
ILLINOIS
Beckman Institute for Advanced
Science & Technology

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Urbana, Illinois 61801


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2018

# CONNECTIONS


ILLINOIS
Beckman Institute for Advanced
Science & Technology

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ILLINOIS
Beckman Institute for Advanced Science & Technology

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**How will an infant's life be different from the life of an octogenarian?** At the Beckman Institute for Advanced Science and Technology, we may not be able to predict the future, but we're committed to shaping it. We do it by being on the forefront of advancements in technology. We do it through a commitment to developing breakthrough scientific methods, and we do it by being an innovator in materials development.

At Beckman, the connections we make between science and engineering go hand in hand to advance society and to improve health across the lifespan so that we can impact all lives—from the infant to the octogenarian—for the better.

# THE SKY'S THE LIMIT

Even the most successful efforts require re-imagining over time. In fact, an organization's commitment to thoughtful and periodic assessment of where it is and where it's headed is central to shaping its future.

Arnold Beckman knew that. After a long and successful career "selling instruments to scientists," he decided to direct his philanthropic efforts toward the advancement of scientific research. In 1977, he and his wife established the Arnold and Mabel Beckman Foundation as the vehicle to do just that. At the time, he defined the foundation's mission as "supporting basic scientific research in the fields of chemistry, biochemistry, and medicine."

The Beckmans envisioned that all the foundation's assets would be donated during their lifetimes, and they generously set out building scientific centers dedicated to the foundation's mission. The Beckman Institute for Advanced Science and Technology at Illinois is one of the five centers established through the Beckmans' generosity and vision.

But after the death of his wife, Dr. Beckman re-envisioned the foundation so that it would continue in perpetuity. That re-imagining led to an expanded mission statement: "To support leading-edge research in the fields of chemistry and life sciences, broadly interpreted, and particularly to foster the invention of methods, instruments, and materials that open up new avenues of research and application in these disciplines and related sciences."

It wasn't an overhaul of the original mission, but rather a fine-tuning that envisioned more opportunities in scientific areas not yet explored.

At the Beckman Institute for Advanced Science and Technology, we're following Dr. Beckman's example. At our leadership retreat in May 2018, we also took time for thoughtful assessment. And like Dr. Beckman, we decided to build on the mission we've had for nearly 30 years—to firmly plant our flag and then sink it in a bit deeper.

That's why we are proposing a fine-tuned mission statement: "The Beckman Institute for Advanced Science and Technology stimulates a culture of interdisciplinary collaboration at the intersection of science and engineering through the innovation and application of technologies, methods, and materials for societal impact."

Collaborative culture and diverse science are at the heart of our success. It's what makes us agile and nimble and able to pivot on a dime. It creates the possibility of being known for many things, not just one. It allows us to have a big vision and to execute on it. Just like Dr. Beckman did.

Sincerely,

Jeff Moore
Director, Beckman Institute for
Advanced Science and Technology

*Professor Nancy McElwain works with a study participant in the Early Child Development Lab at the University of Illinois.*

# CRUCIAL CONNECTIVITY

## WHY BECKMAN?

"The Beckman environment allows us to focus on questions that are at the intersection of multiple disciplines, including neuroscience, developmental psychology, signal processing, and material sciences. It brings together many expert minds ready to forge new paths of inquiry and to lend the kind of innovative spirit and support that is integral to research success."

NANCY McELWAIN

Connections

HARLEY JOHNSON

MARK HASEGAWA-JOHNSON

RYAN LARSEN

BRAD SUTTON

HOLLY TRACY

NANCY DODGE

Solving problems. Engaging in conversation. Developing confidence. Such important cognitive, social, and emotional milestones start with brainpower. And between infancy and 3 years old, children build plenty of it.

In fact, by a child's third birthday, the brain will have reached 80 percent of its adult volume and will have processed nearly 1,000 trillion connections between neurons.

With such a rapid rate of brain development, researchers are examining what factors shape that crucial connectivity during these early years.

One of those researchers is Nancy McElwain, a professor in the Department of Human Development and Family Studies and a member of the Beckman Institute's Social and Emotional Dimensions of Well-being Group.

"There is tremendous plasticity in the brain in the first years of life, and that brain development is shaped, in part, by the infant's repeated experiences with parents and other primary caregivers," McElwain said. "The infant-caregiver relationship can have lasting effects on infants, and the more we can do early on to support healthy development, the bigger the payoff will be for children and their families."

## A Beckman First

McElwain is conducting a study funded by the National Institute of Mental Health that examines how caregiving impacts brain development and social and emotional well-being. Part of that work includes a first for the Beckman Institute's Biomedical Imaging Center (BIC)—conducting functional and structural scans of infants during natural sleep.

"We scan infants at 3 months of age and again at 12 months to help us to examine how the brain develops and becomes organized over time," she said. "We are especially interested in understanding how early caregiving processes shape connectivity among the large-scale networks in the brain by the end of the first year of life."

It's one aspect of a project that McElwain is conducting with Eva Telzer, an assistant professor of psychology and neuroscience at the University of North Carolina. Behavioral interaction is another.

The caregiver and the baby visit the behavior lab four times in the first year at three-month intervals. During the visit, observational data is collected on the interactions between the two during various levels of engagement. Cardiac activity also is measured. Between visits, interaction is monitored by way of a recorder used by the caregiver to capture the baby's vocalizations and baby-caregiver interactions in the home.

While McElwain is experienced in collecting such behavioral data, she is especially grateful for the imaging expertise Beckman collaborators and BIC staff bring to the work. She said that Brad Sutton, a professor of bioengineering and BIC's technical director, and Ryan Larsen, a BIC research scientist, who are also co-investigators of the study, "were instrumental in developing the scan protocol and ensuring it would run smoothly. We also relied on the expertise of BIC imaging specialists Nancy Dodge and Holly Tracy to implement the protocol."

It's not always easy. "Scanning babies while asleep brings special challenges," McElwain said. "We worked as a team and learned how best to accomplish the scans and how to put the parents at ease. Educating parents about the imaging process has also been important."

## Data Collection Innovation

Future steps on this project rely on additional Beckman collaborations. Mark Hasegawa-Johnson, a professor of electrical and computer engineering, and Harley Johnson, a professor of mechanical science and engineering, are working with McElwain to expand the remote collection of behavioral and physiological data. This part of the project is supported by the Social Science and Behavioral Research Initiative at the University of Illinois.

"With Harley's expertise, we're developing a 'SMART shirt' that has a built-in recorder and cardiac monitor that we can give parents to collect synchronized ECG and vocalization data in the home," McElwain said. "We will pilot it in the fall and aim to collect data from both children and their caregivers.

"Working with Mark and his graduate student, Yijia Xu, we will be able to process the vocalization and cardiac data in a more nuanced way, so that we can measure the emotional signals babies and parents are sending and receiving. By incorporating physiological measurement and brain imaging with behavioral data, we hope to provide a more complete picture of development in the context of infant-caregiver relationships. We hope to follow these families over time to understand how these relationship dynamics contribute to children's long-term health and well-being."

# GUIDING INFLUENCE

When Narayana Aluru received a job offer at the University of Illinois in 1998, he asked his Ph.D. adviser at Stanford if he knew anyone at Illinois who could provide guidance as he started his career. The adviser reached out to two professors who agreed to meet the young scientist.

Aluru still recalls his good fortune at stepping into the Beckman Institute to meet Karl Hess and Umberto Ravaioli, whose influence continues to inspire him 20 years later.

"My first thought was how impressive the building was," he said of the Beckman Institute. "Then I met Karl and Umberto and realized the people and the opportunities for collaboration were even more impressive."

Both men were professors of electrical and computer engineering at the time. Ravaioli, whose primary interest is nanotechnology, is now a senior assistant dean in the College of Engineering. Hess, a foremost expert in electron transport and a research group co-chair, retired in 2006.

"I didn't learn until much later that Karl was one of the founding members of the Beckman Institute," Aluru said. "They were both so gracious and interested in my research. Karl said my work would be a good fit with Beckman's focus on interdisciplinary research and invited me to become an affiliate."

The rest, as they say, is history. "When I came to Illinois, I had a vision of my career path," Aluru said. "I had a five-year plan and a 10-year plan. And though I did pursue that plan, my research career really has been shaped more by the collaborations and opportunities that have come about as a result of my affiliation with Beckman. The big questions my research has focused on have been influenced by Karl and Umberto and so many other talented colleagues here."

## Studying Nanosystems

What are some of those questions and who are some of those collaborators?

The early questions were about nanofluidics, that is, how fluids behave in very small regions. Hess and Ravaioli introduced Aluru to their approaches on how biological ion channels work, which informed his research and furthered his Beckman collaborations.

In the years that followed, Aluru, a professor of mechanical science and engineering, and his research group within the Computational Multiscale Nanosystems Group have focused on advancing the field of computational nanotechnology by developing new computational methods at various length scales and employing them to understand fundamental issues in nanofluidics, nanoelectromechanical systems, nanomaterials, and nanobiotechnology.

"We focus on wide-ranging applications, such as water desalination, energy storage and production, water-energy nexus, electromechanical sensors and actuators, DNA and protein sensing and sequencing, and nanopower generation," Aluru said.

With Beckman collaborators Joe Lyding, a professor of electrical and computer engineering, and Arend van der Zande, an assistant professor of mechanical science and engineering, as well as SungWoo Nam, an associate professor of mechanical science and engineering, Aluru is investigating mechanical and electrical properties of emerging materials, such as 2D materials, for potential applications as ultra-sensitive sensors and electronic devices.

## Extending Collaboration

Other Beckman collaborations include Aluru's work with Emad Tajkhorshid, a professor of biochemistry. "Our group collaborated with Emad's group on understanding rapid water permeation in aquaporins," Aluru said. "Specifically, we developed thermodynamic insights into unique water transport properties of aquaporins. We are also collaborating on understanding proton transport in confined environments."

In addition, he has partnered with Rohit Bhargava, a professor of bioengineering, over the years on microfluidics research. "More recently, we have been collaborating on chemical reactions in microfluidic channels," Aluru said. "We plan to continue our collaboration by integrating uncertainty quantification and stochastic approaches into simulation of microfluidic platforms that Rohit is developing."

Today, Aluru continues his work with Ravaioli as well, focusing on cyber-physical issues. He also is a collaborator on the new nanomanufacturing node recently awarded to the University of Illinois by the National Science Foundation. On that project, he collaborates with Ravaioli as well as Beckman affiliate Kimani Toussaint, an associate professor of mechanical science and engineering.

It's been a busy 20 years since Aluru first stepped foot inside the Beckman Institute and met with Hess and Ravaioli.

"I hope to continue to contribute and benefit from the vibrant and intellectual atmosphere at Beckman, and I hope I can inspire younger faculty to engage in exciting research at Beckman, just the same way I was inspired by senior faculty at Beckman when I was a younger faculty member," he said.

## WHY BECKMAN?

"Being part of the Beckman Institute really shapes a scientist's research career. The intellectual atmosphere, the vibrant collaborations, and the infrastructure create possibilities that lead to significant scientific contributions."

NARAYANA ALURU

*Connections*

KARL HESS

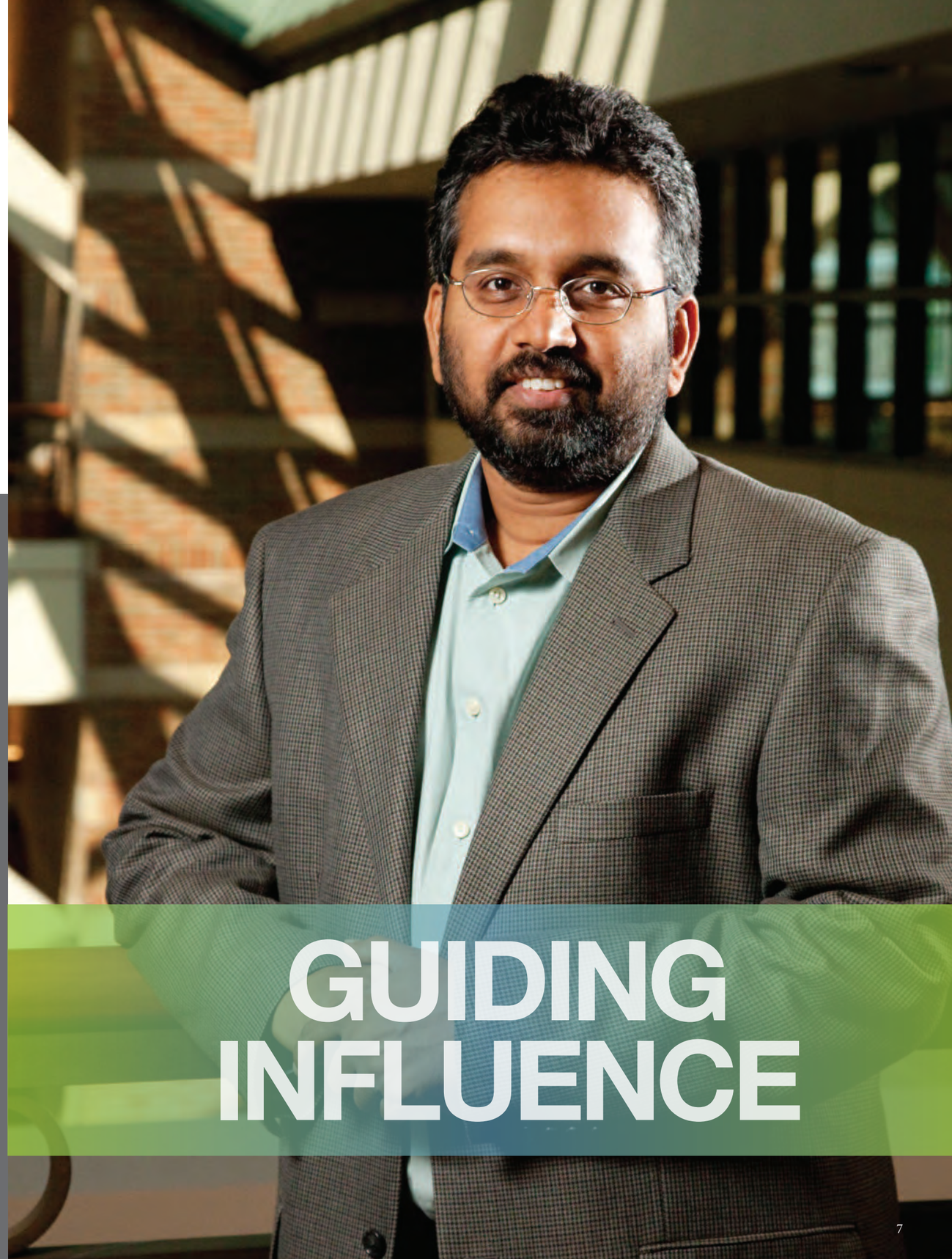
JOE LYDING

ROHIT BHARGAVA

UMBERTO RAVAIOLI

EMAD TAJKHORSHID

AREND VAN DER ZANDE



# COMMITTED TO MEMORY

## WHY BECKMAN?

"Beckman is in a league of its own in terms of diversity of expertise and opportunities for collaboration. There is a real commitment to push the envelope to stay at the forefront of scientific discovery and a built-in flexibility that allows us to move in a different direction when a new path emerges."

SANDA DOLCOS

FLORIN DOLCOS

Connections

LIZ STINE-MORROW

GABRIELE GRATTON

MONICA FABIANI

BRAD SUTTON

THOMAS HUANG

Florin and Sanda Dolcos' connections go way back. Both grew up in the same neighborhood of a Transylvanian city in Romania, went to the University of Bucharest, and studied in the same department. They even have a vivid recollection of being partners in a folk dance as preschool classmates.

Today, that partnership is inspiring research that helps us understand how the emotional aspects of memories impact well-being and what strategies are most effective in facilitating responses to emotions.

"One of our research goals is to provide people in need with a set of effective tools to cope with emotional challenges," said Florin Dolcos, the leader of the Beckman Institute's Social and Emotional Dimensions of Well-being Group and an associate professor of psychology.

With an estimated 40 million adults suffering from anxiety and depression in our country, it's research that holds great promise for improving people's lives.

"Everyone has unpleasant memories," said Florin. "When these memories come to mind, it's difficult for us to focus our attention away from the emotion that the memories elicit. That causes us to be distracted and not able to stay focused on the tasks at hand. For people who struggle with anxiety, depression, or post-traumatic stress disorder, the distraction is so extreme that it impacts their day-to-day lives. Developing strategies to stay focused is certainly important for those people, but it's really helpful for everyone. We can all benefit from learning ways to control our attention and emotional responses."

How do you do that? "By not allowing yourself to concentrate on the worst emotions and instead thinking about the context of the same events, like a friend who was there or what the weather was like," said Florin. "This strategy will take your mind away from the unwanted emotions associated with a negative memory."

### Focused Attention

A recent paper published in *Cerebral Cortex* explained the research undertaken by the Dolcos Lab, together with Alexandru Iordan, a former Beckman Institute Graduate Fellow who is now a postdoctoral research fellow at the University of Michigan.

The researchers asked participants to complete questionnaires about various events in their lives. Then during a functional MRI (fMRI) scan, they introduced cues to trigger unpleasant autobiographical memories concurrently with a cognitive task. In half of the memories, participants were told to focus on the emotional aspects of the memories. In the others, they were told to focus on the context, details like those Florin suggested: what the weather was like, who they were with, or what time of year it was.

The fMRI results indicated that participants had better cognitive performance when focused on the contextual details rather than the emotional content of their unpleasant memories.

The regions of the brain responsible for processing emotions showed increased activity when participants focused on the emotion of the event, and less activity in regions associated with executive function, such as focused attention. The opposite was true for those who were asked to focus on the context of the event. For them, the areas of the brain associated with emotion and distraction had a reduced response, and the executive function region showed an increased response.

"By training people to use a strategy of focusing on context when distressing memories come to mind, we can help anyone better cope with emotional situations," said Sanda Dolcos, a research assistant professor of psychology.

This strategy is an alternative to one many people employ when faced with negative memories—suppression, which Sanda said can actually increase anxiety in the long-term.

"By shifting the focus, rather than suppressing the memory, people can actually see the same memory in a new way. With enough practice, the intrusive nature of the distressing memories will be reduced. Plus, it's a strategy that doesn't impair cognitive performance, and people can use it any time they need to. It holds promise for helping people with situations in everyday life."

## UNDERSTANDING BRAIN DYNAMICS

Are there personality traits that can protect an individual's brain against emotional distress? Matt Moore, in collaboration with Florin and Sanda Dolcos, conducted a study of 85 healthy college students to find out.

"In this study, we wanted to look at commonalities across brain regions and across personality traits that contribute as protective factors," said Moore, a 2018 Beckman Institute Postdoctoral Fellow. "We targeted a number of regions in the prefrontal cortex, looking specifically at the volume of those regions using structural magnetic resonance imaging. We did a confirmatory factor analysis, which is basically a statistical approach for testing whether there is a common factor underlying the observed measurements.

"We extracted these factors, one at the brain level, one at the personality level, and found that larger volume in this set of brain regions was associated with higher levels of protective personality traits, such as optimism."

The findings were recently published in *Personality Neuroscience,* and the next step is to use this information to create ways for individuals to learn how to combat anxiety and depression.

Moore is also working with Florin and Sanda Dolcos, and other Beckman collaborators on advancing the use of simultaneous multimodal brain imaging (fMRI, EEG, and optical imaging) to clarify the spatio-temporal aspects of neural processing associated with cognitive, affective, and social decision-making tasks.

"Using all three modalities provides us with a unique opportunity to understand the dynamics of the brain," said Moore. "And Beckman is on the forefront of multimodal imaging because we have both the intellectual resources and the state-of-the-art equipment to conduct such collaborative, interdisciplinary, and pioneering work."

# KEEPING IT PERSONAL

## WHY BECKMAN?

"Strong academic, interdisciplinary research, like the kind that's possible at Beckman, provides a synergistic approach that lays the foundation for the development of integrated solutions that lead to early disease detection and precision treatments."

DIPANJAN PAN

*Connections*

WAWRZYNIEC DOBRUCKI
JEFFERSON CHAN
EMAD TAJKHORSHID
ROHIT BHARGAVA
NARAYANA ALURU
MICHAEL OELZE

Personalized medicine is all about precision. It's about developing new diagnostic approaches and technologies that help us understand disease at the molecular level so that determinations can be made about an individual's susceptibility to disease, his or her prognosis, and the response to treatment. Dipanjan Pan, an associate professor of bioengineering and member of the Bioimaging Science and Technology Group, is focused on moving personalized medicine forward.

"The overarching goal of our research is to develop translatable nanomedicine that can quickly reach clinical use," Pan said. It's work that covers a lot of ground, from biosensing and early disease detection, to basic drug discovery and controlled delivery, to evaluation of the effectiveness of that delivery.

"We look at ways to detect disease early because that allows for more options for intervention," said Pan, an expert in nanomaterials. "Then after we determine the most effective therapy, we look to deliver it in such a way that normal healthy cells are minimally affected, so we lessen the severe side effects for the patient. Once you have the therapy in place, we want to know if it's working, so we use imaging to look for molecular changes that let us know how effective the treatment is. We look at ways to combine imaging and treatment to improve outcomes."

### From the Lab to the Start-Up

The work begins in his lab, the MatMed Laboratory for Materials in Medicine, located in the Biomedical Research Center at Carle Foundation Hospital. "Strong academic research is the heart of the process," said Pan. "Whatever progress we make toward our goal starts in the academic lab. It's that work that leads to the development of a technology that needs to be translated."

And, for Pan, it also can lead to the establishment of a start-up company to move that technology forward.

Vitruvian Biotech is one of Pan's companies. It develops innovative diagnostic tests and therapeutics for central nervous system disorders, oncology, and metabolic disease. KaloCyte Inc., which develops next-generation synthetic blood, and InnSight Tech, which creates biosensors to gauge ocular trauma, are two others.

According to Pan, the interdisciplinary focus and state-of-the-art resources at the Beckman Institute make it a great environment for his multifaceted work, which involves synthetic chemistry, biology, imaging science, and medicine.

"Beckman is a melting pot of vast amounts of scientific activity directed by world-renowned experts in computational science, imaging, and basic science," said Pan. "Such interdisciplinary expertise is the key for success in today's biomedical science realm."

### Advancing Medicine

For Pan, that strong interdisciplinary collaboration with scientists and clinicians has led to integrated solutions that advance medicine.

For instance, with Rohit Bhargava, a professor of bioengineering, Pan is using vibrational spectroscopy to examine tissue for early detection of disease. With Emad Tajkhorshid, a professor of biochemistry and the director of Beckman's Theoretical and Computational Biophysics Group, he is exploring how agents enter cancer cells. In collaboration with Jefferson Chan, an assistant professor of chemistry, Pan is working on developing a photoacoustic molecular probe that can lead to better disease diagnosis and treatment while eventually disappearing from the body. With Narayana Aluru, a professor of mechanical science and engineering, he is advancing the understanding of how synthetic blood agents flow within a blood vessel. Pan is also collaborating with Michael Oelze, a professor of electrical and computer engineering, to use a combination of chemotherapeutics and ultrasound for modulating immune response in cancer.

For such collaborative work and more, Pan was named the winner of the 2018 College of Engineering Dean's Award for Excellence in Research.

What lies ahead? More research with more promise. Pan is slowly moving forward on an ambitious project to develop a nanovaccine for cancer. "We're looking at using some of the research at Beckman to come up with an image-guided approach where we will be able to make people immune from cancer."

# MAGNETIC ATTRACTION

## WHY BECKMAN?

"At Beckman, we have a strong spirit of interdisciplinary collaborations, open-minded colleagues, and a broad variety of expertise that uniquely position us to be at the frontiers of discovering new science and developing innovative technologies to address important health care problems."

FAN LAM

Connections

KING LI

RYAN DILGER

ARON BARBEY

BRAD SUTTON

ZHI-PEI LIANG

GENE ROBINSON

If you're interested in biomedical imaging research, says Fan Lam, the Beckman Institute offers a one-of-a-kind environment to pursue it. After all, Beckman and the Urbana campus have strong ties to discoveries that have long propelled innovations in the field of imaging. Those strong ties drew Lam to the University of Illinois.

His doctoral adviser was Zhi-Pei Liang, an expert in magnetic resonance imaging and a member of Beckman's Bioimaging Science and Technology Group. For 17 years, Liang worked with Illinois chemist Paul Lauterbur, an MRI pioneer and winner of the 2003 Nobel Prize.

Lauterbur was Liang's mentor, and Liang, a professor of electrical and computer engineering, was Lam's. All three are part of the strong connections of imaging discovery at Beckman.

"When I was considering graduate schools, I was lucky to get a chance to talk with Zhi-Pei, and his passion, vision, and exemplary work in the field convinced me that this is where I should be," Lam said.

Liang has said the same about Lauterbur, who gave a lecture that put Liang, then a graduate student at Case Western Reserve University, on a research path that he has pursued ever since.

"Paul had the strongest influence on me, my research, and my approach to pursuing scientific dreams," said Liang, who was recruited to Illinois by Lauterbur in 1989.

Lam continues the connection. After earning his master's and Ph.D. from Illinois in electrical and computer engineering, Lam was named a Beckman Institute Graduate Fellow in 2012 and a Beckman Institute Postdoctoral Fellow in 2015. This year, he joined the Illinois faculty as an assistant professor of bioengineering and as a full-time faculty member in Beckman's Bioimaging Science and Technology Group.

### Future Discoveries

Lam's work focuses on the development and application of advanced magnetic resonance (MR) imaging technologies to study brain functions, diagnose and characterize diseases, and monitor treatment.

"There are many molecules in the brain, such as metabolites and neurotransmitters, which play important roles in various brain functions and provide abundant information in characterizing different types of diseases," Lam said. "My research focuses on developing imaging tools to visualize these molecules in the brain non-invasively. Specifically, I'm developing a set of MR spectroscopic imaging (MRSI)-based technologies which will allow us to detect and quantify these molecules without the need of injecting any contrast agents into the body."

But there are challenges. "These molecules typically have three to four orders of magnitude lower concentrations than water molecules," Lam said. "Existing imaging methods to acquire their information are very slow and offer very poor spatial resolution, preventing them from being practically useful."

Lam is developing new models, data acquisition strategies, and quantitative analysis and computational tools to address the speed, resolution, and sensitivity challenges for MRSI—and its integration with other neuroimaging technologies to study brain functions at normal and diseased states.

During his postdoctoral fellowship, Lam also contributed to the evolution of SPICE (spectroscopic imaging by exploiting spatiospectral correlation), an advance in MRSI technology that has been in development by Liang's group for more than a decade.

"Now we are able to achieve whole brain mapping of a number of metabolites in just five minutes with resolution matching that of a standard functional MRI scan," Lam said. "This is already more than an order of magnitude improvement over any existing methods. My goal is to make noninvasive mapping of the metabolic profiles of neural tissues into reality. This could lead to early diagnosis of diseases, better and more efficient treatment, and more importantly, move us toward the goal of better understanding the molecular basis of brain function and diseases."

As a faculty member, Lam will continue to focus on advancing this work while also "exploring ways to integrate physics-driven modeling and machine learning methodology to develop the next generation of intelligent and efficient imaging systems."

It's all part of propelling innovation in MRI, which started at Beckman decades ago. "It's a privilege to be part of continuing that proud tradition of discovery in the field of imaging," Lam said.

# FIND. FIGHT. FOLLOW.

Find. Fight. Follow. That's how Fatemeh Ostadhossein describes how nanoparticles can be used to solve biomedical challenges—first, to detect disease at an early stage; second, to target and treat disease; and third, to evaluate the outcome of the treatment.

"Nanoparticles show great promise for finding, fighting, and following a variety of diseases, including cardiovascular disease, cancer, infections, and genetic disorders," said Ostadhossein, a Ph.D. student in bioengineering. "The main goal of my research is to integrate materials science, advanced materials characterization, and biomedical engineering to develop smart nanomaterials for biomedical imaging for early disease diagnosis, to develop smart biomaterials for drug delivery applications, and to assess the safety of the nanomaterials for the ultimate translation from bench to bedside."

Her work with Dipanjan Pan, associate professor of bioengineering and member of the Bioimaging Science and Technology Group, provides the opportunity to do just that. His MatMed Laboratory for Materials in Medicine "has a firm grounding in organic chemistry and biology, which is a combination you find in very few labs," said Ostadhossein. "I feel very fortunate to work with Dr. Pan, who is a global leader and has a proven record in the invention of new nanotechnology platforms for various biomedical applications."

Ostadhossein's research efforts also are aided by the staff and the state-of-the-art equipment in Beckman's Microscopy Suite, including the transmission electron microscope (TEM), scanning electron microscope (SEM), atomic force microscope, confocal microscope, and microCT. "Beckman has groundbreaking technologies for imaging nanoparticles," she said.

What information can the Microscopy Suite technology provide? "The application of each of these devices depends on the particular stage of my research project," Ostadhossein said. "If I am focused on the synthesis step, then I need to characterize my samples, for instance, by TEM and SEM. If I need to see the interaction of materials I developed and follow in biological environments, I use confocal microscopy for cell imaging or IVIS Spectrum CT imaging for small animal imaging."

After earning her Ph.D., Ostadhossein plans to complete postdoctoral work and eventually establish her own academic lab. "I'd like to continue to do work at the intersection of material sciences and biology, working on both my current research on nanoparticles in terms of imaging and therapy and also focusing on developing biomaterials that can be used for regenerative medicine."

## WHY BECKMAN?

"Beckman is a great facility for conducting research in biology and in the characterizations of nanoparticles. The resources here are outstanding. I feel especially fortunate to have access to groundbreaking imaging technologies and expert staff that aid our research efforts."

FATEMEH OSTADHOSSEIN

### Connections

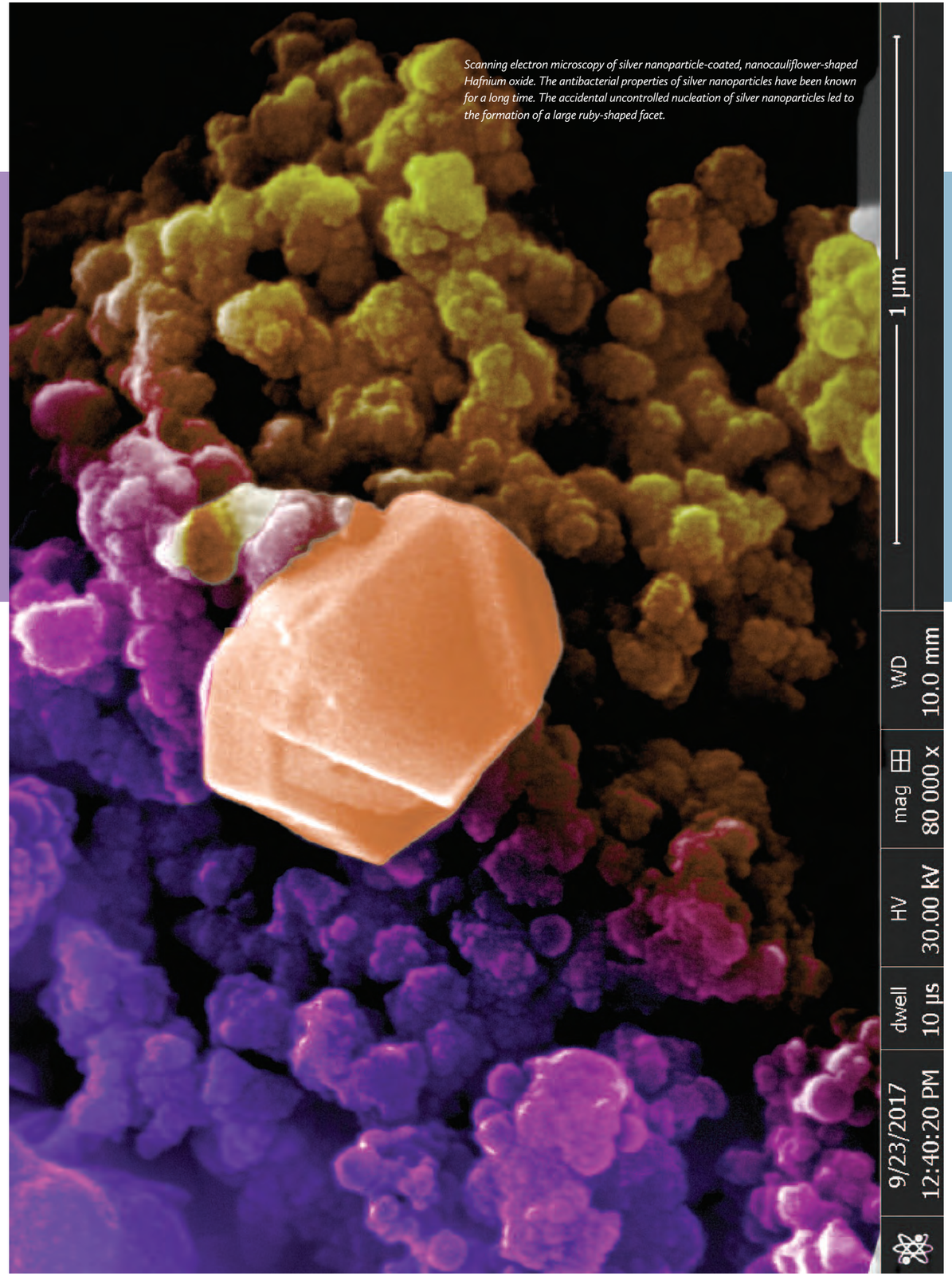
DIPANJAN PAN

IWONA DOBRUCKA

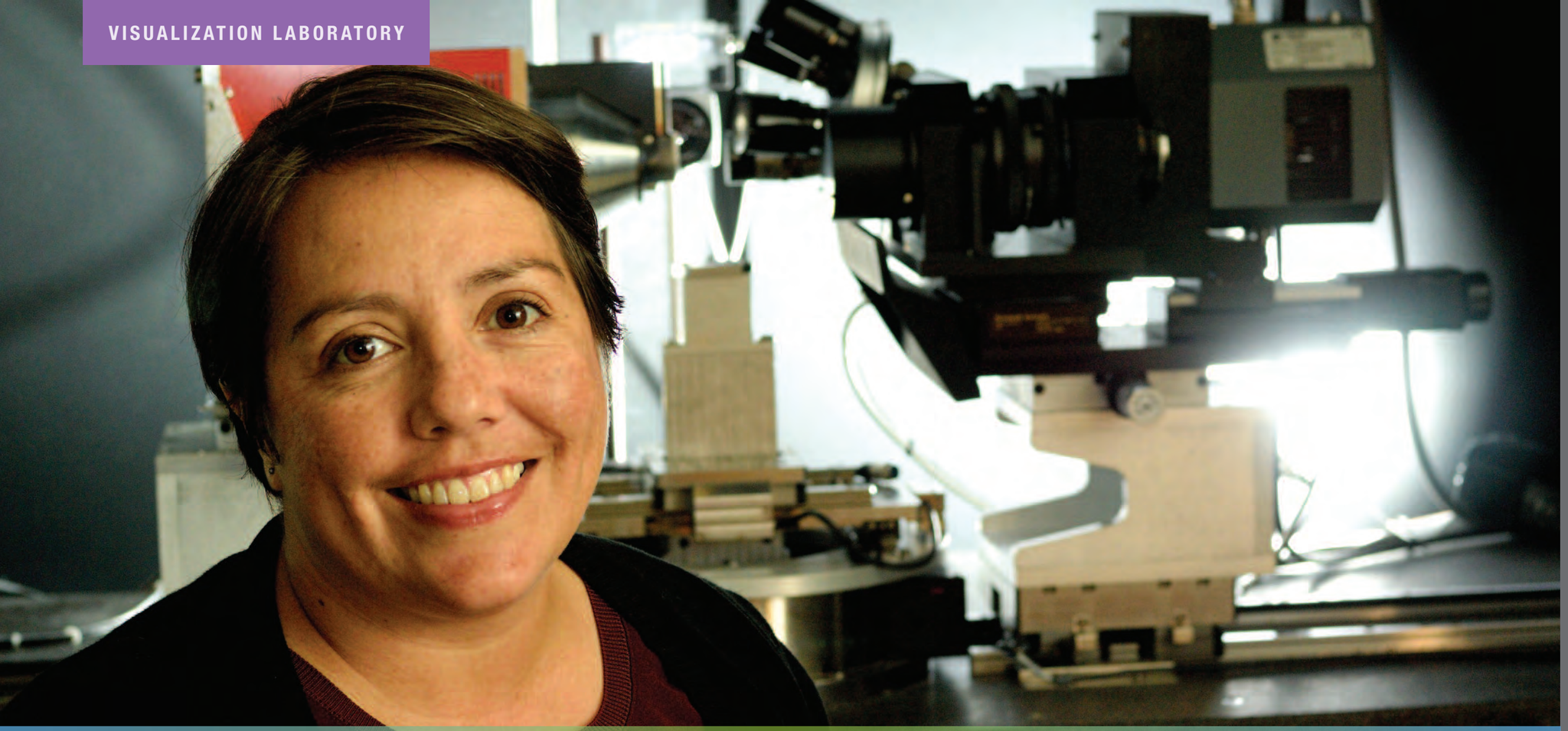
SCOTT ROBINSON

CATE WALLACE

LEILEI YIN




*Scanning electron microscopy of silver nanoparticle-coated, nanocauliflower-shaped Hafnium oxide. The antibacterial properties of silver nanoparticles have been known for a long time. The accidental uncontrolled nucleation of silver nanoparticles led to the formation of a large ruby-shaped facet.*



# SMART BONES

## WHY BECKMAN?

"Working with fellow Beckman members, faculty and staff, who are open to—and encouraging of—pushing forward new applications for the technologies and imaging capacities available at Beckman has been the most impactful part of being at the institute."

MARIANA KERSH

Connections

ROHIT BHARGAVA

RYAN LARSEN

TRAVIS ROSS

BRAD SUTTON

Baseball players. Postmenopausal women. NBA stars. Even sheep and horses. They all have something in common. They have smart bones.

Most living things do, said Mariana Kersh, an assistant professor of mechanical science and engineering who has studied athletes, animals, aging women, and many other groups as part of her research on the mechanical and structural properties of bone, cartilage, and connective tissue.

"Bone is very smart. It is constantly optimizing and adapting," said Kersh, a member of the Beckman Institute's Bioimaging Science and Technology Group. "Bone is always turning over. In fact, over our lifetimes, our bones are replaced several times."

The how and why of bone adaptation and the role of muscle forces on bone is the focus of Kersh's work. She uses computational models to make these determinations, and she uses the Visualization Laboratory (Vis Lab) at Beckman to help her do it.

"First, we use previously developed musculoskeletal models, which tell you what your muscle forces are during a given activity," Kersh said. "And then we combine them with finite element models, which are what we develop at Beckman using CT data and the Molecular Imaging Lab. It's a lot of data, and we need to have a way to process it efficiently."

That's where the Vis Lab comes in. "This is a great resource for us in our research," she explained. "The Vis Lab has the FiniteElement software that we need for the mechanical predictions as well as software for the initial imaging processing. The availability of these resources and the support of the Vis Lab staff enhances the efficiency of our work."

In addition, it helps Kersh and her team gain valuable insights. "We can now begin to answer questions that up until now we could not," Kersh said. "For instance, What is the nature of bone growth? What is the nature of bone adaptation? How does this manifest itself in different populations who are prone to fractures, such as basketball players who are more prone to tibial stress fractures? What does healthy bone porosity look like as we examine osteoporosis in women? How does exercise influence bone properties?"

### Fighting Fractures

Kersh is interested in pursuing all of these questions. She has a grant from the NBA and General Electric to examine how muscle fatigue might influence fracture risk. She's published an article in the *Journal of Bone and Mineral Research* about how advancing age and reduced exercise impact bone formation. She's tracking professional baseball pitchers to see how their bone size and bone density changed after their careers ended. She's even collecting data from sheep as they exercise on a treadmill to evaluate the effect of differences in mechanical loading on the adaptation process in bone.

The goal of Kersh's current research, she said, is twofold. "The two best outcomes from our work would be identifying the actual structural measurements that tell you whether or not this is healthy bone or bone that might be at risk of fracture. The other is understanding the role between muscle and bone. We know bone is particularly elastic when you're young and that you have a lot of opportunity to change it. What we don't know is what exercises we could do as children, young adults, and even into middle age that might actually increase the strength of bone in the areas that we know are likely to fracture. When we understand how exercise influences bone properties, we'll be able to advance the science even further."

# WHAT'S UP, POSTDOCS?

## 4 QUESTIONS

The Beckman Institute Postdoctoral Fellows Program provides an opportunity for young scientists to spend several years doing independent research in the behavioral and biological sciences, chemistry, engineering, or physics before launching formal academic careers. We introduce you to two of these promising researchers and scholars.

MICHELLE RODRIGUES

**Beckman Institute Postdoctoral Fellow**
Researches the role that social support plays in mediating the impact of stressful experiences.

JAMILA HEDHLI

**Beckman-Brown Interdisciplinary Postdoctoral Fellow**
Conducts engineering-based imaging research, which focuses on developing novel diagnostic and therapeutic methods in the fight against diabetes-associated cardiovascular disease.

### 1 Why did you decide to pursue your research at Beckman?

**Michelle:** After earning undergraduate degrees in psychology; and ecology, ethology, and evolution here at Illinois, I completed my master's and Ph.D. degrees in anthropology—the master's at Iowa State and the Ph.D. at Ohio State. I decided to pursue research at Beckman because my research is inherently interdisciplinary, and Beckman provides many opportunities to discuss and collaborate across disciplines.

**Jamila:** I was teaching math and science at two community colleges in New Jersey while completing my master's degree in biomedical sciences at Rutgers, and I was considering going to medical school. Wawrzyniec Dobrucki was speaking at a seminar at one of the community colleges, and we struck up a conversation. He asked me if I knew about the bioengineering program at Illinois. After learning more about the interdisciplinary nature of the program and the resources at Beckman, I thought it was a strong fit for my career aspirations. And that certainly has been the case.

### 2 Who do you collaborate with in your research?

**Michelle:** For my main research project on stress in female scientists, I am collaborating with Kate Clancy, an associate professor of anthropology, and Liz Stine-Morrow, a professor of educational psychology, as well as Ruby Mendenhall, an associate professor of sociology. I'm also collaborating on additional projects: one that focuses on friendship, depression, and stress in adolescent girls is a collaboration with Kate Clancy; Carla Hunter, an associate professor of psychology; and Jenny Amos, a teaching associate professor of bioengineering. The other is on social communication in aging, with Liz Stine-Morrow, Kate Clancy, and fellow Beckman Institute Postdoctoral Fellow Si On Yoon.

**Jamila:** Dr. Dobrucki is an assistant professor in bioengineering and my adviser. In his lab, we have conducted research on the multidimensional analysis of stem cell therapy for peripheral arterial disease (PAD) in diabetic mice. We also developed new radio-labeled PET-CT tracers to detect active blood-vessel remodeling in PAD. More recently, my research has shifted toward the development of ultrasound probes for early disease detection. In collaboration with Michael Insana, a professor of bioengineering, we were able to develop a new power Doppler ultrasound technology that, without any exogenous contrast enhancement (i.e., no radioactive control agent) or specialized equipment, is sensitive enough to detect spatiotemporal changes in blood perfusion within muscle. As the 2018 Beckman-Brown Interdisciplinary Postdoctoral Fellow, I will conduct research into the development of gas-filled "smart bubbles" for ultrasound imaging of ovarian cancer. For that work, I will collaborate with Jeff Chan, an assistant professor of chemistry; King Li, the dean of the Carle Illinois College of Medicine; and Dobrucki.

### 3 What is the inspiration for your work at Beckman?

**Michelle:** My research is inspired by my own experiences and those of my friends. Most of my past research has been on social relationships in non-human primates, and my dissertation research examined stress and female friendship in spider monkeys to test the "tend-and-befriend" hypothesis. which proposes that women have evolved to seek friendship in times of stress as part of our primate heritage. When discussing academic stressors with my friends, we always joke about how important it is for us to "tend-and-befriend." My current research is directly studying how those dynamics work for female scientists. The big question I'm trying to understand is if female scientists—especially female scientists of color—have enough opportunities to form and rely on social networks to deal with the stressors they experience.

**Jamila:** The interdisciplinary environment and the breadth of knowledge across the sciences—from engineering to chemistry to imaging to stem cell biology—inspires strong collaborations. The people and the state-of-the-art imaging resources at Beckman give me the inspiration and the confidence to focus on work that has a translational property, where I can take ideas from the bench to the clinic so that there can be real benefits for patients.

### 4 What opportunities has your affiliation with Beckman provided?

**Michelle:** Beckman has provided opportunities to engage in research discussions across disciplinary boundaries as well as broader opportunities to communicate with other audiences. I'm very interested in science communication and public engagement, and Beckman has supported many of these opportunities, such as the Story Collider event in the fall with the 21st Century Scientists.

**Jamila:** I feel fortunate to have received both a graduate fellowship and a postdoc fellowship from the Beckman Institute as well as a Nadine Barrie Smith Fellowship. As a result of travel opportunities provided by these fellowships, I had the opportunity to attend the 2017 American Heart Association conference where I was the finalist for the Jay D. Coffman Early Career Investigator Award. I've also had the chance to travel to the National Institutes of Health and gain valuable information on writing grants.

"To be able to see the link from basic science going all the way through the entire spectrum to applied work happening simultaneously with students side by side is fundamentally exciting. As an engineer, there is nothing better than seeing your work being applied and commercially relevant to industry."

*Scott White*

# In Tribute: Scott White

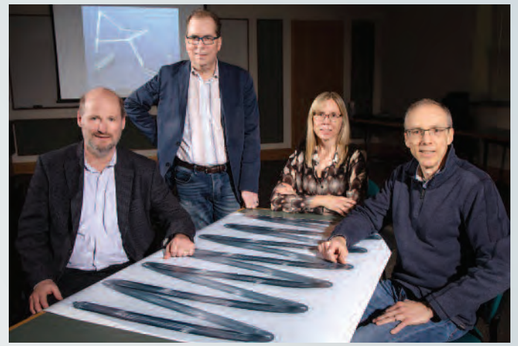
Scott R. White, an innovator of self-healing and self-regulating materials and a professor of aerospace engineering, died of cancer May 28, 2018, at age 55.

White was an internationally recognized expert in autonomous materials—materials that can adapt or respond on their own. His research group at the Beckman Institute developed self-healing plastics, electronics, batteries, and coatings; coatings and materials that indicate when they are damaged or strained; self-destructing devices to reduce electronic waste; and many other innovations to make materials safer and more reliable on both the micro and macro scale.

"Scott worked at the forefront of research in self-healing materials. Yet along with a brilliant mind, persistence, tenacity, and foresight were some of the traits that made Scott who he was," said Jeff Moore, the director of the Beckman Institute and a longtime collaborator of White. "Scott had been fighting cancer over a number of years, but throughout this process, he managed to forge ahead in his research pursuits. He cared deeply about his students and pushed them to reach their best. After every big paper he would start the next meeting by saying, 'Don't rest on your laurels.'"

White joined the Illinois faculty in 1990 after earning a doctorate in engineering mechanics from Pennsylvania State University earlier that same year. He held more than 40 patents and co-founded two start-up companies. He received widespread recognition for his work, including a Humboldt Research Award in 2013, the American Society for Composites Outstanding Research Award in 2014, and *Scientific American* magazine's "SciAm 50" award in 2007. He also received multiple teaching and mentorship awards for his work with students at Illinois.

White is survived by his wife, Nancy Sottos, a professor of materials science and engineering, three children, two grandchildren, and his parents.



*Scott White (standing) and longtime Beckman collaborators (from left) Philippe Geubelle, professor of aerospace engineering; Nancy Sottos, professor of materials science and engineering; and Jeff Moore, professor of chemistry.*

*Current and former students of Scott White's Autonomous Materials Systems Group gather at the celebration of life held on June 3.*

# Cullom Connection

## EARLY YEARS

Arnold (standing on step) with siblings at their family home

**Arnold Beckman was born in Cullom, Illinois, in 1900** and grew up in this home in the small farming community. During an interview in 1978, Dr. Beckman described how a discovery in the home's attic when he was 9 years old initiated his interest in chemistry. "Steele's *Fourteen Weeks in Chemistry*, printed in 1867, was a textbook used by my aunt. I don't know where she went to school, but this textbook was up in the attic. About half the book was instructions for carrying out simple experiments, and that intrigued me, and in this little town I tried to carry out these experiments. My father was interested, and he built me a little shed—we called it a shop—out there, about 8 by 10 feet, in which I fixed up a bench and tried to carry out the simple experiments, getting chemicals from the local drugstore."

*Photo courtesy of Caltech Archives*

## 100 YEARS LATER

Kara Johnson and Jeff Moore on a visit to Cullom

Just over 100 years after the picture of Arnold Beckman and his siblings, was taken in front of their home, Jeff Moore, director of the Beckman Institute, and Kara Johnson, associate director for administration at Beckman, traveled to Cullom with a number of Beckman employees to visit the home and other Beckman historical sites. "The Beckman home in Cullom is only 50 miles from the home of the Beckman Institute in Urbana," said Moore. "It was a great opportunity for our administrative team to advance connections with the community where Arnold Beckman first developed his interest in science."

Students from Cullom enjoy a day at the Beckman Institute

## NEXT GENERATION

The connections continued in 2018 when Ana Vieira, a Cullom resident and a teacher's aide in the local schools, brought 40 lively students from TriPoint High School to the Beckman Institute for a tour and the Midwest premiere of the documentary on the life of Dr. Beckman, "The Instrumental Chemist: The Incredible Curiosity of Arnold O. Beckman." Vieira has her own Beckman Institute connection. Five years ago, she was a frequent visitor to the Microscopy Suite at Beckman. At the time, she was working with Phillip Newmark, a professor in the School of Molecular and Cellular Biology, and used the services of the Microscopy Suite to create images of schistosomes, which are parasitic flatworms. Scott Robinson, manager of the Microscopy Suite, says one of Vieira's images is still on display there.

# Advancing the Beckman *Vision*

"Brad Sutton has established active and meaningful relationships with Carle physicians. That collaboration exemplifies the benefits and impact that occur when Illinois researchers learn what is relevant, important, and challenging to the Carle physicians while they, in turn, gain from the experiences and expertise of Beckman researchers."

*Jeff Moore, director, Beckman Institute for Advanced Science and Technology*

Arnold Beckman had a bold vision and a generous spirit. His example continues to inspire the work of researchers across the Beckman Institute—researchers like Brad Sutton, the 2018 recipient of the Beckman Institute Vision and Spirit Award.

Sutton is a professor of bioengineering, the technical director of the Biomedical Imaging Center at the Beckman Institute, and a faculty member of the Carle Illinois College of Medicine. His work focuses on improving the physiological information available from magnetic resonance imaging (MRI) through the development of integrated pulse sequence and image reconstruction methods.

Sutton's technological achievements have been a core part of the Beckman Institute's work in cognitive aging. His algorithms are key to quantitatively assessing brain structure and function along with its age-related changes. Sutton also has been instrumental in developing techniques to evaluate brain elasticity (MR elastography) and neuromuscular coupling in the speech and swallowing system.

"Brad epitomizes what it means to be a Beckman Institute researcher," said Jeff Moore, the director of the Beckman Institute. "He counts more than 20 Illinois faculty members as collaborators, and many more outside the university. His developments in MR technology have found immediate application in problems relating to tissue mechanical properties to the cognitive neurosciences, fast data acquisition and processing, and they have impacted other domains of interventional and developmental neuroscience. Brad truly can make our MRIs sing."

The Vision and Spirit Award recognizes Sutton's contribution to advancing the mission of the Beckman Institute. It honors his efforts to foster collaboration in pursuit of bold endeavors that meet short-term research goals and inspire future long-term work.

"It's great to get an award based on collaboration because I can't take credit for it," Sutton said. "It's really about the people here that I work with on a daily basis—people who have the dream with you and then actually expect those dreams to come true … who could ask for more?"

Sutton earned his bachelor's degree in general engineering from the University of Illinois, followed by a master's in biomedical and electrical engineering and a Ph.D. in biomedical engineering, both from the University of Michigan.

"To say that I owe my career to the Beckman Institute is an understatement," he said. "I've been here all 15 years since my Ph.D., and I know of no other way to do science than the way it's done in this institute. What we have at Beckman is very unique. Yes, we collaborate, but we also trust, respect, and share a vision, and we really work together to make these things come true."

# Fulfilling the Beckman *Legacy*

Solving problems and producing scientific breakthroughs through interdisciplinary collaborations are the heart of Arnold Beckman's legacy. It's why he established the Arnold and Mabel Beckman Foundation.

According to Anne Hultgren, the foundation's executive director, it's that vision that continues to inform the work of the foundation more than 40 years later.

"Dr. Beckman championed the interdisciplinary approach his entire career," Hultgren said. "He was at the forefront of looking outside his classical field of science to solve problems and led a revolution in interdisciplinary science that now looks commonplace. We all now know that exciting breakthroughs come when you're working in the creases between the fields."

The foundation works to support those breakthroughs not only through the establishment of five Beckman institutes and centers, including ours at the University of Illinois, but by funding research in emerging scientific areas.

One of those research initiatives is the foundation's recent $12.5 million investment in cryogenic-electron microscopy (cryo-EM). This technology holds great promise in the field of structural biology because of its ability to reveal an unprecedented level of molecular detail.

"The technique has been around since the 1970s," Hultgren said, "but the technology has been enhanced to such a degree that you can see native protein structures within cells. You can see how the cells are functioning without breaking them apart."

## Collaborating with Foundation Partners

Five research institutions were selected to receive $2.5 million each toward this state-of-the-art cryo-EM instrumentation. Johns Hopkins University School of Medicine, Massachusetts Institute of Technology, the University of Pennsylvania Perelman School of Medicine, the University of Utah, and the University of Washington School of Medicine were chosen based on their potential to accelerate fundamental research and discovery that was already underway.

The Beckman Institute also has a role to play. As the home of the NIH Center for Macromolecular Modeling and Bioinformatics, the institute has the modeling and computational tools and expertise to serve as a resource for researchers using the emerging cryo-EM technique.

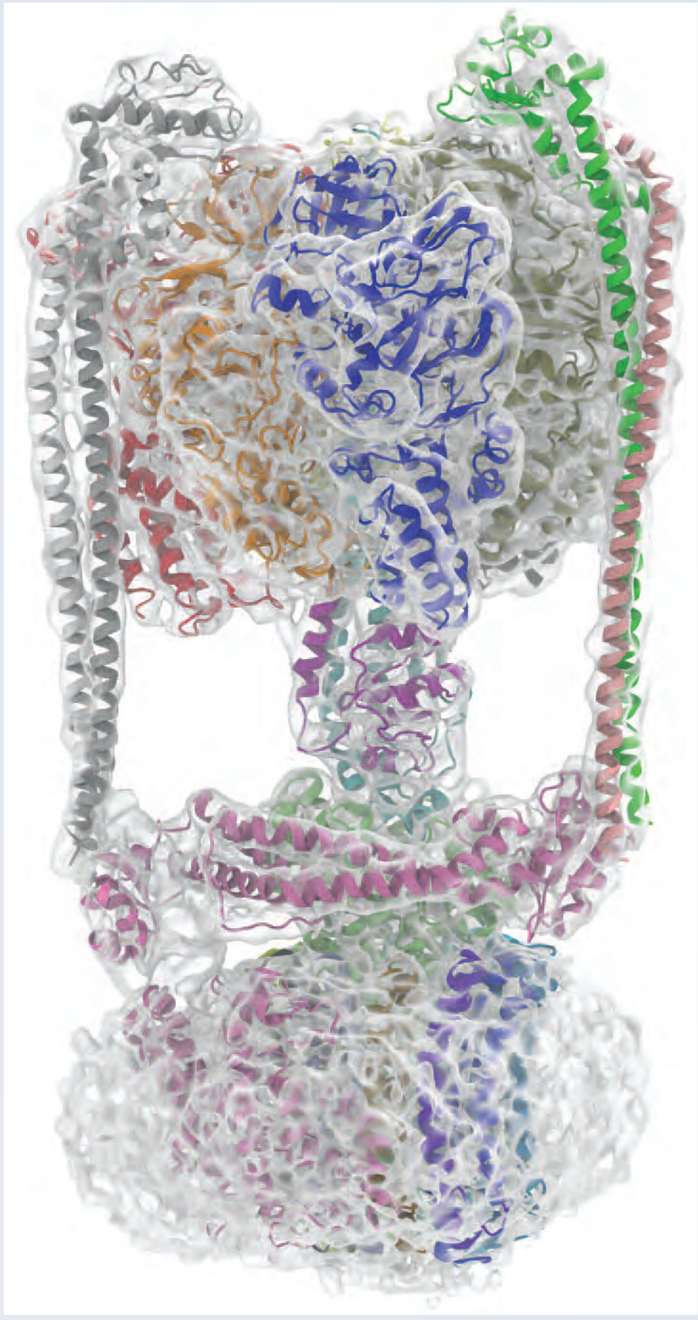
"The 'resolution revolution' has turned cryo-EM very quickly into a major technique for atomic structure determination of biomolecules," said Emad Tajkhorshid, a professor of biochemistry, biophysics, and bioengineering, the leader of Beckman's Theoretical and Computational Biophysics Group, which is home to the NIH Center for Macromolecular Modeling and Bioinformatics. "In addition to the pressing need for training the community in experimental techniques related to sample preparation and data acquisition, there is an equally significant need for training in cryo-EM-related computational techniques, which are not only crucial for processing 2D images collected from the microscopes and converting them into 3D density maps, but also to translate the resulting EM density maps into reliable atomic models, which is the ultimate goal of structural biological studies."

That's why the Beckman Institute is organizing and hosting a workshop dedicated to techniques "that will equip interested researchers with the computational tool repertoire required for successful completion of cryo-EM-based structure determination projects," Tajkhorshid explained.

And while the workshop, scheduled for spring 2019, will provide practical, relevant, hands-on training, it also does something else. It supports the kind of collaboration envisioned by Arnold Beckman when he established the foundation.

"Through this collaboration, we're finding synergies and making connections to help realize Arnold Beckman's vision," said Jeff Moore, the director of the Beckman Institute. "It's a golden opportunity to link the world-leading expertise in macromolecular modeling that's here at our Beckman Institute with other innovative scientific activities the Beckman Foundation supports."

Hultgren agrees. "It's great to see the Beckman Institute at Illinois take a leadership role in looking for collaborative ways to extend the science and bring additional expertise to the work supported by the foundation. We're very proud of the new cryo-EM centers and the work being done by all the institutes."

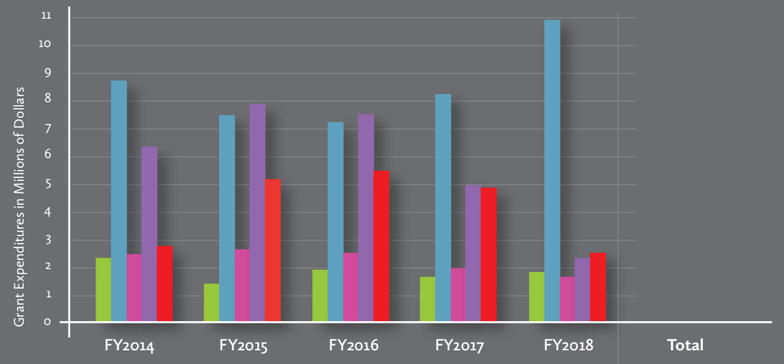


*Molecular structure of V-type ATPase overlaid on its cryo-EM density obtained from nanodisc-embedded samples. Image created by Beckman Institute researchers at the NIH Center for Macromolecular Modeling and Bioinformatics using visual molecular dynamics.*

"[The cryo-EM project] is a golden opportunity to link the world-leading expertise in macromolecular modeling that's here at our Beckman Institute with other innovative scientific activities the Beckman Foundation supports."

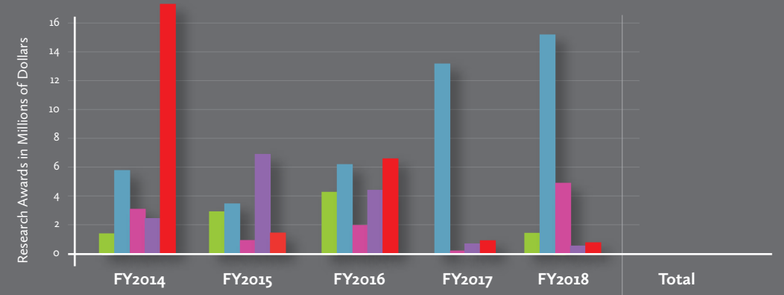
*Jeff Moore, director, Beckman Institute for Advanced Science and Technology*

## Sponsored Research Expenditures by Funding Source[1]




| | FY2014 | FY2015 | FY2016 | FY2017 | FY2018 | Total |
|---|---|---|---|---|---|---|
| DOD | $2,328,861 | $1,490,392 | $1,976,766 | $1,745,031 | $1,865,302 | $9,406,353 |
| NIH | $8,718,725 | $7,486,994 | $7,172,547 | $8,248,505 | $10,949,550 | $42,576,321 |
| NSF | $2,398,696 | $2,794,666 | $2,425,976 | $1,979,136 | $1,744,547 | $11,343,020 |
| Abbott[2] | $6,249,854 | $7,990,755 | $7,595,835 | $4,939,757 | $2,314,442 | $29,090,644 |
| Other | $2,839,996 | $5,190,458 | $5,367,047 | $4,801,522 | $2,642,876 | $20,841,899 |
| Total | $22,536,132 | $24,953,265 | $24,538,172 | $21,713,952 | $19,516,717 | $113,258,237 |

## Sponsored Research Awards by Funding Source[3]




| | FY2014 | FY2015 | FY2016 | FY2017 | FY2018 | Total |
|---|---|---|---|---|---|---|
| DOD | $1,617,249 | $2,911,793 | $4,135,476 | $- | $1,500,000 | $10,164,518 |
| NIH | $5,798,307 | $3,442,188 | $6,035,109 | $13,068,414 | $15,144,136 | $43,488,154 |
| NSF | $3,012,333 | $983,154 | $1,970,753 | $112,882 | $5,956,822 | $12,035,944 |
| Abbott[2] | $2,381,765 | $6,743,022 | $4,234,195 | $632,624 | $529,767 | $14,521,373 |
| Other | $16,870,368 | 1,684,956 | $6,420,286 | $824,323 | $735,361 | $26,535,294 |
| Total | $29,680,022 | $15,765,113 | $22,795,819 | $14,638,243 | $23,866,086 | $106,745,282 |

[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 and 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] Funding from Abbott Nutrition supports the Center for Nutrition, Learning, and Memory. This is made possible by a partnership between the University of Illinois and Abbott Nutrition. This center includes participation by the Carl R. Woese Institute for Genomic Biology, and departments from the College of Agricultural, Consumer, and Environmental Sciences; the College of Applied Health Sciences; the College of Liberal Arts and Sciences; and the College of Veterinary Medicine.

[3] The Beckman Institute primarily possesses interdisciplinary research grants that have multiple faculty from multiple departments. Total funding for multiyear awards is reported in the fiscal year of the award notice. The numbers reflected on this page include all Beckman awards, including those awarded to faculty, staff, and others.



## 2017-18 BECKMAN FACULTY ACHIEVEMENTS

**17**
Invention disclosures

**14**
Patents issued

**19**
Patents filed

**1,289**
Published papers