older Adults' Speech Perception. *Human Factors* **2010,** 52, 479-491.

Cao, L.; Qi, G.-J.; Tsai, S. F.; Tsai, M.-H.; Del Pozo, A.; **Huang, T. S.**; Lim, S.; Zhang, X., Multimedia Information Network: Structure, Inference and Applications. In *Social Network Data Analytics*, Aggarwal, C., Ed. Kluwer Academic Publishers: **2011**.

Coleman, T. P.; Sarma, S. S., A Computationally Efficient Method for Nonparametric Modeling of Neural Spiking Activity with Point Processes. *Neural Computation* **2010,** 22, (8), 2002-2030.

Dapore, A. J.; King, M. R.; Harter, J.; Sarwate, S.; **Oelze, M. L.**; Zagzebski, J. A.; **Do, M. N.**; Hall, T. J.; **O'Brien, W. D.**, Analysis of Human Fibroadenomas using Three-Dimensional Impedance Maps. *IEEE Transactions on Medical Imaging* **2011,** 30, (6), 1206-1213.

Dlugonski, D.; Wojcicki, T. R.; **McAuley, E.**; Motl, R. W., Social Cognitive Correlates of Physical Activity in Inactive Adults with Multiple Sclerosis. *International Journal of Rehabilitation Research* **2011,** 34, (2), 115-120.

Do, M. N.; Nguyen, Q. H.; Nguyen, H. T.; Kubacki, D.; Patel, S. J., Immersive Visual Communication. *IEEE Signal Processing Magazine* **2011,** 28, (1), 58-66.

Duda, A. M.; **Levinson, S. E.**, *Nonlinear Dynamical Multi-Scale Model of Associative Memory*, IEEE Proceedings of the 9th International Conference on Machine Learning and Applications (ICMLA), **2010**; pp 867-872.

Erickson, K. I.; Voss, M. W.; Prakash, R. S.; Basak, C.; Szabo, A.; Chaddock, L.; Kim, J. S.; Heo, S.; Alves, H.; White, S. M.; Wojcicki, T. R.; Mailey, E.; Vieira, V. J.; Martin, S. A.; Pence, B. D.; Woods, J. A.; **McAuley, E.**; **Kramer, A. F.**, Exercise Training Increases Size of Hippocampus and Improves Memory. *Proceedings of the National Academy of Sciences of the United States of America* **2011,** 108, (7), 3017-3022.

Fu, W. T., A Dynamic Context Model of Interactive Behavior. *Cognitive Science* **2011**, 35.

Fu, Y.; Guo, G. D.; **Huang, T. S.**, Age Synthesis and Estimation via Faces: A Survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence* **2010,** 32, (11), 1955-1976.

Girju, R.; Paul, M. J., Modeling Reciprocity in Social Interactions with Probabilistic Latent Space Models. *Natural Language Engineering* **2011,** 17, 1-36.

Hart, J. M.; Molina, L. F.; Resendiz, E.; Edwards, J. R.; **Ahuja, N.**; Barkan, C. P. L., Development of a Machine Vision System for the Inspection of Heavy-Haul Railway Turnout and Track Components. *Proceedings of International Heavy Haul Association Conference*, Calgary, Canada, June **2011**.

He, J. B.; Becic, E.; Lee, Y. C.; **McCarley, J. S.**, Mind Wandering Behind the Wheel: Performance and Oculomotor Correlates. *Human Factors* **2011,** 53, (1), 13-21.

Higgins, J. S.; **Wang, R. F.**, A Landmark Effect in the Perceived Displacement of Objects. *Vision Research* **2010,** 50, (2), 242-248.

Husain, F. T.; Medina, R. E.; Davis, C. W.; Szymko-Bennett, Y.; Simonyan, K.; Pajor, N. M.; Horwitz, B., Neuroanatomical Changes Due to Hearing Loss and Chronic Tinnitus: A Combined VBM and DTI Study. *Brain Research* **2011,** 1369, 74-88.

Kim, H.; Martin, K.; **Hasegawa-Johnson, M.**; Perlman, A., Frequency of Consonant Articulation Errors in Dysarthric Speech. *Clinical Linguistics & Phonetics* **2010,** 24, (10), 759-770.

Kirlik, A., Brunswikian Theory and Method as a Foundation for Simulation-Based Research on Clinical Judgment. *Simulation in Healthcare* **2011,** 5, (5), 255-259.

Law, K. L.; **Do, M. N.**, Multidimensional Filter Bank Signal Reconstruction From Multichannel Acquisition. *IEEE Transactions on Image Processing* **2011,** 20, (2), 317-326.

Lobdell, B. E.; Allen, J. B.; **Hasegawa-Johnson, M. A.**, Intelligibility predictors and neural representation of speech. *Speech Communication* **2011,** 53, (2), 185-194.

Lopez-Nicolas, G.; Gans, N. R.; Bhattacharya, S.; Sagues, C.; Guerrero, J. J.; **Hutchinson, S.**, Homography-Based Control Scheme for Mobile Robots With Nonholonomic and Field-of-View Constraints. *IEEE Transactions on Systems Man and Cybernetics Part B-Cybernetics* **2010,** 40, (4), 1115-1127.

Loucks, T. M. J.; **Shosted, R. K.**; De Nil, L. F.; Poletto, C. J.; King, A., Coordinating Voicing Onset with Articulation: A Potential Role for Sensory Cues in Shaping Phonological Distinctions. *Phonetica* **2010,** 67, (1-2), 47-62.

Mathewson, K. E.; Fabiani, M.; Gratton, G.; **Beck, D. M.; Lleras, A.**, Making waves in the stream of consciousness: Eliciting predictable oscillations in visual awareness with pretarget entrainment at 12 Hz. *Visual Cognition* **2010,** 18, (1), 137-141.

McDonagh, D.; Thomas, J., Rethinking design thinking: Empathy Supporting Innovation. *Australasian Medical Journal* **2010,** 3, (8), 458-464.

Morrow, D. G.; Wilson, E. H., Medication adherence among older adults: a systems perspective. In *Aging in America Volume II: Physical and Mental Health*, Cavanaugh, J. C.; Cavanaugh, C. K., Eds. Praeger: Santa Barbara, CA, **2010**; pp 211-239.

Narayanan, S.; Varatkar, G. V.; **Jones, D. L.**; Shanbhag, N. R., Computation as Estimation: A General Framework for Robustness and Energy Efficiency in SoCs. *IEEE Transactions on Signal Processing* **2010,** 58, (8), 4416-4421.

Payne, B. R.; Gao, X.; **Stine-Morrow, E.**, Measures of Reading Skill Dissociate Online Reading Processes among Older Adults. *Gerontologist* **2010,** 50, 148-148.

Rao, S.; Tron, R.; Vidal, R.; **Ma, Y.**, Motion Segmentation in the Presence of Outlying, Incomplete, or Corrupted Trajectories. *IEEE Transactions on Pattern Analysis and Machine Intelligence* **2010,** 32, (10), 1832-1845.

Tang, H.; **Hasegawa-Johnson, M.**; **Huang, T.**, A Novel Vector Representation of Stochastic Signals Based on Adapted Ergodic HMMs. *IEEE Signal Processing Letters* **2010,** 17, (8), 715-718.

Themanson, J. R.; Pontifex, M. B.; **Hillman, C. H.**; **McAuley, E.**, The relation of self-efficacy and error-related self-regulation. *International Journal of Psychophysiology* **2011,** 80, (1), 1-10.

Vo, L. T. K.; Walther, D. B.; **Kramer, A. F.**; Erickson, K. I.; Boot, W. R.; Voss, M. W.; Prakash, R. S.; Lee, H.; Fabiani, M.; Gratton, G.; **Simons, D. J.**; **Sutton, B. P.**; **Wang, M. Y.**, Predicting Individuals' Learning Success from Patterns of Pre-Learning MRI Activity. *PLOS One* **2011,** 6, (1).

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2010 – June 30, 2011

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*
Jianjun Cheng, *Materials Science and Engineering*
Michael Insana, *Bioengineering*
Jianming Jin, *Electrical and Computer Engineering*
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

Rohit Bhargava
Campus Award for Exceptional Promotion & Tenure Dossier 2011
Xerox Award for Faculty Research, 2011
Fellow, Center for Advanced Study, 2010
Teaching Academy Faculty Fellow in Engineering, 2010

Marni D Boppart
Faculty Listed as Excellent, 2010

Stephen A Boppart
Fellow, IEEE, 2011

Kenneth S Suslick
Fellow, Guggenheim Memorial Foundation, 2011
Fellow, American Chemical Society, 2010

Bradley P Sutton
Engineering Council Award for Excellence in Advising, 2011
Distinguished Reviewer for Magnetic Resonance in Medicine, 2011

Yingxiao (Peter) Wang
Fellow, Center for Advanced Study, 2010

William D O'Brien
NIH MERIT Award, 2011

INTIM INVENTION DISCLOSURES

Faculty members from the Integrative Imaging research theme were inventors on 11 invention disclosures (6% of the 182 invention disclosures filed by campus) during FY2011.

INTIM SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Integrative Imaging research theme were inventors on the following 10 patent applications (6.1% of the 165 patent applications filed by the campus) and five patents issued (7.2% of the 69 patents issued to campus) during FY2011 (Beckman Institute IntIm faculty members are listed in bold):

Amy Oldenburg, **Stephen Boppart**, Vasilica Crecea, and Xing Liang, "Magnetomotive Optical Coherence Tomography," Patent issued July 6, 2010, Patent Number 7,751,057.

Haohua Tu and **Stephen Boppart**, "Compression of Supercontinuum Pulse Generated in All Normal-Dispersion Photonic Crystal Fiber," Patent filed August 26, 2010, Application Number 61/377,155.

Rohit Bhargava, Rohith Reddy, and F. Pounder, "Automated Detection of Breast Cancer Lesions in Tissue," Patent filed August 31, 2010, Application Number 61/378,763.

Adam Zysk, Steven Adie, Matthew Leigh, Julian Armstrong, David Sampson, and **Stephen Boppart**, "Method and Apparatus for Measurement of Optical Properties in Tissue," Patent issued August 31, 2010, Patent Number 7,787,129.

Haohua Tu and **Stephen Boppart**, "Optical Frequency Up-Conversion of Femtosecond Pulses into Targeted Single Bands in the Visible and Ultraviolet," Patent filed September 14, 2010, Application Number 12/807,772.

Xavier Llora, Anil Kodali, and **Rohit Bhargava**, "Optimally Tailored Raman Spectroscopic Probes for Ultrasensitive and Highly Multiplexed Assays," Patent filed October 27, 2010, Application Number 61/407,233.

Rohit Bhargava, **Paul Carney**, and Brynmor Davis, "Infrared Microspectroscopy for Intact Fibers," Patent filed November 8, 2010, Application Number 12/941,159.

Stephen Boppart and Woong Gyu Jung, "Apparatus for Biomedical Imaging," Patent filed November 15, 2010, Application Number 12/946,805.

Rohit Bhargava, Jin Kwak, and Saurabh Sinha, "Automated Prostate Tissue Referencing for Cancer Detection and Diagnosis," Patent filed January 5, 2011, Application Number 61/429,935.

Paul Carney, Steven Adie, and **Stephen Boppart**, "Computational Adaptive Optics with Interferometric Synthetic Aperture Microscopy and Other Interferometric Imaging," Patent filed January 24, 2011, Application Number 61/435,569.

Yingxiao Wang, Shaoying Lu, Mr. Mingxing Ouyang, "Fret-Based Membrane-Type 1 Matrix Metalloproteinase Biosensor and Methods for Using the Same," Patent Filed March 23, 2011, Application Number 13/057,488.

Gabriel Popescu and Zhuo Wang, "Jones Phase Microscopy of Transparent Samples," Patent issued May 10, 2011, Patent Number 7,940,399.

Albert Feng, Charissa Lansing, Robert Bilger, Bruce Wheeler, Herbert Bachler, and **William O'Brien**, "Intrabody Communication with Ultrasound," Patent issued May 17, 2011, Patent Number 7,945,064.

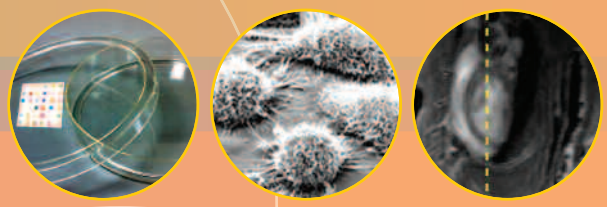
Santosh Tripathi, **Kimani Toussaint**, **Paul Carney**, and Brynmor Davis, "Second-Order Nonlinear Susceptibility of a Nanoparticle Using Coherent Optical Microscopy," Patent filed June 6, 2011, Application Number 13/154,014.

Paul Carney and Daniel Marks, "Multiplex Near-Field Microscope with Diffractive Elements," Patent issued June 28, 2011, Patent Number 7,969,650.

INTIM GRANTS AWARDED *($4,661,556)*

Stephen Boppart and Woong Gyu Jung, Samsung, "3D Endomicroscopy using Optical Coherence Tomography Toward Multimodal Imaging," 9/1/2010 – 8/31/2011, $100,000.

Stephen Boppart, Hyun Joon Kong, **Mark Shannon**, and **Marni Boppart**, NSF, "Advanced Optical Imaging of 3-D Cell Dynamics in Engineered Skin," 9/1/2010 – 8/31/2013, $600,000.



Gabriel Popescu, Lynford Goddard, **Stephen Boppart**, **Martha Gillette**, and **Jennifer Lewis**, NSF, "MRI: Development of Spatial Light Interference Microscope (SLIM) as Shared Facility for Materials and Life Sciences," 9/1/2010 – 8/31/2014, $1,372,869.

Stephen Boppart, **Douglas Simpson**, and **Scott Carney**, NIH, "Intraoperative OCT for Determining Lymph Node Statusand Staging Cancer," 9/30/2010 – 8/31/2014, $2,588,687.

INTIM SELECTED PUBLICATIONS

Abbey, C. K.; Nguyen, N. Q.; **Insana, M. F.**, Optimal Beamforming in Ultrasound Using the Ideal Observer. *IEEE Transactions on Ultrasonics Ferroelectrics and Frequency Control* **2010,** 57, (8), 1782-1796.

Ashtekar, S.; Scott, G.; **Lyding, J.**; **Gruebele, M.**, Direct observation of two-state surface dynamics on amorphous silicon. *Physical Review Letters* **2011,** 106.

Benalcazar, W. A.; Chowdary, P. D.; Jiang, Z.; Marks, D. L.; Chaney, E. J.; **Gruebele, M.**; **Boppart, S. A.**, High-Speed Nonlinear Interferometric Vibrational Imaging of Biological Tissue With Comparison to Raman Microscopy. *IEEE Journal of Selected Topics in Quantum Electronics* **2010,** 16, (4), 824-832.

Brinegar, C.; Schmitter, S. S.; Mistry, N. N.; Johnson, G. A.; **Liang, Z. P.**, Improving Temporal Resolution of Pulmonary Perfusion Imaging in Rats Using the Partially Separable Functions Model. *Magnetic Resonance in Medicine* **2010,** 64, (4), 1162-1170.

Carney, P. S.; **Boppart, S. A.**, Interferometric synthetic aperture microscopy eliminates OCT compromises. *Laser Focus World* **2011,** 47, (1), 35-+.

Carney, P. S.; **Boppart, S. A.**, Depth of field and resolution meet in new OCT approach. *BioOptics World* **2011,** 4, 19-23.

Chen, Y.; **Ostoja-Starzewski, M.**, MRI-based finite element modeling of head trauma: spherically focusing shear waves. *Acta Mechanica* **2010,** 213, (1-2), 155-167.

Chowdary, P. D.; Jiang, Z.; Chaney, E. J.; Benalcazar, W. A.; Marks, D. L.; **Gruebele, M.**; **Boppart, S. A.**, Molecular Histopathology by Spectrally Reconstructed Nonlinear Interferometric Vibrational Imaging. *Cancer Research* **2010,** 70, (23), 9562-9569.

Dapore, A.; King, M. R.; Harter, J.; Sarwate, S.; **Oelze, M. L.**; Zagzebski, J. A.; **Do, M. N.**; Hall, T. J.; **O'Brien Jr., W. D.**, Analysis of Human Fibroadenomas using Three-dimensional Impedance Maps. *IEEE Transactions on Medical Imaging* **2011,** 30, 1206-1213.

Davis, B. J.; **Carney, P. S.**; **Bhargava, R.**, Theory of Infrared Microspectroscopy for Intact Fibers. *Analytical Chemistry* **2011,** 83, (2), 525-532.

Ding, H. F.; Wang, Z.; Nguyen, F. T.; **Boppart, S. A.**; Millet, L. J.; Gillette, M. U.; Liu, J. M.; **Boppart, M. D.**; **Popescu, G.**, Fourier Transform Light Scattering (FTLS) of Cells and Tissues. *Journal of Computational and Theoretical Nanoscience* **2010,** 7, (12), 2501-2511.

Feng, L. A.; Musto, C. J.; Kemling, J. W.; Lim, S. H.; Zhong, W. X.; **Suslick, K. S.**, Colorimetric Sensor Array for Determination and Identification of Toxic Industrial Chemicals. *Analytical Chemistry* **2010,** 82, (22), 9433-9440.

Flannigan, D. J.; **Suslick, K. S.**, Inertially confined plasma in an imploding bubble. *Nature Physics* **2010,** 6, (8), 598-601.

George, S.; Bhalerao, S. V.; Lidstone, E. A.; Ahmad, I. S.; Abbasi, A.; Cunningham, B. T.; **Watkin, K. L.**, Cytotoxicity screening of Bangladeshi medicinal plant extracts on pancreatic cancer cells. *BMC Complementary and Alternative Medicine* **2010,** 10.

Haldar, J. P.; Hernando, D.; **Liang, Z. P.**, Compressed-Sensing MRI with Random Encoding. *IEEE Transactions on Medical Imaging* **2011,** 30, (4), 893-903.

Hernando, D.; Karampinos, D. C.; King, K. F.; Haldar, J. P.; Majumdar, S.; **Georgiadis, J. G.**; **Liang, Z. P.**, Removal of Olefinic Fat Chemical Shift Artifact in Diffusion MRI. *Magnetic Resonance in Medicine* **2011,** 65, (3), 692-701.

Huang, W.; Cao, X. Y.; **Zhong, S.**, Network-based comparison of temporal gene expression patterns. *Bioinformatics* **2010,** 26, (23), 2944-2951.

Kodali, A. K.; Llora, X.; **Bhargava, R.**, Optimally designed nanolayered metal-dielectric particles as probes for massively multiplexed and ultrasensitive molecular assays. *Proceedings of the National Academy of Sciences of the United States of America* **2010,** 107, (31), 13620-13625.

Kwon, B.; Wang, C.; Park, K.; **Bhargava, R.**; **King, W. P.**, Thermomechanical Sensitivity of Microcantilevers in the Mid-Infrared Spectral Region. *Nanoscale and Microscale Thermophysical Engineering* **2011,** 15, (1), 16-27.

Lu, S.; **Wang, Y.**, FRET Biosensors for Cancer Detection and Evaluation of Drug Efficacy. *Clinical Cancer Research* **2011,** 16, (15), 3822-3824.

Malandraki, G. A.; Perlman, A. L.; Karampinos, D. C.; **Sutton, B. P.**, Reduced Somatosensory Activations in Swallowing With Age. *Human Brain Mapping* **2011,** 32, (5), 730-743.

Nasse, M. J.; Walsh, M. J.; Mattson, E. C.; Reininger, R.; Kajdacsy-Balla, A.; Macias, V.; **Bhargava, R.**; Hirschmugl, C. J., High-resolution Fourier-transform infrared chemical imaging with multiple synchrotron beams. *Nature Methods* **2011,** 8, (5), 413-416.

Nguyen, N. Q.; Abbey, C. K.; **Insana, M. F.**, An Adaptive Filter to Approximate the Bayesian Strategy for Sonographic Beamforming. *IEEE Transactions on Medical Imaging* **2011,** 30, (1), 28-37.

Park, K.; Millet, L. J.; Kim, N.; Li, H. A.; Jin, X. Z.; **Popescu, G.**; **Aluru, N. R.**; Hsia, K. J.; **Bashir, R.**, Measurement of adherent cell mass and growth. *Proceedings of the National Academy of Sciences of the United States of America* **2010,** 107, (48), 20691-20696.

Park, Y.; Best, C. A.; Kuriabova, T.; Henle, M. L.; Feld, M. S.; Levine, A. J.; **Popescu, G.**, Measurement of the nonlinear elasticity of red blood cell membranes. *Physical Review E* **2011,** 83, (5).

Perry, J. L.; Kuehn, D. P.; **Sutton, B. P.**; Goldwasser, M. S.; Jerez, A. D., Craniometric and Velopharyngeal Assessment of Infants With and Without Cleft Palate. *Journal of Craniofacial Surgery* **2011,** 22, (2), 499-503.

Sakoglu, U.; Pearlson, G. D.; Keihl, K. A.; **Wang, M. Y.**; 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,** 23, 351-366.

Siriani, D. F.; **Carney, P. S.**; Choquette, K. D., Coherence of Leaky-Mode Vertical-Cavity Surface-Emitting Laser Arrays. *IEEE Journal of Quantum Electronics* **2011,** 47, (5), 672-675.

Spielberg, J. M.; **Miller, G. A.**; Engels, A. S.; Herrington, J. D.; **Sutton, B. P.**; Banich, M. T.; **Heller, W.**, Trait approach and avoidance motivation: Lateralized neural activity associated with executive function. *Neuroimage* **2011,** 54, (1), 661-670.

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

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2010 – June 30, 2011

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*
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 Pysiology*
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

Jean-Pierre Leburton
Associate Member, Royal Academy of Belgium, 2011

Joseph W Lyding
Fellow, IEEE, 2011

Eric Pop
Presidential Early Career Award for Scientists and Engineers, 2010

Paul Braun
Young Alumnus Award, UIUC, Materials Science and Engineering Alumni Board, 2011

William P. King
Society of Manufacturing Engineers, "Innovations that will Change Manufacturing," 2011

John A. Rogers
National Academy of Engineering, 2011
Lemelson-MIT Prize, 2011

M&ENS INVENTION DISCLOSURES

Faculty members from the Molecular and Electronic Nanostructures research theme were inventors on nine invention disclosures (4.9% of the 182 invention disclosures filed by campus) during FY2011.

M&ENS SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Molecular and Electronic Nanostructures research theme were inventors on the following 19 patent applications (11.5% of the 165 patent applications filed by the campus) and 11 patents issued (15.9% of the 69 patents issued to campus) during FY2011 (Beckman Institute M&ENS faculty members are listed in bold):

Alexey Bezryadin and Mikas Remeika, "Nanowire Structures and Electrical Devices," Patent issued July 6, 2010, Patent Number 7,749,922.

Dahl-Young Khang, Shawn Mack, **John Rogers**, Heung Cho Ko, Zhengtao Zhu, Etienne Menard, Yugang Sun, Ralph Nuzzo, Keon Jae Lee, and Matthew Meitl, "Printable Semiconductor Structures and Related Methods of Making and Assembling," Patent filed July 27, 2010, Application Number 12/844,492.

Chang Liu, Nannan Chen, Jonathan Engel, Jack Chen, and Zhifang Fan, "Conformal Mesh for Thermal Imaging," Patent issued August 3, 2010, Patent Number 7,768,376.

Apratim Dhar, **Martin Gruebele**, Simon Ebbinghaus, and Douglas McDonald, "Temperature Jump Dynamics Microscope," Patent filed August 16, 2010, Application Number 61/374,001.

Gregory Gratson and **Jennifer Lewis**, "Directed Assembly of Three-Dimensional Structures with Micron-Scale Features," Patent issued September 7, 2010, Patent Number 7,790,061.

Debapriya Mazumdar, Juewen Liu, and **Yi Lu**, "Lateral Flow Devices," Patent issued September 21, 2010, Patent Number 7,799,554.

Ralph Nuzzo, **John Rogers**, Etienne Menard, Keon Jae Lee, Dahl-Young Khang, Yugang Sun, Matthew Meitl, Zhengtao Zhu, Heung Cho Ko, and Shawn Mack, "Printable Semiconductor Structures and Related Methods of Making and Assembling," Patent issued September 21, 2010, Patent Number 7,799,699.

Dae-Hyeong Kim, Brian Litt, Jonathan Viventi, Fiorenzo Omenetto, Yonggang Huang, David Kaplan, and **John Rogers**, "Implantable Biomedical Devices on Bioresorbable Substrates," Patent filed September 28, 2010, Application Number 12/892,001.

John Rogers, "Waterproof Stretchable Optoelectronics," Patent filed September 30, 2010, Application Number 61/388,529.

Yi Lu, Jieqian Zhang, **Paul Kenis**, and Zidong Wang, "Nucleic Acid-Mediated Shape Control of Nanoparticles for Biomedical Applications," Patent filed September 30, 2010, Application Number 61/404,410.

John Rogers and Jang-Ung Park, "High Resolution Printing of Charge," Patent filed November 16, 2010, Application Number 12/947,120.

Muhammad Alam, **John Rogers**, Qing Cao, and Ninad Pimparkar, "SWNTs for Thin Film ICs on Flexible Substrates," Patent filed December 8, 2010, Application Number 12/996,924.

Winston Timp, **Oleksii (Aleksei) Aksimentiev**, Utkur Mirsaidov, **Gregory Timp**, and Jeffrey Comer, "Characterizing Stretched Polynucleotides in a Synthetic Nanopassage," Patent filed December 17, 2010, Application Number 12/971,240.

John Rogers, "Materials for Multifunctional Balloon Catheters with Capabilities in Cardiac Electrophysiological Mapping and Ablation Therapy," Patent filed December 21, 2010, Application Number 61/425,451.

Yi Lu and Juewen Liu, "Aptamer-Based Colorimetric Sensor Systems," Patent filed January 18, 2011, Application Number 13/008,568.

Paul Braun and Xindi Yu, "Variably Porous Structures," Patent issued January 18, 2011, Patent Number 7,872,563.

Junghoon Yeom and **Mark Shannon**, "Method of Forming a Patterned Layer of a Material on a Substrate," Patent filed January 27, 2011, Application Number 13/015,299.

William King and Jungchul Lee, "Device for Calorimetric Measurement," Patent filed February 18, 2011, Application Number 13/059,812.

Yi Lu and Juewen Liu, "Aptamer Based Colorimetric Sensor Systems," Patent issued February 22, 2011, Patent Number 7,892,734.

Yi Lu and Jing Li, "Nucleic Acid Enzyme Biosensors for Ions," Patent issued March 8, 2011, Patent Number 7,902,353.

John Rogers, Dae-Hyeong Kim, Rak Kim, Fiorenzo Omenetto, and David Kaplan, "Waterproof Stretchable Optoelectronics," Patent filed March 11, 2011, Application Number 13/046,191.

Yi Lu and Juewen Liu, "Fluorescence Based Biosensors," Patent issued March 15, 2011, Patent Number 7,906,320.

Joseph Lyding, Joshua Wood, and Charishma Subbaiah, "Asymmetric Magnetic Field Carbon Nanotube Separation Method, Device and System," Patent filed March 17, 2011, Application Number 61/453,798.

Jongseung Yoon, **John Rogers**, Heung Cho Ko, Ralph Nuzzo, Alfred Baca, Etienne Menard, Matthew Meitl, "Release Strategies for making Transferable Semiconductor Structures, Devices and Device Components," Patent filed March 24, 2011, Application Number 13/071,027.

John Rogers, Alfred Baca, Jongseung Yoon, **Angus Rockett**, Ralph Nuzzo, "Arrays of Ultrathin Silicon solar Microcells," Patent Filed March 23, 2011, Application Number 13/120,486.

John Rogers, Ralph Nuzzo, Heung Cho Ko, Alfred Baca, Etienne Menard, Jongseung Yoon, and Matthew Meitl, "Release Strategies for Making Transferable Semiconductor Structures, Devices and Device Components," Patent issued April 26, 2011, Patent Number 7,932,123.

Heung Cho Ko, Matthew Meitl, Michael Motala, **John Rogers**, Sang Il Park, Jong-Hyun Ahn, Jongseung Yoon, Ralph Nuzzo, Chang-Jae Yu, Alfred Baca, Mark Stoykovich, and Etienne Menard, "Optical Systems Fabricated by Printing-Based Assembly," Patent filed May 4, 2011, Application Number 13/100,774.

John Rogers, Ralph Nuzzo, Matthew Meitl, Dahl-Young Khang, Keon Jae Lee, Zhengtao Zhu, Yugang Sun, and Etienne Menard, "Pattern Transfer Printing by Kinetic Control of Adhesion to an Elastomeric Stamp," Patent issued May 17, 2011, Patent Number 7,943,491.

Dahl-Young Khang, Ralph Nuzzo, Yugang Sun, Matthew Meitl, Etienne Menard, Zhengtao Zhu, Keon Jae Lee, and **John Rogers**, "Methods and Devices for Fabricating and Assembling Printable Semiconductor Elements," Patent filed May 23, 2011, Application Number 13/113,504.

John Rogers and Dae-Hyeong Kim, "Flexible and Stretchable Electronic Systems for Epidermal Electronics," Patent filed June 10, 2011, Application Number 61/495,623.

M&ENS SELECTED GRANTS AWARDED

($578,767)

Scott White, Society of Engineering, "Administrative support for the Society of Engineering Science, Inc.," 7/1/2010 – 6/30/2011, $10,365.

Jeffrey Moore, **Rohit Bhargava**, Ralph Nuzzo, **John Rogers**, and **Nancy Sottos**, NSF, "MRI: Acquisition of a Confocal Raman Microscope for Non-destructive Imaging of Complex Heterogeneous Materials," 10/1/2010 – 9/30/2013, $459,111.

Umberto Ravaioli and Richard Braatz, NSF/Northwestern University, "NCLT: For the development of Nanoscale Science and Engineering Educators with Leadership capabilities," 10/1/2009 – 3/31/2011, $109,291.

M&ENS SELECTED PUBLICATIONS

Aragon, A. A.; Smith, K. J.; **Geubelle, P. H.**; **White, S. R.**, Multi-Physics Design of Microvascular Materials for Active Cooling Applications. *Journal of Computational Physics* **2011,** 230, 5178-5198.

Ashtekar, S.; Scott, G.; **Lyding, J.**; **Gruebele, M.**, Direct Visualization of Two-State Dynamics on Metallic Glass Surfaces Well Below T-g. *Journal of Physical Chemistry Letters* **2010,** 1, (13), 1941-1945.

Beiermann, B. A.; Davis, D. A.; Kramer, S. L. B.; **Moore, J. S.**; **Sottos, N. R.**; **White, S. R.**, Environmental Effects on Mechanochemical Activation of Spiropyran in Linear PMMA. *Journal of Material Chemistry* **2011**, DOI: 10.1039/C0JM03967E.

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

Braun, P. V., MATERIALS SCIENCE Colour without colourants. *Nature* **2011,** 472, (7344), 423-424.

Chen, Z.; Jiang, Y. B.; Dunphy, D. R.; Adams, D. P.; Hodges, C.; Liu, N. G.; Zhang, N.; Xomeritakis, G.; Jin, X. Z.; **Aluru, N. R.**; Gaik, S. J.; Hillhouse, H. W.; Brinker, C. J., DNA translocation through an array of kinked nanopores. *Nature Materials* **2010,** 9, (8), 667-675.

Estrada, D.; **Pop, E.**, Imaging dissipation and hot spots in carbon nanotube network transistors. *Applied Physics Letters* **2011,** 98, (7).

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Frauenfeld, J.; Gumbart, J.; van der Sluis, E. O.; Funes, S.; Gartmann, M.; Beatrix, B.; Mielke, T.; Berninghausen, O.; Becker, T.; **Schulten, K.**; Beckmann, R., Cryo-EM structure of the ribosome-SecYE complex in the membrane environment. *Nature Structural & Molecular Biology* **2011,** 18, (5), 614-621.

Freddolino, P. L.; Harrison, C. B.; Liu, Y. X.; **Schulten, K.**, Challenges in protein-folding simulations. *Nature Physics* **2010,** 6, (10), 751-758.

Ger, M. F.; Rendon, G.; Tilson, J. L.; **Jakobsson, E.**, Domain-Based Identification and Analysis of Glutamate Receptor Ion Channels and Their Relatives in Prokaryotes. *PLOS One* **2010,** 5, (10).

Grashoff, C.; Hoffman, B. D.; Brenner, M. D.; Zhou, R. B.; Parsons, M.; Yang, M. T.; McLean, M. A.; **Sligar, S. G.**; Chen, C. S.; Ha, T.; Schwartz, M. A., Measuring mechanical tension across vinculin reveals regulation of focal adhesion dynamics. *Nature* **2010,** 466, (7303), 263-266.

Grosse, K. L.; Bae, M. H.; Lian, F. F.; **Pop, E.**; **King, W. P.**, Nanoscale Joule heating, Peltier cooling and current crowding at graphene-metal contacts. *Nature Nanotechnology* **2011,** 6, (5), 287-290.

Gruebele, M., ANALYTICAL BIOCHEMISTRY Weighing up protein folding. *Nature* **2010,** 468, (7324), 640-641.

Hayashi, T.; Miner, K.; Yeung, N.; Lin, Y.-W.; **Lu, Y.**; Moenne-Loccoz, P., Spectroscopic characterization of mononitrosyl complexes in heme-nonheme diiron centers within the myoglobin scaffold (Fe_BMbs). *Biochemistry* **2011,** 50, 5939-5947.

He, K. T.; Koepke, J. C.; Barraza-Lopez, S.; **Lyding, J. W.**, Separation-Dependent Electronic Transparency of Monolayer Graphene Membranes on III-V Semiconductor Substrates. *Nano Letters* **2010,** 10, (9), 3446-3452.

Jung, I. W.; Xiao, J. L.; Malyarchuk, V.; Lu, C. F.; Li, M.; Liu, Z. J.; Yoon, J.; Huang, Y. G.; **Rogers, J. A.**, Dynamically tunable hemispherical electronic eye camera system with adjustable zoom capability. *Proceedings of the National Academy of Sciences of the United States of America* **2011,** 108, (5), 1788-1793.

Kim, R. H.; Kim, D. H.; Xiao, J. L.; Kim, B. H.; Park, S. I.; Panilaitis, B.; Ghaffari, R.; Yao, J. M.; Li, M.; Liu, Z. J.; Malyarchuk, V.; Kim, D. G.; Le, A. P.; Nuzzo, R. G.; Kaplan, D. L.; Omenetto, F. G.; Huang, Y. G.; Kang, Z.; **Rogers, J. A.**, Waterproof AlInGaP optoelectronics on stretchable substrates with applications in biomedicine and robotics. *Nature Materials* **2010,** 9, (11), 929-937.

Kokhan, O.; Wraight, C. A.; **Tajkhorshid, E.**, The Binding Interface of Cytochrome c and Cytochrome c(1) in the bc(1) Complex: Rationalizing the Role of Key Residues. *Biophysical Journal* **2010,** 99, (8), 2647-2656.

Leckband, D., Design Rules for Biomolecular Adhesion: Lessons from Force Measurements. In *Annual Review of Chemical and Biomolecular Engineering*, **2010**; Vol. 1, pp 365-389.

Lee, K. I.; Toghraee, R.; **Jakobsson, E.**; **Ravaioli, U.**, A Study of Brownian Dynamics Simulation for Ion Transport Through a Transmembrane Pore with a Molecular Adapter. *Journal of Computational and Theoretical Nanoscience* **2010,** 7, (12), 2547-2554.

Lei, C.; Duch, M.; Robertson, I. M.; **Rockett, A.**, Effects of solution-grown CdS on Cu(InGa)Se-2 grain boundaries. *Journal of Applied Physics* **2010,** 108, (11).

Lin, Y.-W.; Yeung, N.; Gao, Y.-G.; Miner, K.; Tian, S.; Robinson, H.; **Lu, Y.**, Roles of glutamates and metal ions in a rationally designed nitric oxide reductase based myoglobin. *Proceedings of the National Academy of Sciences of the United States of America* **2010,** 107, 8581-8586.

Luan, B. Q.; **Aksimentiev, A.**, Control and reversal of the electrophoretic force on DNA in a charged nanopore. *Journal of Physics-Condensed Matter* **2010,** 22, (45).

Lyding, J. W., SURFACE CHEMISTRY Molecular cart-wheeling. *Nature Chemistry* **2011,** 3, (5), 341-342.

Mathew, D. C.; **Luthey-Schulten, Z.**, Influence of Montmorillonite on Nucleotide Oligomerization Reactions: A Molecular Dynamics Study. *Origins of Life and Evolution of Biospheres* **2010,** 40, (3), 303-317.

Naraghi, M.; Arshad, S. N.; **Chasiotis, I.**, Molecular orientation and mechanical property size effects in electrospun polyacrylonitrile nanofibers. *Polymer* **2011,** 52, (7), 1612-1618.

Naughton, M. S.; Brushett, F. R.; **Kenis, P. J. A.**, Carbonate resilience of flowing electrolyte-based alkaline fuel cells. *Journal of Power Sources* **2011,** 196, (4), 1762-1768.

Park, K.; Millet, L. J.; Kim, N.; Li, H. A.; Jin, X. Z.; **Popescu, G.**; **Aluru, N. R.**; Hsia, K. J.; **Bashir, R.**, Measurement of adherent cell mass and growth. *Proceedings of the National Academy of Sciences of the United States of America* **2010,** 107, (48), 20691-20696.

Radadia, A. D.; Stavis, C. J.; Carr, R.; Zeng, H. J.; **King, W. P.**; Carlisle, J. A.; **Aksimentiev, A.**; Hamers, R. J.; **Bashir, R.**, Control of Nanoscale Environment to Improve Stability of Immobilized Proteins on Diamond Surfaces. *Advanced Functional Materials* **2011,** 21, (6), 1040-1050.

Rogers, J. A., ELECTRONICS A diverse printed future. *Nature* **2010,** 468, (7321), 177-178.

Sottos, N. R.; **Moore, J. S.**, MATERIALS CHEMISTRY Spot-on healing. *Nature* **2011,** 472, (7343), 299-300.

Sumant, P. S.; **Cangellaris, A. C.**; **Aluru, N. R.**, A conformal mapping-based approach for fast two-dimensional FEM electrostatic analysis of MEMS devices. *International Journal of Numerical Modelling-Electronic Networks Devices and Fields* **2011,** 24, (2), 194-206.

Trabuco, L. G.; Schreiner, E.; Eargle, J.; Cornish, P.; Ha, T.; **Luthey-Schulten, Z.**; **Schulten, K.**, The Role of L1 Stalk-tRNA Interaction in the Ribosome Elongation Cycle. *Journal of Molecular Biology* **2010,** 402, (4), 741-760.

White, S. R.; **Geubelle, P. H.**, Self-healing materials: Get ready for repair-and-go. *Nature Nanotechnology* **2010,** 5, 247-248.

Xiong, F.; Liao, A. D.; Estrada, D.; **Pop, E.**, Low-Power Switching of Phase-Change Materials with Carbon Nanotube Electrodes. *Science* **2011,** 332, (6029), 568-570.

More than 8,000 visitors explored the March 2011 Beckman Institute Open House.

The Beckman Institute is an interdisciplinary research endeavor that shares its discoveries with the world. These efforts engage the public in many ways, including an innovative new program that is turning older adults into scientists.

This past year, a **Citizens Scientist** program was created in collaboration with the Institute for Genomic Biology, the Neuroscience program, and the Osher Lifelong Learning Institute (OLLI) at the University of Illinois. The program recruited OLLI members and then trained them to work in research labs — most affiliated with the Beckman Institute — with the mission of creating "a new community of citizens and scientists here at the University of Illinois that together will learn about, and discover new knowledge." A dozen OLLI members are taking part, and their work was highlighted in a poster session held at the OLLI building.

One of the traditional and still popular ways to share the story of Beckman research is through open house events. The biennial **Beckman Institute Open House** held in March of 2011 boasted its largest number of exhibits ever, with more than 8,000 visitors taking part in the fun and learning during the two-day event.

Open House 2011 featured the return of the Illinois Simulator Laboratory and its virtual reality environments like the flight and driving simulators after a hiatus due to its moving to a south campus location. In addition, Bert the iCub humanoid robot from Steve Levinson's Language Acquisition and Robotics group made its debut and was a popular attraction. Other exhibits included presentations on ongoing Beckman projects involving advances in imaging technologies, speech recognition, and neuroscience research, to name a few.

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. 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, has 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.

In addition, outside speakers have been brought to Beckman in order to explore current scientific topics and issues. In 2011 Pulitzer Prize-winning journalist and novelist **Matt Richtel** from the *New York Times* spoke on issues involving the press and science. The SmithGroup Lecture was presented in 2010, with Palm Pilot inventor and entrepreneur **Jeff Hawkins** speaking on neuroscience and machine intelligence.

The Beckman Institute is also home to training programs such as a campus effort to train researchers in how to collaborate in interdisciplinary neuroengineering projects. The institute plays host to training seminars and schools, such as the Nanobiophotonics Summer School held annually.

Beckman's educational outreach program Bugscope, operated by the Imaging Technology Group's Microscopy Suite, is now in its 12th year of bringing science into classrooms worldwide in a unique and memorable way. 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.

These efforts show that the Beckman Institute is more than a campus research facility. It is dedicated to scientific research that has benefits to larger communities and to sharing the science with those communities.

BECKMAN FACILITY:
BIOMEDICAL IMAGING CENTER

Since moving from its south campus location to the Beckman Institute in 2010, the Biomedical Imaging Center (BIC) has transformed itself from a facility with state-of-the-art magnetic resonance imaging (MRI) capabilities to one that now includes advanced optical, ultrasound, and molecular imaging modalities. The addition of these new instruments and several new staff members reinforce BIC's status as one of the premier campus-based imaging facilities.

Tracey Wszalek was named as Director of the Biomedical Imaging Center in 2011 after serving for many years as Associate Director. She takes over BIC as the core Beckman facility has undergone tremendous growth in terms of the number of users and in the expansion of its imaging modalities. BIC began on the south campus as a facility for magnetic resonance imaging but since moving into the Institute, added a Micro-PET/SPECT/CT machine for dynamic molecular imaging, a High Frequency Ultrasound Imaging System, and a frequency-domain diffusive optical imaging (DOT) system for advanced optical imaging. Wszalek said the diverse roster of imaging instruments now positions BIC perfectly for a center grant proposal.

"If not already there, we are enormously close to having all of the equipment and personnel necessary for generating a very compelling center grant application," she said.

The array of imaging modalities means BIC will now include four separate laboratories to house them and the research projects they serve. There is the Magnetic Resonance Imaging Laboratory (MRIL) for BIC's three magnets — the whole-body 3T MAGNETOM Trio MRI scanner, the 14T (600) MHz Varian NMR system, and the 3T Allegra headscanner — that play host to a wide variety of MRI and functional MRI studies focusing on humans and biological and materials samples.

Two labs are home to two imaging modalities that were added just last year. The Ultrasound Imaging Laboratory (UIL) plays host to a Visualsonics Vevo 2100 High Frequency Ultrasound Imaging System that gives researchers the ability to use ultrasound at frequencies up to about 55 megahertz, a capability that provides high resolutions for imaging samples such as tumors in animal models. The Molecular Imaging Laboratory (MIL) is home to the Micro-PET/SPECT/CT machine that performs dynamic molecular imaging, especially for researchers involved in pre-clinical medical research.

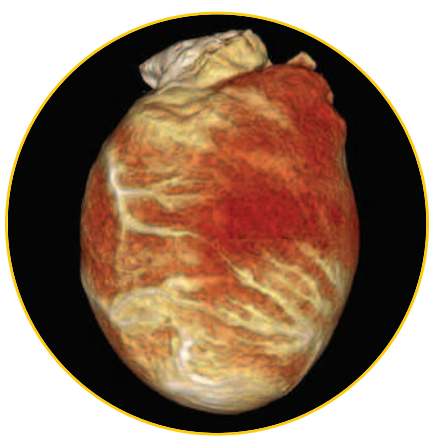
The fourth lab features BIC's new optical imaging system that was purchased and installed in 2011 and will be running experiments in the fall. The Diffuse Optical Imaging Laboratory (DOIL) boasts a unique frequency-domain diffusive optical imaging (DOT) system that was acquired with a grant from the National Institutes of Health from a proposal led by Beckman faculty member Gabriele Gratton. The DOT system is based on the same optical tomography method for recording event-related optical signals (EROS) from the brain used at the Cognitive Neuroimaging Laboratory (CNL) Gratton directs with Beckman colleague Monica Fabiani.

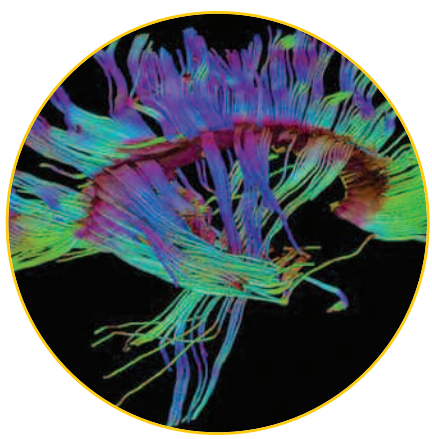
The diversity of studies taking place at BIC demonstrates the broad capabilities of this Beckman facility.

Current research projects include using MR to assess the impact of applying a cooling helmet in a variety of clinical settings. This work is being led by Dr. John Wang, a neurosurgeon at Carle Hospital. The MR systems are also engaged in functional studies of the impact of cardiovascular fitness on neurophysiology and cognition. The VisualSonics ultrasound system is being used to non-invasively monitor the progress of bone regeneration in frogs *in vivo*. The Micro-PET/SPECT/CT system is studying cardiac function in diabetic rat models.

Many of the research projects employing BIC's imaging modalities have real-world impact. However, Wszalek said, that is not the only goal of the Center.

"BIC seeks to both generate meaningful translational products and to pursue science that advances the field of imaging in general," she said. "All of our modalities are driven by the same principal to do things that are not only successful, but have broad significance in the field. We want high resolution, informative images to be the default; acquiring unique, impactful data that has not been acquired elsewhere is our mission."





Biomedical Imaging Center Capabilities:

Magnetic Resonance Imaging Laboratory (MRIL)

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.

MAGNETOM Allegra 3T MRI Headscanner

Primarily used for cognitive studies; also includes capabilities for animal scanning, including scans for clinical analyses.

MAGNETOM Trio Whole-body 3T MRI Scanner

This magnet is 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

These mock magnets are 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.

Ultrasound Imaging Laboratory (UIL)

High-resolution Ultrasound

A Visualsonics 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 a high degree of resolution to study topics such as disease development and processes in animal models.

Molecular Imaging Laboratory (MIL)

MicroPET/SPECT/CT

A molecular imaging instrument (MicroPET/SPECT/CT) used for imaging dynamic biological and material systems that was installed in the spring of 2011. 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.

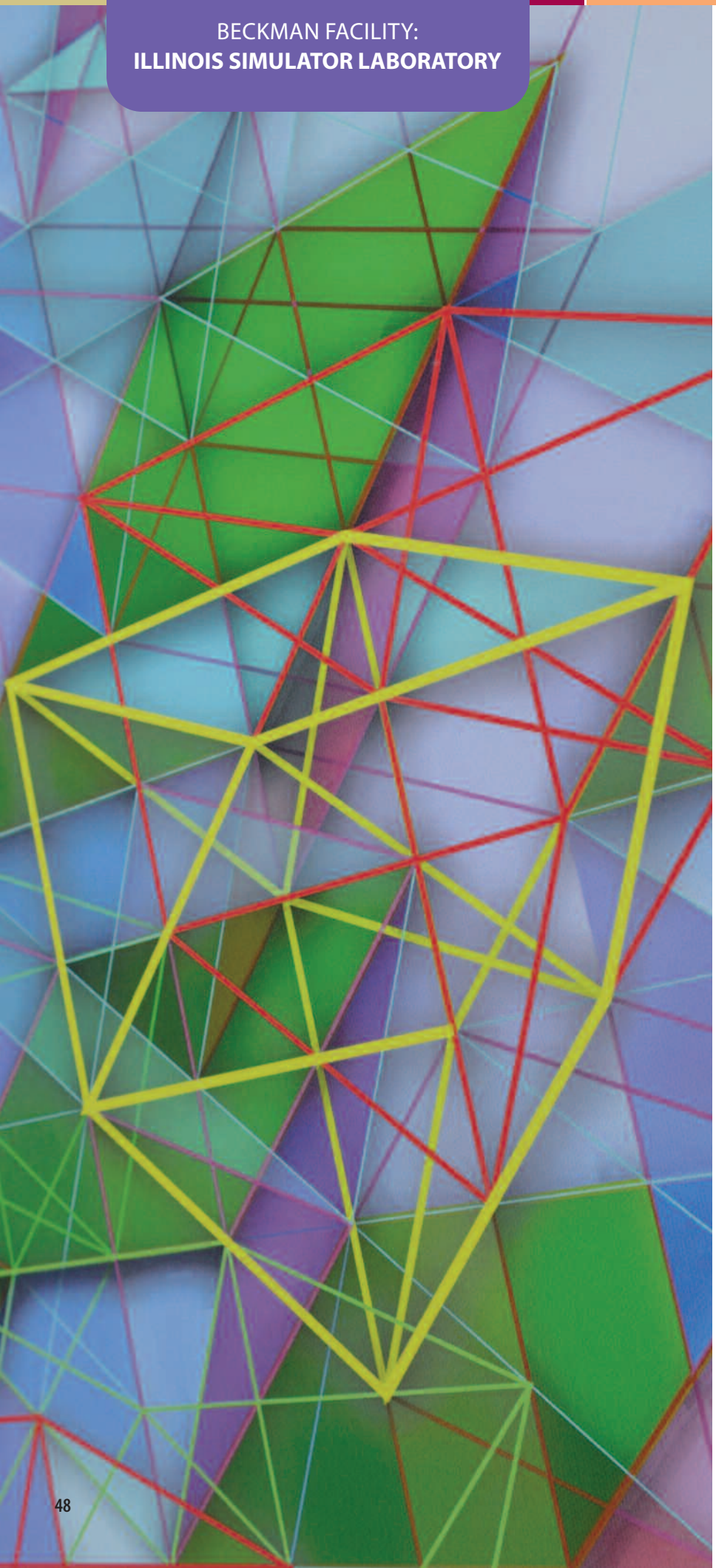
Diffuse Optical Imaging Laboratory (DOIL)

Frequency-domain Diffusive Optical Imaging System

An optical tomography imaging method that records event-related optical signals (EROS) from the brain. Using an ISS 128-source, 24-detector Dual-Imagent system from ISS, the technology has the ability to record up to 1,536 channels (source-detector combinations) for human and animal recordings, with the capability of recording four wavelengths.

Wawrzyniec Dobrucki, research scientist and adjunct faculty member in Bioengineering, works with the new Siemens Inveon MicroPET/SPECT/CT imaging system.

BECKMAN FACILITY:
ILLINOIS SIMULATOR LABORATORY



The Illinois Simulator Laboratory (ISL) has thrived after the move last year to its south campus location. The Beckman facility's highly advanced visualization environments for studies in human multimodal perception, cognition, human factors, and other areas have been extremely popular with researchers, according to ISL Director Hank Kaczmarski.

Kaczmarski said the move from the Beckman building has meant that ISL is better able to adapt to the needs of researchers from a variety of disciplines.

"If we need more facility space for a grander project, we control the ability to create that space. So we need to work more closely with researchers and students than when we could find space in a corner of the Beckman building," he said. "Our biggest concern was we were afraid nobody would come out here. The opposite is the case."

The Illinois Simulator Laboratory features two 3-D immersive virtual reality environments, the CAVE™ and the six-sided Cube, as well as a flight simulator, driving simulator, motion capture suite, a virtual reality experimental room, and virtual reality Immersadesks™. Kaczmarski said the Immersadesks and an audio visualization project in the Cube, in particular, have been expanding research boundaries in ways that show the rare capabilities of the Illinois Simulator Laboratory.

One of the three Immersadesks is being used as a testbed for developing strategies for teaching surgery in a virtual environment, with Beckman faculty members John Rogers from Material Science and Engineering and Torrey Loucks from Speech and Hearing Science involved in the project. They are presently using 3-D images rendered from CT scans of animal body parts that are displayed on a horizontal Immersadesk. Eventually, participants will use a virtual scalpel to learn and practice surgery on a virtual patient as sensors monitor their movements, giving haptic feedback to the "surgeon".

There are also two vertical Immersadesks in separate, isolated rooms that are part of an experiment which tests remote collaborations. Kaczmarski said the research is looking at what happens, for example, when virtual

rescuers in different locations try to locate a missing person, sometimes getting the same information from a screen, or sometimes different sorts of information — such as one seeing infrared resolution while another sees visual resolution, either with or without audio communication — while they are collaborating on a joint task.

The audio visualization project is called FODAVA (foundation of data analysis and visual analytics) but also known around ISL as "milliphone" because the technology represents turning a thousand sources of audio into a single visualization. Led by Beckman faculty members Thomas Huang and Mark Hasegawa-Johnson, the project has been able to take audio data like recordings and other large audio files and create graphical visualizations, such as a spectrograph, that make it much easier for users to examine that data.

"It is the kind of project that really highlights research that only Beckman could pull together," Kaczmarski said. "The facilities we have make the display of the visuals possible. This really stretches research because of the people and the equipment that we have at Beckman."

Kaczmarski said the CAVE is "booked solid" with experiments such as those using modified treadmills for testing both children in a study called FITKids, and older adults in several studies, including those involving pedestrians and a new study on the effects of acting on cognition.

"These are going on simultaneously and sequentially during the course of a week," Kaczmarski said. "Depending on when the kids are available or the older adults are available, we swap out the treadmills and recalibrate everything and get ready for the next set of experiments. So the CAVE is just phenomenally busy."

The flight simulator and its eye-tracking technology are being used for research by Beckman faculty member Alex Kirlik in a project funded by the FAA and NASA that studies the next generation of air traffic control systems. Previous studies were concerned with pilot interaction with air traffic control systems; the current phase of the project involves air traffic controllers interacting with multiple, elaborate displays.

"We want to find out how you get them to navigate this visual landscape that is way more complicated than the human brain can normally absorb," Kaczmarski said.

Kaczmarski said that ISL is always looking for new collaborations.

"If the worst problem I have is to put another addition on this building, my life would be perfect," he said. "I think over the next year we're going to try to go for more complex research, and I know that over the next year we are going to be involved in more large-group efforts to put in bids for collaborative research that nobody else in the world can do."

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.

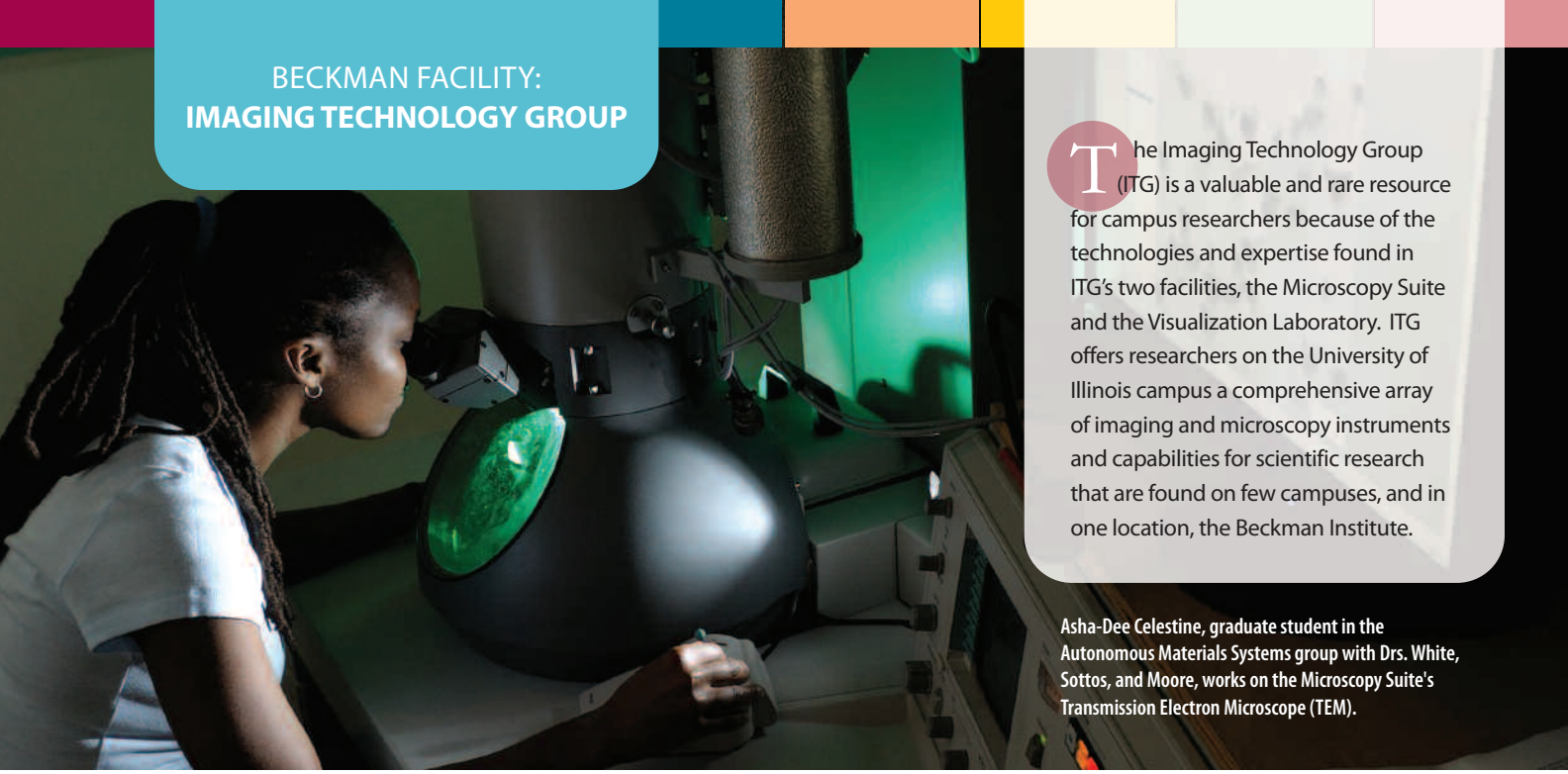
• Flight Simulator
Based on a Frasca 142 simulator cockpit, the ISL flight simulator has been continuously updated to meet aviation human factors researchers' requirements with state-of-the-art displays and other technologies. Featuring both a large-screen environment and LCD cockpit displays, the flight 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.

• 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.

• 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.

• Immersadesks
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.
The Immersadesks™ support monocular and stereo vision, head, eye, and hand tracking, and incorporate surround sound speaker systems. Two of the displays are portable, useful for demonstrating technologies at symposia and workshops, while a horizontal display ImmersaDesk is appropriate for "sand table" style applications.

BECKMAN FACILITY:
IMAGING TECHNOLOGY GROUP



The Imaging Technology Group (ITG) is a valuable and rare resource for campus researchers because of the technologies and expertise found in ITG's two facilities, the Microscopy Suite and the Visualization Laboratory. ITG offers researchers on the University of Illinois campus a comprehensive array of imaging and microscopy instruments and capabilities for scientific research that are found on few campuses, and in one location, the Beckman Institute.

Asha-Dee Celestine, graduate student in the Autonomous Materials Systems group with Drs. White, Sottos, and Moore, works on the Microscopy Suite's Transmission Electron Microscope (TEM).

Microscopy Suite

The Microscopy Suite continues to add to its array of instruments and resources, with new technologies and staff members able to push the limits of its four main modes of imaging: light microscopy, scanned probe microscopy, electron microscopy, and computed tomography (CT).

In order to maximize the capabilities of the instruments, this past year Dianwen Zhang, a Ph.D. in Biophysics, joined the facility as a light microscopist/spectroscopist.

"We are very lucky to have him," Microscopy Suite manager Scott Robinson said. "He began by benchmarking and improving the efficiency of every one of the instruments for which he is responsible."

The Suite is also preparing for a new addition to its roster of light microscopes: a confocal Raman imaging system that provides three-dimensional information on the location of molecules in tissue samples and in materials such as polymers. Robinson said the new system has capabilities, including performing transmitted Raman and reflected Raman microscopy, that aren't found anywhere else on campus.

"What you're going to be able to do is take a tissue sample and map the positions of molecules within it," Robinson said. "So if you have a heterogeneous sample where you have different molecules in different areas, you're going to be able to use Raman spectroscopy to show where those particular areas are with an x, y, and z map. You'll be able to look where particular chemical moieties are in biological samples as well as materials samples."

Robinson said the changes mean their facility is even better equipped to serve the needs of researchers, including a growing number from across campus and the country that are using the resource.

"We buy very complex instruments because we want people to be able to do everything conceivable with them," Robinson said. "Anything that somebody can think of that can be done, they are going to want to come along and do it. As long as it's not against the laws of physics we want to be able to accommodate them. What we want to do in the Microscopy Suite is have enough imaging modalities that we don't have to turn someone away."

Visualization Laboratory

The Visualization Laboratory is a premier campus support facility thanks to the wide variety of scientific imaging technologies and services it offers researchers and others at the University of Illinois. The Vis Lab provides graphics services such as image enhancement for journal covers and presentations, scientific research support that includes image analysis, animation and video production, 2-D and 3-D object scanning and printing, and audio production, just to name a few of its capabilities.

The Visualization Laboratory's fourth floor location in the Beckman Institute offers highly advanced equipment such as an ultra high-speed camera, a soundproof audio booth, a full-color 3-D printer, and new computer workstations that can power the most demanding of visualization tasks. The staff at the Vis Lab can provide highly professional assistance with images for journals or presentations, or for scientific research. Since 2010, the lab has had more than 20 covers, as well as other images, selected for use by journals, including an image chosen for the cover of the journal *Science*.

Visualization Laboratory manager Travis Ross wants to see users take advantage of all of the lab's visualization capabilities, especially those involving 3-D applications.

"My agenda is to grow these technologies and make the Vis Lab something that the university looks to as an expert in this area," he said. "We have great cameras, all the software applications, 3-D modeling tools, Amira, COMSOL, MATLAB. It's very versatile. Our goal is to make sure that everyone who's in the lab doing research has what they need."

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. The Skyscan Micro-CT also incorporates a tensile and compression stage.

• Light Microscopy
Suite users have access to 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 high-end stereozoom microscope with color-corrected imaging at 120,000 frames per second and wide lenses for large samples. These are in addition to other light microscopes, light-scattering particle sizing systems, and instruments capable of a number of different types of spectroscopy, from UV to visible light to NearIR and Raman.

• Scanned Probe Microscopy
This includes 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 a large number of optional imaging modalities, is an essential component of the Bugscope project, which has run continuously for more than 12 years. The transmission electron microscope (TEM), for which the Suite has designed and built a variety of specialized holders, has 2-Angstrom resolution and operates at accelerating voltages of up to 200 kV.

• Sample Preparation Equipment
The wide range of microscopes and spectroscopy equipment requires a comparable range of sample preparation instrumentation, from a critical point dryer to an ultramicrotome to a dual-metal evaporator, which is another example of an instrument that was designed and fabricated in response to requests from numerous researchers.

Visualization Laboratory Capabilities:

• Graphics Services
The Visualization Laboratory provides assistance with graphics and illustrations, including cover art and other images for journals and presentations. Working from concepts, photos, or other imagery, the Vis Lab staff members are able to render super high-resolution, professional quality images.

• Image Analysis
This capability includes obtaining qualitative and quantitative information from 2-D and 3-D image sets, including object detection, feature extraction and measurements, cell counting, and other microscopic results for scientific research.

• Scientific Visualization
Visualization capabilities include imaging, modeling, and simulating data, presented in various digital media formats: 2-D image, 3-D image, video, and animation, for both analysis and presentation.

• 3-D Object Scanning
The Vis Lab offers multi-point laser detection to create three-dimensional surface geometry of real-world objects; also used for object measurement and three-dimensional modeling.

• Audio Booth
The lab contains a soundproof audio booth for high-quality, professional audio recording and mixing, as well as a video editing suite for voiceovers or transfers from videos.

• 3-D Modeling
This capability allows for geometric modeling in three-dimensional space, using parameters based both on actual and simulated x-y-z directionals.

• Animation and Video Production
These facilities offer the ability to produce moving image sequences, created as communication resources for scientific presentation and for understanding of research findings.

• Color 3-D Printing
These 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
The Vis Lab offers 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
This capability offers high-magnification photography and video to capture research objects and scientific processes, for analysis and presentation purposes.

The Beckman Institute Fellows Program has, in its almost two decades of existence, afforded more than 70 postdoctoral scientists the rare opportunity to pursue their research goals unburdened by teaching or other work responsibilities. Postdoctoral researchers from across the country and around 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 the period 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 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.

Current Beckman Institute Fellows

2011 Fellows

Jonathan Fan

Jonathan earned a Ph.D. in Applied Physics from Harvard University in May, 2010. His research interests include creating new technologies and developing new concepts for cancer therapeutics. He is exploring novel flexible nanomedicine constructions that can be tailored both before and as they are administered. His goal is to improve the efficacy of nanomedicine phototherapy in the targeting and treatment of tumors.

Kyle Mathewson

Kyle earned a Ph.D. in Psychology from the University of Illinois. He has worked for more than three years in Beckman's Cognitive Neuroimaging Laboratory with Institute researchers Monica Fabiani and Gabriele Gratton. During his time at Illinois and Beckman, Kyle's research involved cognitive neuroscience, with a focus on attention and awareness in the human visual system. He plans to spend his time as a Beckman Fellow studying the prediction and control of brain states that influence subsequent perception, learning, brain activity, and even consciousness. He plans to take the research outside of traditional laboratory settings, monitoring brain a ctivity during virtual reality situations, in order to predict performance in more ecologically valid environments. Techniques and technology will be developed to monitor and adaptively manipulate these predictive brain states in order to improve cognitive function.

Meredith Silberstein

Meredith completed a Ph.D. in Mechanical Engineering from the Massachusetts Institute of Technology this spring. Her research interests are in the area of alternative energy harvesting and conversion methods that can perform electrochemical functions while maintaining mechanical integrity. Her work is aimed at developing microstructurally-based models for electro- and/or chemo-mechanically coupled materials that will facilitate system level design and design of new multifunctional composite materials. At Beckman Meredith plans to focus on mechanochemical transduction in synthetic material design, specifically characterization and development of mechanophores.

Joseph Toscano

After completing his Ph.D. in Cognition and Perception at the University of Iowa, Joseph joined the Fellows program to continue his research looking at how the perceptual system uses context information during speech perception. At Beckman he plans to use computational modeling and neuroimaging methods to investigate continuous cue encoding and categorization during speech processing,

apply his approaches to spoken word recognition, and examine effects of prosody and audiovisual speech.

Thomas van Dijk
Thomas van Dijk earned his Ph.D. in Physics at Vrije University in Amsterdam. His dissertation has a focus on theoretical and experimental studies in optical coherence theory, while his main areas of research include computed imaging, inverse problems, statistical optics and plasmonics. Van Dijk is interested in exploring theoretical frontiers in bio-optics, which uses light to study, manipulate, and treat biological samples, toward advancing the design of experimental methods and analysis of results. He plans to concentrate his work on problems in the imaging and diagnosis of disease in order to meet both clinical and research needs.

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 earned his Ph.D. in Cognitive Science from Johns Hopkins University in the fall of 2010. He was 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 earned a Ph.D. in the Energy and Resources Group at the University of California at Berkeley. 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 investigates 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 focuses 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 focuses 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 uses 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

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 non-conscious 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

Jongsick Kim
Jongsick joined Beckman's Biophotonics Imaging Laboratory, headed by Institute researcher Stephen Boppart, after serving as a postdoctoral research associate at the University of Pittsburgh. He earned his Ph.D. at Pittsburgh in Bioengineering. As the second Carle — Beckman Fellow, his project involving oncololgy-related research is titled "Magnetomotive optical coherence tomography (MM-OCT) image-guided hyperthermia of tumor lesions using targeted magnetic nanoparticles (MNPs)." Kim's goals include demonstrating real-time diagnostic MM-OCT imaging with molecular specific contrast enhancement of tumors, and enlarging the role of OCT technology as a diagnostic imaging modality.

Postdoctoral Fellows Program Alumni *(listed by class)*

2008
Michael Walsh (Carle Foundation Hospital/Beckman Institute Fellow), Ph.D. from Lancaster University in the United Kingdom
Agustín Mihi, Ph.D. from the University of Seville
Amy Shih, Ph.D. from the University of Illinois at Urbana-Champaign
Jacob Eisenstein, Ph.D. from the Massachusetts Institute of Technology

2007
Derek Hoiem, Ph.D. from Carnegie Mellon University
Zhi Jiang, Ph.D. from Purdue University
Séverine Lepage, Ph.D. from the University of Liège, Belgium
Jongseung Yoon, Ph.D. from the Massachusetts Institute for Technology

2006
Joseph B. Geddes III, Ph.D. from Pennsylvania State University
Yael Gertner, Ph.D. from the University of Pennsylvania
Ming Hsu, Ph.D. from the California Institute of Technology
Mark Neider, Ph.D. from Stony Brook University
Stephanie Rinne, Ph.D. from the University of Illinois
Sarah Brown-Schmidt, Ph.D. from the University of Rochester
Dirk Bernhardt-Walther, Ph.D. from the California Institute of Technology

2005
Chandramalika Basak, Ph.D. from Syracuse University
Emma Falk, Ph.D. from Helsinki University
Silvio Savarese, Ph.D. from CalTech
Zhihong Zeng, Ph.D. from the Chinese Academy of Sciences

2004
Byron McCaughey, Ph.D. from Tulane University
Michelle Meade, Ph.D. from Washington University, St. Louis
Timothy Nokes, Ph.D. from the University of Illinois, Chicago
Maxim Raginsky, Ph.D. from Northwestern University

2003
Joshua Ballard, Ph.D. from the University of Colorado
Richard Godijn, Ph.D. from Vrije Universiteit, Amersterdam
Mathews Jacob, Ph.D. from the Swiss Federal Institute of Technology
Ryan Kershner, Ph.D. from the Massachusetts Institute of Technology

2002
Tyler Bruns, Ph.D. from the University of Illinois
Stan Colcombe, Ph.D. from the University of Illinois
Diego Diaz, Ph.D. from Cornell University
Sarah Grison, Ph.D. from the University of Wales
Cristina Iani, Ph.D. from the University of Bologna

2001
Michael Bevan, Ph.D. from Carnegie Mellon University
Donald Cannon, Ph.D. from Penn State University
Christina Grozinger, Ph.D. from Harvard University
Jesse Spencer-Smith, Ph.D. from Indiana University

2000
John Paul Minda, Ph.D. from SUNY, Buffalo
Slava Rotkin, Ph.D. from Ioffe Institute, Russia
Ilya Zharov, Ph.D. from University of Colorado

1999
Dale Barr, Ph.D. from University of Chicago
Hong Hua, Ph.D. from the Beijing Institute of Technology
Jason McCarley, Ph.D. from the University of Louisville
Lolita Rotkina, Ph.D. from the Ioffe Physico-Technical Institute

1998
Michal Balberg, Ph.D. from the Hebrew University of Jerusalem
Gregory DiGirolamo, Ph.D. from the University of Oregon

1997
Brendan Frey, Ph.D. from the University of Toronto
Tammy Ivanco, Ph.D. from McMaster University

1996
Srinivas Akella, Ph.D. from Carnegie Mellon University
Jose Jimenez, Ph.D. from Columbia University
Chen Liu, Ph.D. from the Techinion-Israel Institute of Technology

1995
Prahlad Gupta, Ph.D. from Carnegie Mellon University
Gregory Zelinsky, Ph.D. from Brown University

1994
Barbara Church, Ph.D. from Harvard University
Narayan Srinivasa, Ph.D. from the University of Florida

1993
Andreas Herz, Ph.D. from Heidelberg University
Rejeev Sharman, Ph.D. from the University of Maryland

1992
Andrew Nobel, Ph.D. from Stanford University
Efrat Shimshoni, Ph.D. from The 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.

Sumit Ashtekar

A doctoral candidate in Chemistry at the University of Illinois, Sumit Ashtekar has a research goal of unlocking the mystery of glass transition. Sumit uses ultrahigh vacuum scanning tunneling microscopy in order to gain insight into something that has eluded scientific explanation: a fundamental understanding of the physical processes involved when glasses undergo a rapid and super-exponential increase in viscosity when cooled around the glass transition temperature. He works with Beckman Institute faculty members Joe Lyding and Martin Gruebele in his research.

Jessie Chin

Jessie Chin is a Ph.D. candidate in Educational Psychology who earned a Master's at Illinois in Human Factors. Jessie's research focus will be on modeling differences in cognitive foraging behavior between younger and older adults. Her research goals include developing a mathematical model of age differences in cognitive foraging for information and demonstrating the adaptation process in interactive learning of dynamic cognitive foraging tasks for both basic research purposes and for applications such as design of web interfaces for senior users. She is working with Beckman faculty members Elizabeth Stine-Morrow, Dan Morrow, and Wai-Tat Fu.

Amy Maduram

Amy Maduram is in the Medical Scholars and Neuroscience programs at Illinois, working toward a Ph.D. in Neuroscience/Neuroengineering and an M.D. Amy's research integrates neuroscience and engineering to investigate how individual demyelinating neurons in well-defined neuronal networks influence our sensations of pain. The work has potential applications in the development of new therapies for alleviating pain. Amy collaborates with Beckman faculty Jonathan Sweedler, William Olivero, and Douglas Jones in her research efforts.

Feng Xiong

Feng Xiong is a Ph.D. candidate in Electrical Engineering at Illinois with a research interest in ultra-low power phase change memory for data storage. As a Beckman Graduate Fellow, Feng will explore the fundamental limits at which data storage is possible in phase-change materials. When used for information storage, they have the speed of dynamic random access memory but without its disadvantages such as volatility. Feng works with Eric Pop and William King in his research endeavors.

Yue Zhuo

Yue Zhuo is working toward a Ph.D. in Bioengineering at Illinois. Her research is aimed at understanding the molecular mechanism governing migration and cancer metastasis at subcellular levels. Yue uses fluorescence resonance energy transfer sensors to study cancer cell dynamics and migration with an ultimate goal of developing highly integrative image analysis paradigms which can bridge the field of fluorescence live cell imaging and quantitative science. Yue is working with Beckman researchers Peter Wang and Zhi-Pei Liang.

Private Support—Key to Sustaining a World-Class Institute

Private support for the world-class research that takes place at the Beckman Institute has been a major contributor to its success for more than 20 years. Funding from the Arnold and Mabel Beckman Foundation and other foundations, as well as corporations and individuals, has made possible programs like the Beckman Fellows and the Beckman Support Fund. In the past two years, donations from generous individuals and foundations have led to the creation of scholarships and funds to support students and postdoctoral researchers in a number of important areas. These include the **Erik Haferkamp Memorial Fund,** the **Nadine Barrie Smith Memorial Fund,** the **Thomas and Margaret Huang Fund for Graduate Research,** the **Carle Foundation Hospital — Beckman Institute Fellow award,** and the **Beckman Institute Scholarship Fund.**

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 projects, and the people who make interdisciplinary research at the Beckman Institute a reality.

State support for the University of Illinois has dropped by more than half in the last few decades, making private support more important than ever. This is especially true when it comes to supporting the students who perform so much of the work that takes place in research groups. The Beckman Fellows program has supported postdoctoral and graduate fellows for more than 15 years, with the Carle Foundation Hospital —Beckman Institute Fellow program entering its third year. It is hoped these newer scholarship and memorial funds will generate the kinds of research successes that have come out of those other programs.

"Real generosity toward the future lies in giving all to the present."
– Albert Camus

Scholarships and Fellowships

The Arnold and Mabel Beckman Foundation began funding Fellows programs at the Beckman Institute in 1991, and that support for the Postdoctoral and Graduate Fellows programs continues today. In recent years, scholarship and memorial funds have been created to further support undergraduate, graduate, and postdoctoral researchers. The Nadine Barrie Smith Memorial Fund supports women engineers in medical imaging, with Yue Wang and Cac Nguyen chosen in 2011 as the first recipients of this award. The Erik Haferkamp Memorial Fund supports undergraduate research in neuroscience, with Shi Chen selected as the first recipient in 2011. The Thomas and Margaret Huang Fund for Graduate Research supports graduate research in human-computer intelligent interaction, the area of focus for Beckman faculty member Tom Huang. The Carle Foundation Hospital - Beckman Institute Fellow provides support for a recent Ph.D. or M.D./Ph.D. to conduct oncology-related research. Jongsick Kim was chosen as the second Carle-Beckman Fellow in 2011. In addition, the Beckman Institute Scholarship Fund is used to help train students to become the next generation of scientists and engineers, teachers, and business leaders. The Beckman Support Fund was created to sustain undergraduate and graduate student research and to enable ongoing upgrades to scientific equipment and facilities.

Corporate and Foundation Giving

Many corporations and foundations help make research at the Beckman Institute possible (see page 59). From the continuous support of the Beckman Foundation since the Institute opened in 1989, to donors such as Carle Foundational Hospital, Ellis Medical Foundation, the American Chemical Society, and the American Heart Association, private organizations have been and continue to be vital to the Institute's research success. Corporate donors also play an important role in supporting research at Beckman. Prominent companies such as Google, Samsung, Pfizer, and NEC Laboratories are among those who have made generous contributions to work at the Institute. In addition, individuals can double the impact of their gift if they work at one of the thousands of corporations that match or even exceed their employees' charitable contributions. These gifts also serve to fulfill membership requirements in university donor recognition groups for individuals as they are credited with the entire amount of the gift, including any matching gifts. More information on matching gifts can be found online at http://www.beckman.illinois.edu/giving.

Giving Perspectives

Andrew Webb, Jean Smith, and Arnette Bosch, donors, Nadine Barrie Smith Memorial Fund

"In the 1990s Nadine was inspired to follow an academic career by the support she received from fellow female engineers at the University of Illinois. As a professor, she made this type of support and mentoring a key component of her research and teaching, in turn inspiring a new generation of successful, motivated female engineers. The Nadine Barrie Smith Memorial Fund is dedicated to honoring her spirit and inspiration for generations to come." *— Andrew Webb*

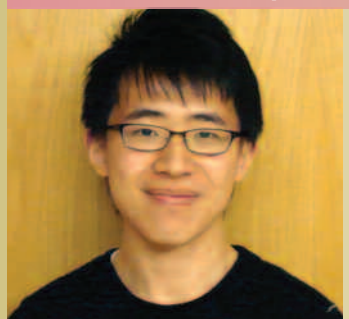
Yue Wang, student recipient, Nadine Barrie Smith Graduate Fellowship

"Getting the Nadine Barrie Smith Scholarship is a great honor for me. It means a lot to me not only because my previous work has been valued by the community but also it gives me the impetus to work harder on my career path. For me, the scholarship embodies the good will and hope of the Smith family to young researchers. It gives me confidence and courage to go further in my career to be a great professor like her. I am sincerely grateful for this scholarship."

Cac Nguyen, student recipient, Nadine Barrie Smith Graduate Fellowship

"When I saw the Nadine Barrie Smith Fellowship announcement on the Beckman website, it talked about biomedical imaging for women, so it was perfect for a student like me. Also, I looked at the profile and saw she was a student and then faculty here. So that is similar to me too. I'm a student here and I will go back to my home country to be faculty. I came here on a fellowship and will go back to help students in my own country, to give them the knowledge I learned here."

Shi Chen, student recipient, Erik Haferkamp Memorial Scholarship



"The project I am working on this summer is an important part of the research focus in my lab and will become the foundation of my future research cooperating with the other lab members in the next two years. Earning the Haferkamp Scholarship helps me to concentrate on this independent research project as a full-time researcher and motivates me to invest as much effort as possible in the study of neuroscience as Erik Haferkamp himself did."

Jongsick Kim, postdoctoral recipient, Carle Foundation Hospital - Beckman Institute Fellow

"This fellowship improves the quality of my research. If I had to teach that amount of time, it would sacrifice time that I could be doing research. I was very excited to get this fellowship. I didn't really expect it but I'm honored."

INDIVIDUAL DONORS

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Mrs. Arnette Bosch
Mrs. Jean S. Smith

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Dr. Mario E. Zelaya
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CORPORATE AND FOUNDATION DONORS

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Arnold and Mabel Beckman Foundation

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Carle Foundation Hospital
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Society for Psychophysiological Research
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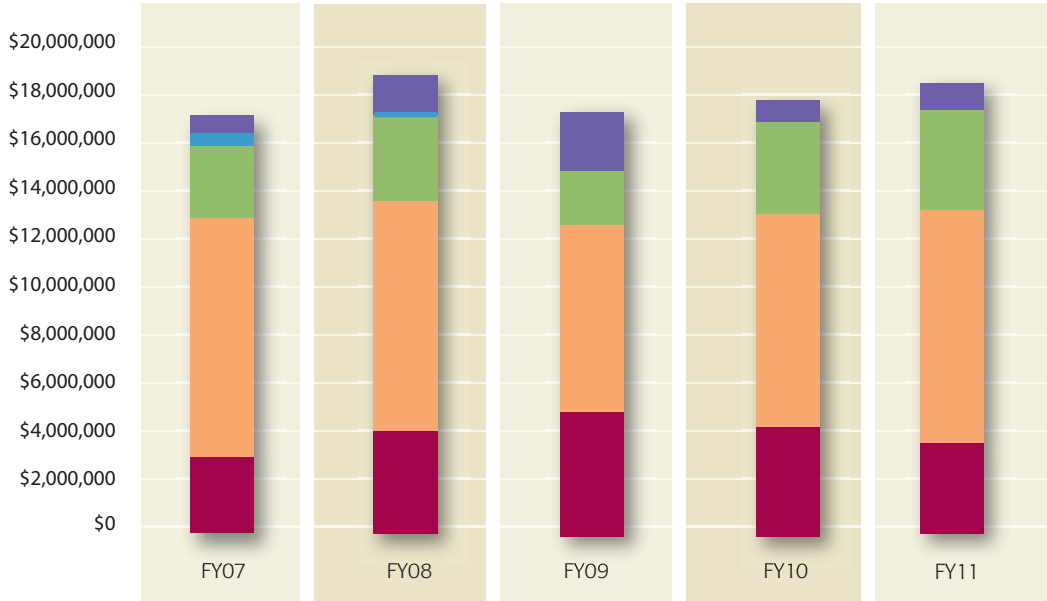
Research Expenditures **by Funding Source**[1]



	FY07	FY08	FY09	FY10	FY11
DOD	$ 3,172,803	$ 4,217,584	$ 5,238,196	$ 4,358,155	$ 3,869,004
NIH	$ 9,889,110	$ 9,444,099	$ 7,518,406	$ 9,072,558	$ 9,705,827
NSF	$ 3,004,266	$ 3,596,633	$ 2,310,613	$ 3,403,358	$ 4,050,734
IBHE	$ 512,229	$ 223,626	$ (1,674)	$ -	-
Other	$ 1,008,914	$ 1,151,309	$ 2,578,214	$ 1,075,980	$ 770,525
Total	$ 17,587,322	$ 18,633,251	$ 17,643,755	$ 17,910,050	$ 18,396,090

Research Awards **by Funding Source**[2]

	FY07	FY08	FY09	FY010	FY11
DOD	$ 11,012,039	$ 7,030,763	$ 2,115,780	$ 2,831,689	$ 3,001
NIH	$ 7,450,733	$ 15,036,128	$ 5,234,846	$ 7,488,077	$ 13,879,105
NSF	$ 2,349,181	$ 4,628,500	$ 1,693,264	$ 6,747,793	$ 2,578,574
Other	$ 5,262,943	$ 1,917,393	$ 666,790	$ 683,834	$ 894,094
Total	$ 26,074,896	$ 28,612,784	$ 9,710,680	$ 17,751,393	$ 17,354,774

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.

BECKMAN INSTITUTE CONTACT INFORMATION

The Beckman Institute for Advanced Science and Technology
University of Illinois at Urbana-Champaign
405 North Mathews Avenue
Urbana, IL 61801
Phone: 217-244-1176
Fax: 217-333-2922
Web: beckman.illinois.edu

Director:
Art Kramer
Phone: 217-244-8373
Email: a-kramer@illinois.edu

Associate Director for Administration:
Mike Devocelle
Phone: 217-244-8380
Email: mdevocel@illinois.edu

Biological Intelligence Research Theme Co-chairs:
Jennifer Cole
Phone: 217-244-1116
Email: jscole@illinois.edu

Mark Nelson
Phone: 217-244-1371
Email: m-nelson@illinois.edu

Human-Computer Intelligent Interaction Research Theme Co-chairs:
Thomas Huang
Phone: 217-244-1638
Email: thuang1@illinois.edu

Dan Morrow
Phone: 217-244-1828
Email: dgm@illinois.edu

Integrative Imaging Research Theme Co-Chairs:
Stephen Boppart
Phone: 217-244-7479
Email: boppart@illinois.edu

Zhi-Pei Liang
Phone: 217-244-4023
Email: z-liang@illinois.edu

Molecular and Electronic Nanostructures Research Theme Co-Chairs:
Narayana Aluru
Phone: 217-333-1180
Email: aluru@illinois.edu

Nancy Sottos
Phone: 217-244-6901
Email: n-sottos@illinois.edu

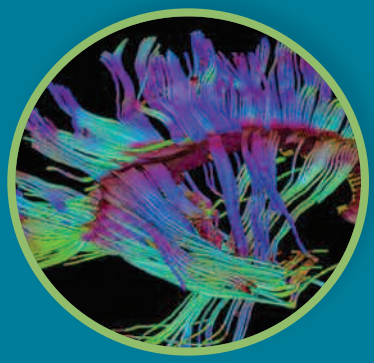
Biomedical Imaging Center
Tracey Wszalek, Director
Phone: 217-333-3149
Email: traceyws@illinois.edu

Illinois Simulator Laboratory
Hank Kaczmarski, Director
Phone: 217-244-5412
Email: kacmarsk@illinois.edu

Imaging Technology Group
Scott Robinson, Microscopy Suite
Phone: 217-265-5071
email: sjrobin@illinois.edu

Travis Ross, Visualization Laboratory
Phone: 217-244-9033
Email: travisr@illinois.edu

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, Pat Mayer, and the Beckman Institute Communications Office.



Beckman Institute

FOR ADVANCED SCIENCE AND TECHNOLOGY

University of Illinois at Urbana-Champaign
405 North Mathews Avenue
Urbana, Illinois 61801, U.S.A.
beckman.illinois.edu