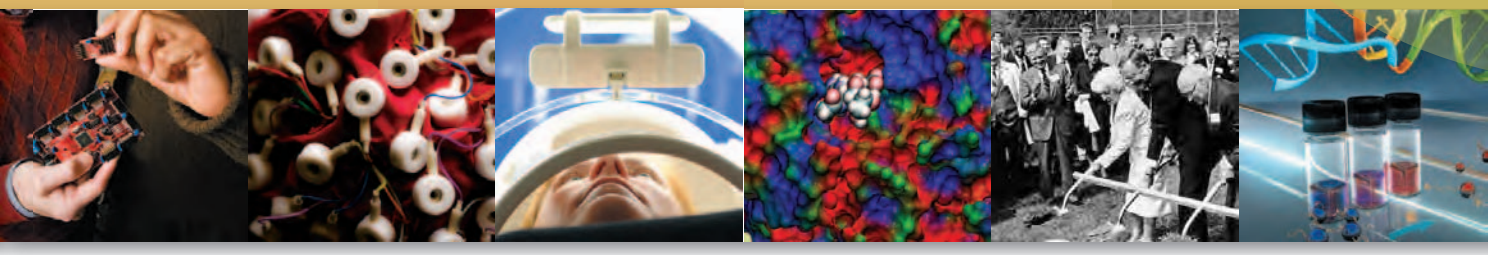
Annual Report **2008-2009**

Beckman Institute for Advanced Science and Technology

1989-2009



IMAGINING POSSIBILITIES WITHOUT BOUNDARIES

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 (see page 4)
- Human-Computer Intelligent Interaction (see page 10)
- Integrative Imaging (see page 16)
- Molecular and Electronic Nanostructures (see page 24)

The Beckman Institute is also home to two strategic initiatives (see page 40) that seek to unify campus activities in their respective areas:
- Imaging
- Social Dimensions of Environmental Policy

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

To assist research efforts, the Beckman Institute provides state-of-the-art resources for faculty, staff, and students, including the:
- Biomedical Imaging Center (see page 42)
- Illinois Simulator Laboratory (see page 44)
- Imaging Technology Group (see page 46)

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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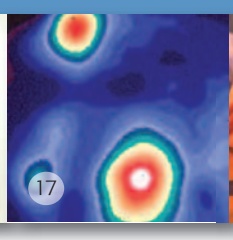
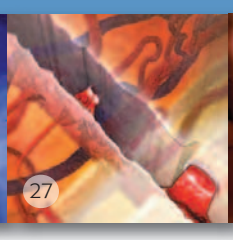
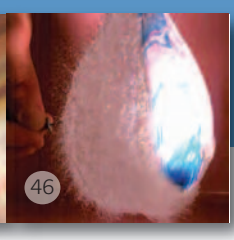






Director's **Message**

Imagining possibilities without boundaries. That philosophy has been at the core of the Beckman Institute since its inception in the 1980s. As we review the accomplishments of this past year it is also important to reflect on the imagination and determination of our faculty, staff, and students who have each contributed to our long-standing, global reputation of being a leader in interdisciplinary research.

In this past year there has been much change and growth at the Beckman Institute. As I write my inaugural Director's Message, I would like to extend thanks to Pierre Wiltzius for serving as the Institute's Director from 2001 to 2008. Like Founding Director Ted Brown, and his successor, Jiri Jonas, Pierre provided vision for the future while also upholding the traditions that are strongly in place at the Institute.

I am very pleased to be on board during the Beckman Institute's 20th Anniversary year. On April 16 we held a celebration that brought back many Beckman friends and family. The gala event featured remarks from Chancellor Richard Herman; Stanley Ikenberry, President Emeritus; Mort Weir, Chancellor Emeritus; Patricia Beckman, daughter of Arnold and Mabel Beckman; Jiri Jonas, Director from 1993-2001; Pierre Wiltzius, Director from 2001-2008, and a keynote speech from Ted Brown, the Institute's Founding Director. This celebration was a great time to reflect on the past 20 years with people with both past and present connections to the Institute.

As I write this message, we are also looking forward to our 20th Anniversary Symposium which will be held October 5-7, 2009, starting in the evening of October 5. The anniversary planning committee has done a tremendous job in putting together an excellent program, that features an evening keynote address from Nobel Laureate Susumu Tonegawa. The morning session keynote speakers are Thomas R. Insel, Director of the National Institute of Mental Health, and nanoscientist Charles M. Lieber of Harvard University. The program also includes some of our very own world-renowned researchers. It is sure to be an interesting and enjoyable meeting that I hope will bring our Beckman family and friends back to campus.

Earlier I alluded to change and growth that has occurred at the Institute this past year. One of the most exciting – and arduous – of these changes is the space swap between the Biomedical Imaging Center and the Illinois Simulator Laboratory. I am pleased to report that this well-orchestrated place swap is progressing very well and is on schedule. The Illinois Simulator Laboratory staff is now moved to their south campus location and the Biomedical Imaging Center is putting the final pieces in place in the Beckman Institute basement. The new 3T whole body magnet was delivered on July 8 and is expected to be fully operational in the coming months. Special thanks to our operations staff and the ISL and BIC staffs for their diligence and patience with this project.

Our research themes are thriving and have also seen changes this past year. For the first time in 15 years a new theme was added to our roster: Integrative Imaging. This theme will initially be comprised of two groups that were formerly a part of our Biological Intelligence theme: Bioimaging Science and Technology and the Bioacoustics Research Laboratory. Stephen Boppart and Zhi-Pei Liang are serving as co-chairs for this new theme.

The Molecular and Electronic Nanostructures research theme went through its external review this year, which happens every four years. The review committee was very pleased with the presentations and the high-level scientific activity that is being carried out within the individual research groups. They were also pleased with activity that is taking place across research groups.

Our other two research themes, Biological Intelligence and Human-Computer Intelligent Interaction, are also doing very well. I invite you to

Imagining Possibilities Without Boundaries

review their sections of this annual report to get up to date on their research activities.

All of the Beckman Institute research themes, and for that matter the Beckman Institute as a whole, will be reviewed in November of 2009 by our External Advisory Committee. We look forward to this opportunity as it provides us with invaluable external views on what we are doing well and where we can improve or change.

The Beckman Institute also added two new strategic initiatives this year: Imaging and Social Dimensions of Environmental Policy (SDEP). These campus-wide initiatives are both seeking to unify efforts in their respective areas. The strategic initiative on Imaging is led by Stephen Boppart and will be building a collaborative community of faculty, researchers, and students in imaging science, imaging technology, and the application, use, and interpretation of images. SDEP is led by Jesse Ribot and is aiming to understand the social, political, and economic forces that are shaping just and sustainable environmental policy. As the Beckman Institute enters its third decade it will be very interesting to see how both of these initiatives develop and grow.

Also emerging this year is a developing initiative, Healthy Bodies, Brains, Minds, and Communities. This fledgling effort sprung from a position paper put together with input from numerous faculty members with expertise in health-related issues. This growing initiative will capitalize on the Institute's existing strength in the life sciences, the social and behavioral sciences, and engineering.

In the past year Beckman Institute faculty members authored over 750 publications and were inventors on 12 issued patents and 37 patent applications. They also received numerous honors and awards. Among the especially notable honors and their recipients are: Stephen Boppart who was named Fellow of SPIE, the International Society for Optical Engineering; Kenneth Suslick who was named a Fellow of the Materials Research Society; Yingxiao Wang who received the National Science Foundation Early Career Award; Gabriele Gratton who was elected the President of the Society for Psychophysiological Research; Narendra Ahuja and Thomas Huang who received the HP Open Innovation Research Award; and Nicholas Fang who was named one of the world's 35 Top Young Innovators by *Technology Review.*

In June the Beckman Institute was host to a wonderful celebration that honored Bill Greenough, one of our founding faculty members and a co-chair of the Biological Intelligence research theme. Bill is moving to Emeritus status, and to honor him his colleagues organized a day-long symposium that featured numerous scientists with connections to Bill and his renowned neuroscience research. We wish Bill the very best as he begins the transition to Emeritus status, with however a full affiliation with the Beckman Institute.

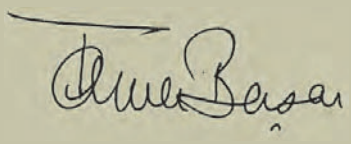
Beckman Institute faculty members also continue to be very active in garnering funding in these particularly challenging times. Some of the major funding awards include a $1.2 million supplement award from the US Army Research Office to Paul Braun and his collaborators for their research on "Self-Assembly of 3-D Multifunctional Ceramic Composites for Photonics and Sensors." Wendy Heller, Greg Miller, Brad Sutton and their collaborators also received nearly $1.2 million from NIH for their research on executive function. There were many other large awards that are too numerous to mention here. Our faculty should be extremely proud of their ability to attract major funding dollars at this time.

As grant funding becomes increasingly competitive, we are more and more thankful for the generous support of the Beckman Foundation. The Foundation has been a tremendous supporter of the Beckman Institute and without their continued funding we would not be able to maintain the level of excellence that we are accustomed to achieving.

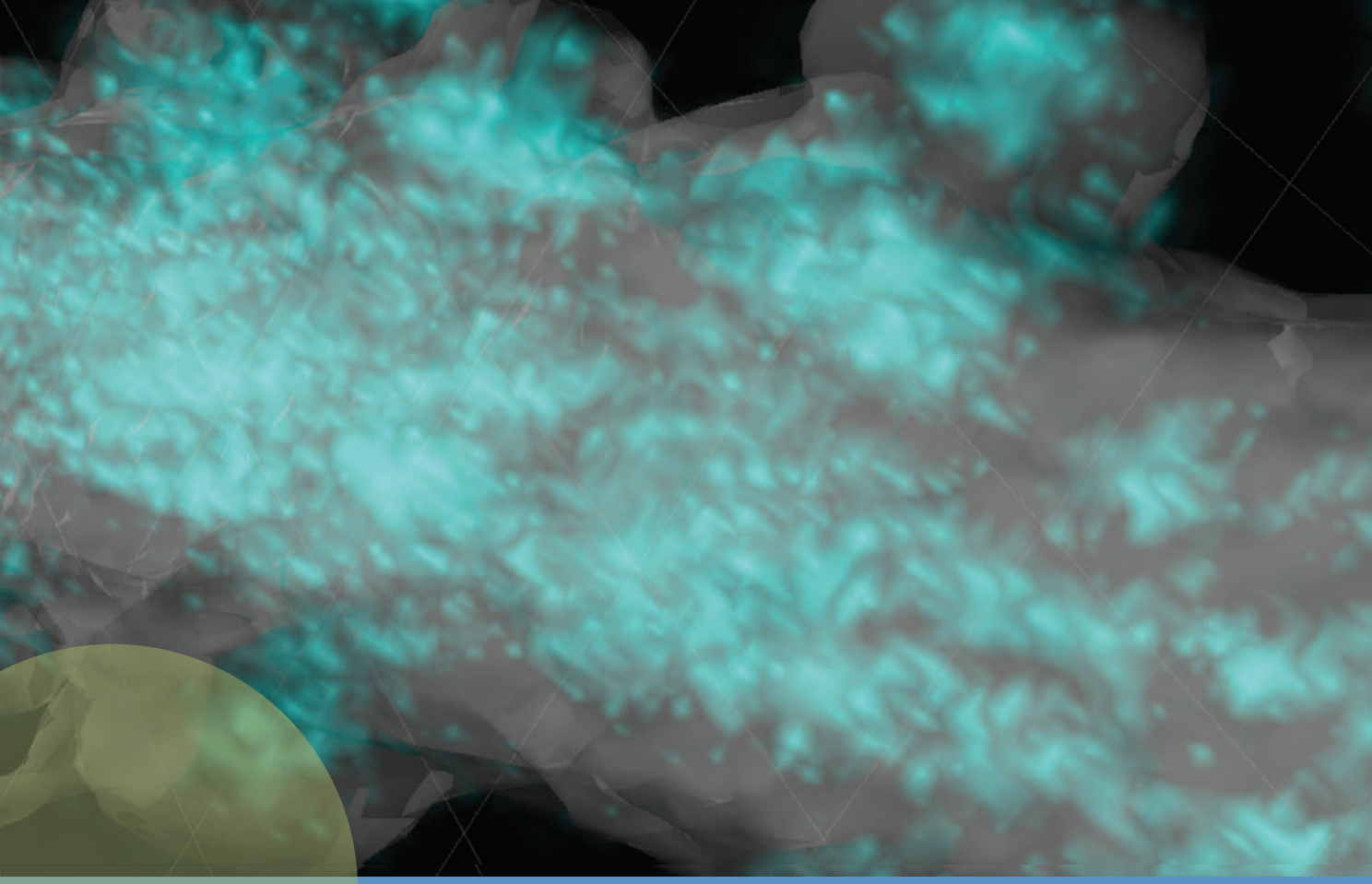
Additionally, in an effort to further supplement research, operations, and capital efforts, we have recently added a Development Office at the Beckman Institute. Fundraising will of course be one of the goals of this newly created office, but another important goal will be to connect with Beckman Institute "alumni." We hope to build lasting relationships with those of you who have spent time here and have helped shape the Institute into what it is today.

Over the years the Beckman Institute has always been involved in various educational outreach efforts. Perhaps one of our most visible – and popular – is our biennial Open House. In March we were pleased to open our doors to thousands of enthusiastic visitors of all ages. I believe we left a lasting impression with our guests and I thank all the exhibitors and volunteers for making this possible. Additional congratulations go to Bugscope for keeping its outreach program thriving for 10 years. Over this period, they have interacted with hundreds of children from around the world to give them an inside look at both microscopy and entomology.

As you can see this has been an incredible year of change, growth, and activity at the Beckman Institute. I hope you enjoy perusing the pages of this report to learn more about how we have been imagining possibilities without boundaries.



Tamer Başar, Interim Director



OVERVIEW: BIOLOGICAL INTELLIGENCE

Biological Intelligence was one of three original research themes created in 1994, but the concept of an entire area centered on studies of the brain, intelligence, and behavior was included in the earliest discussions about creating a multi-disciplinary research facility on campus.

When Beckman Institute Founding Director Ted Brown sought out two University of Illinois faculty members to chair separate committees to create proposals for such a center, he tapped current Biological Intelligence research theme Co-chair **William Greenough** to head one of them. Greenough's committee report envisioned a "Center for Biology, Behavior, and Cognition" and when the Beckman Institute officially opened in 1989, studies involving psychology and neuroscience were a critical element of its research life.

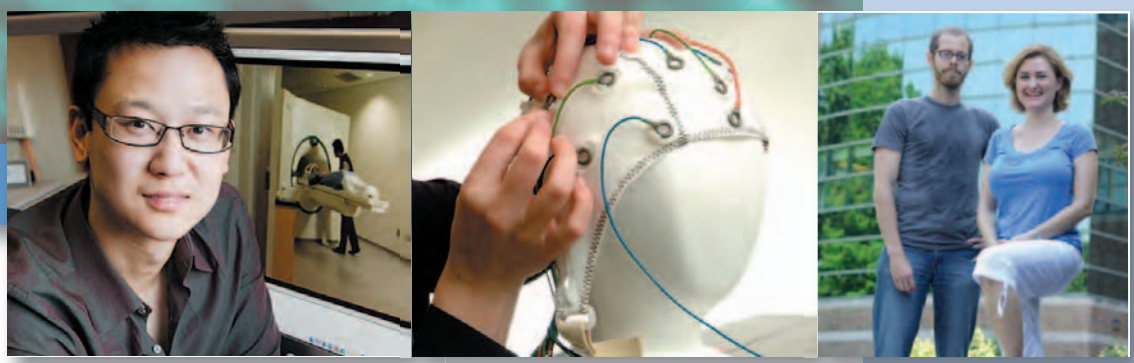
Twenty years later, faculty from Psychology are joined in the Biological Intelligence (BioIntel) research theme by those from departments like Linguistics, Chemistry, Electrical and Computer Engineering, and Molecular and Integrative Physiology, as they explore topics involving the brain and cognition from the level of molecules and cells to higher expressions of intelligence such as language acquisition and behavior.

The BioIntel research theme is comprised of three groups: Cognitive Neuroscience, Cognitive Science and NeuroTech. Cognitive Neuroscience research involves studying the relationships between brain function and structure and cognitive functions like memory, emotion, and attention. Cognitive Science researchers study higher mental processes and how humans represent knowledge and process information with a focus on learning and language. Work in the NeuroTech group bridges the gap between fundamental neuroscience research and technological application areas at the molecular, cellular, and systems level.

These research lines may take different paths in research involving disorders and diseases but they are all geared toward increasing our understanding and finding ways to prevent or treat them. For example, in the fight against Fragile X syndrome, the most common cause of inherited mental impairment and the most common known cause of autism, Greenough has led research into the neural processes associated with the disorder. Fellow NeuroTech group members **David Clayton** and **Stephanie Ceman** are using the zebra finch songbird as a model to gain insight into the speech pathology of those suffering from Fragile X syndrome.

Other researchers tackle behavioral issues such as the genetic and environmental causes of alcoholism and drug addiction (**Justin Rhodes**), economic choices (**Ming Hsu**), and anxiety (**Greg Miller and Wendy Heller**), to name a few. BioIntel researchers also investigate brain function at its most basic levels, looking at communication between neurons (**Charles Cox**) and the chemistry of the brain (**Jonathan Sweedler**).

A wide variety of research topics focus on higher forms of intelligence such as memory (**Neal Cohen**, who studies amnesia and **Brian Gonsalves**, who just earned funding for his project involving neural bases of memory), the mechanisms of sound pattern recognition in animals (**Albert**



Biological Intelligence Research Groups

- Cognitive Neuroscience
- Cognitive Science
- NeuroTech

Feng), learning (**Brian Ross**), and emotional processes (**Wendy Heller**).

The study of linguistics continues to be a key element of research within BioIntel. **Jennifer Cole** led a large transcription study that has created the largest prosody-labeled speech corpus in existence. Language research within BioIntel is diverse and includes issues such as language comprehension (**Susan Garnsey**), computer modeling of language processing (**Gary Dell**), spoken language acquisition (**Cynthia Fisher**), and sentence processing and comprehension (**Kiel Christianson**).

BioIntel researchers use and/or integrate advanced technologies in their work to study an array of brain and cognitive issues and for applications in real-world situations. **Chilin Shih** uses a rare electromagnetic articulometer to digitally record movements of what are called articulators (lower jaw, tip and body of the tongue and lips) during speech production. **Monica Fabiani** and **Gabriele Gratton** created an optical imaging system called EROS (short for event-related optical signal), which can identify changes in the light scattering properties of brain tissue related to neuronal activity. **Kara Federmeier** uses event-related brain potentials (ERPs) to study semantic knowledge in younger and older adults. **Sharon Tettegah** incorporates digital technologies like virtual world software programs into her work in educational psychology. Others use computational methods to advance understanding of neurobiology, including simulating neural systems (**Thomas Anastasio**).

Together the work of BioIntel researchers provides for a comprehensive study of the brain's workings and its manifestations in higher forms of intelligence.

Top image:

CaMK spine stain image provided by the William T. Greenough Laboratory.

Inset images from left to right:

Ming Hsu uses tools including MRI for his research on economic choices.

An example of an electrophysiological cap used in Kara Federmeier's laboratory.

Eamon Caddigan and Diane Beck are researching where and how the human brain encodes and discriminates between complex natural scenes.

HIGHLIGHTS: BIOLOGICAL INTELLIGENCE

David Clayton

Songbirds and Fragile X Syndrome

The drive to understand Fragile X syndrome (FXS), the most common cause of inherited mental impairment and the most common known cause of autism, is a major focus of researchers within the Biological Intelligence (BioIntel) research theme. One current project in this area involves BioIntel researchers David Clayton and Stephanie Ceman and graduate student Claudia Winograd, who are using the songbird as a model to gain insight into the speech pathology of those suffering from Fragile X syndrome. Clayton, who led a successful effort to have the whole genome of the zebra finch songbird sequenced, uses songbird models to understand human brain function, while Ceman's research involves the molecular basis of disease, with a focus on the fragile X mental retardation protein (FMRP). The team characterized FMRP in areas of the songbird brain, including one analogous to a region in the human brain that has been shown to be involved in speech. Creating a specific antibody to songbird FMRP, they were able to show that FMRP was elevated in a region of the brain in developing songbird males that is involved in learning songs. The results suggested an important role for the protein in sensorimotor learning, a crucial aspect of human cognitive development, including the learning of speech. Speech impairment in those with Fragile X syndrome is often characterized by delayed and affected speech, so the researchers are looking at how the underlying mechanisms involved in these disorders are related to the absence of FMRP.

Training Grants Awarded for Psycholinguistics and Mental Health Issues

Two important new training grants in the Biological Intelligence research theme were recently funded: one involving language and another for cognitive neuroscience. Kay Bock from the Cognitive Science group is director on a language training grant from the National Institutes of Health (NIH) for training the next generation of psycholinguistic researchers. The program trains recent Ph.D.'s with backgrounds in linguistics and neuroscience about new methods in experimental psycholinguistics, particularly in the use of eye-tracking, event-related brain potentials, and computational modeling. Joining Bock in the training program are Beckman faculty members Gary Dell, Jennifer Cole, Cynthia Fisher, Brian Ross, Chilin Shih, Duane Watson, Kiel Christianson, Kara Federmeier, Susan Garnsey, and Elizabeth Stine-Morrow. Greg Miller, head of the Cognitive Neuroscience group at Beckman, is director of a grant from the National Institute of Mental Health (NIMH) for training in cognitive psychophysiology about advanced methods for "identifying normal and abnormal cognitive processes that inform our understanding of psychopathology and emotional dysregulation." The program is designed to train individuals in a range of backgrounds from psychology to neuroscience to bioengineering in applying methods and new technologies, particularly multimodal neuroimaging techniques, to mental health issues. In addition to Miller, Beckman faculty involved with this program include Diane Beck, Neal Cohen, Monica Fabiani, Kara Federmeier, Susan Garnsey, Brian Gonsalves, Gabriele Gratton, Wendy Heller, Arthur Kramer, Zhi-Pei Liang, Bradley Sutton, and Michelle Wang.

Cell to Cell Signaling Center Earns Five-year Renewal

Jonathan Sweedler of the NeuroTech group heads the Center on Cell-Cell Signaling, a resource that provides proteomics and bioinformatics technologies to neuroscience researchers from the University of Illinois and other universities. In 2009 a five-year grant was renewed for funding by the National Institute on Drug Abuse. Work at the Center seeks to advance technologies in the area of proteomics, which is the study of an organism's complete complement of proteins. One focus of the Center's work involves studying mechanisms of addiction in the central nervous system. Sweedler writes that the Center is "built around the overarching theme of cell to cell signaling, integrating research groups with expertise in the fields of analytical chemistry and bioinformatics with those in biological and behavioral neuroscience in a unified, directed approach to discovery of the intricacies of intercellular signaling."

Jonathan Sweedler

Among those working with the Center are Beckman researchers William Greenough, Martha Gillette, David Clayton, and Gene Robinson.

Gabriele Gratton, Monica Fabiani, Kyle Mathewson, and Diane Beck

Researchers Find Two-year-olds Gain Useful Knowledge of Syntactic Behavior

Research by Cognitive Science group member Cynthia Fisher is showing that children as young as two years old and even younger have remarkable abilities when it comes to learning the structural building blocks of their native language. Fisher, director of the Language Acquisition Laboratory at Illinois, and graduate student Sylvia Yuan reported in 2009 on their study looking at "whether the syntactic structure in which a novel verb occurs is meaningful to children even without a concurrent scene from which to infer the verb's semantic content." The researchers found evidence that, by overhearing novel verbs used in sentences, two-year-olds can keep track of the sentence structure in which a new verb appears, even without a concurrent scene providing cues to the verb's semantic content. They can then later use that information in guiding interpretation of the verb. The researchers found the effect held even during next-day testing, but "disappeared if no novel verb accompanied the test events." Fisher writes that the test results show "that 2-year-olds have amazing abilities to take in and remember multiple kinds of information about a new word – even before they have much information about the kinds of events that verb describes."

Emerging Collaborations Between Neuroscientists, Cognitive Scientists, and Engineers

That the Beckman Institute is truly an interdisciplinary research facility is exemplified in two current collaborations between members of the Biological Intelligence research theme and scientists from electrical and computer engineering in one project, and computer science in another. BioIntel researchers Monica Fabiani and Gabriele Gratton are joining with Human-Computer Intelligent Interaction (HCII) research theme members Art Kramer, Jason McCarley, and Todd Coleman in a proposal to create a center to enhance cognitive performance in the use of measures of brain function. Jont Allen and Todd Coleman from the Electrical and Computer Engineering Department at the University of Illinois and HCII's Artificial Intelligence group, reported in 2009 on their development of a computational model that uses neural spiking in auditory nerve fibers to represent complex sounds. Coleman's research uses statistical and computational approaches to understand brain function, with a focus on developing dynamical, closed-loop feedback systems for brain-machine interfaces, with potential applications in devices such as prostheses. He seeks to understand how the brain represents information by investigating how neuron "spike trains" encode information and has begun to design novel, non-invasive brain-machine interface applications. One of Allen's research interests involves developing mathematical models of cochlear implants. Together, their model could be used in guiding the design of the next generation of cochlear implant so that the artificial spiking timings it uses are statistically "close" to what happens in a normal ear, for better sound reproduction. In another project, Diane Beck from the Cognitive Neuroscience group is collaborating with Beckman Fellow Dirk Walther, and Stanford University computer vision researcher Fei-Fei Li on a project that is applying statistical pattern recognition techniques from the computer vision field to neuroimaging data from functional Magnetic Resonance Imaging (fMRI) studies. Their methods – using algorithms that are able to analyze activity patterns across the brain – have already shown advances over more traditional techniques for analyzing fMRI data. The method shows better predictive power than current ones because of its greater sensitivity and an ability to characterize behavioral states that were previously thought to be too subtle for fMRI analysis. The researchers write that the algorithms could be "taught to identify brain patterns associated with a range of human behaviors in the healthy and diseased state that can then be used as biomarkers for normal and pathogenic brain processes." The method could lead to increased use of fMRI for brain-related health issues.

Alpha Phase Predicts Visual Awareness

Three members of the Cognitive Neuroscience (CN) group discovered a new mechanism that explains how the visual system often fails to perceive stimuli from the environment that at other times would be readily detectable. BioIntel Co-chair Monica Fabiani, and fellow CN members Gabriele Gratton and Diane Beck, collaborated with graduate student Kyle Mathewson and Tony Ro from the City University of New York on a study that showed, for the first time, that when a "pulsed inhibition" mechanism of the human visual system was in effect, such as when people are tired, they perceive the visual world not as a continuous stream but more like the frames of a film. These "frames" form the apparently seamless movie of our conscious awareness, even though we are in fact sometimes missing important visual targets in the environment. This rapid oscillation effect of pulsed inhibition on conscious awareness means the visual system is "sampling" the environment every hundred milliseconds, in what they refer to as a fallback system. Gratton compared the oscillation mechanism the researchers discovered to the anti-lock braking system (ABS) of an automobile that assumes control from the driver of a car. The researchers found that the oscillation mechanism takes over when the "top down" regions of the brain that are in control in attentive states give way during relaxed states in which alpha waves are present. The researchers say that the implications of the finding are many. For one, it informs us that seeing or not seeing things in our environment is not always a conscious choice. The work also has potential relevance in areas where the alertness and attentiveness of machine operators is an important concern, such as a nuclear power plant or public transit. The project continues with Beckman researchers Alejandro Lleras and Dan Simons recently joining the effort.

People are fascinated with things like ESP but the stuff that we do all the time with language is probably more miraculous and magical than ESP could ever be.

– Kay Bock

Researcher **Profile**

Language production is one of the most basic and important capabilities humans have, but until the 1980s theories about language production were rare and until the 1990s experimental studies of the topic were rarer still. Then along came Kay Bock.

Bock, a Professor in the Department of Psychology and member of the Beckman Institute's Cognitive Science group, is considered a giant in the field of psycholinguistics thanks in large part to her pioneering work in the area of language production. She has been such a pioneer, in fact, that Beckman and Psychology Department colleague Gary Dell says that the main research lines in language production all trace back to discoveries made by Bock.

"All of the interesting things, she found them," Dell said.

That includes, Dell said, topics such as structural priming and verb and pronoun agreement production; in addition she was the first to create experimental studies of language production, later incorporating the use of eye-tracking equipment into them. Dell describes her status succinctly. "Kay Bock is the world's top psycholinguist studying language production."

That's quite an accomplishment for a person who grew up, she says, in "a Pennsylvania coal holler" and whose path to linguistics began with a search for the exotic, which in her slice of Pennsylvania meant learning a foreign language from a person of color.

"Into this very closed little world comes a black woman to teach Spanish," Bock said. "So she was very exotic to us but she also was just an extraordinary teacher. Her name was Delores Chapman. I *loved* the idea of

Well Said: "Kay Bock is the world's top psycholinguist studying language production"

learning a foreign language. When I went off to college I wanted to be a language major and I was still looking for exotic so I became a Russian major."

As seems to be the case with many in the field, it was the difficulties she encountered learning foreign languages that first got Bock interested in linguistics questions during her undergraduate days at Bucknell.

"It's the effort that it takes to learn a foreign language that really gets you engaged with what the problems are in talking," Bock said. "Because native language is simple we don't notice it, we just do it. When you are trying to learn another language and realize how incredibly difficult the performance is, how much has to go into it and how much you don't know, it is at that point that people get interested in either linguistics itself or psycholinguistics."

For Bock it was the latter.

"In the course of my undergraduate career, I ran into the intersection between language and psychology," Bock said. "That was psycholinguistics. So I very quickly added psychology, and had a dual major in Russian and psychology. That intersection was much more fascinating than just the language. I was lucky to have, at my undergraduate institution, one of the very first psycholinguists in the United States."

Bock made the most of her opportunity. She later earned a Ph.D. from the University of Illinois, joined the faculty here, and then the Beckman Institute in 1991. At least two of her papers from the 1980s involving language production – one from 1982 in *Psychological Review* on the cognitive psychology of syntax and another in *Cognitive Psychology* from 1986 on structural priming – are considered keystones in the fields of psycholinguistics.

"Her paper in 1986 on structural priming and language production is *the* most important experimental paper in the field of language production," Dell said. "It showed, better than any other paper, that when we talk we actually form an abstract plan of the sentence in terms of its grammatical structure. That paper has now defined 20 years of research on the nature of how people use their knowledge of grammar or the syntactic structure of a sentence when they speak."

"The most important thing that I think I've done is open the way for a lot of people to do this kind of work."

In the 1990s her collaboration with W.J.M. Levelt, Director of the Max Planck Institute of Psycholinguistics and a father of the field, produced among other important results, a widely cited paper that is considered a "placemarker" for standard theories of language production in psycholinguistics. Another important, more recent collaboration with Beckman colleague Neal Cohen has to do with language production in amnesiacs. The study's results showed that even though people with amnesia couldn't remember a sentence they had recently spoken, they will still use the structure of that sentence later on in producing language, demonstrating that language learning was implicit.

"It was just a really striking result," Bock said. "It really is built in, at least after the age of two or three when you've learned language. (This collaboration) wouldn't have happened at all without Beckman. Neal is a psychologist but he's doing research on amnesia *here*. That came about only because of Beckman."

Bock said being at Beckman also made it possible for her to collaborate with Dell, who *she believes* is the world's top psycholinguist studying language production. Regardless, Bock's research, papers, and her introduction of standard experimental techniques – and some not-so-standard methods like using eye-tracking – to the study of language production have all made her highly regarded in the field of psycholinguistics.

"The most important thing that I think I've done is open the way for a lot of people to do this kind of work," Bock said of the study of language production. "That is now a central part of the psychology of language."

And all of Bock's work originated with her ongoing interest in language.

"Language is one of the most underappreciated things we do and it's because we do it all the time," she said. "People are fascinated with things like ESP but the stuff that we do all the time with language is probably more miraculous and magical than ESP could ever be. We are capable of transmitting fairly precise, specific ideas from mind to mind.

"In talking, if you just look at the physical elements, we produce four to five syllables a second and we do all this using more muscle fibers than any other mechanical performance of the human body. The fact that we can all do it is really incredible."

OVERVIEW: HUMAN-COMPUTER INTELLIGENT INTERACTION

When plans were being made to create a new type of scientific center at the University of Illinois in the early 1980s, parallel committees were formed to explore two broad areas of research: one for materials science, computers and computation, and the other for biology, behavior and cognition. In 1994, a bridge was formed between those original ideas with the creation of the Human-Computer Intelligent Interaction research theme as one of the core areas of study at the Beckman Institute.

The Human-Computer Intelligent Interaction (HCII) research theme features a great variety of projects studying everything from the way people interact with electronics and other everyday devices, to how factors like body movements or aerobic exercise can affect our brains, to advancing computer vision and Internet search engines. Research is concentrated in three research groups: Artificial Intelligence, Human Perception and Performance, and Image Formation and Processing.

Artificial Intelligence researchers explore topics such as robotics, brain-machine interfaces, image processing, computational aspects of biological intelligence, and human interactions with computers. Work in the Human Perception and Performance group takes on questions involving the mechanisms of perception and the relations between perception and action, including studies of cognitive functions like visual attention and memory as they relate to task performance, human interactions with visual displays, and spatial navigation. Image Formation and Processing researchers are concerned with the acquisition, manipulation, and synthesis of images, including the topics of computerized imaging, image-video transmission, storage, and manipulation, and the modeling and analysis of images and scenes.

Understanding and enhancing the human-computer interface for basic science research and for future applications has always been the main goal of the Human-Computer Intelligent Interaction (HCII) research theme. Some of its researchers have been working in these areas since the Beckman Institute opened in 1989.

HCII co-chairs **Arthur Kramer** and **Thomas Huang** have been at Beckman since 1989 and 1990, respectively, doing research that exemplifies the wide variety of work that goes on in this research theme. Kramer studies visual search and attention in real-world and laboratory environments, driver and pedestrian distraction, and cognitive and fitness training effects on human performance and brain function. Huang is a world-recognized leader in computer vision and signal processing research, and now is breaking new ground in the areas of gender and emotion recognition software for applications such as consumer displays.

The human equation of the HCII research theme includes work that has a positive impact on people's lives. **Deana McDonagh** includes students with disabilities in her industrial design

Human-Computer Intelligent Interaction

- Artificial Intelligence
- Human Perception and Performance
- Image Formation Processing

classes and projects, while **Jont Allen** is working to improve hearing aid technology, and Kramer, **Edward McAuley**, and **Charles Hillman** are studying the cognitive benefits of exercise. **Elizabeth Stine-Morrow's** Senior Odyssey project continues to grow and have success as both a research experiment and intervention program for older adults.

Research into how we interact with the world is also part of HCII. **Alejandro Lleras** is finding evidence that body movement affects thoughts and emotions, while **Dan Simons** is expanding his work on people's perceptions – and frequent misperceptions – when it comes to assessing their own cognitive abilities regarding attention, visual perception, and memory.

Many HCII researchers use computational modeling in their projects, including **Roxanna Girju** (for text comprehension and applications like future search engines), **Todd Coleman** and **Tim Bretl** (non-invasive brain-machine interface applications for use in devices like prostheses), **Dan Roth** (learning theory and language acquisition), **Pierre Moulin** (processing image and video signals), and **Fatima Husain** (auditory, speech, and language processing in the brain).

Whether they are using computers to understand human behavior and create new tools for people, or improving the computer experience for humans, researchers within HCII continue to lead the way in an area that has become an integral part of our lives in the twenty years since the Beckman Institute first opened.

Top image:

A detail of an electrode cap that is used to record the brain's electrical signals of test subjects during task performance in Todd Coleman's lab.

Inset images from left to right:

A concept drawing from an industrial design project led by faculty member Deana McDonagh.

Research participants from Liz Stine-Morrow's Senior Odyssey program gather in the lab.

A screen capture from the Illinois Simulator Laboratory's Cube. The scene is from research conducted by France Wang and her collaborators.

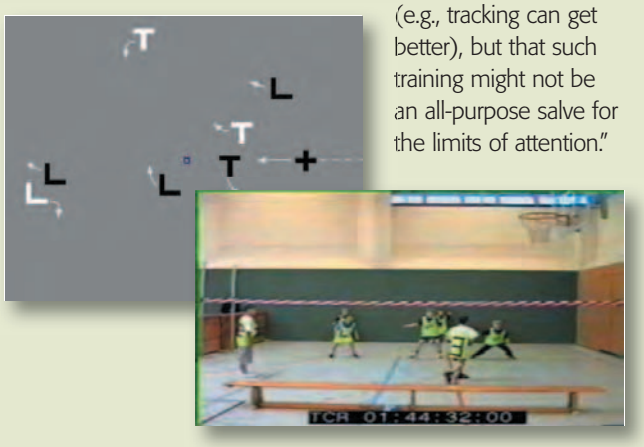
Researchers Find Humans Can Make Judgments in Four-dimensional Space

Frances Wang

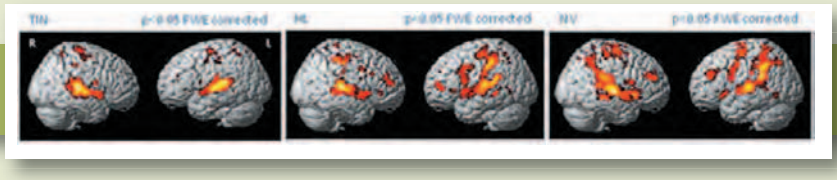
Frances Wang wanted to go where no researcher has gone before in studying human perception, so her project involving four dimensions required a special kind of experimental setting. Thanks to the Beckman Institute's rare immersive virtual reality environment the Cube, Wang and her collaborators were uniquely able to explore human perception in a four-dimensional space and make some surprising discoveries. A member of the Human Performance and Perception group, Wang's research focuses on human spatial cognition and visual perception. Her work has often used the unique capabilities of the six-sided Cube, which is part of the Illinois Simulator Laboratory's (ISL) array of advanced visualization environments. Wang and her collaborators, including Beckman faculty member George Francis and ISL staff member James Crowell, looked at whether or not humans who are accustomed to the three-dimensional world we normally inhabit could gain an intuitive understanding of a four-dimensional space. Writing in *Psychonomic Bulletin & Review,* Wang and her collaborators posed this central question for the study: "It is a long-lasting question whether human beings, who evolved in a physical world of three dimensions, are capable of overcoming this fundamental limitation to develop an intuitive understanding of four-dimensional space." The authors state that past research has used analogy and graphic illustrations to test such possibilities, but empirical studies producing objective results have never been performed before. In their study, subjects were able to visualize four-dimensional objects and then, in a task performance experiment using virtual geometric shapes and a gamepad for responses, were tested on their ability to form four-dimensional mental representations and learn four-dimensional spatial relationships. The researchers theorized that if "participants can learn four-dimensional spatial relationships, then their judgments should correlate with the actual distance and angles." Their results showed "evidence that people with basic geometric knowledge can learn and make spatial judgments on familiar, two-dimensional entities embedded in four-dimensional space viewed in virtual reality with minimal exposure to the task and no feedback to their responses." The test subjects' judgments "incorporated information from both the 3-D projection and the fourth dimension, and the underlying representations were not algebraic in nature, but based on visual imagery strategies." The results of the study "suggest that human spatial representations are not completely constrained by our evolution and development in a 3-D world." Summing up, Wang writes: "Our study showed that people with basic geometric knowledge are capable of learning 4-D objects visually and making basic spatial judgments in 4-D space."

Expertise Doesn't Always Help When it Comes to Detecting Unexpected Objects

Why do humans sometimes miss important objects that are clearly in their field of view, such as a driver failing to notice a motorcycle turning in front of them? Dan Simons of the Human Perception and Performance group and leader of the Visual Cognition Laboratory at Beckman, has been discovering surprising answers to questions involving attention as part of his research into the cognitive and perceptual aspects of our conscious visual experiences. Simons' particular focus is on two areas of attention and the visual world – change blindness, which he describes as "the failure to notice large changes to visual scenes", and inattentional blindness, described as "the failure to notice unusual and salient visual events when attention is otherwise engaged and the events are unexpected." Two papers by Simons and collaborators published in 2009 explored these topics in one project involving expertise in sports and another involving task training, and found that expertise in team sports and ability to perform tasks do not help an individual in noticing unexpected objects. In one paper, Simons and his collaborators reported that expertise in team sports didn't play a role in basic attention abilities, and that expert athletes were no more likely to notice unexpected objects in an inattentional blindness task. Another paper looked at whether individuals who are better at performing a task (in this case tracking and monitoring objects) were better at noticing unexpected objects than those who were not as adept at the task. The researchers found that aptitude at performing the task was not predictive of noticing unexpected objects. Simons said the findings have important implications for training, writing that the results suggest "that basic abilities can improve (e.g., tracking can get better), but that such training might not be an all-purpose salve for the limits of attention."



A figure and screen capture from Dan Simon's research that is exploring whether expertise can help people detect unexpected objects in a scene.

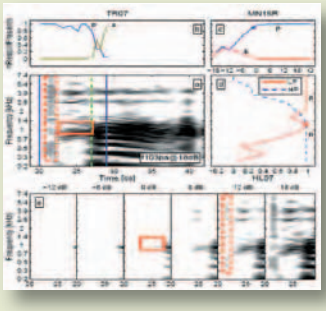


Fatima Husain studies tinnitus using MR imaging to focus on auditory, speech, and language processing in the brain.

Husain Does Innovative Work on Tinnitus

Fatima Husain, an Assistant Professor of Speech and Hearing Science and member of the Human Perception and Performance group, studies tinnitus, or ringing in the ears, in an innovative way that could have implications for future treatments of the disorder. Husain's research focus is on auditory, speech, and language processing in the brain using functional Magnetic Resonance Imaging (fMRI) and computational modeling techniques. Husain combines those techniques in studying tinnitus, an approach that allows for studies of greater populations of the disorder and, therefore, a greater ability to discover commonalities among sufferers toward developing future treatments. She wrote this about her investigations of tinnitus: "What is it that is common? Can we figure out the brain functions, regions, and mechanisms that underlie this disorder? If we can get there, then we are halfway to developing therapies and our own interventions." In the past year she has had three papers published and had a successful neuro-engineering Integrative Graduate Education and Research Traineeship (IGERT) grant proposal funded by the National Science Foundation. In addition, Husain was chosen to give an oral presentation at the Society for Neuroscience on using music to investigate the neural basis of tinnitus.

Allen's Discovery Could Lead to Improved Hearing Aids

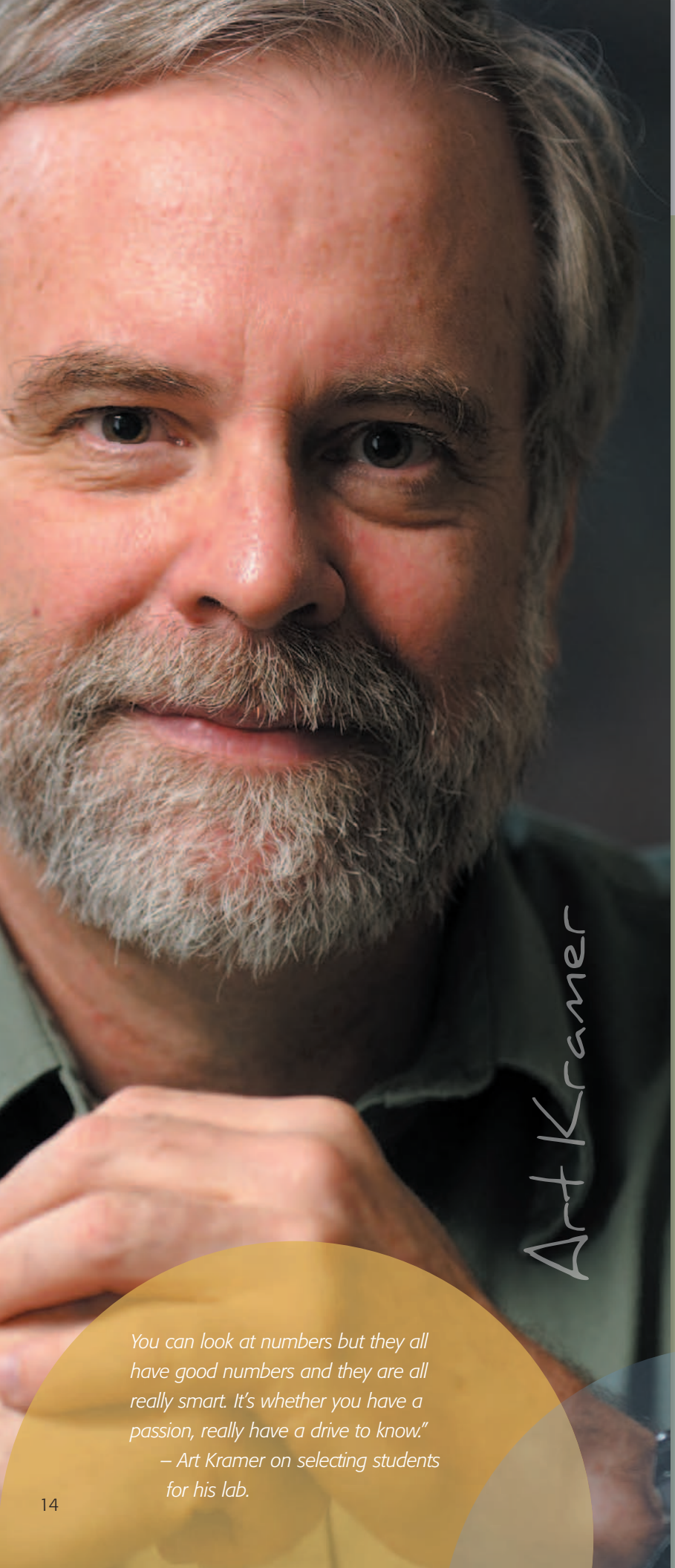


Researcher Jont Allen and his group are using advanced statistical and computational methods to better understand speech processing patterns and to ultimately improve hearing aids and cochlear implants.

The effectiveness of hearing aids has improved in recent years with the advent of digital hearing technologies but recreating natural human speech, especially in noisy environments, remains a challenge for researchers in the field. Artificial Intelligence group member Jont Allen is at the forefront of trying to understand the process of human speech, especially as it applies to advancing hearing aid technology. Allen's Human Speech Recognition group uses statistical and computational methods to better understand speech processing patterns in an effort to improve upon devices like hearing aids and cochlear implants. Allen writes that by using his group's "computer-based Fourier analysis/synthesis methods, it is now possible to modify real speech sounds." Applying their methods to real speech sounds, they were recently able to confirm research from the 1950s suggesting that "consonants were coded by short bursts of energy, placed in proximity of the onset of the vowel" and showed that the manipulation of these small bursts of energy transforms "in a predictable manner, one consonant sound to another, producing natural modified speech sounds." They also found that by extending this method to continuous speech sentences, it was possible to "create confounded sentences from natural speech." These discoveries have important implications for hearing aid technology, especially in noisy environments. Allen said that by identifying in a predictable manner the acoustic feature a person is listening for, that feature can be enhanced in a hearing aid technology, reducing the negative impact of background noise on listeners.

Huang's Group Laying Groundwork in Field of Soft Biometrics

Tom Huang has been recognized both in the United States and internationally for his foundation-laying work in the fields of image processing and computer vision, but his current research in the area of "soft biometrics" could turn out to be just as groundbreaking. Huang, Co-chair of the Human-Computer Intelligent Interaction research theme and head of the Image Formation and Processing group at Beckman, has been a leader in developing biometric technologies like face-recognition software that can identify people based on individual traits in a field known as hard biometrics. Now Huang and his group are exploring new ground in soft biometrics, or computation-based analysis of characteristics such as gender, age group, ethnicity, and emotion. Their previous work led to real-time algorithms that can provide frontal-view face detection for potential applications like public displays that adapt to viewers based on their particular characteristics. The technology could be used, for example, in public places like train stations or elevators; using a camera and face-recognition software the system would gather data that could tailor an advertisement or message on the display based on factors like the viewer's gender or emotional state. The software could also be used, for example, at a fast-food restaurant to collect data for marketing purposes, such as which age or gender group prefers certain types of food. The challenge the group is now undertaking involves creating software that can recognize these characteristics without ideal frontal-face views. They have developed three methods in which the algorithmic classifier may be either, trained on every view available, or trained for a set number of views, or a frontal-view classifier that adapts when a frontal view is not available. They have found that a combination of the three methods is the most efficient approach. In another project involving recognition of gender and ethnicity, Huang's group collaborated with Neal Cohen from the Biological Intelligence research theme to study human efficiency at detecting those traits. The results suggested that "computer and human performances are generally similar; however, in some cases, the computer performance is quite a bit better."



You can look at numbers but they all have good numbers and they are all really smart. It's whether you have a passion, really have a drive to know."
– Art Kramer on selecting students for his lab.

Researcher **Profile**

For a man who has carved out a high-profile career in the world of science, Art Kramer sometimes takes a decidedly unscientific approach to choosing which students get to join his world-renowned research laboratory. Often, he goes with his instincts.

"My students tell me it's always bizarre with me because I might talk to them on the phone for an hour and just tell them 'yeah, you're in," Kramer said with a laugh.

Kramer's method of selecting students and postdoctoral researchers for his lab has a lot to do with his own background.

"I don't always pick students who have had all the privileges in life," Kramer said. "That's important for me because I left home when I was 15 and I didn't have a lot of privileges when I was a young man. I look for students who have gone through the best colleges and had good training but I also take risks. I was a risk; there was no doubt about that.

"I was just lucky that somebody took a risk with me. I try to do the same thing."

Kramer took advantage of the chance he was offered in ways that are almost too numerous to mention. He is one of the country's premier researchers in the areas of cognitive neuroscience, cognitive and brain plasticity, aging, attention, perception, and human factors, while studying topics

A Beckman Original, Kramer Keeps Producing Research and Researchers

such as the effects of cognitive and fitness training on human performance and brain function, visual and laboratory search in real-world environments, and driver and pedestrian distraction. He has testified before Congress, been featured on the *CBS Evening News*, and is quoted frequently in national publications like *Newsweek* and the *Washington Post*. Some of his many professional honors include election as a fellow of both the American Psychological Association and the American Psychological Society.

"I was just lucky that somebody took a risk with me. I try to do the same."

As a faculty member and administrator, Kramer serves as a Swanlund Chair (the University's highest endowed title) Professor in the Department of Psychology. At Beckman, Kramer is Director of the Biomedical Imaging Center and is Co-chair of the Human-Computer Intelligent Interaction research theme. As if those responsibilities weren't enough, Kramer is leading an effort to develop a new initiative at Beckman called Healthy, Bodies, Brains, Minds, and Communities that will focus on health-related research.

Kramer also has the distinction of being a Beckman original, coming to the Institute when it opened in 1989. He says that if it weren't for Beckman, he probably would have moved on by now.

"It has been a breath of fresh air," Kramer said of his 20-year association with the Institute. "I was in a traditional department but like many of us I always had interests which went beyond the department I was in. The ability to not just walk across campus and talk about research that crosses disciplinary boundaries, but to be in the same building and walk down the hall and eat with people in the cafeteria, I think, has really promoted a number of projects that we have been involved in over the years."

While the research accomplishments, honors, and titles are impressive, Kramer said he derives the most satisfaction from working with students. Before prospects join his Human Perception and Performance laboratory, however, Kramer lets them know what is in store for them.

"It's frustrating at times and it doesn't pay a lot of money and you have to love it," Kramer said. "I tell the students if you want a nine-to-five job, given your intellect, you can make a hell of a lot more money doing other things. This is not your job. It has to be part of your life."

Kramer looks for that dedication and a love of discovery when assessing applicants for his group.

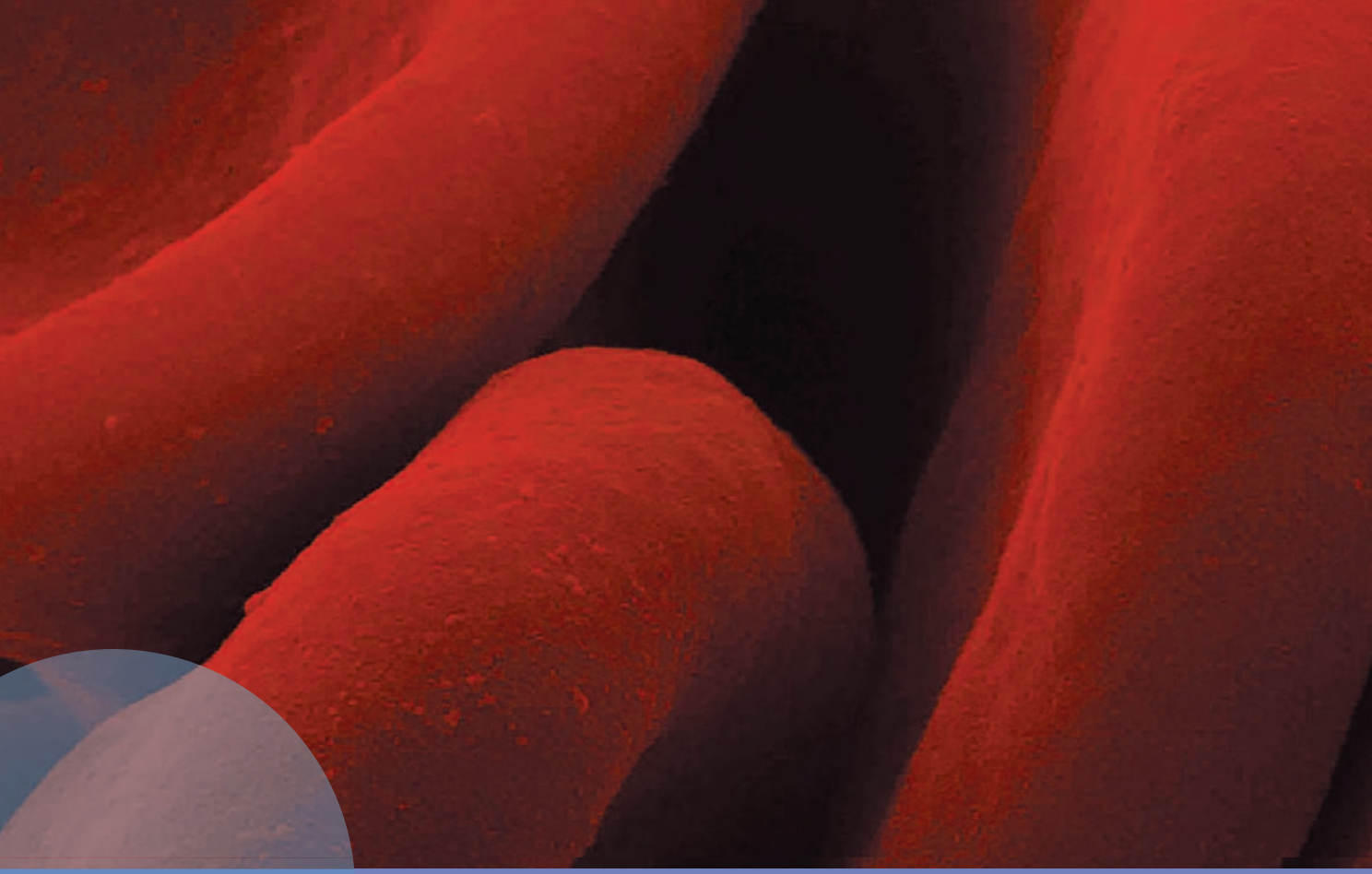
"You can look at numbers, but they all have good numbers and they are all really smart. It's whether you have a passion, really have a drive to know," he said. "Not everybody completes their degree, but a lot of people in my lab do. I'm also very loyal. If a student starts with me and they work hard, I'm going to do my best to help them successfully complete their degree."

One of his former lab members, Ruchika Prakash, earned an academic position at Ohio State this past year. While in Kramer's lab, Prakash added a new dimension to Kramer's work on the effects fitness training can have on the brain and cognition. Prakash started a research line that looked at the cognitive and brain effects of fitness training on people with multiple sclerosis.

"She came up with that research, not me," Kramer said. "That is why she is first author on all the papers. She made it her line of research and it got her an assistant professorship right out of grad school."

The first student to get a Ph.D. under Kramer was David Strayer, who is now at the University of Utah, making new discoveries and national news involving driver distraction, a line that grew out of research he worked on with Kramer at Beckman.

"My first graduate student is actually a full professor now, which makes me feel pretty old," Kramer said with a laugh.



OVERVIEW: INTEGRATIVE IMAGING

Five years after the Beckman Institute opened, work was focused around three research themes. In a testament to the increasing importance that images and imaging data play in science, medicine, and our everyday lives, Integrative Imaging (IntIm) was formed this year, becoming the first new research theme at Beckman in 15 years.

More and more researchers from fields as disparate as psychology and materials science are relying on imaging as a critical component of their work. Because of that fact, the Integrative Imaging research theme was formed to bring together imaging people, ideas, and technology in an interdisciplinary effort with a grounded vision for the science of imaging.

Co-chairs for the new Integrative Imaging research theme are two of the most well-known and respected imaging researchers on campus, **Stephen Boppart** and **Zhi-Pei Liang**. In their introduction to the IntIm theme, Boppart and Liang write that the theme's mission is to "foster the interdisciplinary discovery of fundamental principles in imaging science, new enabling technologies for the next generation of imaging instruments, and novel techniques for basic and translational research."

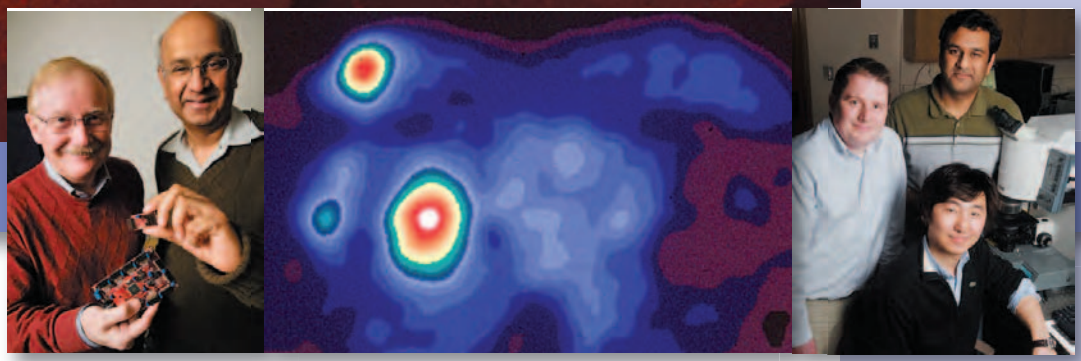
Integrative Imaging was created as a big tent research theme, with fields as diverse as neuroscience, biomedicine, and engineering included. IntIm includes members who use imaging technology for research and other scientific purposes and others who are involved in the design, engineering, and optimization of imaging instruments and methods, and some who are engaged in both efforts. Some researchers develop new algorithms to improve image signals, while others make innovative use of light or sound waves to create new types of imaging techniques. The imaging modalities found in the Integrative Imaging research theme include magnetic resonance imaging (MRI), x-ray computed tomography (CT), ultrasound (US), and optical imaging.

Research within IntIm is centered in two groups: the Bioacoustics Research Laboratory (BRL) and the Bioimaging Science and Technology group (BST).

Work in the Bioacoustics Research Laboratory is concerned with the interaction of ultrasound with biological materials and the area of ultrasound imaging as it applies to biology and medicine. Bioacoustics Research Laboratory (BRL) leader **William O'Brien** and fellow BRL member **Michael Oelze** are currently involved in a project that seeks to use high intensity focused ultrasound as a cancer treatment.

Bioimaging Science and Technology faculty members seek to improve imaging techniques and use imaging to deepen our understanding of biological processes toward better disease diagnosis and treatment. Because of the importance of imaging to medicine, many of the projects involving imaging in this theme have potential or current biomedical applications. For example, Boppart developed an optical technique using optical coherence tomography (OCT) in his laboratory at Beckman for non-invasive or minimally invasive detection of breast cancer that is now being tested in clinical use.

Bioimaging Science and Technology group researchers apply theory to the development of algorithms for improved signal performance



Integrative Imaging Research Groups

- Bioacoustics Research Lab
- Bioimaging Science and Technology Group

(**Scott Carney)**, while others apply engineering solutions to improve images **(Brad Sutton)**, and some work to improve MRI signals, imaging processing, and pattern recognition **(Liang)**.

Several researchers are involved in imaging studies and applications related to the brain. **Michelle Wang** has developed novel statistical methods for application to brain-related MRI studies. **John Wang** is creating modalities for imaging thermal properties of the brain. **Kenneth Watkin** has developed a battlefield helmet for monitoring brain injuries.

The methods used for imaging in this theme are widely varied. **Rohit Bhargava** is developing ways to include chemical information in imaging techniques to provide information about structural change over time. **Gabriel Popescu** uses light scattering, interferometry, and microscopy to quantify structure and dynamics of cells and tissues.

Others in BST use imaging as an integral part of their research work. **Marni Boppart** employs imaging in her research into cellular biomechanics and skeletal muscle; this past year she made a discovery about the role that a bone marrow stem cell population plays in skeletal muscle.

Discussions looking at the modeling of multiscale biological networks are under way between Integrative Imaging members and faculty from the Institute for Genomic Biology, the Information Trust Institute and the Coordinated Science Laboratory. This research line which includes researchers **Michael Insana** and Bhargava, would introduce computer modeling of larger biological systems into the field of systems biology.

With its origins in our Anniversary Year, the Integrative Imaging research theme is testimony to the fact that research at the Beckman Institute continues to evolve and remain as vital as it was 20 years ago.

Top image:

Biological imaging has made tremendous strides with the influx of new imaging methods and tools. This image shows a close-up of red blood cells.

Inset images from left to right:

Kenneth Watkin (left) and Ravi Iyer have developed communications technology that will transfer real-time blast injury data to first responders.

Photo by L. Brian Stauffer.

This image provided by John Katzenellenbogen is an example of how researchers are using imaging agents and agent chemistry to change the appearance of what is imaged in specific and meaningful ways.

Clockwise from left: Beckman researchers William King, Rohit Bhargava and postdoctoral research associate Keunhan Park have demonstrated a method for simultaneous structural and chemical characterization of samples at the femtogram level (a femtogram is one quadrillionth of a gram).

Photo by L. Brian Stauffer.

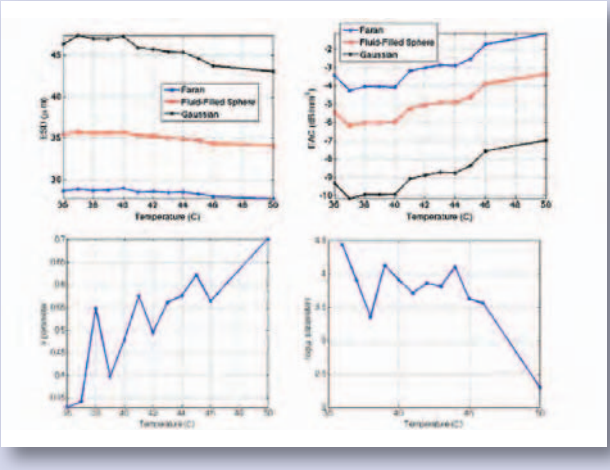
Intra-operative OCT imaging in surgical oncology. A portable OCT system (lower left) was used for imaging tumor margins and lymph nodes (top middle) as well as needle-biopsy placement (top right). Representative images of negative and positive tumor margins are shown. In contrast to the abundant adipose cells along the negative margin, the positive margin exhibits highly heterogeneous scattering regions, with the highest scattering regions (arrows) corresponding to foci of tumor cells, as confirmed by histology. Photos and images courtesy of Carle Foundation Hospital and the Beckman Institute for Advanced Science and Technology.

OCT System's Clinical Use Successful

The potential of an optical imaging technique developed at the Beckman Institute for real-time, detailed, high-resolution visualization and surgical guidance is now being realized through a breast cancer research collaboration between Bioimaging Science and Technology group researchers Stephen Boppart and Scott Carney and physicians at Carle Foundation Hospital. In his lab at Beckman Boppart developed an imaging technique using optical coherence tomography (OCT) that, as he writes, is the "optical analogue to ultrasound, except reflections of light are detected rather than sound" for performing "optical biopsies, generating images that resemble histological sections, but without removal and staining of tissue." The benefits of the OCT system over traditional diagnostic methods for tissue analysis and for guiding physicians during surgery and other procedures are many. The OCT system provides doctors with real-time information during an optical biopsy or surgery, eliminating time-consuming, expensive, and often, post-surgical, lab work. In addition the system is able to provide cellular level information, as well as spatial localization, over large tissue sections, making it possible to quickly sample tissue masses, tumor margins, and lymph nodes in real-time. This means that physicians will be able to gather the diagnostic information they need during procedures or surgeries, knowing, for example, whether all of the tumor cells have been removed. Boppart, who is also a physician, has been developing the OCT system for years; he is joined in the project by Carney, whose efforts have enabled advances in image reconstruction algorithms for automated tissue classification. The OCT system has been in clinical use at Carle Hospital and this past year enough results from 75 patients were collected to report on the value of the technology. Datasets on resected tumor masses and lymph nodes were gathered from optical images and marked before the tissue was sent for histological analysis; subsequent results confirmed the OCT analysis. Boppart writes that the OCT results for "lymph node features correlated well with histology" and that "intra-operative imaging using OCT and refractive index needles also showed strong correlations, suggesting their future use in guiding biopsy needles to abnormal tissue during outpatient procedures."

Making New Discoveries in Cellular Processes and Biosensors

Yingxiao (Peter) Wang of the Bioimaging Science and Technology group develops technologies involving genetically encoded reporters and does research on related cellular processes. His research had several breakthroughs this past year, including the discovery of a platform for developing fluorescent resonance energy transfer (FRET) biosensors that led to important new findings about a cancer-related enzyme called Src. Among several discoveries involving Src, Wang's group found that the Src molecule and another molecule, Rac, mutually regulate each other but have distinct subcellular patterns when activated; that mechanical stimulation activates Src with a speed 40 times faster than chemical stimulation; and that the Src activities are regulated differentially at different compartments on the plasma membrane. All of the findings have relevance to biomedical investigations into Src-dependent signaling and its relation to cancer growth. In addition, this past year Wang's lab developed the first FRET biosensor to detect the activity of MT1-MMP, a critical enzyme for cancer invasion and metastasis.



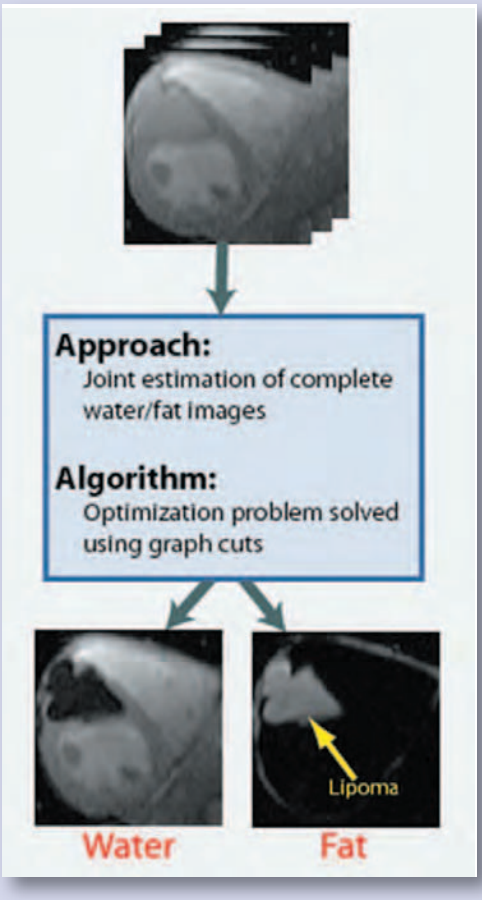
The Bioacoustics Research Laboratory's objective is to develop and validate a quantitative ultrasound model-based imaging technique that will allow the noninvasive staging, monitoring, and assessment of HIFU treatment of tumors in vivo.

Using High Intensity Focused Ultrasound as a Cancer Treatment Method

Michael Oelze and William O'Brien of the Bioacoustics Research Laboratory are investigating high intensity focused ultrasound (HIFU) as a method for cancer treatments involving hyperthermia (exposing body tissue to high temperature) and ablation (destroying tumors with extreme temperature using a needle). HIFU, which has the advantage of targeting small regions, has been successfully demonstrated in animal models and limited clinical studies. Oelze and O'Brien are working to develop a "quantitative ultrasound (QUS) model-based imaging technique that will allow the noninvasive staging, monitoring, and assessment of HIFU treatment of tumors in vivo." Such a treatment option would not only reduce the need for compacted invasive surgery but might also allow the treatment of tumors that are inoperable through other invasive means. By using quantitative ultrasound techniques for HIFU methods, the researchers report they will be able to take advantage of the QUS technique's sensitivity to microstructural changes in tissues and superior ability over current algorithms for monitoring temperature elevation caused by high intensity focused ultrasound. The researchers have begun experiments involving the technique on what are called tissue-mimicking phantoms.

Separating Water and Fat for MRI a Boost for Imaging, Diagnosis

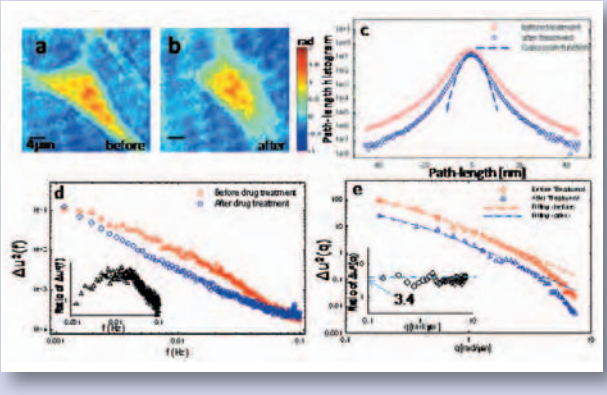
One of the main research areas for IntIm Co-chair Zhi-Pei Liang of the Bioimaging Science and Technology group is to develop advanced technology for the next generation of magnetic resonance imaging (MRI) systems capable of imaging structures, functions, and metabolism in high resolution. A current project of Liang's research group is to develop an MRI capability for revealing signals originating from different chemical species such as water and fat. Liang said that developing the ability to separate water and fat addresses a longstanding problem in MRI and will result in many applications. Liang and his graduate student Diego Hernando, along with collaborators Justin Haldar from their group and staff scientist Dr. Peter Kellman from the National Institutes of Health, developed a novel, powerful method that enables robust water and fat separation under practical experimental conditions. Their technique has important implications for disease diagnosis – one example is its ability to enable accurate tissue characterization and detection of lipomas and fatty infiltration in cardiac diseases. For this work, Hernando received the prestigious I. I. Rabi Award at the annual meeting of the International Society for Magnetic Resonance in Medicine, held in 2009.



The image at right illustrates how Zhi-Pei Liang's group is developing an MRI capability for revealing signals originating from different chemical species such as water and fat.

Advancing MRI Techniques for Biomedical and Scientific Applications

Brad Sutton of the Bioimaging Science and Technology group works to advance magnetic resonance imaging (MRI) by developing novel methods to image both structures and physiological functions. Sutton collaborates with researchers from both the physical sciences and life sciences in advancing MRI techniques for a variety of projects involving basic science, biomedical engineering, and other applications. In one project with David Kuehn from the Department of Speech and Hearing Science, Sutton is working to optimize image acquisition and reconstruction phases of MRI experiments involving the dynamic imaging of speech and swallowing. Sutton reports the work has enabled the ability to match anatomical measures with acoustic features in co-recorded speech samples. In projects with John Georgiadis of the Molecular and Electronic Nanostructures research theme, Sutton is working to advance diffusion-weighted MR techniques to improve *in vivo* imaging of biological tissues. In one project, motion-robust diffusion-weighted techniques are being developed to give researchers the ability to non-invasively see very small displacements of water in various tissues in the body. Sutton writes that this can "result in information such as which way cell membranes are oriented in axons in the brain, giving information about the axons that connect different brain regions. However, since the imaging technique is sensitive to these very small displacements, it is also sensitive to larger displacements from subject movement during the scan. Our technique allows for robust correction of subject motions, allowing for high-resolution scans of the microstructure of the brain. This includes the ability to image small nerve fiber pathways that are involved in specialized tasks in the brain." In another project involving diffusion-weighted magnetic resonance imaging, they have improved image resolution of complex microstructures in the brain. MRI provides a non-invasive method for probing the microstructure of tissues, but the technique, while sensitive to the presence and orientation of microscopic structures, provides information at larger scales, making it hard to characterize those structures. Sutton and Georgiadis are developing a method for high-resolution imaging with diffusion, achieving sub-millimeter images in the brain stem.



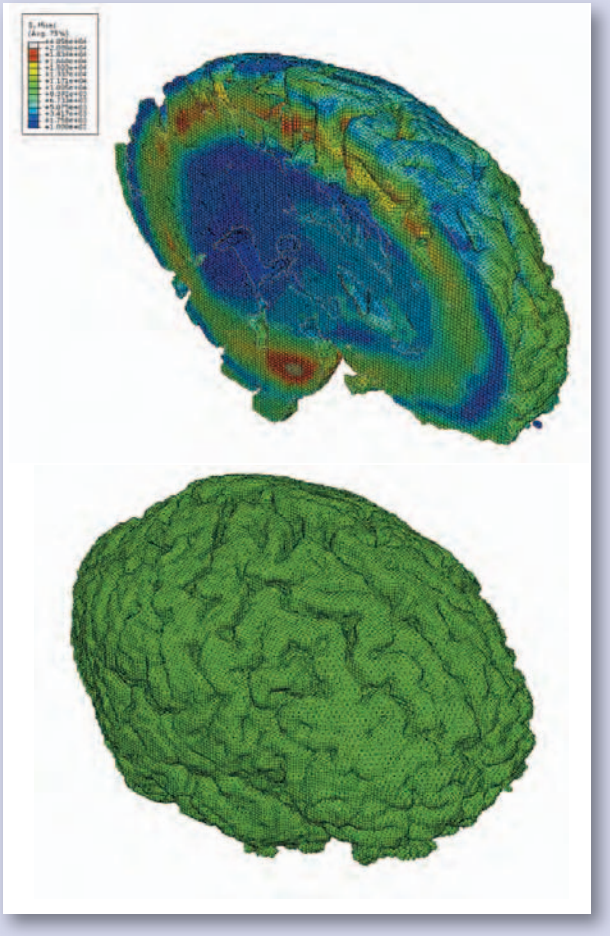
This series of images is from the Quantitative Light Imaging Laboratory. They are developing novel optical methods based on light scattering, interferometry, and microscopy to quantify structure and dynamics of cells and tissues.

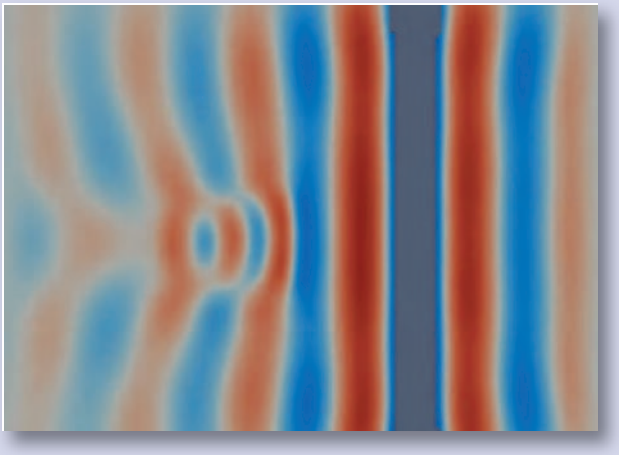
Developing a Fourier Transform Light Scattering Method

Gabriel Popescu's Quantitative Light Imaging Laboratory focuses on developing novel optical methods based on light scattering, interferometry, and microscopy to quantify structure and dynamics of cells and tissues. The lab does research at the interface between technology development, basic biological studies, and clinical applications. Popescu and post-doctoral researcher Huafeng Ding made a discovery this past year regarding elastic (static) light scattering, which, Popescu writes, has "made a broad impact in understanding inhomogeneous matter, from atmosphere and colloidal suspensions to rough surfaces and biological tissues." Popescu's lab used Fourier transform light scattering (FTLS) as a "novel approach that combines the high spatial resolution associated with optical microscopy and intrinsic averaging of light scattering techniques" and, in collaboration with fellow Bioimaging Science and Technology group member Stephen Boppart, employed FTLS to quantify the scattering properties of various tissue types. Popescu writes that "FTLS can set the basis for a novel, imaging-based cell sorting instrument, which will provide greater cell morphology information than current flow cytometry," and that the "remarkable features of FTLS are due to the interferometric experimental geometry and the reliable phase retrieval. We anticipate that this type of measurement will enable new advances in life sciences, due to the ability to detect weak scattering signals over broad temporal (milliseconds to hours) and spatial (fraction of microns to centimeters) scales."

Stress Waves in Traumatic Brain Injury

Martin Ostoja-Starzewski and Brad Sutton of the Bioimaging Science and Technology group are working to improve our understanding of mild traumatic brain injury (mTBI). Ostoja-Starzewski, who works at the intersection of mechanics and transport phenomena, is using measures from MRI to build a biomechanical model of the head and brain to predict how the brain will deform during impact. Sutton, who develops novel methods to image structure and physiological function using magnetic resonance imaging (MRI), writes that the work is "important for predicting neural damage in explosive impacts to soldiers or collisions in football players that result in traumatic brain injury" and that the "dynamic magnetic resonance imaging is able to examine deformations of the head under mild impact at high temporal resolution (100 frames per second)." Ostoja-Starzewski reports on the development of "a 3-D finite element (FE) model for transient dynamic response of cranium and brain tissues" that is able to "grasp complex patterns of transient dynamics within the multi-scale brain microstructure down to the level of 1 mm." The model is currently being validated, including one test involving mild brain trauma experienced by football players equipped with Head Impact Telemetry System (HITS) helmets that record impact data.





Michael Insana and his collaborators show in the above image that when shear waves are introduced into a medium and encounter a soft region they will change wavelength in a manner that is characteristic of the viscoelastic properties.

Ultrasonic Shear-wave Elasticity Imaging

Bioimaging Science and Technology group member Michael Insana seeks to develop new ultrasonic instrumentation and methods for imaging soft tissue microstructure, elasticity and blood flow, with an important focus on advancing techniques for ultrasonic imaging of the breast toward non-invasive cancer detection. One of Insana's long-running projects, funded by the National Institutes of Health, focuses on imaging breast tissue to determine its elasticity, since tissue stiffness is one method of diagnosing disease processes involving local inflammatory responses. In this project, Insana used shear acoustic waves to characterize tissue structures in the breast and tissue-like media (in this case a gelatinous hydrogel used to test the method) in order to visualize mechanical properties that can provide diagnostic information about cancer growth. Insana writes that when these shear waves encounter a soft region it "will change wavelength in a manner that is characteristic of the viscoelastic (viscous and elastic) properties. Thus nodules can be detected noninvasively."

Beckman researchers Martin Ostoja-Starzewski and Brad Sutton are developing 3-D finite element (FE) models for transient dynamic response of cranium and brain tissues. The top image at left shows a frame taken at 6 ms shat shows spherically convergent waves of von Mises stress on the brain. The bottom image shows an FE mesh of the brain after eight smoothing iterations.

Here I can easily find the experts and we can have lunch or coffee together and right away I think 'oh yeah we can do all these new things.' So that's really a reward of being here.

– Yingxiao (Peter) Wang

Researcher **Profile**

Integrative Imaging faculty member Yingxiao (Peter) Wang was one of the stars of the reflections video shown at the Beckman 20th Anniversary Celebration in April. The video featured faculty, staff, and students expressing their sentiments about Beckman, with Wang's clip providing a fitting finale.

"Hopefully I can stay here the rest of my life," Wang said, drawing the kind of affirming audience reaction any movie producer would love to provoke. Wang, however, said he felt a little embarrassed.

"I didn't know that would be on the video," he said with a laugh. "After I saw that, I thought 'oh no.' Obviously, I said something that was not very scientific. I'm an assistant professor, I'm not tenured yet. All these things very much depend on how things develop."

So far, things are developing quite well. An Assistant Professor in the Bioengineering Department and member of the Bioimaging Science and Technology group at Beckman, Wang has already made an impact on campus and in his discipline of bioengineering.

In 2009 he won a National Science Foundation Early Career Award grant to develop a molecular stress biosensor for studying mechanotransduction, the cellular process that converts mechanical signals into biochemical responses. His interdisciplinary research collaborations have

Wang A Rising Star at Beckman

resulted in papers in top-tier scientific journals such as the *Proceedings of the National Academy of Sciences* and produced technologies that could be used for detecting cancer.

Wang decided to come to the University of Illinois four years ago in large part because of the opportunity to engage in interdisciplinary, translational research at the Beckman Institute.

"A lot of scientists go for the discovery. For us we are more interested in seeing how our discovery or research progress can have a relatively direct and immediate impact on our society in a broad sense."

"It was one of my top choices, so I applied here and I specifically asked to join Beckman," Wang said. "At that time Professor Bruce Wheeler was our interim chair at Bioengineering and was saying there are some other spaces on campus, but I insisted. I said, please, I really want to get into Beckman. That was part of my package.

"I also had heard that Beckman had very good coordination among different disciplines, and that you could really talk to different kinds of experts. Particularly in the kind of research I am interested in, we concentrate at the interface of different disciplines: engineering, molecular biology, chemistry, biophotonics. Beckman is one of the few places where you would find all of this expertise. So it was a major reason to come here."

Much of Wang's research as part of the Integrative Imaging theme at Beckman is aimed at manipulating large proteins in live cells toward the development of technologies like biosensors for detecting cancer. In that research line, Wang's approach is to get the body's own cells to do the sensing work.

"What we are doing is developing molecular sensors or molecular probes that we can introduce into the cell and then hijack the cell's system so it produces colorful proteins, or colorful molecules inside," Wang said "Whenever you poke a cell, the cell will sense it, and that will cause biochemical activity that causes the color change. So we can visualize the color change in the cell, and know exactly where the molecular activity has been turned on. That color change is important for detecting cancer."

Wang said the biosensor technology will provide real-time, molecular scale information toward detection and diagnosis of cancer. The biosensors may also be used to test the efficacy of cancer-fighting drugs. He estimates that the actual clinical use of this biosensing technology is about two to three years away.

Developing a new method for detecting cancer faster and at a scale that would greatly enhance treatment methods is exactly the kind of end result Wang's research approach aims at achieving.

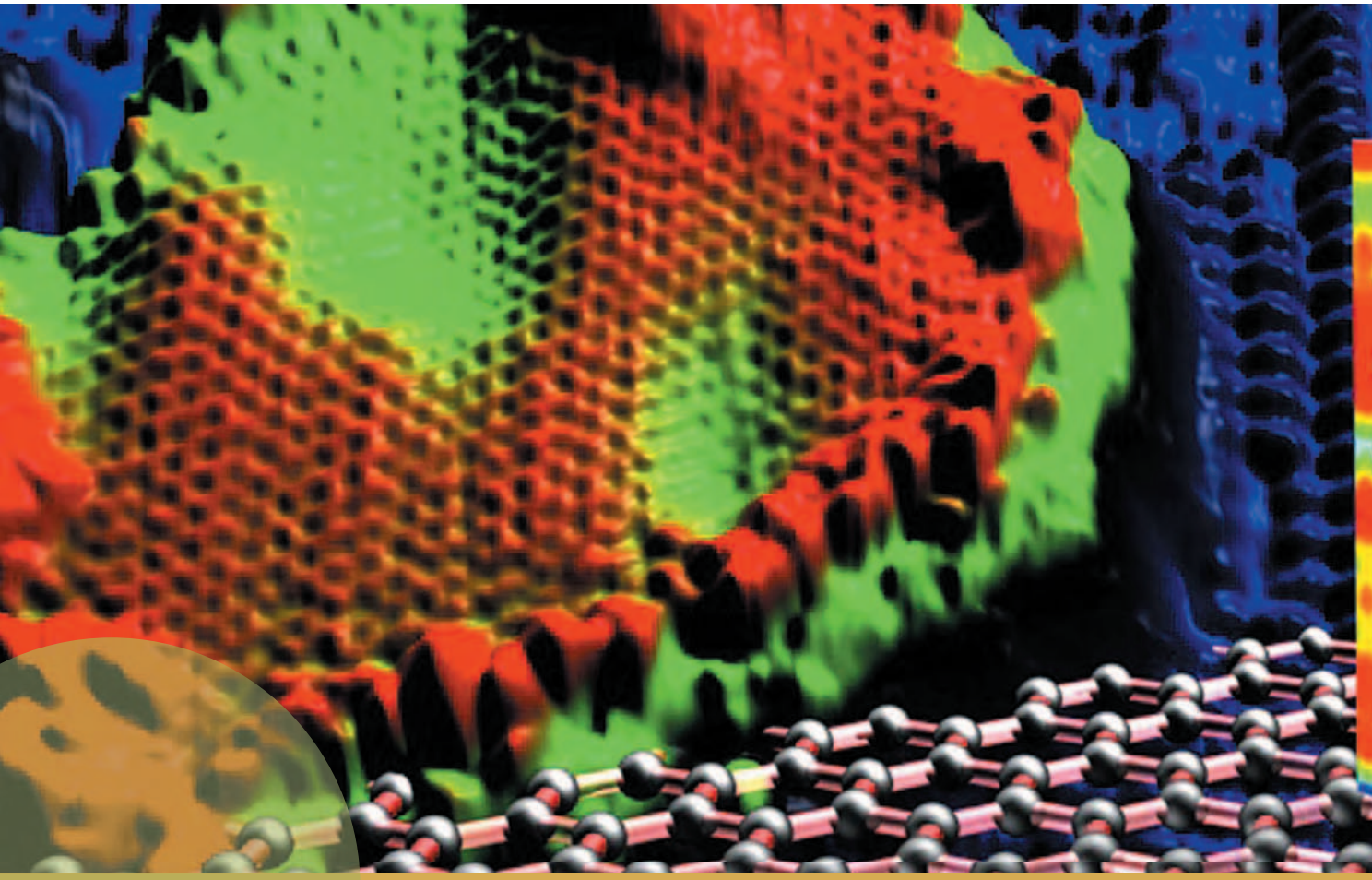
"A lot of scientists go for the discovery," Wang said. "For us we are more interested in seeing how our discovery or research progress can have a relatively direct and immediate impact on our society in a broad sense."

When Wang says "us", he is including everyone in his lab.

"I think the students and the postdocs also get excited when we publish things and people start to ask us for our tools," he said. "Students like that because they feel they are really useful and those tools can change other researchers' work. They can see the direct impact, not like in maybe 30 years, something will happen."

In 30 years Wang may be working with a new generation of students, on a new generation of research, but the setting, he hopes, will be the same.

"I really enjoy the interdisciplinary environment because research is so diverse but a lot of times I feel like I am limited," Wang said. "Here I can easily find the experts and we can have lunch or coffee together and right away I think 'oh yeah we can do all these new things.' So that's really a reward of being here."



OVERVIEW: MOLECULAR & ELECTRONIC NANOSTRUCTURES

They work with materials as diverse as glass and human enzymes, in research lines that explore everything from carbon nanotubes to acoustic waves, on projects that were unthinkable when the Beckman Institute first opened 20 years ago. But today, thanks to huge increases in computing power over the last two decades and an interdisciplinary approach that brings different researchers together for work at the nanoscale, the Molecular and Electronic Nanostructures (M&ENS) research theme is making the impossible a reality.

One of three original research themes at Beckman, work in M&ENS has the broad mission of understanding chemical and physical processes and structures at the nanometer scale, as well as advancing the development of nanoscale applications, including creating software for basic science and translational research projects.

There are six groups making up the M&ENS research theme. The 3-D Micro- and Nanosystems (3-DMN) group develops strategies for assembling and studying those structures. Research in the Autonomous Materials Systems (AMS) group is centered around the design of autonomic multifunctional materials systems. Members of the Computational Electronics (CE) group perform computational modeling of electronic transport and optical processes in solids and construct computational simulations of materials and device behavior. Computational Multiscale Nanosystems (CMN) research uses computational methods in the design of nanosystems. The Nanoelectronics (NE) group develops electronic and optical systems for the fabrication and probing of biological, nanoelectronic, and other molecular scale systems. The Theoretical and Computational Biophysics (TCB) group uses both theory and computational methods to explore biological structures and functions.

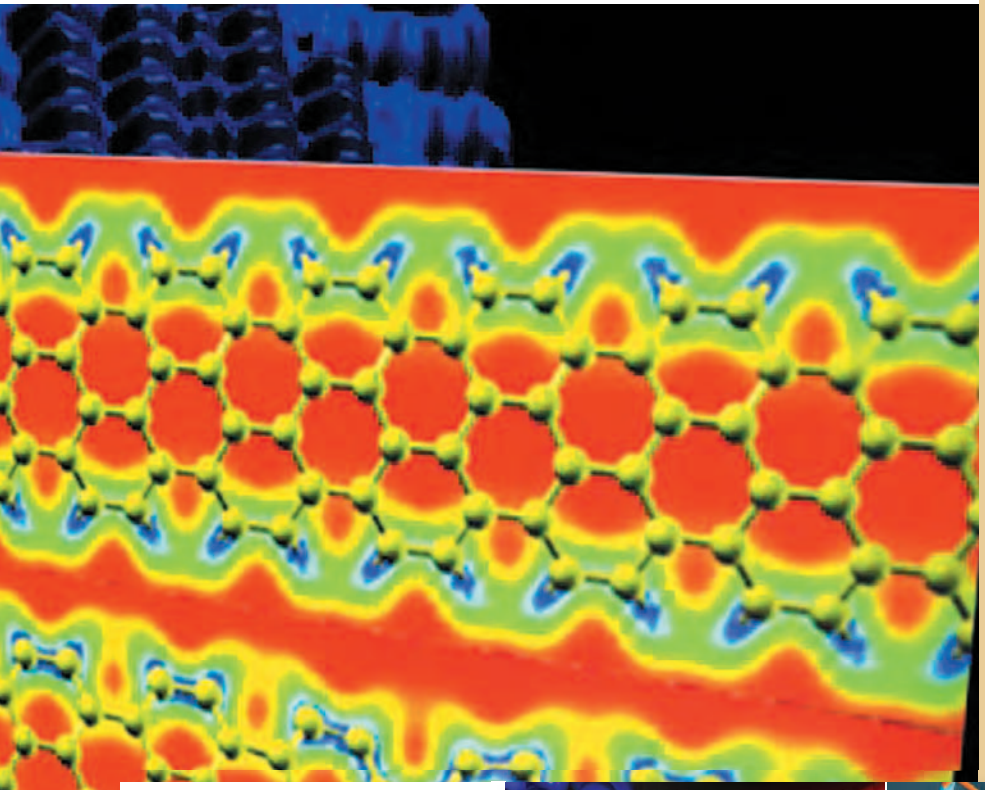
The Theoretical and Computational Biophysics group, led by **Klaus Schulten**, is celebrating its 20th year as a National Institutes of Health Resource for Macromolecular Modeling and Informatics, as well as 20 years at Beckman doing pioneering research in state-of-the-art molecular dynamics simulations.

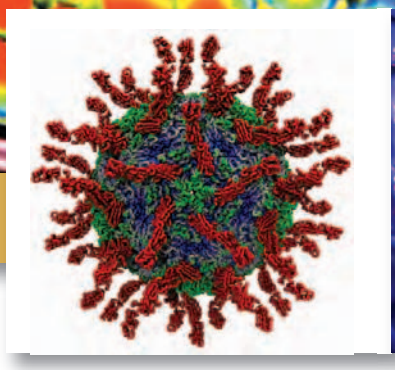
Another Beckman original, Nanoelectronics group leader **Joe Lyding**, has also been a pioneer in creating technology – building Illinois's first scanning tunneling microscope (STM) and inventing the ultrastable STM – that he uses to research materials like carbon nanotubes, and that was used by fellow NE group member **Martin Gruebele** for groundbreaking research into the dynamics of glass molecules.

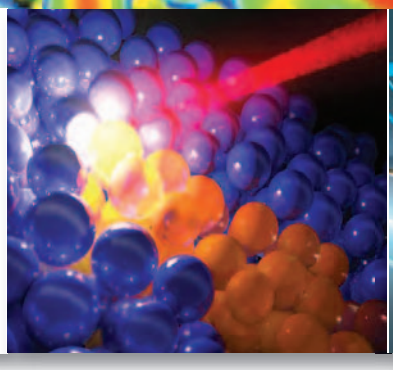
Most of the research in the Molecular and Electronic Nanostructures research theme involves topics that have real-world applications, or the potential for applications, in industry, science, medicine, or our everyday environments.

Min-Feng Yu led a project that created a nanoneedle that has potentially important biomedical applications. **William King** studies the thermal properties of materials toward applications in the automotive, pharmaceutical, and other industries.

The Autonomous Materials Systems group continues to be a world leader in the research and design of self-healing materials and systems. They







are developing new design approaches such as for self-healing coatings (**Scott White** and **Paul Braun**), as well as developing new ways to advance self-healing reactions, such as work on mechanochemical reactions in solid state polymers (Braun, White, **Nancy Sottos**, and **Jeff Moore**).

Work in projects involving biological processes also saw breakthroughs this past year. **Stephen Sligar** developed a prototype of a nanoparticle biosensor for detection of binding of an enzyme critical for drug metabolism. **Umberto Ravaioli** is part of a collaboration that includes the Mayo Clinic College of Medicine that used a simulation method he developed called BioMOCA to study ion conduction in a biological receptor. **Eric Jakobsson**'s group developed a new force field for simulation of membranes.

Many projects investigate topics surrounding microelectromechanical (MEMS) and nanoelectromechanical (NEMS) systems. **Ioannis Chasiotis'** group used MEMS tools to develop a completely new method to quantify interfacial strength of nanofibers and nanotubes. Computational Electronics group members had breakthroughs in the area of understanding thermoelectric issues in carbon nanotubes (**Jean-Pierre Leburton**) and in the area of exchange coupling of spins in double quantum dots (**Matthew Gilbert**).

A growing number of research lines within M&ENS involve fluidics. These range from biological topics such as lipid membranes (**Steve Granick**), to development of innovative water purification methods (**Mark Shannon**), to using DNA as an enzyme for testing materials like metals in water (**Yi Lu**), to using computational methods such as molecular dynamics simulations of nanometer scale flows (**Jonathan Freund**) and water flow in carbon nanotubes (**Narayana Aluru**).

In 2009 the research within M&ENS continues to expand and break new ground as researchers within this theme carry on a 20-year tradition of work at the nanoscale.

IMAGINING POSSIBILITIES WITHOUT BOUNDARIES 1989-2009 BECKMAN INSTITUTE

Molecular & Electronic Nanostructures Research Groups

- 3-D Micro and Nanosystems
- Autonomous Materials Systems
- Computational Electronics
- Computational Multiscale Nanosystems
- Nanoelectronics
- Theoretical & Computational Biophysics

Top image:

An image illustrating work in nanoelectronics and nanomaterials.

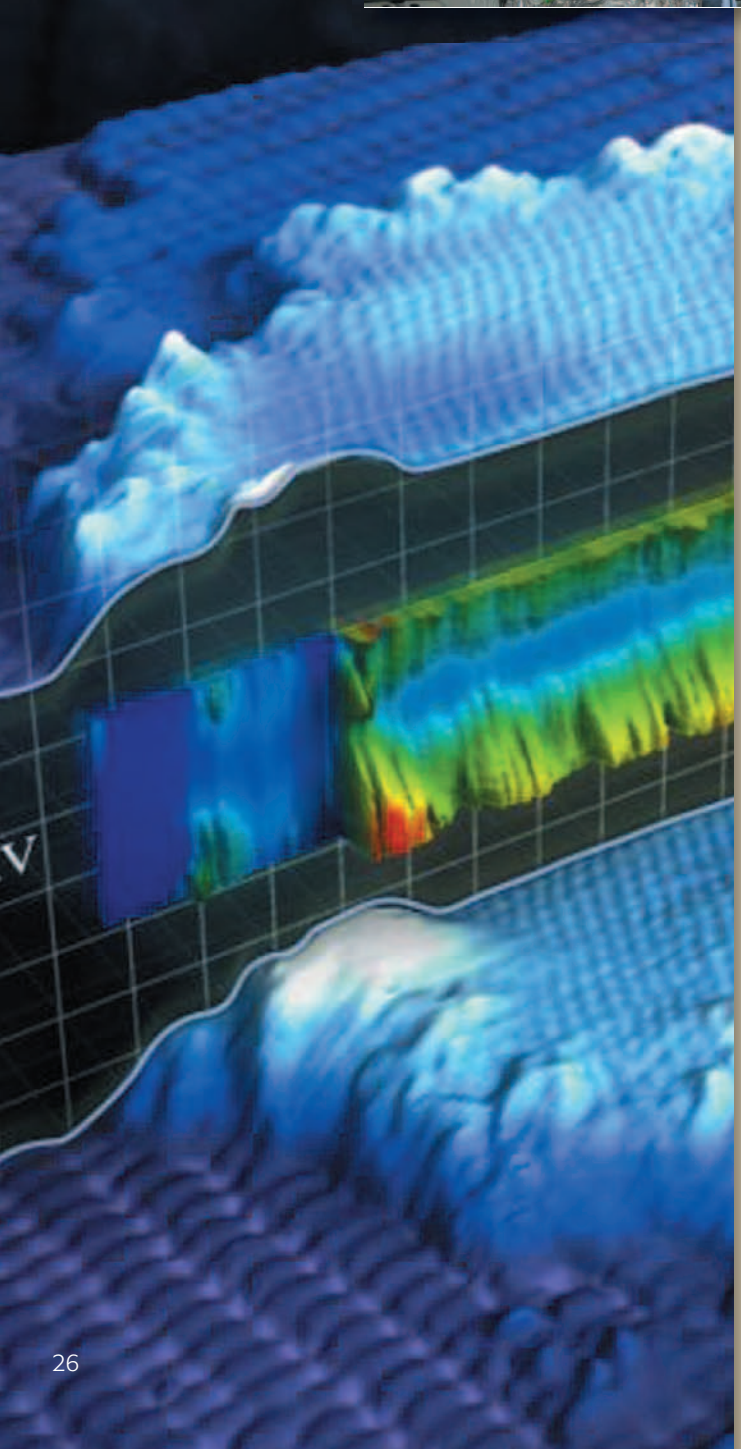
Inset images from left to right:

An image from the Theoretical and Computational Biophysics group of an all-atom model of the poliovirus capsid with 60 receptors bound to the capsid.

This 3-D graphic accompanied the January 2009 Advanced Materials cover that featured the article "Direct Laser Writing of Photoresponsive Colloids for Microscale Patterning of 3-D Porous Structures" by Matthew George, Jennifer Lewis, and Paul Braun. The image was created by the Imaging Technology Group's Visualization Laboratory.

Beckman researcher Yi Lu and his collaborators are progressing with the development of biosensors by integrating functional DNA molecules with different types of nanomaterials. The image was featured on the April 7, 2009 cover of the Journal of Materials Chemistry and was created by the Imaging Technology Group's Visualization Laboratory.

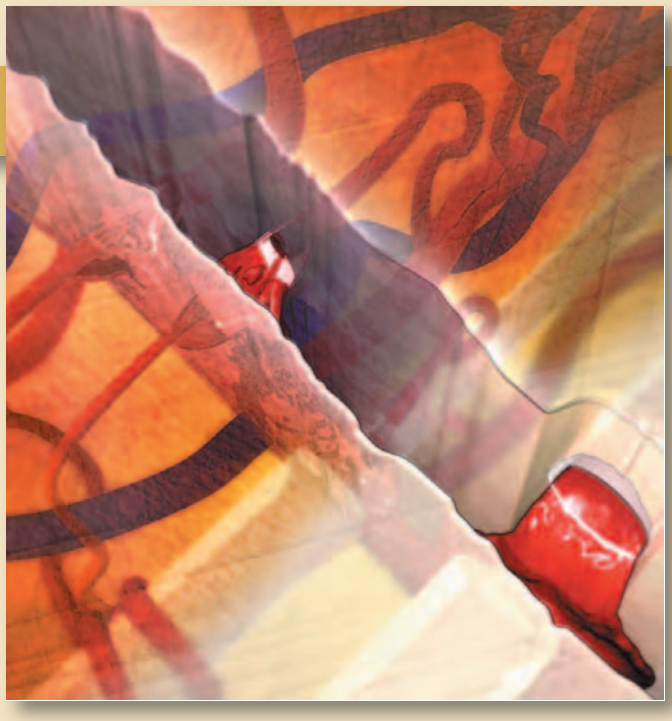
From left to right: Martin Gruebele, Greg Scott, Felipe Olivarez, and Sumit Ashtekar.



Gruebele, Lyding Groups Work to Visualize Glass in New Way

Martin Gruebele and Joe Lyding of the Nanoelectronics group have given new insight into one of the oldest technologies known to man. Gruebele and Lyding have been collaborating for about 15 years, but in a completely new research line, Gruebele adopted Lyding's scanning tunneling microscope (STM) technology to visualize glass in a way that hadn't been done before. Gruebele said that there is no comprehensive theory of how glasses work and that past bulk experiments were able to provide information about the time it took for a process to take place, but not describe the actual dynamics of the process. With Lyding's help, an STM was built in the Gruebele laboratory and used to create a multi-hour movie that allowed visualization of the molecular movements of glasses in a way that has never been done before. Recording movements sometimes at a rate of a frame every five minutes, they were able to observe a mysterious process in the field of glass dynamics called beta-relaxations. Gruebele writes that graduate student Sumit Ashtekar of his group "directly observed metallic clusters making positional transitions between two equilibrium sites, and measured the rate distribution and equilibrium constants for many clusters" and that "unlike past bulk experiments, this technique completely separates homogeneous (same at all sites) and heterogeneous (changing even at one site) movements of glasses." Gruebele said that being able to finally visualize dynamics like the differences between heterogeneous and homogeneous movements in glasses is important for developing applications like metallic glasses that are used in products such as electronic device casings.

The image at left was created by the Imaging Technology Group's Visualization Laboratory for Joe Lyding's research group. Lyding has proven that the orientation of atoms along the edges of the graphene lattice would affect the material's electronic properties.



Self-healing research by the Autonomous Materials Group as illustrated by the Imaging Technology Group's Visualization Laboratory.

Continuous Self-healing of Microvascular Systems

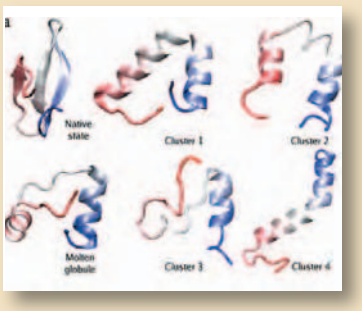
An important line of research within the Autonomous Materials Systems (AMS) group involves microvascular self-healing systems, which are vascular circulatory systems integrated in materials. In 2009 AMS members Nancy Sottos, Scott White, Jennifer Lewis, and Jeff Moore, as well as research group members Kathleen Toohey and Christopher Hansen, demonstrated repeated self-healing of epoxy polymers by using a microvascular supply system to continuously transport healing agents. They were able to show, as they wrote in *Advanced Functional Materials*, microvascular self-healing of a brittle coating by "supplying fluid healing agents from an underlying network of microchannels. By using dual independent networks filled with a two-part healing chemistry (epoxy resin and curing agent) (we) demonstrate repeated healing of damage in the coating up to 16 consecutive times." The research is supported by an Air Force Office of Scientific Research MURI program grant.

Mechanochemical Transduction Demonstrated in Solid State Polymers

Autonomous Materials Systems (AMS) group members Nancy Sottos, Scott White, Jeff Moore, Paul Braun, and collaborator Todd Martinez and members of their research groups advanced research into self-healing materials by demonstrating the triggering of a mechanochemical (turning mechanical energy into chemical energy) reaction in solid state polymers. In earlier work Moore and his collaborators had created a mechanically active polymer unit called a mechanophore for driving and controlling chemical reactions for use in self-healing materials. As they wrote about this most recent advance for *Nature* magazine in 2009, the latest project involved grafting mechanophores called spiropyrans into "elastomeric and glassy polymers and stressed to a critical level at which point a vivid color change was initiated via an electrocyclic ring-opening reaction." They report that the value of spiropyran mechanophores is that "they can serve as molecular probes to aid in understanding the effects of stress and accumulated damage in polymeric materials, thereby providing an opportunity for assessment, modification and improvement prior to failure." The research is part of a U.S. Army Research Office MURI program that is yielding greater understanding of mechanophores toward improvements in their design, leading to new classes of dynamically responsive polymers that can locally remodel, reorganize, or regenerate in response to mechanical stress.

TCB Group Provides Unprecedented Insight into Protein Folding

The Theoretical and Computational Biophysics (TCB) group, led by Klaus Schulten, continued to break new ground with its ability to dynamically visualize a molecular-scale world of the processes and structures found in nature. One line of research at TCB uses the group's molecular dynamics simulations software to study an essential component of cellular function called protein folding, the process by which linear chains of amino acids, a protein's building blocks, fold into a functional three-dimensional protein. This past year a team led by Schulten and Martin Gruebele from the Nanoelectronics group was able to obtain unprecedented insight into this process by performing multiple-microsecond folding simulations of the villin headpiece subdomain protein. Recent improvements in the performance of TCB's molecular dynamics simulation program NAMD allowed for simulations of the structure of the protein, as well as revealing aspects of the process such as the orienting process that sections of the protein go through in order to form a structure. The researchers at TCB write that the results of the simulations "were in agreement with a long-standing theory on protein folding known as the folding funnel hypothesis, and show that proteins fold through a series of stages, with fewer and fewer different shapes available as they approach the final folded structure."



The Theoretical and Computational Biophysics group obtained unprecedented insight into the protein folding process by performing multiple-microsecond folding simulations of the villin headpiece subdomain protein.

Beckman researcher Jean-Pierre Leburton (left) and graduate student Marcelo Kuroda collaborated on a theory that gives insight into the absence of the thermoelectric effect in metallic carbon nanotubes. Photo by L. Brian Stauffer.

.Advancing the Understanding of Carbon Nanotube Thermoelectric Issues

Jean-Pierre Leburton leads the Computational Electronics group, investigating issues involving semiconductor nanostructures. He and graduate student Marcelo Kuroda reported in 2008 on their discovery involving a law of semiconductor physics that adds to our understanding of how metallic carbon nanotubes (CNTs) might be used in electronic devices. One such use could be as interconnects for integration with silicon-based electronics. Their paper, *Restricted Wiedemann-Franz Law and Vanishing Thermoelectric Power in One-Dimensional Conductors*, addressed thermoelectric effects involving metallic CNTs, an important issue for understanding and designing future technology such as interconnects. Their research has shown that the thermoelectric effect, a necessary property for semiconductor technology, is stripped away in metallic CNT systems. In their paper they are able to explain some of the fundamental physics underlying these systems, giving a consistent picture of thermoelectric transport in metallic carbon nanotubes. They write that "in metallic carbon nanotubes under external electric fields or thermal gradients the carrier populations in different directions of motion have different temperatures as a consequence of self-consistent carrier-heat transport. In this context, the fundamental Wiedemann-Franz law that related the electric conductivity and the thermal conductivity is restricted to each direction of charge carrier motion with their specific temperature, with the consequence that the thermoelectric power vanishes due to electron-hole symmetry, which is validated by experiment." Leburton said the finding is especially important for understanding the relation between current and heat flow in one-dimensional conductors.

Developing Nanofibers, Nanoneedles for Scientific, Industrial Uses

Min-Feng Yu of the Nanoelectronics group collaborated with Ning Wang of the Integrative Imaging research theme in developing a nanoneedle that can deliver tiny amounts of materials, and be used as an electromechanical probe and optical biosensor. Yu, who studies small-scale behavior of materials, had previously demonstrated a direct-write nanomanufacturing technique for high-speed, continuous fabrication of nanofibers in complex shapes and unlimited lengths, including individual nanowires. The technique is based on the rapid evaporation of solvents from inks, using a glass micropipette with an aperture as small as 100 nanometers in a process that creates freestanding nanofibers, suspended or stacked nanofiber arrays, and a continuously wound nanofiber roll. The technique makes feasible production-scale fabrication of nanofibers for their increased use in nanoscale templating, structuring, and other economical industrial applications. Yu said that the nanomanufacturing technique previously developed for fabricating nanofibers of unlimited length was also used to make thin and high-aspect ratio nanoneedles and even hollow nanoneedles. Using the nanoneedle the researchers were able to deliver individual fluorescent quantum dots into a cell's cytoplasm and nucleus, and then detect and track the dots for studying molecular mechanics and physical properties inside the cells. Yu said the nanoneedle will be particularly useful for scientific biomolecular studies while the nanofibers have potential industrial applications in composites and devices such as microscale inductive coils used in electronics.

Improving Self-healing Polymer Coatings

Paul Braun and Scott White of the Autonomous Materials Systems (AMS) group, along with group member Soo Hyoun Cho, fashioned a dual capsule approach for self-healing polymer coatings that protects the healing components from adverse chemical reactions with the coating materials. Original work by the AMS group on self-healing polymers used microencapsulated healing agents and catalysts that were released in response to stress or damage. As reported in *Advanced Materials* in 2009, the dual capsule approach encapsulates a chemical catalyst and healing agent in separate microcapsules that are dispersed in a polymeric coating, thereby protecting the healing components. They write that damage to the coating "releases the encapsulated components and triggers the self-healing chemistry so that the substrate is recoated and protected from environmental attack" and that the "microcapsule motif also provides a delivery mechanism for corrosion inhibitors, antimicrobial agents, and other functional chemicals."

This December 2, 2008 cover of the Proceedings of the National Academy of Sciences of the United States of America (PNAS) accompanies the feature article describing stretchable circuits developed by Beckman researcher John Rogers and his collaborators.

Fang Develops First Acoustic Superlens

Nicholas Fang's research involving nanophotonics, acoustics and their implications for nanomanufacturing took a big step forward in 2009 with his demonstration of a tight focusing of ultrasound waves using the world's first-ever acoustic "superlens" that was developed in his lab. Fang's research as part of the 3-D Micro- and Nanosystems group focuses on what are called acoustic metamaterials, or man-made materials that have a negative refractive index in that they bend sound waves in different directions than normal materials. The acoustic superlens used to focus the ultrasound waves was created using an aluminum plate with transmission channels that work as inductors and an array of Helmholtz resonators of negative refraction that serve as cavities for resonating waves and are tuned to interact with ultrasound waves. Leilei Yin from Beckman's Microscopy Suite and graduate student Shu Zhang worked with Fang on the project. The most obvious potential applications of acoustic metamaterial technology is in high-resolution clinical ultrasound imaging, but other possible uses include cloaking devices such as might be used on a submarine.

Biological Activity of Nanoparticles

Steve Granick of the 3-D Micro- and Nanosystems group discovered a method of stimulating patchiness in phospholipids, an important advancement for using phospholipid membranes as biomaterials and biosensors. Granick and his research group used charged nanoparticles for their experiments, studying the interactions between the nanoparticles and membranes that were formed from single-component lipids. They showed that when the nanoparticles bind to the membrane, the phase state of phospholipid vesicles is transformed and that a phospholipid membrane can coexist in both solid and liquid phases (the patchiness property) depending on what binds to it. Granick writes that patchy functional properties are fundamental to using phospholipid membranes "as biomaterials and biosensors as well as a multitude of cellular activity" and that this discovery "sheds light on the potential biological activity of nanoparticles that increasingly are exposed to living systems through adventitious environmental contact as well as by design." The work was published in *Proceedings of the National Academy of Sciences (USA).*

Practical Carbon Nanotube Transistor Created

Just last year John Rogers and his collaborators built the world's first all-carbon nanotube transistor radio while at the same time creating a new type of radio frequency analog electronics technology. In 2009 Rogers, a member of the 3-D Micro- and Nanosystems group, and his collaborators added to the technology by creating the highest speed *practical* carbon nanotube transistor yet developed. Rogers said the accomplishment provides "a clear roadmap for the development of an RF analog electronics technology based on carbon nanotubes." Rogers said that because carbon nanotubes (CNTs) are mechanically strong and flexible, they can be integrated with thin sheets of plastic for flexible electronics. And since their intrinsic properties exceed those of silicon, they have excellent potential for use in very high performance systems. Rogers writes that the CNT transistor "achieved frequencies approaching 10 GHz" and that "systematic analysis established the key operating characteristics as well as quantitative description with compact device models similar to those used for conventional inorganic transistors." In addition, the same team demonstrated the first digital logic circuits using carbon nanotubes. The work is supported by the National Science Foundation.

Aluru Makes Breakthroughs Involving Water Transport in Carbon Nanotubes

Narayana Aluru of the Computational Multiscale Nanosystems group made two important discoveries involving water transport in carbon nanotubes (CNTs) that have implications for creating extremely efficient nanofluidics devices for water purification, drug delivery, and many aspects of nano-manufacturing. Using molecular dynamics simulations, Aluru and graduate student Sony Joseph discovered a molecular mechanism that governs the relationship between orientation and water flow. They demonstrated that orienting the water molecules through electrical or chemical methods enhances the rapid transport of water in CNTs. The researchers also report finding that in long carbon nanotubes, "when the orientation of the water molecules is maintained along one direction, a net water transport along that direction can be attained" and that "this mechanism can be used to pump water through nanotubes."

If I wasn't in love with living systems and trying to learn about them, I would have become a pure mathematician. But I couldn't see myself only in the world of mathematics. I wanted to apply this logical thinking and approach to living systems.
– Klaus Schulten

Researcher **Profile**

It took about thirty years but in the late 1990s technology finally started to catch up with Klaus Schulten's dreams.

As a young student in Germany, Schulten was fascinated by the natural world but his talents lay in mathematics and physics. He figured that one way to combine both interests would be to use computational methods to study nature.

"When I was a young man, my goal was to look with mathematical and computational means at the inside of cells, one atom at a time, to decipher how living systems work," Schulten said. "That is what strived for and I never deflected from this goal. Initially I was very far away from my goal because the information wasn't there and the computer power wasn't there, but that happened over the last 20 years. That's what makes my life at the Beckman so rewarding, because my long dream was finally fulfilled."

The reality of Schulten's research work today probably goes beyond anything he imagined many years ago. He is a Swanlund Professor of Physics (the highest endowed title at the University of Illinois), and at Beckman leads the Theoretical and Computational Biophysics (TCB) group, considered one of the premier groups in the world doing dynamic molecular scale simulations of biological processes and systems.

According to TCB's Web site, the group "utilizes advances in physical theory and computing to model organisms across many levels of organization, from molecules to cells to networks" using the "most

Schulten Living His Dream at Beckman

advanced molecular modeling, bioinformatics, and computational technologies." Those technologies include the supercomputer at the National Center for Supercomputing Applications (NCSA) at Illinois, used to perform dynamic simulations of biological structures and processes in ways that have never been done before.

Schulten is a Beckman original, starting his TCB group when the Institute opened in 1989, and it has been breaking new ground in visualizing and analyzing nature's workings ever since. Schulten grew up in Westphalia, Germany, earning a bachelor's degree in physics from the University of Muenster in 1969, and a Ph.D. in chemical physics from Harvard University in 1974. After professorships in Germany, he came to the University of Illinois in 1988 in part because his wife and fellow TCB researcher, Zan Luthey-Schulten, is a native of Illinois.

While Schulten's aptitudes and degrees are in the physical sciences, his passion is derived from the natural world.

"I'm really a mathematician who loves living systems," he said. "I am sort of between the chairs: mathematics is my ability and my love is living systems. If I wasn't in love with living systems and trying to learn about them, I would have become a pure mathematician. But I couldn't see myself only in the world of mathematics. I wanted to apply this logical thinking and approach to living systems."

That approach has taken the form of using computers to create often astounding simulations of processes such as water transport in cells and the first simulation of an entire life form, the complete satellite tobacco mosaic virus.

Schulten said that around 10 years ago, computers became powerful enough to do the kinds of simulations of biological systems and processes that he had always envisioned. Over the years TCB has developed software programs called NAMD and VMD that allow users to visualize in images and movies biological processes that had previously been left to the imagination.

"People always tell us that that is what is unique about this group, that we are leaders in the scientific applications and in the development of the software."

"The best picture that we can give for what we do is that we are building a computational microscope," Schulten said of the software's functionality. "We are building a computational microscope because we literally give people pictures of living systems at very small scales as they move in time. That is almost like a fantasy but computing today is so accurate and powerful that this is actually being realized more and more."

In 2009 TCB is recognized as a world leader in software development and research collaborations involving basic science and biomedical topics. The group's simulation of water transport through membrane channels was used to illuminate this previously mysterious biological process, and used in the Nobel Prize announcement for its discoverers. Other important scientific collaborations involved TCB illuminating how photosynthetic life forms harvest sunlight, looking at how antiviral medications interact with the swine flu virus, and in showing that a toxic molecule may play a critical role in how birds navigate.

To date, the Theoretical and Computational Biophysics group has earned more than $20M in grants for developing its software tools and has more than 160,000 users worldwide. The TCB Web site has more than one million unique visitors every year, and the group puts on software training seminars and training workshops all over the world. Schulten said that because of their success, they can be selective about which projects TCB collaborates on as a research partner.

"Probably the reason for our success is that we do both software development as well as the science," Schulten said. "People always tell us that that is what is unique about this group, that we are leaders in the scientific applications and in the development of the software."

Schulten says his dream became a reality not just because of advancements in computing power but also because of the faculty, students, postdocs and staff members he works with at TCB and at Beckman. It's a collaboration of people and technology that was a few years in the making, but looks to be as successful in the future as it has been in the past two decades.

"I always wanted to do what I'm doing and now I can do it," Schulten said.

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2008 – June 30, 2009

Biological Intelligence Research Theme Faculty
(name followed by home department)

Cognitive Neuroscience
Diane M Beck, *Psychology*
Neal J Cohen, *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*
Ming Hsu, *Economics*
Torrey M Loucks, *Speech and Hearing Science*
Gregory A Miller, *Psychology*
Denise C Park, *Psychology*
Richard S Powers, *English*
Sharon Y Tettegah, *Curriculum and Instruction*

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

NeuroTech
Thomas J Anastasio, *Molecular and Integrative Physiology*
Stephanie S Ceman, *Cell and Developmental Biology*
David F Clayton, *Cell and Developmental Biology*
Charles (Lee) Cox, *Molecular and Integrative Physiology*
Albert S Feng, *Molecular and Integrative Physiology*
Roberto Galvez, *Psychology*
Martha L Gillette, *Cell and Developmental Biology*
William T Greenough, *Psychology*
Douglas L Jones, *Electrical and Computer Engineering*
Janice M Juraska, *Psychology*
Richard J Kollmar, *Molecular and Integrative Physiology*
Mark E Nelson, *Molecular and Integrative Physiology*
Justin S Rhodes, *Psychology*
Gene E Robinson, *Entomology*
Edward J Roy, *Psychology*
Jonathan V Sweedler, *Chemistry*

SELECTED HONORS AND AWARDS

Aaron Benjamin
Hohenboken Award for Excellence in Undergraduate Teaching, 2009

Kiel Christianson
Participating investigator in NIH Training Grant (Language Processing: A Training Program T32-HD055272), led by Kathryn Bock (Psychology)

David F Clayton
Fellow of the Canadian Institute for Advanced Research

Jennifer S Cole
Appointed General Editor of *Laboratory Phonology,* a journal published by the newly formed Association for Laboratory Phonology

Kara Federmeier
UIUC Arnold O. Beckman Research Award, Magnetoencephalographic investigations of brain networks involved in language comprehension, 2009
Helen Corley Petit Scholar

Gabriele Gratton
President of the Society for Psychophysiological Research, 2009

Brian H Ross
Chair-elect, Psychonomic Society, 2009

Chilin Shih
Keynote address, The Second Theoretical Phonology Conference, Taipei, Taiwan, 2009.

Jonathan V Sweedler
James R. Eiszner Family Chair in Chemistry

SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Biological Intelligence research theme were inventors on the following two patents issued (4.8% of the 42 patents issued to campus) during FY2009 (Beckman Institute faculty members are listed in bold):

Bruce Flachsbart, **Mark Shannon**, **Paul Bohn**, and **Jonathan Sweedler**: "Multilayer Microfluidic Nanofluidic Device," Patent Issued November 4, 2008, Patent Number 7,445,027.

Crista Malick, Qi Xie, Mitesh Parikh, Steven Franke, **Douglas Jones**, Jeffrey Larsen, Christopher D. Schmitz, and Francois Callias: "Electrode Placement for Wireless Intrabody Communication between Components of a Hearing System," Patent Issued March 31, 2009, Patent Number 7,512,448.

INVENTION DISCLOSURES

Faculty members from the Biological Intelligence research theme were inventors on 3 invention disclosures (1.5% of the 203 invention disclosures filed by campus) during FY2009.

SELECTED GRANTS AWARDED

Monica Fabiani, Ed Maclin, Gabriele Gratton, NSF, "Functional brain imaging by tunable mult-spectral event-related optical signal (EROS)," 10/14/08-9/19/09.

Tracey Wszalek, and Brad Sutton, Procter & Gamble, "Functional and dynamic MRI of swallowing," 7/1/08-6/30/09.

Boris Odintsov, NIH-Southern Illinois University, "Central Correlates of chronic tinnitus assessed with functional imaging and spectroscopy in an animal model," 8/1/08-7/31/11.

Diane Beck, Dirk Bernhardt-Walther, NIH, "CRCNS:fMRI pattern analysis of neural correlates of natural scene categories," 8/1/08-7/31/12.

Wendy Heller, Greg Miller, Brad Sutton, NIH-University of Colorado, "Project 3. Effects of emotion on executive function," 8/22/08-1/31/13.

Bill Greenough and Lee Cox, NIH-University of Washington, "Fragile X research center," 7/1/08-6/30/13.

Ivan Jean Weiler, Bill Greenough, Novartis Pharmaceutical, "Test of ERK & PP2A activation in leucocyte samples," 9/1/08-5/31/09.

Jennifer Cole, NSF, "Collaborative research: Landmark-based robust speech recognition using prosody-guided models of speech," 4/10/09-5/31/10.

Bill Greenough, Fraxa Foundation, "Provision of fMRI knowckout mice to select investigators," 21//09-1/31/10.

Gabriele Gratton, Monica Fabiani, Ed Maclin, Sandia National Laboratory, "Functional brain imaging by tunable multi-spectral event-related optical signal (EROS)," 10/14/08-9/19/09.

Bill Greenough, NIH-ARRA Funding, "Therapeutic motor training and fetal alcohol effects," 7/1/09-6/30/11.

SELECTED PUBLICATIONS

Banich, M. T.; Mackiewicz, K. L.; Depue, B. E.; Whitmer, A. J.; Miller, G. A.; Heller, W., Cognitive control mechanisms, emotion and memory: A neural perspective with implications for psychopathology. *Neuroscience and Biobehavioral Reviews* **2009,** 33, (5), 613-630.

Barreiro, A. K.; Bronski, J. C.; Anastasio, T. J., Bifurcation theory explains waveform variability in a congenital eye movement disorder. *Journal of Computational Neuroscience* **2009,** 26, (2), 321-329.

Beatty, J. A.; Sylwestrak, E. L.; Cox, C. L., Distinct populations of projection neurons in the rat lateral parafascicular thalamic nucleus and their cholinergic responsiveness. *Neuroscience* **2009,** 162, (1), 155-173.

Benjamin, A. S.; Diaz, M.; Wee, S., Signal detection with criterion noise: applications to recognition memory. *Psychological Review* **2009,** 116, (1), 84-115.

Bora, A.; Annangudi, S. P.; Millet, L. J.; Rubakhin, S. S.; Forbes, A. J.; Kelleher, N. L.; Gillette, M. U.; Sweedler, J. V., Neuropeptidomics of the Supraoptic Rat Nucleus. *Journal of Proteome Research* **2008,** 7, (11), 4992-5003.

Brockmann, A.; Annangudi, S. P.; Richmond, T. A.; Ament, S. A.; Xie, F.; Southey, B. R.; Rodriguez-Zas, S. R.; Robinson, G. E.; Sweedler, J. V., Quantitative peptidomics reveal brain peptide signatures of behavior. *Proceedings of the National Academy of Sciences of the United States of America* **2009,** 106, (7), 2383-2388.

Cheever, A.; Ceman, S., Translation regulation of mRNAs by the fragile X family of proteins through the microRNA pathway. *RNA Biology* **2009,** 6, (2), 175-178.

Christianson, K.; Cho, H. Y., Interpreting null pronouns (pro) in isolated sentences. *Lingua* **2009,** 119, (7), 989-1008.

Duff, M. C.; Hengst, J.; Tranel, D.; Cohen, N. J., Hippocampal amnesia disrupts verbal play and the creative use of language in social interaction. *Aphasiology* **2009,** 23, (7), 926-939.

Evans, K. M.; Federmeier, K. D., Left and right memory revisited: Electrophysiological investigations of hemispheric asymmetries at retrieval. *Neuropsychologia* **2009,** 47, (2), 303-313.

Gratton, G., Rykhlevskaia, E., Wee, E., Leaver, E., and Fabiani, M., Does white matter matter? Spatiotemporal dynamics of task switching in aging. *Journal of Cognitive Neuroscience* **2009,** 21, (7), 1380-1395.

Helfer, J. L.; Calizo, L. H.; Dong, W. K.; Goodlett, C. R.; Greenough, W. T.; Klintsova, A. Y., Binge-like postnatal alcohol exposure triggers cortical gliogenesis in adolescent rats. *Journal of Comparative Neurology* **2009,** 514, (3), 259-271.

Hsiao, E. Y.; Schwartz, M. F.; Schnur, T. T.; Dell, G. S., Temporal characteristics of semantic perseverations induced by blocked-cyclic picture naming. *Brain and Language* **2009,** 108, (3), 133-144.

Larsen, E.; Iyer, N.; Lansing, C. R.; Feng, A. S., On the minimum audible difference in direct-to-reverberant energy ratio. *Journal of the Acoustical Society of America* **2008,** 124, (1), 450-461.

Onishi, K. H.; Murphy, G. L.; Bock, J. K., Prototypicality in sentence production. *Cognitive Psychology* **2008,** 56, 103-141.

Powers, R., The Book of Me. *GQ* November, **2008.**

Scott, R. M.; Fisher, C., Two-year-olds use distributional cues to interpret transitivity-alternating verbs. *Language and Cognitive Processes* **2009,** 24, (6), 777-803.

Shih, C., Linking phonology and phonetics: An implementation model of tones. In *Interfaces in Chinese Phonology*, Hsiao, Y.; Hsu, H.; Wee, L.; Ho, D., Eds. Academic Sinica: Taipei, **2008**; pp 99-120.

Sweedler, J. V., et al, Bovine genome sequencing and analysis consortium, the genome sequence of taurine cattle: a window to ruminant biology and evolution. *Science* **2009,** 324, 522-528.

Ueno, M.; Garnsey, S. M., An ERP study of the processing of subject and object relative clauses in Japanese. *Language and Cognitive Processes* **2008,** 23, (5), 646-688.

Winograd, C.; Clayton, D.; Ceman, S., Expression of fragile X mental retardation protein within the vocal control system of developing and adult male zebra finches. *Neuroscience* **2008,** 157, (1), 132-142.

Wonnacott, E.; Watson, D. G., Acoustic emphasis in four year olds. *Cognition* **2008,** 107, (3), 1093-1101.

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2008 – June 30, 2009

Human-Computer Intelligent Interaction Research Theme Faculty
(name followed by home department)

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

Human Perception and Performance
Wai-Tat Fu, *Human Factors Division*
Charles H Hillman, *Kinesiology and Community Health*
Fatima T Husain, *Speech and Hearing Science*
Derek Hoiem, *Computer 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*
George W McConkie, *Psychology*
Deana C McDonagh, *Industrial Design*
Daniel G Morrow, *Human Factors Division*
Daniel J Simons, *Psychology*
Jacob J Sosnoff, *Kinesiology and Community Health*
Jesse B Spencer-Smith, *Psychology*
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*
Yi Ma, *Electrical and Computer Engineering*
Pierre Moulin, *Electrical and Computer Engineering*
Klara Nahrstedt, *Computer Science*

SELECTED HONORS AND AWARDS

Narendra Ahuja
TA Stewart-Dyer/Frederick Harvey Trevithick Prize, Institution of Mechanical Engineers, 2008
Open Innovation Research Award, Hewlett-Packard, 2009

Minh N Do
Young Author Best Paper Award, IEEE Signal Processing Society, 2008

Mark A Hasegawa-Johnson
Associate Editor, Journal of the Acoustical Society of America, July 2009
Invited Lecture, National Academy of Engineering Japan-America Frontiers of Engineering, 2008

Thomas S Huang
Academician, Academia Sinica, Taiwan, ROC, 2008
Open Innovation Research Award, Hewlett-Packard, 2009

Fatima T Husain
Distinguished Mentor Award, awarded by the NIH Post-baccalaureate IRTA Fellows Committee, National Institutes of Health, June 2008
Chosen to attend Lessons For Success: Developing the Emerging Scientist workshop hosted by ASHA in Rockville, MD, April 2009

Edward McAuley
Appointed Chair, Psychosocial Risk and Disease Prevention Study Section, National Institutes of Health
Invited to participate on the NIH Distinguished Editorial Panels, the group responsible for evaluating critiques of ARRA Challenge Grants and assigning final impact evaluations

Jason S McCarley
Arnold O. Beckman Award from University of Illinois Campus Research Board

Dan G Morrow
Honorary fellow, Human Factors & Ergonomics Society, 2008
Associate Editor, Journal of Experimental Psychology: Applied, 2009

Dan Roth
Fellow, AAAI (Association for the Advancement of Artificial Intelligence), 2009

Ryan K Shosted
William and Flora Hewlett International Research Travel Grant, 2009

Elizabeth A L Stine-Morrow
Member, NRC Panel on Adolescent and Adult Literacy, 2009-2011

SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Human-Computer Intelligent Interaction research theme were inventors on two patent applications (1.4% of the 143 patent applications filed by the campus) and on the following two patents issued (4.8% of the 42 patents issued to campus) during FY2009 (Beckman Institute faculty members are listed in bold):

Jilin Tu and **Thomas Huang**: "Method of Performing Shape Localization," Patent Issued November 18, 2008, Patent Number 7,454,039.

Ziyou Xiong, **Thomas Huang**, and Makoto Yoshida: "Method for Detecting Objects in an Image Using Pair-Wise Pixel Discriminative Features," Patent Issued June 16, 2009, Patent Number 7,548,637.

INVENTION DISCLOSURES

Faculty members from the Human-Computer Intelligent Interaction research theme were inventors on 3 invention disclosures (1.5% of the 203 invention disclosures filed by campus) during FY2009.

SELECTED GRANTS AWARDED

Thomas Huang, Yamaha Motors, "Some machine learning issues in soft biometrics," 1/1/08-12/31/08.

Art Kramer, Ed McAuley, Neal Cohen, NIH, "Influences on fitness on brain and cogntion," 8/15/08-6/30/09.

Mark Hasegawa-Johnson, Thomas Huang, Hank Kaczmarski, NSF, "FODA-VA-Partner visualizaing audio for anomaly detection," 9/1/08-8/31/09.

Mark Hasegawa-Johnson, Dirk Bernhardt-Walther, Tom Huang, NSF, "RI-Medium: Audio diarization towards comprehensive description of audio events," 9/1/08-8/31/09.

Ron Carbonari, Yi Ching Lee, DOD Army-Parallel Consulting, "Increasing Tacit Knowledge of driving hazards risk assessment and crash mitigating behaviors," 9/1/08-8/31/10.

Stephen Levinson, Sandia National Laboratory, "Algorithmic models capable of perception and control," 1/1/09-5/31/09.

Jason McCarley, Donald Talleur, Hank Kaczmarski, FAA, "Data communication part-task simulation pilot performance," 3/3/09-9/2/10.

Art Kramer, Jason McCarley, Mark Neider, Dan Simons, Cognifit, "Assessing the efficacy of training interventions to improve driving performance of older adults," 11/1/08-10/31/09.

SELECTED PUBLICATIONS

Allen, J.; Li, F., Speech perception and cochlear signal processing. *IEEE Signal Processing Magazine* **2009,** 26, (4), 73-77.

Boot, W. R.; Kramer, A. F.; Simons, D. J.; Fabiani, M.; Gratton, G., The effects of video game playing on attention, memory, and executive control. *ACTA Psychologica* **2008,** 129, (3), 387-398.

Bretl, T.; Lall, S., Testing static equilibrium for legged robots. *IEEE Transactions on Robotics* **2008,** 24, (4), 794-807.

Campbell, L. H.; McDonagh, D., Visual narrative research methods as performance in industrial design education. *Qualitative Inquiry* **2009,** 15, (3), 587-606.

Daya, E.; Roth, D.; Wintner, S., Identifying Semitic roots: Machine learning with linguistic constraints. *Computational Linguistics* **2008,** 34, (3), 429-448.

Erickson, K. I.; Prakash, R. S.; Kim, J. S.; Sutton, B. P.; Colcombe, S. J.; Kramer, A. F., Top-down attentional control in spatially coincident stimuli enhances activity in both task-relevant and task-irrelevant regions of cortex. *Behavioural Brain Research* **2009,** 197, (1), 186-197.

Fernandes, A. L.; Raginsky, M.; Coleman, T. P., A Low-complexity universal scheme for rate-constrained distributed regression using a wireless sensor network. *IEEE Transactions on Signal Processing* **2009,** 57, (5), 1731-1744.

Fu, W. T.; Anderson, J. R., Dual learning processes in interactive skill acquisition. *Journal of Experimental Psychology-Applied* **2008,** 14, (2), 179-191.

Gans, N.; Hutchinson, S., Multi-Attribute Utility analysis in the choice of a vision-based robot controller. *The International Journal of Optomechatronics* **2008,** 2, (3), 326-360.

Husain, F. T.; Patkin, D.; H., T.-V.; Braun, A. R.; Horwitz, B., Distinguishing the Processing of Gestures from Signs in Deaf Individuals: An fMRI Study. *Brain Research* **2009,** 1276, 140-50.

Hutchinson, S., Untitled. *IEEE Transactions on Robotics* **2008,** 24, (6), 1261-1261.

Kirlik, A., Brunswikian resources for event-perception research. *Perception* **2009,** 38, (3), 376-398.

Ma, Y.; Yang, A. Y.; Derksen, H.; Fossum, R., Estimation of subspace arrangements with applications in modeling and segmenting mixed data. *Siam Review* **2008,** 50, (3), 413-458.

Nguyen, H. T.; Do, M. N., Error Analysis for image-based rendering with depth information. *IEEE Transactions on Image Processing* **2009,** 18, (4), 703-716.

Parisi, J. M.; Stine-Morrow, E. A. L.; Noh, S. R.; Morrow, D. G., Predispositional engagement, activity engagement and cognition in older adults. *Aging, Cognition, & Neuropsychology* **2009,** 16, 485-504.

Shosted, R., Acoustic characteristics of Swedish dorsal fricatives. *The Journal of the Acoustical Society of America* **2008,** 123, 3888.

Todorovic, S.; Ahuja, N., Unsupervised Category Modeling, Recognition, and Segmentation in Images. *IEEE Transactions on Pattern Analysis and Machine Intelligence* **2008,** 30, (12), 2158-2174.

Wang, Y.; Moulin, P., Perfectly secure steganogranphy: Capacity, error exponents, and code constructions. *IEEE Transactions on Information Theory* **2008,** 54, (6), 2706-2722.

Wojcicki, T. R.; White, S. M.; McAuley, E., Assessing outcome expectations in older adults: The multidimensional outcome expectations for exercise scale. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences* **2009,** 64, (1), 33-40.

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

Zhu, J.; Lyu, M. R.; Huang, T. S., A Fast 2D Shape recovery approach by fusing features and appearance. *IEEE Transactions on Pattern Analysis and Machine Intelligence* **2009,** 31, (7), 1210-1224.

SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2008 – June 30, 2009

Integrative Imaging Research Theme Faculty
(name followed by home department)

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

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

SELECTED HONORS AND AWARDS

Rohit Bhargava
Everitt Award for Teaching Excellence, UIUC, 2009

Marni Boppart
Ellison Medical Foundation New Scholar Award, 2008

Stephen Boppart
Fellow, SPIE – International Optical Society, 2009
Fellow, Optical Society of America, 2009
Campus Achievement Award for Promotion Dossier, Campus Committee on Promotion and Tenure, 2008
National 4-H Alumni Award for Illinois, 2008

Zhi-Pei Liang
Engineering Council Award for Excellence in Advising, 2008
D. Hernando, P. Kellman, J. P. Haldar, Z.-P. Liang, "Robust water/fat separation in the presence of large field inhomogeneities using a graph-cut algorithm," *Proc. ISMRM, 2009 won the 2009 Isador I. Rabi Award from the International Society of Magnetic Resonance in Medicine.*

Kenneth Suslick
Fellow, Materials Research Society, 2009
Acoustic Society of America Mentor Award, 2009
Charles William Murtiashaw III Lectureship, University of South Carolina, Columbia, 2008

Yingxiao Wang
NSF Career Award, 2009
Xerox Award for Faculty Research, 2009
Advisor to high-school student Richard Wang, a national semi-finalist for the Intel Science Talent Search, 2009
Grainger Award, 2008
Advisor to high-school student Richard Wang, regional finalist for the Siemens Competition in Math, Science and Technology, 2008

SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from the Integrative Imaging research theme were inventors on 17 patent applications (11.9% of the 143 patent applications filed by the campus) and on the following patent issued (2.4% of the 42 patents issued to campus) during FY2009 (the Beckman Institute faculty member is listed in bold):

Daniel Marks and **Stephen Boppart**: "Volumetric Endoscopic Coherence Microscopy using a Coherent Fiber Bundle," Patent Issued November 11, 2008, Patent Number 7,450,243.

INVENTION DISCLOSURES

Faculty members from the Integrative Imaging research theme were inventors on 11 invention disclosures (5.4% of the 203 invention disclosures filed by campus) during FY2009.

SELECTED PUBLICATIONS

Ahmad, A.; Adie, S. G.; Chaney, E. J.; Sharma, U.; Boppart, S. A., Cross-correlation-based image acquisition technique for manually-scanned optical coherence tomography. *Optics Express* **2009,** 17, (10), 8125-8136.

Barbaro, N. M.; Quigg, M.; Broshek, D. K.; Ward, M. M.; Lamborn, K. R.; Laxer, K. D.; Larson, D. A.; Dillon, W.; Verhey, L.; Garcia, P.; Steiner, L.; Heck, C.; Kondziolka, D.; Beach, R.; Olivero, W.; Witt, T. C.; Salanova, V.; Goodman, R., A multicenter, prospective pilot study of gamma knife radiosurgery for mesial temporal lobe epilepsy: seizure response, adverse events, and verbal memory. *Annals of Neurology* **2009,** 65, (2), 167-75.

Boppart, M. D.; Volker, S. E.; Alexander, N.; Burkin, D. J.; Kaufman, S. J., Exercise promotes alpha 7 integrin gene transcription and protection of skeletal muscle. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology* **2008,** 295, (5), R1623-R1630.

Chan, L. L.; Gosangari, S. L.; Watkin, K. L.; Cunningham, B. T., Label-free imaging of cancer cells using photonic crystal biosensors and application to cytotoxicity screening of a natural compound library. *Sensors and Actuators B-Chemical* **2008,** 132, (2), 418-425.

Coussot, C.; Kalyanam, S.; Yapp, R.; Insana, M. F., Fractional derivative models for ultrasonic characterization of polymer and breast tissue viscoelasticity. *IEEE Transactions on Ultrasonics Ferroelectrics and Frequency Control* **2009,** 56, (4), 715-726.

Davis, B. J.; Carney, P. S., Robust determination of the anisotropic polarizability of nanoparticles using coherent confocal microscopy. *Journal of the Optical Society of America a-Optics Image Science and Vision* **2008,** 25, (8), 2102-2113.

Davis, B. J.; Marks, D. L.; Ralston, T. S.; Carney, P. S.; Boppart, S. A., Interferometric synthetic aperture microscopy: computed imaging for scanned coherent microscopy. *Sensors* **2008,** 8, (6), 3903-3931.

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Jacob, M.; Sutton, B. P., Algebraic decomposition of fat and water in MRI. *IEEE Transactions on Medical Imaging* **2009,** 28, (2), 173-184.

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SELECTED FACULTY AWARDS, PATENTS, GRANTS, AND PUBLICATIONS

Covering July 1, 2008 – June 30, 2009

Molecular and Electronic Nanostructures Research Theme Faculty
(name followed by home department)

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

Autonomous Materials Systems
Ioannis Chasiotis, *Aerospace Engineering*
Jonathan Freund, *Materials Science and Engineering*
Philippe H Geubelle, *Aerospace Engineering*
Jennifer A Lewis, *Materials Science and Engineering*
Jeffrey S Moore, *Chemistry*
Nancy R Sottos, *Materials Science and Engineering*
Amy J Wagoner Johnson, *Mechanical Science and Engineering*
Scott R White, *Aerospace Engineering*

Computational Electronics
Matthew Gilbert, *Electrical and Computer Engineering*
Jean-Pierre Leburton, *Electrical and Computer Engineering*
Eric Pop, *Electrical and Computer Engineering*

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

Nanoelectronics
Ilesanmi Adesida, *Electrical and Computer Engineering*
Aleksei Aksimentiev, *Physics*
Alexey Bezryadin, *Physics*
Martin Gruebele, *Chemistry*
Xiuling Li, *Electrical and Computer Engineering*
Joseph W Lyding, *Electrical and Computer Engineering*
Nancy Makri, *Chemistry*
Margery Osborne, *Curriculum and Instruction*
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*
Emadeddin Tajkhorshid, *Biochemistry*

SELECTED HONORS AND AWARDS

Alek Aksimentiev
Beckman fellowship at the Center for Advanced Study (UIUC) for the academic year 2009-2010

Paul Braun
Xerox Award for Faculty Research, College of Engineering, UIUC

Nicholas Fang
SME Outstanding Young Manufacturing Engineers Award, 2009
NSF CAREER Award, 2009

Martin Gruebele
Sackler International Prize in Biophysics, 2008

Iwona Jasiuk
Vinson Lecture, 2009
Journal of Mechanics of Materials and Structures, Co-editor

Jean-Pierre Leburton
Fellow, Institute of Physics, 2008

Joseph W Lyding
Most accessed paper in 2008 for the journal *Nanotechnology*

Nancy Sottos
NASA Certificate of Recognition - for development of self-healing bladder materials, 2009

Scott White
Innovation Discovery Award, Vice Chancellor for Research of the University of Illinois, the Academy for Entrepreneurial Leadership of the University of Illinois, and the Champaign County Economic Development Corporation, 2008
Colombo Prize – Finalist, University of Padua, Italy, 2009

Zaida (Zan) Luthey-Schulten
William and Janet Lycan Professorship in Chemistry

SELECTED PATENTS AND PATENT APPLICATIONS

Faculty members from, and a visitor in, the Molecular and Electronic Nanostructures research theme were inventors on 18 patent applications (12.6% of the 143 patent applications filed by the campus) and on the following seven patents issued (16.7% of the 42 patents issued to campus) during FY2009 (Beckman Institute faculty members are listed in bold):

Munir Nayfeh and **Sahraoui Chaieb**: "Silicon Nanoparticle Nanotubes and Method for Making the Same," Patent Issued September 30, 2008, Patent Number 7,429,369.

Bruce Flachsbart, **Mark Shannon**, **Paul Bohn**, and **Jonathan Sweedler**: "Multilayer Microfluidic Nanofluidic Device," Patent Issued November 4, 2008, Patent Number 7,445,027.

Chang Liu and Nannan Chen: "Flexible Structures for Sensors and Electronics," Patent Issued March 10, 2009, Patent Number 7,501,069.

Hyungsoo Choi (visitor with AMS group): "Organometallic Compounds and their use as Precursors for Forming Films and Powders of Metal or Metal Derivatives," Patent Issued March 24, 2009, Patent Number 7,507,390.

Chang Liu, Jack Chen, and Jonathan Engel: "Microfabricated Pressure and Shear Stress Sensors," Patent Issued March 31, 2009, Patent Number 7,509,869.

John Rogers, Dahl-Young Khang, and Yugang Sun: "Stretchable Form of Single Crystal Silicon for High Performance Electronics on Rubber Substrates," Patent Issued April 21, 2009, Patent Number 7,521,292.

Xuefeng Wang and **Chang Liu**: "Multifunctional Probe Array System," Patent Issued April 28, 2009, Patent Number 7,523,650.

INVENTION DISCLOSURES

Faculty members from the Molecular and Electronic Nanostructures research theme were inventors on 16 invention disclosures (7.9% of the 203 invention disclosures filed by campus) during FY2009.

SELECTED GRANTS AWARDED

Greg Timp, Alexei Aksimentiev, Jean-Pierre Leburton, NIH, "Sequencing a DNA molecule using a synthetic nanopore," 1/6/08-5/31/09.

Greg Timp, NSF, "EMT/BSSE synthetic biological integrated circuits for computing," 9/15/08-8/31/11.

Paul Braun, Sandia National Laboratory, "NNEDC-National Institute for Nanoengineering (NINE)," 5/16/08 – 7/31/09.

Paul Braun, William King, Pierre Wiltzius, ARO, "Self-assembly of 3-D multifunctional ceramic composites fro photonics and sensors," 8/21/08-10/20/09.

Deborah Leckband, Paul Braun, NSF, "Mechanism and dynamics of protein interactions with polymer brushes," 10/1/08-9/30/09.

Erik Jakobsson, Tahir Saif, Yingxiao Wang, "Does mechanical force initiate, enhance, and repair neural connectivity," 8/1/08-7/31/12.

Joe Lyding, Eric Pop, William King, ONR-Northwest, "High throughput sub 10nm fabrication for nanoelectronics," 12/15/08-12/14/10.

Umberto Ravaioli, Eric Jakobsson, NSF, "Network for Computational Nanotechnology," 10//08-9/30/09.

Scott White, NSF, "International Conference on Self-Healing Materials," 1/1/09-11/30/09.

Scott White, ARO, "Graduate student travel funds for attending the Second International Conference on Self-Healing Materials," 5/1/09-4/30/10.

Klaus Schulten, Laxmikant Kale, NSF, "The computational microscope," 5/15/09-4/30/12.

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Blaiszik, B. J.; Caruso, M. M.; McIlroy, D. A.; Moore, J. S.; White, S. R.; Sottos, N. R., Microcapsules filled with reactive solutions for self-healing materials. *Polymer* **2009,** 50, (4), 990-997.

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Kim, K. J.; King, W. P., Thermal conduction between a heated microcantilever and a surrounding air environment. *Applied Thermal Engineering* **2009,** 29, (8-9), 1631-1641.

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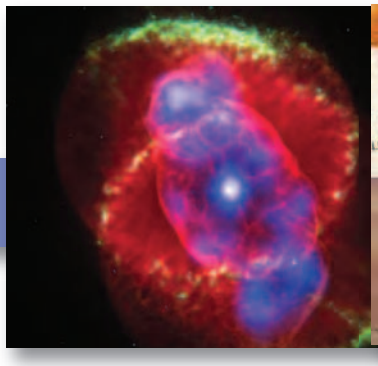
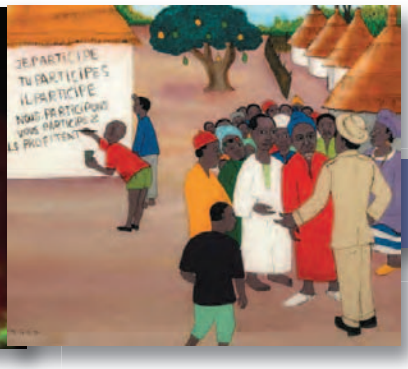
Strategic Initiatives





The Beckman Institute is constantly evolving and changing to reflect current lines of research and to also anticipate fruitful lines of future research. In the past year the Beckman Institute has formalized two new strategic initiatives that could eventually become full-fledged research themes. These strategic initiatives are Imaging and Social Dimensions of Environmental Policy (SDEP).

Strategic Initiative on Imaging

The growing relevance of imaging in almost every research endeavor has led the Beckman Institute to spearhead a campus-wide effort to bring together people, knowledge, resources, and talents to help make Illinois a leader in the use and development of imaging modalities.

Led by Beckman Institute researcher Stephen Boppart, the Imaging initiative will strive to build a cooperative community for imaging on the Illinois campus. Boppart said the initiative is acknowledgement that imaging is not only important for all kinds of research, but also in people's everyday lives.

"Imaging is pervasive in our lives," Boppart said. "If you look at what faculty and researchers do, almost every investigation is about the fundamentals of imaging itself, whether it is using imaging to collect data, or using figures and images to describe your results, you are imaging in some way."

Boppart said the initial plans for the initiative are to reach campus researchers who are developing and/or using imaging modalities and to facilitate research involving imaging. The initiative is also looking to connect with facilities outside of the University, including hospitals or other institutions.

Social Dimensions of Environmental Policy (SDEP)

The Social Dimensions of Environmental Policy (SDEP) strategic initiative is multi-faceted but the overriding goal is to "improve management of earth's environment through research on social and policy dimensions of sustainability."

Led by Jesse Ribot, SDEP will tackle tough issues like climate and vulnerability and how social and political-economic forces are shaping just and sustainable environmental policy. Ribot wants research from SDEP to lend its voice to worldwide discussions about these issues.

"When there are major policy efforts to deal with something like the energy crisis or climate negotiations, the idea is to have a center that will be actively engaged in doing the research that will feed into those policy processes," Ribot said. "Gathering what we know about the social and economic aspects of that problem, energy for example, we would hope to be able to inform those sorts of policy-making processes."

As this new initiative gathers momentum, it will broaden its scope to include research on human rights, justice, and democracy, in relation to water policy, biofuels production, urbanization, forest carbon offsets, biodiversity conservation, extractive industries, and international trade policies.

Beckman Institute **Outreach**

Twenty years of existence was not only a reason to celebrate this past year, but also to share the science and benefits that have come out of the Beckman Institute over the past two decades. In 2008 and 2009 the Beckman Institute saw more public events and outreach efforts than at any time in our history, with the 20th Anniversary Celebration events, Beckman Open House, Bugscope's 10th anniversary, and many other new and continuing outreach activities taking place.

The biennial Beckman Institute Open House was held in March of 2009 with more than 30 exhibits exploring research topics while informing thousands of visitors in fun ways about robots learning grammar, brain-computer interfaces, photosynthesis visualized through 3-D computer simulations, and many other projects. Once again this year, the Open House proved to be a fun way for the general public to learn about the important and interesting work that takes place at the Institute.

One month later a special event was held to celebrate the official dedication and opening of the Beckman Institute 20 years before in April of 1989. All three former Institute directors, Ted Brown, Jiri Jonas, and Pierre Wiltzius, returned for the celebration, as did Patricia Beckman, daughter of Arnold and Mabel Beckman, and Arne Beckman, their grandson. Also on hand were former University of Illinois officials who were instrumental in the creation of Beckman, as well as current University and Institute officials, faculty, and staff. The Beckman Institute 20th Anniversary Year will conclude with a three-day symposium in October of 2009 looking at past, present, and future directions of interdisciplinary research and the Beckman Institute.

In addition, 2009 marked the 10-year anniversary of Beckman's educational outreach program Bugscope. Operated by the Imaging Technology Group's Microscopy Suite, Bugscope has given remote control of an electron microscope via the Internet to thousands of students from more than 250 classrooms since it was started in March of 1999 with a grant from the National Science Foundation (NSF).

While those important events helped make the 2008-09 academic year a special one, other outreach efforts continued while new ones were begun. The public and educational outreach efforts at the Beckman Institute are as varied as the research that takes place here.

A new strategic initiative at the Institute, the Social Dimensions of Environmental Policy (SDEP), seeks to improve the management of earth's environment through research on social and policy dimensions of sustainability in part by joining the worldwide discussion about the impact climate change is having on developing societies.

Beckman researchers are also involved in multi-university educational outreach programs such as the Illinois Space Grant Consortium, part of a NASA effort to fund undergraduate research and summer work/research programs, and the Network for Computational Nanotechnology (NCN) at Illinois. NCN is part of nanoHub, a multi-university Web-based resource for research, education and collaboration in nanotechnology; part of NCN's efforts include workshops, seminars and schools, one of which was a summer school session held in July of 2009 at the Beckman Institute.

Other outreach efforts involve people from the community, such as the Senior Odyssey project created by Beckman researcher Elizabeth Stine-Morrow as both an intervention program to promote healthy cognitive aging and as a research project. In June of 2009, a team of study participants from Senior Odyssey aged 60 and over entered the Odyssey of the Mind World Finals competition and finished third in its division in a problem solving competition against university students.

All of these programs, projects, and events are helping to fulfill an important part of the Beckman Institute mission of giving back to the campus, community, and world at large.

Biomedical Imaging Center Now a Fixture of Beckman Institute Building

With its move to a new home inside the Beckman Institute building and a key addition to its lineup of powerful magnetic resonance machines, the past year has been a historical one for the Biomedical Imaging Center (BIC). Along with the completion of a more than year-long move from its former home on the south campus, BIC is also celebrating an important new piece of equipment and a large increase in its number of users from the campus and beyond. BIC's 600 MHz Varian NMR system was moved into the Beckman basement in 2008, with installations of a new whole-body 3T MRI scanner called the MAGNETOM Trio and the 3T Allegra headscanner in the Beckman basement taking place in 2009. BIC associate director Tracey Wszalek said the move is already leading to more usage.

"One of the reasons we are so busy and acquiring new customers is because our profile has been raised as a result of coming into Beckman," Wszalek said. "A lot of people who had not been aware of what we had going on are now becoming aware of us. It's been fabulous because we are riding a wave right now. It feels like a brand new entity and it's been fun."

The MAGNETOM Trio is a powerful magnet for imaging the entire body that was acquired in 2009. It will allow researchers looking at current research topics such as fat deposition in the body, swallowing, cardiac issues, and cartilage in the knee, a novel imaging tool for their research.

In addition to a new magnet, BIC's assets now include two mock magnets – a mock 3T Allegra headscanner and a mock Trio magnet – that are housed in a first floor room at Beckman. They will be used to prepare test subjects for experiments in those magnetic resonance machines and for tours of the facility. The new facilities, equipment, and people make BIC a unique MR research center.

"We are certainly one of the few in the world that combines access to this kind of equipment with the kind of support we have for a variety of disciplines and questions," Wszalek said. "There's really not much that we aren't willing to look at."

About the Biomedical Imaging Center

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

The Biomedical Imaging Center utilizes the 3T whole body "mock" magnet. The mock magnet is used to prepare test subjects for experiments.

Biomedical Imaging Center Equipment:

- **600 MHz Varian NMR system**
  Used for micro-imaging and spectroscopic measurements, such as high-resolution imaging of very small samples, including biological tissue, liquid samples, and non-living samples.
- **3T Allegra headscanner**
  Primarily used for cognitive studies; also includes capabilities for animal scanning, including scans for clinical work.
- **MAGNETOM Trio Whole-body 3T MRI scanner (July 2009)**
  Wszalek said this new acquisition will become a workhorse for many of the cognitive studies now taking place in the headscanner, as well as being used in animal studies, including clinical care scans for animal patients, and imaging many other types of samples.
- **3T Allegra Mock Magnet and MAGNETOM Trio Mock Whole-body 3T MRI scanner**
  These new mock magnets are used to prepare test subjects for experiments in the actual magnets, as well as for tours and other educational outreach programs to explain how magnetic resonance imaging works.

Illinois Simulator Laboratory

Top image:

Ron Carbonari operates the Illinois Simulator Laboratory's flight simulator.

Inset:

View of the ISL Flight Simulator from the control room.

The address changed and so did the name, but the Beckman Institute's world-renowned advanced visualization laboratory continued providing technologies and support for researchers across campus. Formerly known as the Integrated Systems Laboratory, the facility is now known as the Illinois Simulator Laboratory (ISL) and it has a new home on south campus in the former Biomedical Imaging Center building. During the move from the Beckman Institute building to its new facility, the ISL continued to serve researchers and is now embarking on a new era in its surroundings on the south campus. The flight simulator, motion capture suite, and immersive reality environments the Cube and the CAVE™ were all installed in the new building by the spring of 2009 with the final piece of equipment, the driving simulator, moving into the building in the fall of 2009. Although a new room was built for the Cube, the existing building spaces worked well for the other environments. ISL director Hank Kaczmarski said the move has allowed ISL to improve and expand its capabilities.

"It was an opportunity to put in a new generation of computational and visualization gear to drive these spaces," Kaczmarski said. "It only comes by once in a career so we're going to take advantage of it. Getting everything moved went so well that we are able to think beyond it now and it's really exciting."

About the Illinois Simulator Laboratory

The Illinois Simulator Laboratory provides researchers with an amazing array of highly advanced visualization environments for studies in human multimodal perception, cognition, human factors, and other areas. Two 3-D immersive reality environments, the CAVE and the six-sided Cube, are ideal for multimodal and human perception studies. The flight simulator is used by aviation human factors researchers, while the driving simulator continues to be a platform for studying topics such as driver distraction.

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, moved to a newly renovated space adjacent to the Cube in 2006, and now to the new ISL facility, the CAVE continues to function as a prototyping facility for the Cube and as a research environment in its own right. Several Immersadesks are in the same environment, connected to specialized graphics computers, enabling users to quickly develop, test, and remotely demonstrate new applications.
- **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.
- **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 to surround the test subject drivers with eight projected moving images. These images, and a fully integrated eye-tracking system, allow researchers to gather data on how humans interact with the automobile.
- **Motion Capture Suite**
  Used by kinesiologists for the analysis of human motion, the Motion Capture Suite features a Motion Analysis ten camera motion capture system, force-feedback plates, video outputs, and gigabit networking that allows researchers to store data for later analysis or to connect with other visualization environments for real-time collaborative research.
- **CANVAS and the Traveling CANVAS (Collaborative Advanced Navigation Virtual Art Studio)**
  CANVAS is a room-sized immersive 3-D environment with origins in CAVE™ technology. It is a scalable, reconfigurable display technology that facilitates the creation and display of immersive art works. It is collaborative because it can be connected to an array of geographically dispersed immersive virtual spaces, has advanced navigation to allow viewers in different locations to interact with virtual art, and allows for the creation and presentation of virtual art that exists not in two- or three-dimensional spaces, such a painting or sculpture, but in the multi-dimensional world of virtual images.

Change and Growth for **Imaging Technology Group**

The ability to visualize science has become essential to doing research in many fields, and it is an integral means of sharing their work for researchers in virtually every discipline. That is why the facilities and capabilities of the Beckman Institute's Imaging Technology Group (ITG) are such a valuable resource for campus researchers. The combined capabilities of the ITG's two groups, the Microscopy Suite and the Visualization Laboratory, are truly extraordinary for a university facility. The Microscopy Suite and the Visualization Lab have not only maintained service levels during the past year as renovation work took place, but even managed to expand their capabilities with new technology and additional space.

Microscopy Suite

Several months of renovation and construction in the Beckman basement have been accompanied by the addition of a comprehensive array of computed tomography (CT) instruments to the Microscopy Suite, giving this premier microscopy facility a fourth imaging modality. The basement renovation created an entirely new room for housing the Microscopy Suite's instruments for computed tomography, an imaging method that produces internal images of three-dimensional structures. The lineup of CT instruments includes two micro- and one nano-CT unit for high resolution imaging at one micron and below scales, as well as a Skyscan CT that can achieve five-micron resolution. With the new instruments, Microscopy Suite manager Scott Robinson said they can now offer capabilities that are unparalleled for a campus facility.

"We have the best range and the best set of options compared to anywhere I can think of in the country – just because we have really beautiful high-end instrumentation and really good people to run it and it's all located in one place," he said. "What we have are really nice solutions to most people's problems and it's going to help people from biology to polymer chemistry, and for any small scale stuff, it's going to be really good."

The Microscopy Suite is nearly unrivaled in the country as a campus facility for doing microscopy at amazingly small scales with incredible resolutions. The Suite boasts instruments for scanned probe microscopy, light microscopy, and electron microscopy; in addition, part of the renovation project created a special darkened room for a fluorescence correlation spectroscopy unit.

Renu John (foreground) of the Bioimaging Science and Technology Group uses the Imaging Technology Group's Visualization Laboratory.

Inset (top): The Visualization Laboratory's high speed video camera captures a water balloon popping at the 2009 Beckman Institute Open House.

Inset (bottom): Undergraduate student, Rohun Palekar, uses the Imaging Technology Group's Transmission Electron Microscope (TEM). Palekar is working with Beckman researcher Rohit Bhargava.

Visualization Laboratory

Located on the fourth floor of the Beckman Institute, the Visualization Laboratory missed out on the location moves that affected Beckman's other facilities. But the Visualization Lab did go through a remodeling the year before that opened up not only more space for this state-of-the-art facility, but also a new perspective. Visualization Lab

manager Darren Stevenson said the lab is now more user-friendly for things like meetings and collaborative efforts involving researchers' imaging needs, while still offering premier technological capabilities to meet their visualization needs.

Stevenson said the new ultra high speed camera system can visualize at 150,000 frame rates per second, allowing researchers such as those working on fractures to break the video down at precisely the moment they want.

The camera system, which includes improvements from the original system that Stevenson has added, is being used by researchers from the life sciences as well, giving the Visualization Lab a unique tool.

"It's the only one of its kind on campus," he said. "Most (systems) are usually capped at 30 frames per second, so the researchers wanted faster rates. Word is getting out and new groups are coming in who have heard about it."

Microscopy Suite capabilities:

- **Micro- and Nano-computed Tomography**
  The four Micro and Nano-CT instruments permit the collection of 3D x-ray datasets of materials, biomaterials, and biological samples with resolutions ranging from 5 microns to 50 nanometers, with 'hard' or 'soft' x-rays, and with a variety of choices for magnification/field of view.
- **Light Microscopy**
  Suite users may choose from laser scanning confocal microscopes with standard and multi-photon imaging capabilities; an inverted fluorescence microscope with structured illumination and the ability to create seamless mosaics of images in x, y, and z; a highly sophisticated upright microscope with fluorescence and DIC as well as comprehensive stereology and nerve-tracing software packages; and a color-corrected and photo-capable stereozoom dissecting microscope, among other basic microscopes.
- **Scanned Probe Microscopy**
  Near-field scanning optical microscopy (NSOM) and atomic force microscopy (AFM), with its many permutations, are available.
- **Electron Microscopy**
  Includes both an Environmental Scanning Electron Microscope (ESEM) with field-emission electron gun and many other capabilities and options, as well as a Transmission Electron Microscope (TEM) that operates at accelerating voltages of up to 200 kV.
- **Lightscattering/Spectral Analysis**
  Taking advantage of our ability to deliver laser light, collimated visible light, or high-energy electrons to the surfaces of samples in a variety of media, the Microscopy Suite provides two types of light-scattering particle sizing systems, UV/Vis and NearIR spectroscopy, Raman spectroscopy, fluorescence correlation spectroscopy, surface plasmon resonance imaging, and energy-dispersive spectroscopy.
- **Sample preparation equipment**
  Glo-discharge, osmium plasma, sputter coater, critical point dryer, lowspeed diamond saw, and ultramicrotome, among other pieces of specialized equipment, aid Microscopy Suite users in preparing samples.

Visualization Laboratory capabilities:

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

Beckman Institute **Postdoctoral Fellows Program**

For a few select young scientists, the dream of pursuing their research goals unfettered by the responsibilities of teaching or working in industry becomes a reality at the Beckman Institute. Postdoctoral researchers from across the country and the world have taken part in the Beckman Institute Fellows Program since 1992 and gone on to careers in academia, government, industry, and business. The Beckman Fellows Program nurtures independent research in a stimulating and supportive interdisciplinary environment that allows young scientists to advance their research during a period that bridges the time between earning a Ph.D. and beginning a professional career. The Beckman Institute Fellows are selected based on evidence of professional promise, capacity for independent work, outstanding achievement, and interdisciplinary work research interests that correspond to one or more of the Beckman Institute's research themes. Applications for the Beckman Institute Fellows program are accepted during the Fall semester and the announcement of the selected Fellows is made in late February/early March of the Spring semester. The program is supported by the Arnold and Mabel Beckman Foundation.

Current Beckman Institute Fellows

2009 Fellows

Jeremy Brooks

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

Nanshu Lu

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

David Mayerich

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

Nathan Parks

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

Edward Wlotko

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

2008 Fellows

Jacob Eisenstein

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

Agustín Mihi

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

Amy Shih

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

Joel Voss

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

2007 Fellows

Derek Hoiem

Derek received his Ph.D. in Robotics at Carnegie Mellon University. While a Beckman Fellow his research focused on computer vision with an emphasis on learning appearance models and image-based scene understanding. Derek has

departed the Fellows Program and is now an Assistant Professor in Computer Science at Illinois.

Zhi Jiang
Zhi earned a Ph.D. in Electrical and Computer Engineering from Purdue University, where he worked as a post-doctoral research associate in the area of spectral pulse shaping of ultrafast optical pulses. While at Purdue, Zhi built the first grating-based, spectral line-by-line pulse shaper. At Beckman he is applying optical pulse shaping techniques and coherent control to improve biomedical imaging applications such as optical coherence tomography (OCT).

Séverine Lepage
Séverine earned her Ph.D. in Aerospace and Mechanical Engineering at the University of Liège, Belgium. She departed the Beckman Institute in August of 2008.

Jongseung Yoon
Jongseung was a Postdoctoral Fellow at the Massachusetts Institute for Technology, where he received his Ph.D. in Materials Science and Engineering. His research seeks to understand the physical properties and microstructure of soft and hybrid materials such as polymer/inorganic composites, and to control their structure and patterning for applications in advanced photonic, phononic, and electronic technologies. At Beckman he has been focused on new approaches for creating low cost and high-performance photovoltaic devices with unusual characteristics, including large area and lightweight construction, mechanical flexibility/stretchability, semi-transparency, and ultrathin-form-factor micro-optic concentrator design.

2006 Fellows

Joseph B. Geddes III
Joe earned his Ph.D. in Engineering Science and Mechanics from the Pennsylvania State University where his work focused on the time-domain optical response of inhomogenous, anisotropic, and nonlinear materials like chiral sculptured thin films to excitation by ultrashort optical pulses. At Beckman he has extended his research in the design and optical interrogation of complex materials. His projects have included analysis of curved photodetector arrays for improved cameras, design of highly nonlinear metal-dielectric composites, and optical pulse shaping for coherent control of Raman microscopy.

Yael Gertner
Yael received her Ph.D. in Computer Science from the University of Pennsylvania. Since then she has been working as an experimental psychologist, first as an NRSA fellow, and then as a Beckman Fellow. Her research interests deal with how children acquire words and rules of their native languages and how these processes can be modeled using computational tools. Gertner plans to pursue further research in this area using experimental psycholinguistics and techniques from computational learning theory. She will use the knowledge derived from the experiments to design better learning algorithms that use the same features children use and obtain the same feedback that children obtain.

Ming Hsu
Ming received his Ph.D. in Social Sciences from the California Institute of Technology. He left the Fellows Program in August of 2008 to take a faculty position in Economics at Illinois.

Mark Neider
Mark's dissertation work examined the role of high level scene factors in modulating visual search performance in realistic scenes. Neider's goals are two-fold: (1) to understand basic visual behavior in the context of real world tasks, and (2) to apply this knowledge to augment human performance in a variety of "everyday" and not so "everyday" tasks and situations.

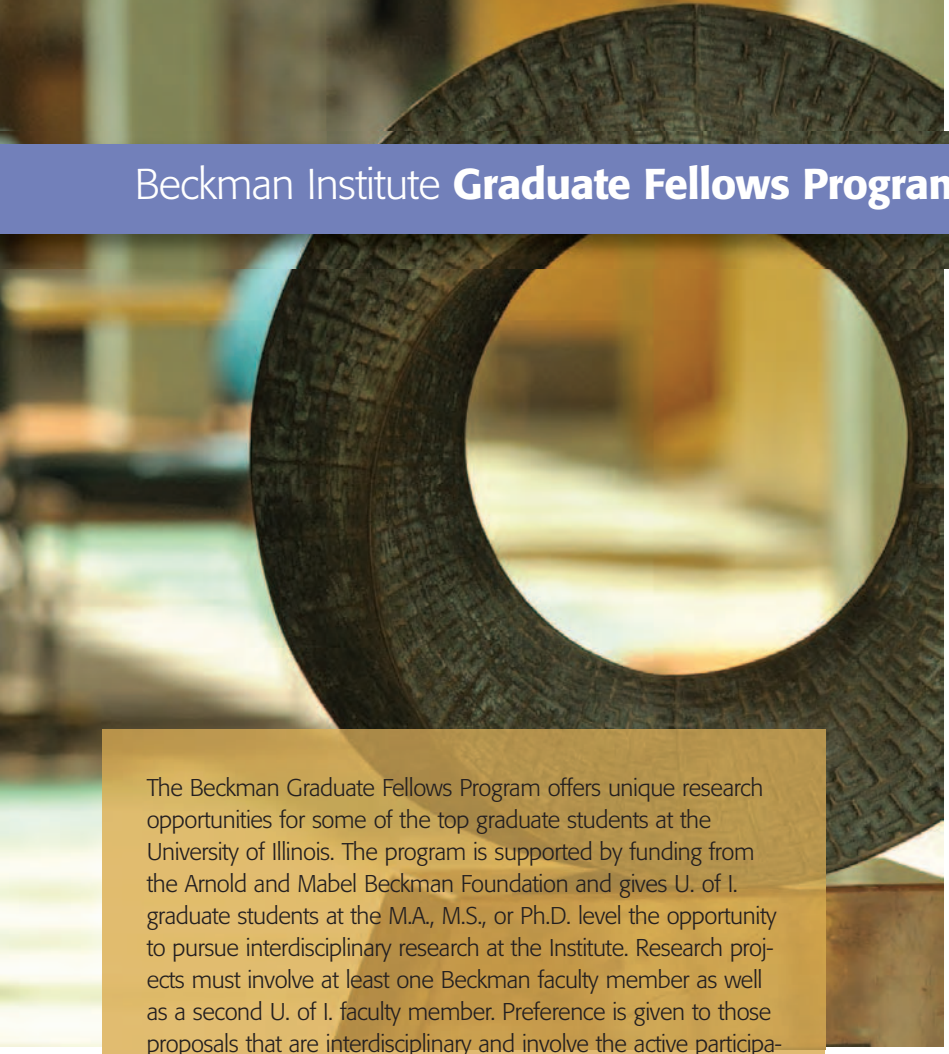
Stephanie Rinne
Stephanie received her Ph.D. in Materials Science and Engineering at the University of Illinois. Her research interests include the non-traditional nano and microfabrication of functional materials, typically for photonics applications. Stephanie has demonstrated 3-D wave-guiding of near-IR light using a complete photonic bandgap material. She has also designed 2-D diffraction gratings to improve the efficiency of thin film silicon solar cells.

Sarah Brown-Schmidt
Sarah received her Ph.D. from the Department of Brain and Cognitive Sciences at the University of Rochester. Her research focuses on the processes that support language production and language comprehension in interactive, conversational settings. She has two primary lines of research: one investigates how the language processing system represents and processes information about the perspective of other individuals while the second examines how speakers transform pre-linguistic thoughts into speech.

Dirk Bernhardt-Walther
Dirk earned his Ph.D. in Computational and Neural Systems at the California Institute of Technology. His thesis was on "Modeling interactions of visual attention and object recognition in human and machine vision." As a Beckman Fellow, he investigates the neural correlates of natural scene perception; he tries to predict training success in complex cognitive tasks from brain activity; and he continues to model visual and auditory attention.

Carle Foundation Hospital/ Beckman Institute Fellow

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



Beckman Institute **Graduate Fellows Program 2009**

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

The 2009 Beckman Institute Graduate Fellows:

Jason Coronel
Jason is working on his Ph.D. in Political Science. His research as part of the Cognitive Neuroscience group at Beckman explores how voters process information about candidates during the course of a political campaign. His novel project uses cognitive neuroscience methods, including event-related potentials (ERPs), to measure both explicit and implicit memory with the goal of determining whether the latter introduces systematic biases into political decision-making. Coronel is testing the role that implicit memory plays in supporting the acquisition of political knowledge by using research participants with impaired explicit memory systems.

Tae-Jin Kim
Tae-Jin is pursuing a Ph.D. in the Neuroscience Program. As a Beckman Graduate Fellow in the Bioimaging Science and Technology group he explores design strategies on how to approach the single-cell imaging of calcium in response to mechanical stimulations by integrating the newly developed FRET biosensor and optical laser tweezers. This research could shed new light on the molecular mechanism by which stem cells perceive external mechanical cues and coordinate signaling pathways to regulate physiological functions.

Xing Liang
A Graduate Fellow in the Bioimaging Science and Technology group, Xing is pursuing his Ph.D. in Electrical and Computer Engineering. His research focuses on measuring biomechanical properties on tissue and cellular levels using multimodal imaging techniques. His work is specifically focused on the biomechanical properties and microenvironment of tumor cells and their vital role in tumor growth. He plans to use optical coherence elastography (OCE), optical coherence microscopy (OCM), Fourier transform light scattering (FTLS), and a multi-photon microscope in his research. The results could be significant in determining a relationship between cancer development and the properties of cancer cells and their microenvironments.

Erik Nelson
Erik is working toward a Ph.D. in Materials Science and Engineering. His research goal in the 3-D Micro- and Nanosystems group is to create a new class of materials: single crystal 3-D photonic crystals (PhCs) that possess electronic functionality. These materials offer incredible potential for highly efficient LEDs for solid state lighting and a reduced cost of information by lowering energy consumption of lasers in fiber optic networks. Erik's research plans include designing 3-D PhC devices of optimal photonic/electronic structure using finite-difference time-domain calculations and modeling of electronic transport, fabricating these structures using phase masks via AFM imprint lithography, and demonstrating an electrically driven 3-D PhC laser.

Michelle Voss
Michelle is working on her Ph.D. in Psychology, Brain, and Cognition. Her research as a member of the Human Perception and Performance Laboratory investigates functional brain systems and memory performance in elderly adults. The study takes a proven, effective, and verified intervention for cognitive decline and uses neuroimaging techniques to document brain changes that accompany such behavioral improvements. She also examines how these benefits can be applied to a broad set of cognitive processes that occur in daily living to improve the quality of life in the aging population. In 2009 Voss won a Paul D. Doolen graduate scholarship for the study of aging.

New Faculty

The Beckman Institute welcomed nine new faculty members this past year who exemplify our commitment to keeping the research done here diverse and on the leading edge of scientific exploration. Jesse Ribot, who is leading a new strategic initiative aimed at improving management of the Earth's environment through research on the social and policy dimensions of sustainability, is a new full-time faculty member. Matthew Gilbert joined the Computational Electronics group as a part-time faculty member to pursue his research into nanoscale devices, physics, and photonics. Further demonstrating Beckman's commitment to diversity, seven new affiliate members represent a wide range of departments from across campus: Annie Tremblay (French) Douglas Simpson (Statistics), Jonathan Waskan (Philosophy), Brian Dill (Sociology), Derek Hoiem (Computer Science), and Rashid Bashir and Olga Milenkovic (Electrical and Computer Engineering).

FULL-TIME FACULTY

Social Dimensions of Environmental Policy Strategic Initiative

Jesse Ribot from the Department of Geography joined the Beckman Institute to lead a new strategic initiative. Ribot leads the Social Dimensions of Environmental Policy (SDEP) initiative that is supported by the Illinois School of Earth, Society and Environment, the campus, and the Beckman Institute. Ribot earned a Ph.D. in Energy and Resources from University of California Berkeley. He came to the University of Illinois after serving for nine years as a Senior Associate at the World Resources Institute (WRI), an environmental think tank in Washington, D.C. Ribot writes that his research is focused on topics of decentralization and democratic local government, natural resource tenure and access, distribution along natural resource commodity chains, and household vulnerability in the face of climate and environmental change.

PART-TIME FACULTY

Molecular and Electronic Nanostructures

Matthew Gilbert is a new faculty member in the Computational Electronics (CE) group. Gilbert, who earned his Ph.D. from Arizona State University, is an Assistant Professor of Electrical and Computer Engineering at the University of Illinois. His research areas include nanoscale devices and physics, semi-classical and quantum transport theory, many-body theory, and nanophotonics.

AFFILIATE FACULTY

Biological Intelligence

Annie Tremblay is an affiliate faculty member in the Cognitive Science (CS) group of the Biological Intelligence (BI) research theme. Tremblay is an Assistant Professor in the Department of French at the University of Illinois. Tremblay earned her Ph.D. from the University of Hawaii in Second Language Acquisition. Her interests include the "relationship between the grammatical knowledge that second language learners acquire and the parsing procedures they develop for putting that knowledge into use."

Jonathan Waskan is an Assistant Professor in the Philosophy Department who rejoins the Institute as a member of the Cognitive Science group. Waskan earned his Ph.D. in the Philosophy-Neuroscience-Psychology Program at Washington University in St. Louis. His research includes topics in the philosophy of cognitive science, including representational formats, levels of explanation, prediction and explanation in the special sciences, connectionism, folk psychology, and theories of content.

Integrative Imaging

Douglas Simpson from the Department of Statistics joined the Beckman Institute's newest research theme as a member of the Bioacoustics Research Laboratory. Simpson's research interests include applied and computational statistics and biostatistics, among other areas. Simpson earned his Ph.D. in Statistics from the University of North Carolina. His honors include being named as a Fellow of the Institute of Mathematical Statistics and the American Statistical Association.

Molecular and Electronic Nanostructures

Rashid Bashir is the Bliss Professor of Engineering in the Department of Electrical and Computer Engineering. Bashir, who earned his Ph.D. from Purdue in 1992, joined the Computational Multiscale Nanosystems group. His research interests include BioMEMS, lab on a chip, nano-biotechnology, interfacing biology and engineering from molecular to tissue scale, and applications of semiconductor fabrication to biology, all applied to solve biomedical problems.

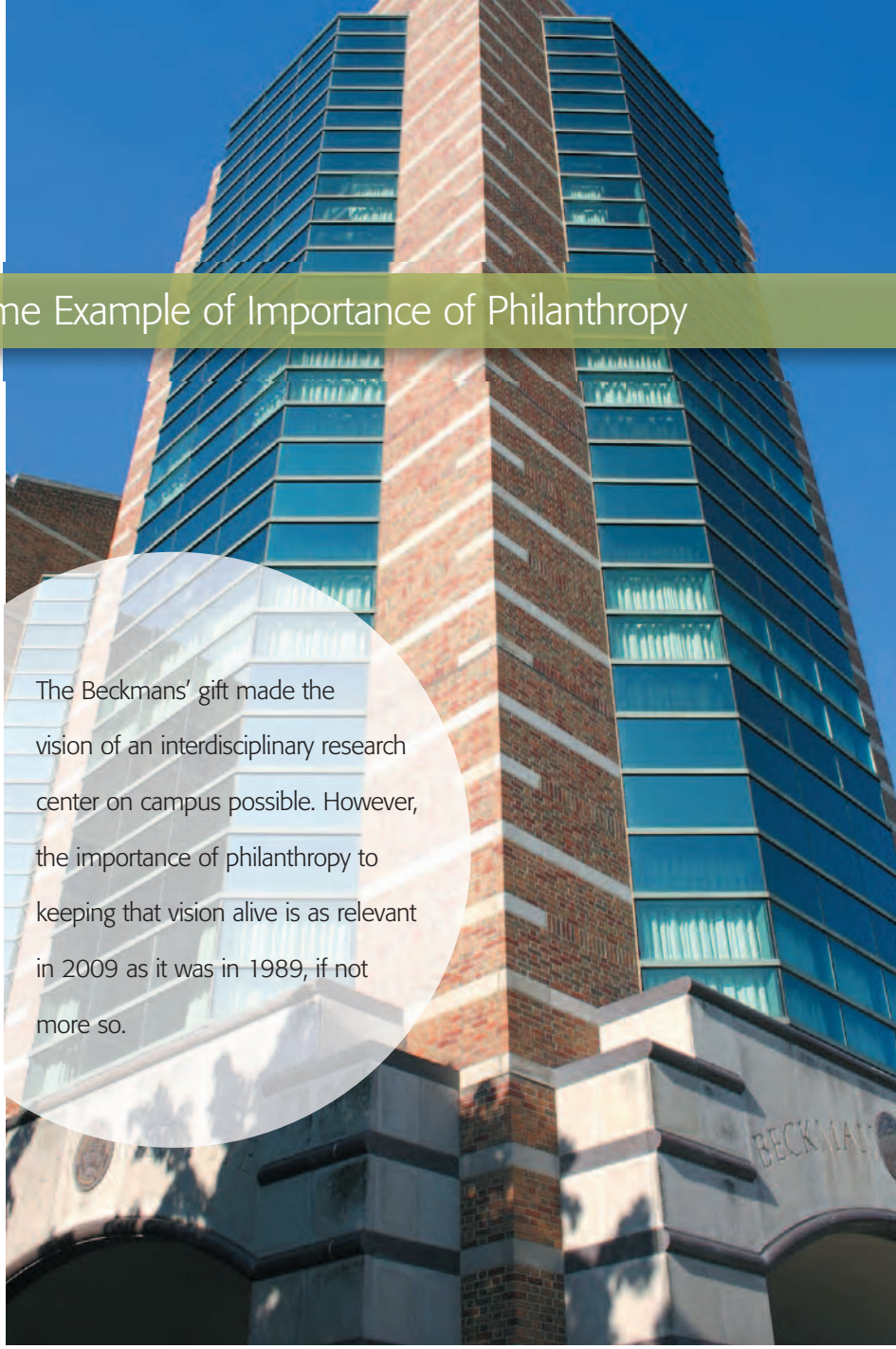
Olgica Milenkovic, an Assistant Professor in the Department of Electrical and Computer Engineering, joined the Computational Multiscale Nanosystems group. Milenkovic earned her Ph.D. in Electrical Engineering and Computer Science-Systems from the University of Michigan. Milenkovic's research interests include analysis of algorithms, bioinformatics, error-control coding (algebraic/iterative), constrained coding, information theory, signal processing, and compressive sensing.

Derek Hoiem is a new Assistant Professor in Department of Computer Science after recently finishing his time as a Beckman Postdoctoral Fellow. A member of the Artificial Intelligence group at the Institute, Hoiem received his Ph.D. in Robotics at Carnegie Mellon University. His main research interest is in general visual scene understanding, which he describes as the "ability to infer general principles and current situations in a way that helps to achieve goals." His research focuses on computer vision with an emphasis on learning appearance models and image-based scene understanding.

Social Dimensions of Environmental Policy Strategic Initiative

Brian Dill is an Assistant Professor of Sociology who is part of the Institute's Social Dimensions of Environmental Policy strategic initiative. Dill earned his Ph.D. in Sociology from the University of Minnesota in 2007. His areas of study include development, democratization, globalization, and Africa.

Beckman Institute Prime Example of Importance of Philanthropy



The concept of giving back was something Arnold and Mabel Beckman took as seriously as any major American philanthropist in the latter part of the 20th Century. They took it so seriously, in fact, that their stated goal was to give away all of their massive fortune before they passed on.

Arnold and Mabel didn't quite manage to do that in spite of generous gifts to several institutions, but they did donate most of their fortune (approximately $400M) and then left enough to make the Beckman Foundation a major source of philanthropic gifts on a yearly basis.

The institute that bears the Beckman name at the University of Illinois likely would not have come into existence, or at least to the scale and scope that it now exists, without the great generosity of Arnold and Mabel. Their $40M megagift in 1985, at the time the largest ever one-time donation to a public university, made possible the building of the Beckman Institute. Gifts from the Beckman Foundation since the Institute opened in 1989 have also been a major force in carrying on the mission of high-level interdisciplinary research that began two decades ago.

The Beckmans' gift made the vision of an interdisciplinary research center on campus possible. However, the importance of philanthropy to keeping that vision alive is as relevant in 2009 as it was in 1989, if not more so. As discussions about building a new research center on campus began in the early 1980s, funding from the state of Illinois to the University of Illinois stood at close to 50 percent of the University's revenue. In 2009 that figure was less than 19 percent, so funding from outside sources such as individuals, corporations, and foundations are important to continuing the tradition of world-class research that takes place at Beckman.

The Beckmans' gift made the vision of an interdisciplinary research center on campus possible. However, the importance of philanthropy to keeping that vision alive is as relevant in 2009 as it was in 1989, if not more so.

Gifts to the Beckman Institute over the years from individuals, foundations, and corporations have been a key factor in maintaining, building, and evolving the research work that goes on here. This past year an office was created to facilitate giving to the Institute and Tim Montague was chosen as Beckman's first Director of Development.

Montague said that gifts to Beckman benefit both the Institute and the donor.

"The benefit to Beckman is that we can continue to be a groundbreaking, world-class interdisciplinary research institute," Montague said. "There are benefits to a donor to consider as well. Arnold Beckman dedicated his life to scientific discovery and entrepreneurism and now the Beckman Institute is a legacy that will carry that forward many decades. Giving to the Beckman Institute will leave a significant legacy."

Montague said that donors' intentions are a very important part of the giving process.

"It is up to the donor to decide how their money will be spent based on what they want to achieve," he said.

Montague said gifts have been used in the past for everything from supporting specific lines of research to supporting graduate students and postdoctoral fellows in their research, to acquiring new equipment. Future goals for donated funds include named professorships and postdoctoral fellowships, as well as a long-range project that would create a proposed 50,000-square-foot addition to the Beckman Institute building.

Support from Non-Profits Important to Maintaining Success

Support from non-profit organizations, especially the Beckman Foundation, has been critical to the success of the Beckman Institute. Ted Brown, the Founding Director of the Beckman Institute and a former member of the Beckman Foundation board, said those funds help continue the Beckman mission.

"The allocation of discretionary funds from the Beckman Foundation is a highly important part of Arnold and Mabel Beckman's legacy, one that sustains the Institute and is essential to its striving to be a world-class interdisciplinary institution," he said.

Brown said that the Beckman Foundation has been the single most important source of outside support for the Institute over its lifetime.

"The funds were especially important in the early years because at that time the Institute was just getting started, and there was a great need to acquire research equipment and to support special projects," he said. "The funds have also been used to initiate and support novel programs, notably the Beckman Postdoctoral Fellows program."

Brown said that money for equipment has been used to get matching funds from outside granting agencies and that Foundation funding made it possible to recruit new faculty members to the campus and to the Beckman, in addition to supporting the Beckman Fellows program.

"The (Fellows) program has had many excellent young researchers who have gone on to careers in research at other top-quality research institutions," Brown said. "It was also adopted by the other Beckman Institutes, though I think we have been the most successful in this area. The Beckman Foundation funds have also been used to support graduate students and in other ways to bolster the aims of the Institute to be a truly interdisciplinary place."

Other foundations and organizations have also given generously over the years, including the Lucille P. Markey Trust, the FRAXA Research Foundation, and the Roy J. Carver Charitable Trust.

Corporate Gifts Essential to Research Efforts

Corporate gifts are a very big part of Beckman Institute research. Companies such as General Motors, Samsung, Microsoft, Yamaha, Bayer, and Mitsubishi have all given money for a variety of projects.

These foundation and corporate gifts are not contractually tied to future commercial application. They are given to support research in a wide variety of areas, including traffic safety, aging and treatment of disorders such as Fragile X syndrome.

Individual Giving Leaves a Legacy at Beckman

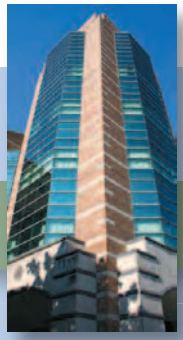
Individual giving also plays an important role in keeping the flow of ideas and innovation passing through the Beckman Institute. Robert Fossum is a member of the Image formation and Processing group and Professor Emeritus in the Department of Mathematics at Illinois. For the past several years he and his wife have funded the Robert and Robin Fossum Distinguished Lecture Series at the Beckman Institute. Lecturers from across the country and a wide variety of disciplines come to the Institute to present talks on current issues in science.

Robert Fossum said he thinks he is the first mathematician to have a part or full-time appointment at Beckman and wanted to show his appreciation by giving something back to the Institute.

"Beckman has been very nice to me," Fossum said. "We give this money and I plan to continue on giving this money because I think it's important for the Institute. It brings people here who maybe wouldn't normally come."

For more information on giving opportunities or to discuss your private giving plans please contact:

Tim Montague
Director of Development
giving@beckman.illinois.edu
217-244-2887



Donors to the Beckman Institute 2008-2009

The Beckman Institute would like to thank the following individuals, corporations, foundations, and public entities for their generous gifts over the past 20 years.

$1,000,000 Plus
Dr. Arnold O. (DEC) and Mrs. Mabel Beckman (DEC)
Arnold and Mabel Beckman Foundation
Lucille P. Markey Trust
Carolyn B. Snider Estate (DEC)
FRAXA Research Foundation

$500,000 – $999,999
Roy J. Carver Charitable Trust
Virgil Richard Sullivan Estate (DEC)
General Motors Technical Education Program
Yamaha Motor Company, Ltd.
Institute for the Study of Aging
IBM Corporation

$100,000 – $499,999
American Chemical Society
Samsung Information Systems of America
NEC Laboratories America, Inc.
James S. McDonnell Foundation
National Alliance for Research on Schizophrenia and Depression
Bayer Corporation
Microsoft Corporation
The Whitaker Foundation
Eastman Kodak Company

$50,000 – $99,999
Carle Foundation Hospital
Goldman Sachs Philanthropy Fund
Mr. Bruce Wonnacott
ArgusSenses Corporation
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Topometrix Corporation
John Deere Company
Mr. Richard A. Lumpkin
Siemens Corporate Research, Inc.
The Lumpkin Family Foundation
Bachmann-Strauss Dystonia & Parkinson Foundation, Inc.
Mr. Lester O. (DEC) and Mrs. Frances M. Johnson (DEC)

$10,000 – $49,999
Mr. Philip J. Meathe
Tektronix, Inc.
Dystonia Medical Research Foundation
KPMG Peat Marwick Foundation
Compaq Computer Corporation
Motorola
Lilly Endowment Inc.
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Early Detect Inc.
Prof. Robert M. and Mrs. Robin K. Fossum
Sigma-Aldrich
FEI Company
Autonomic Materials, Inc.
Biocon Associates
Dr. I. C. Gunsalus (DEC)
ILX Lightwave

Up to $9,999
Phonetact, Inc.
North Atlantic Treaty Organization
Delft Centre for Materials, TU Delft
Dr. Yoko Maemura Fujimoto
National Collegiate Athletic Association
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Dr. John L. Larson
Mr. Arnold Mikon
Mrs. Audrey C. and Dr. Theodore Brown
Kyoto School of Computer Science
CU Aerospace, LLC
IMPACT
ICI Limited
Materials Innovation Institute
Dr. Lawrence P. and Mrs. Evelyn Jennings
National Academy of Sciences
National Research Council
SmithGroup, Inc.
Sun Microsystems, Inc.
Dutch Polymer Institute
Aerotech, Inc.
C. C. Yoder Family
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Fox Development Corporation
Mr. Peter B. and Kim B. Fox
Mr. Martin Clemons Kamerer
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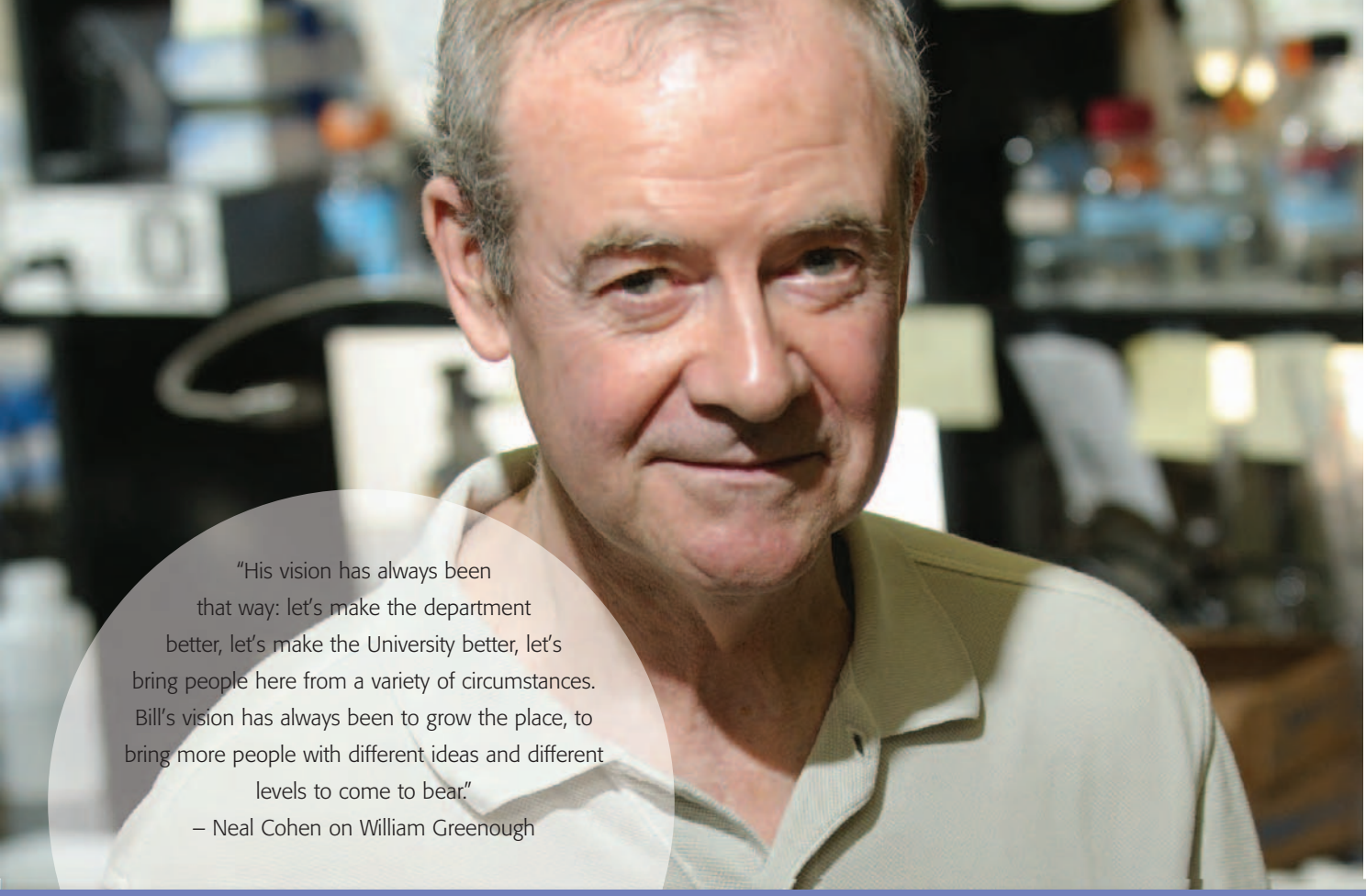
Accenture Foundation, Inc.
Abbott Laboratories
Dr. Van Allen and Mrs. Donna Jalane Anderson
International Society For Stereology
Springer Science+Business Media
Ms. Roshani and Mr. Mukunda B. Shrestha
Mr. Thomas A. Cruse
Eli Lilly and Company
Mr. Howard A. Fraenkel
Scott J. Robinson
Mr. Vasilis M. Kostakis
AlliedSignal Foundation Inc.
Mr. Robert J. Thomas
Joan L. Mitchell PhD
Mrs. JoAnn Ridley Pettinger
Global Impact/Tellabs Operations Inc.
Ms. Zelma Holl (DEC)



"His vision has always been that way: let's make the department better, let's make the University better, let's bring people here from a variety of circumstances. Bill's vision has always been to grow the place, to bring more people with different ideas and different levels to come to bear."
– Neal Cohen on William Greenough

Greenough Work, Achievements Celebrated in 2009

In 2009 William Greenough gave up his duties as a professor at the University of Illinois after a truly remarkable career of teaching, mentoring, and influencing countless students and postdoctoral researchers over the years. In honor of Greenough's service of more than four decades as a faculty member in the University of Illinois Department of Psychology, a special one-day symposium was held in June that drew numerous colleagues, former students, and collaborators from campus and across the country.

Appropriately, the symposium and a dinner honoring Greenough were held at the Beckman Institute, a research center he helped create. Greenough chaired one of two committees formed to explore a new type of research facility on campus in the 1980s, and served as one of its first two associate directors when it opened in 1989. Karl Hess headed the other committee and was the other associate director when the Institute officially opened in 1989.

"Karl and I were the cheerleaders for the Beckman Institute," Greenough said. "Both Karl and I had gotten involved in interdisciplinary endeavors very early in our careers, and in both cases our careers had been redirected by those experiences in very important ways."

Greenough serves as Co-chair of the Biological Intelligence research theme at the Institute and the William Greenough Laboratory located at Beckman continues to break new ground in neuroscience research.

As a researcher, Greenough has been a leader in changing scientific thinking when it comes to nervous system development and the brain. He helped take the concept of brain plasticity from theory to experimental proof to accepted science.

Greenough has won many teaching, professional, and research honors and awards over the years, including election as a member of the National Academy of Sciences in 1992 and as a Fellow of the American Academy of Arts and Sciences in 2006. He has also served as the Center for Advanced Study Director at Illinois since 2000. One of his most recent, and perhaps one of his most treasured honors, is the FRAXA Research Foundation Dedication Award he was given in 2008 for his research involving Fragile X syndrome, the most common cause of inherited mental impairment and the most common known cause of autism.

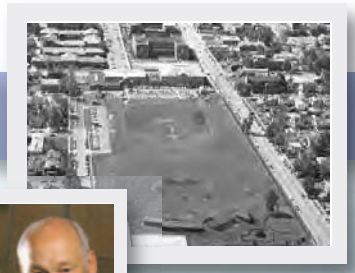
While the teaching and research accomplishments and awards are impressive, Greenough's other contributions on campus, especially as a founding father of the Beckman Institute, are just as remarkable. Biological Intelligence research theme faculty member Neal Cohen said Greenough's impact has been felt across campus.

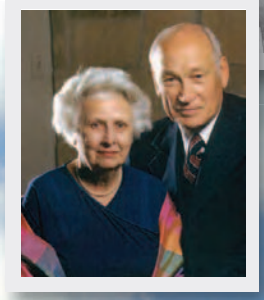
"His vision has always been that way: let's make the department better, let's make the University better, let's bring people here from a variety of circumstances," Cohen said. "Bill's vision has always been to grow the place, to bring more people with different ideas and different levels to come to bear."

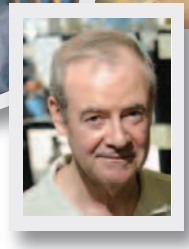
In 2009 the Beckman Institute is celebrating its 20th year as a leading center for doing interdisciplinary research. So it is fitting that in the 20th Anniversary Year, William Greenough was honored as well.

"He really exemplifies that," Cohen said.

Beckman Institute **Celebrates 20th Anniversary**







Symposium, Other Activities Highlight People, Science of Beckman's First 20 Years

It began with a 1983 meeting about using private sources to fund imaginative new projects on the University of Illinois campus. Two years later, Arnold and Mabel Beckman made the largest donation ever given to a public university to build a center at Illinois that would offer an innovative approach to doing research. In April of 1989, the Beckman Institute for Advanced Science and Technology was christened by Arnold, Mabel, the Illinois governor, and numerous other dignitaries, bringing in a new era of research that was truly interdisciplinary.

Twenty years later, the Beckman Institute for Advanced Science and Technology remains one of the leading centers for interdisciplinary research in the country. In 2009 the Institute celebrated 20 years of existence, culminating with the Beckman Institute 20th Anniversary Symposium in October.

On April 16th a Beckman 20th anniversary celebration was held to mark the official opening of the Institute in April of 1989.

Tamer Başar, Interim Director of the Beckman Institute, said the 20th Anniversary celebration is a time to remember and honor the two decades of wide-ranging scientific discovery that has taken place here.

"We are very excited to be celebrating 20 incredible years of science and technology at the Beckman Institute," Başar said. "It is amazing to reflect on the incredible depth and breadth of what has been accomplished by our faculty, staff, and students."

To record and highlight these events, the 20 years of research successes, and the people who have contributed to those successes, a special 20th Anniversary Web page was created to highlight the origins of the Beckman Institute, the changes that have taken place here since its founding, and the many people who helped forge this truly unique research center.

The Beckman Institute 20th Anniversary celebration is part of an exciting year that also included our biennial Open House held in March. In addition, Beckman researchers played host to major international conferences in 2009, and exciting new discoveries and papers are on the horizon as researchers and staff continue the Institute's mission—first tasked 20 years ago—of fostering leading-edge interdisciplinary research.

www.beckman.illinois.edu/anniversary

Beckman Institute Timeline

1980 – Arnold and Mabel Beckman donate $5M worth of stock and 2,000 acres of land to the University of Illinois Campus Research Board.

1983 – University of Illinois officials meet to discuss ways to attract major gifts from the private sector in order to become a world class research institution. Ideas for what Beckman Founding Director Ted Brown describes as "sweeping, imaginative new projects" were sought.

1985 – Arnold and Mabel Beckman decide to donate $40M toward the building of a multidisciplinary research center, contingent upon a $10M matching gift from the state of Illinois.

1987 – In March Ted Brown is named the Founding Director of the Beckman Institute, while Karl Hess and William Greenough are named as Associate Directors. Construction of the Beckman Institute building begins.

1988 – From numerous proposals, 21 research programs and 113 faculty members are selected for the new Beckman Institute for Advanced Science and Technology. The National Center for Supercomputing Applications, one of four supercomputing centers in the country, was also to be housed in the new facility.

1989 – On April 7, the Beckman Institute for Advanced Science and Technology is formally dedicated with a dinner, lecture, and speeches, including one by Arnold Beckman in which he said that the completed facility "exceeded all my expectations."

1992 –The Imaging Technology Group is created. Two imaging groups make up this Beckman primary service facility, the Microscopy Suite and the Visualization Laboratory.

1993 – Jiri Jonas of the Department of Chemistry becomes Beckman's second director.

1994 – Research topics at the Beckman Institute are grouped into three broad themes: Biological Intelligence (BI), Human-Computer Intelligent Interaction (HCII), and Molecular and Electronic Nanostructures (M&ENS).

1995 – The Integrated Systems Laboratory (ISL) is created at Beckman as part of an Army Research Laboratory project. ISL grows into a leading facility for three-dimensional, interactive experiments, adding a rare, six-sided, immersive virtual reality environment, the Cube, in 2000 to what is now a suite of instruments for perceptual psychology and other research projects.

2002 – The Biomedical Imaging Center, started by Nobel Prize winner Paul Lauterbur, becomes one of three primary Beckman Institute service facilities.

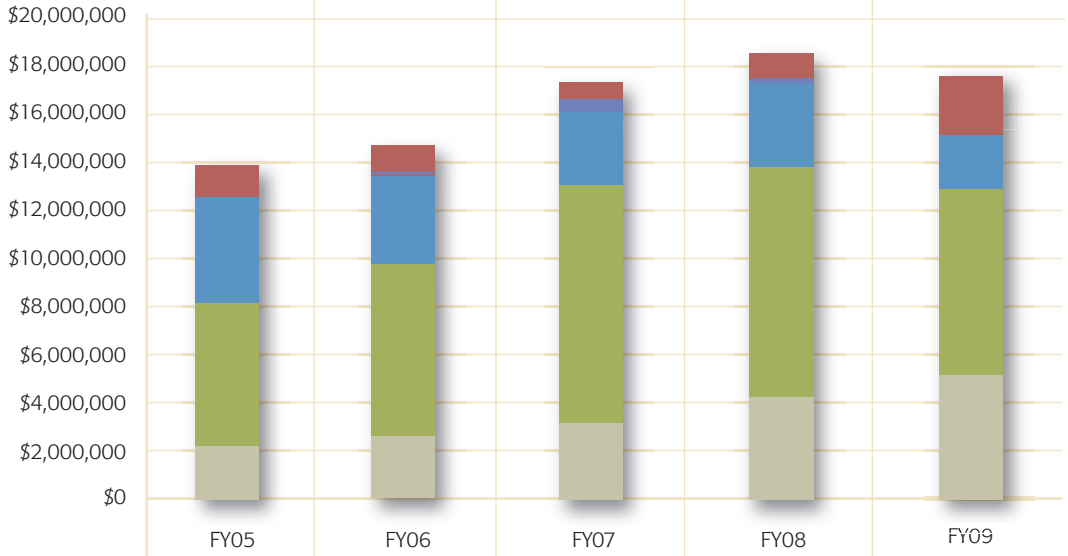
2001 – Pierre Wiltzius is named Director of the Beckman Institute, replacing Jiri Jonas.

2004 – Arnold Beckman dies in May at the age of 104.

2008 – Pierre Wiltzius leaves as Director of the Beckman Institute to take a faculty position in California. Tamer Başar, a Swanlund Endowed Chair Professor of Electrical and Computer Engineering at Illinois, is named as Interim Director of the Institute.

Beckman Institute **Funding 2008-2009**

Beckman Institute Grant Expenditures by Funding Source[1]



	FY05	FY06	FY07	FY08	FY09
DOD	$ 2,322,793	$ 2,603,956	$ 3,172,803	$ 4,217,584	$ 5,238,196
NIH	$ 5,940,245	$ 7,144,039	$ 9,889,110	$ 9,444,099	$ 7,518,406
NSF	$ 4,412,354	$ 3,760,526	$ 3,004,266	$ 3,596,633	$ 2,310,613
IBHE	$ 93	$ 156,333	$ 512,229	$ 223,626	$ (1,674)
Other	$ 1,284,260	$ 1,087,590	$ 1,008,914	$ 1,151,309	$ 2,578,214
Total	$ 13,959,746	$ 14,752,443	$ 17,587,322	$ 18,633,251	$ 17,643,755

Beckman Institute Awarded by Funding Source[2]

		FY06	FY07	FY08	FY09
DOD	$ 6,379,539	$ 191,000	$ 11,012,039	$ 7,030,763	$ 2,115,780
NIH	$ 3,211,450	$ 20,527,604	$ 7,450,733	$ 15,036,128	$ 5,234,846
NSF	$ 2,757,986	$ 1,818,340	$ 2,349,181	$ 4,628,500	$ 1,693,264
Other	$ 709,338	$ 685,903	$ 5,262,943	$ 1,917,393	$ 666,790
Total	$ 13,058,313	$ 23,222,847	$ 26,074,896	$ 28,612,784	$ 9,710,680

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 grants that have multiple faculty investigators from multiple departments. Total funding for multi-year grants is reported in the fiscal year of the award.

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: www.beckman.illinois.edu

Interim Director:
Tamer Başar
Phone: 217-244-8373
Email: director@beckman.illinois.edu

Associate Director:
Van Anderson
Phone: 217-244-8380
Email: van@illinois.edu

Associate Director for Operations:
Mike Smith
Phone: 217-244-1079
Email: mdsmith@illinois.edu

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

Biological Intelligence Research Theme Co-chairs:
Monica Fabiani
Phone: 217-244-1117
Email: mfabiani@illinois.edu

Bill Greenough
Phone: 217-333-4472
Email: wgreenou@illinois.edu

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

Art Kramer
Phone: 217-244-1933
Email: a-kramer@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

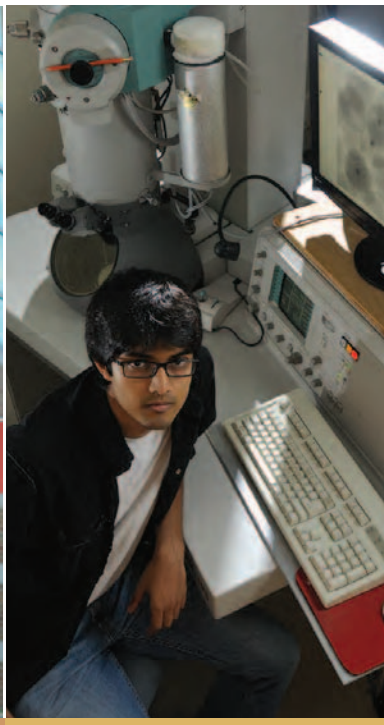
Biomedical Imaging Center
Art Kramer, Director
Phone: 217-244-1933
Email: a-kramer@illinois.edu

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

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

Darren Stevenson, Visualization Laboratory
Phone: 217-244-3074
Email: darrens@illinois.edu

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



IMAGINING POSSIBILITIES WITHOUT BOUNDARIES
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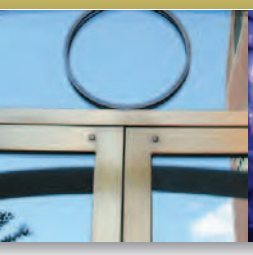
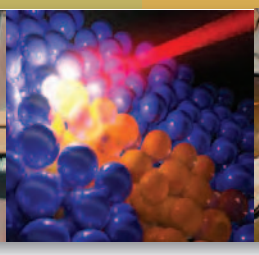
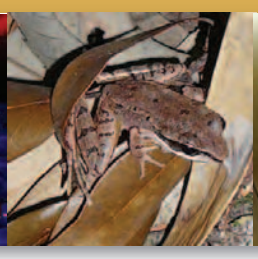
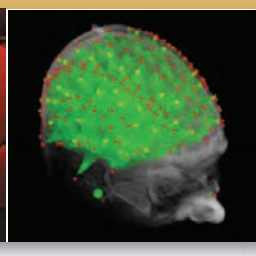
BECKMAN INSTITUTE









Beckman Institute

FOR ADVANCED SCIENCE AND TECHNOLOGY

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