BECKMAN
INSTITUTE
FOR ADVANCED SCIENCE
AND TECHNOLOGY

University of Illinois
at Urbana Champaign
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AND TECHNOLOGY

2016

CONNECTIONS

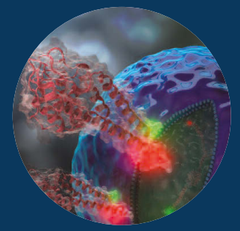
2017

At the Beckman Institute for Advanced Science and Technology, we pursue ideas that haven't yet been envisioned. Here, we explore lines of scientific inquiry that lead to new concepts, innovative ideas, and technological breakthroughs. The work begins with connections that forge interdisciplinary collaborations and scientific advancements.

How do those connections play out across Beckman?

You'll see it throughout our magazine as we share examples of the work being done and the collaborators responsible for it.

Our cover photo provides one such example. It starts with the ingenuity of Mostafa Yourdkhani, a postdoctoral research associate. He is connected to the Autonomous Materials Systems Group and works with Scott White, a professor of aerospace engineering, exploring the self healing properties of materials in this instance, for dental applications in collaboration with Dr. Ana Bedran Russo, an associate professor in restorative dentistry at the University of Illinois at Chicago. That connection leads him to the Microscopy Suite, where he uses the scanning electron microscope to create and enhance images like the one on the cover a cross section of a polynuclear microcapsule embedded in an epoxy resin. That work connects him to the Materials Research Society, where his photo earned top honors in its "Science as Art" competition.



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FOR ADVANCED SCIENCE AND TECHNOLOGY

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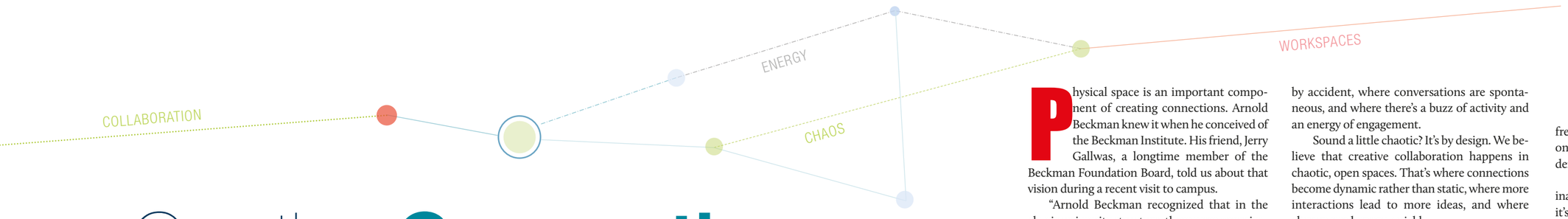


Creating **Connections**

Physical space is an important component of creating connections. Arnold Beckman knew it when he conceived of the Beckman Institute. His friend, Jerry Gallwas, a longtime member of the Beckman Foundation Board, told us about that vision during a recent visit to campus.

"Arnold Beckman recognized that in the classic university structure, there were organizational and physical separations that were not conducive to multidisciplinary research," Gallwas said. "So creating a building where you bring people of different disciplines together was unique and, for the most part, is still unique in universities across the world."

Today, we continue to build on that uniqueness, taking into account the importance of eliminating physical separations and barriers. That's why we're reinventing the institute's collaborative spaces. Our goal is to create an even more dynamic environment—one where people meet by accident, where conversations are spontaneous, and where there's a buzz of activity and an energy of engagement.

Sound a little chaotic? It's by design. We believe that creative collaboration happens in chaotic, open spaces. That's where connections become dynamic rather than static, where more interactions lead to more ideas, and where change can happen quickly.

Even creating chaotic space comes with a little chaos. But, at Beckman, it also comes with a lot of creative collaboration. We found that out this spring in our atrium as we asked people affiliated with the institute to voice their opinions on elements of the building's redesign via Post-It notes. It definitely created a buzz and produced valuable feedback.

Organizational structures by their very nature build walls and hold fast to existing alliances, but that can get in the way of our ability to create new connections and to see things with fresh eyes. The Beckman Institute was founded on the idea of breaking down such barriers and defying the status quo.

It took some chaos, disruption, and reimagination to get us here. More than 25 years later, it's a successful strategy that continues to move us forward.

Sincerely,

Jeffrey Moore
Director, Beckman Institute for Advanced Science and Technology

Brain POWER

When Sepideh Sadaghiani explains her work in cognitive neuroscience, she often quotes philosopher and psychologist William James. In *The Principles of Psychology*, James wrote: "Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our own mind."

This idea that how we perceive the world has more to do with what is in our brain than on what our senses tell us was suggested by James more than 120 years ago. However, it's only been in the last 20 years that neuroscientists have begun to be able to prove it.

Research, like Sadaghiani's, that focuses on functional connectivity imaging is providing the evidence. In her lab at the Beckman Institute, Sadaghiani, an assistant professor of psychology and a member of the Intelligence, Learning, and Plasticity Group within the Intelligent Systems research theme, investigates cognitive control, network connectivity, and the relation between the two in the brain.

"Distant brain regions are in constant communication with each other," she explained. "This communication, which is called functional connectivity, is foundational to all cognition. Functional connectivity is spatially organized into many large brain networks. But how this network organization is maintained and modulated in the service of flexible cognition, which is the mental ability to flexibly process internal and external information and goals, is poorly understood."

Sadaghiani and her team are working to change that. She explained that until recently the assumption had been that the brain is "primarily a reactive machine and mainly fires in response to a stimulus or cognitive challenge, but we're finding overwhelming evidence that most brain activity is in fact intrinsic and not dependent on external events. In fact, a growing body of studies, including ours, suggests that this intrinsic brain activity influences our perception of the world and cognition."

To conduct those studies, Sadaghiani relies on functional magnetic resonance imaging (fMRI), a technique that uses MRI technology to measure brain activity by detecting changes associated with blood flow and electroencephalography (EEG), which permits direct observation of electrophysiological activity of the brain.

"One of the approaches that we use is resting state fMRI, which examines functional connectivity when a person is not being exposed to any particular experimental task, that is, when no cognitive demands are being made," she said. "What we see is that functional connectivity is not random, but rather has a specific structure of well-defined networks in the brain that are consistent across people and are there all the time."

Sadaghiani explains that while neuroscientists have known that the brain has its own internal architecture and that neurons are constantly active independent of incoming information, neuroimaging has provided some real surprises, especially over the past decade.

"We didn't know the complexity of the intrinsic network structure and that it reflects such a large part of brain activity," she said.

"It's estimated that over 90 percent of brain activity is not directly evoked by external information but rather is internal to the brain. What my lab is trying to understand is how this internal activity that is continuously ongoing actually influences the processing of incoming information. This has implications not only in what we know about the healthy brain, but also in what we can learn about abnormal network connectivity and behavior."

CONNECTLAB

INTELLIGENT SYSTEMS

BIOMEDICAL IMAGING CENTER

One example of a functional connectivity state of the brain in topological space, a result of applying complex network theory to the brain.

BIOMEDICAL IMAGING CENTER

The Beckman Institute s Biomedical Imaging Center (BIC) provides state of the art magnetic resonance imaging (MRI) equipment to assist researchers like Sepideh Sadaghiani. Here s what she has to say about the facility and how it contributes to her work.

What BIC equipment do you use?

My lab combines various techniques to address questions about connectivity in the human brain, including functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and simultaneous EEG fMRI. The latter, an example of especially technically challenging multimodal imaging, posits a core strength of BIC, which offers state of the art equipment for such multimodal approaches. The Prisma MRI machines and the higher channel head coils allow for acquisition of multiple image slices of the brain at the same time, resulting in high spatial resolution and faster speeds. The combination of this advanced imaging with concurrent EEG provides new avenues into the study of functional activity.

How do the resources BIC provides contribute to your work?

There has been a long history of multimodal imaging at Beckman. Without having that community, that history, and that commitment, it would have been much harder for me to get started. I appreciate the opportunity to have this high end technological expertise from people who are willing and truly interested in forwarding the imaging capabilities with application. It s been hugely helpful.

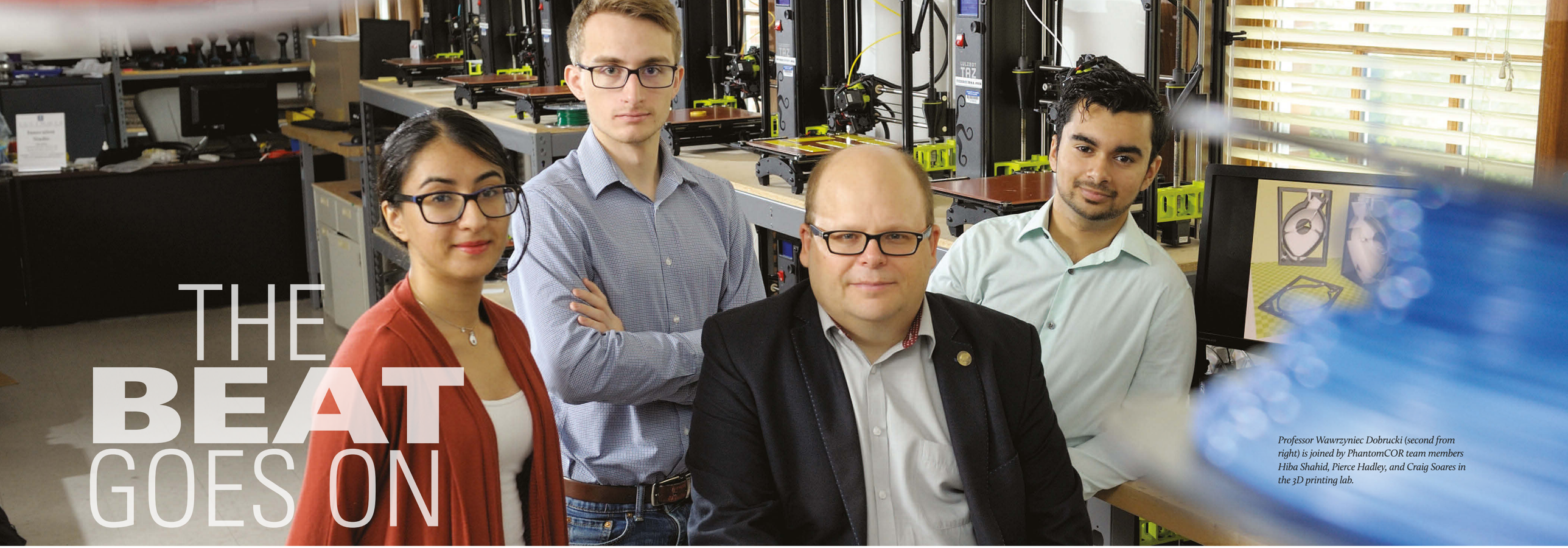
What do the technical capabilities available at Beckman mean for the future?

At the Biomedical Imaging Center, we are able to take advantage of optimal multimodal imaging possibilities that are not available at many sites. We are able to combine fMRI and EEG concurrently, which is still fairly unique. Only a few institutions across the United States have this capability. However, the field is pushing for more multimodal research, which means that at Beckman we are ahead of the curve. And we have the people who are committed to keeping us there.

DEPARTMENT OF PSYCHOLOGY

Regional networks as coded by color: cinguloopercular (CO), frontoparietal (FP), default mode (DM), and dorsal attention (DAT).

THE BEAT GOES ON



Professor Wawrzyniec Dobrucki (second from right) is joined by PhantomCOR team members Hiba Shahid, Pierce Hadley, and Craig Soares in the 3D printing lab.

Each year seniors in bioengineering complete a capstone course where they develop design solutions for projects suggested by professors, industry professionals, and clinicians. In 2015, Wawrzyniec Dobrucki, an assistant professor of bioengineering and of medicine and a member of the Bioimaging Science and Technology Group, shared with the students an idea he had for a potential project—the creation of a heart phantom.

Many were interested but felt it would require more than the academic year to complete. Another group of students, however, heard about the idea and were intrigued by the project's potential. They also were undeterred by a lengthy timeline for development.

Today, that group of students from the Biomedical Engineering Society is working with Dobrucki to develop PhantomCOR, a dynamic, multimodal heart phantom that can be used to test and validate new research protocols and novel imaging strategies.

Over the past 18 months, they have made significant progress. "We now have a working prototype of a two-chamber heart," Dobrucki said. "And we have been able to use magnetic resonance imaging (MRI), x-ray computed tomography (CT), and ultrasound imaging to test how it works."

Dobrucki's idea for a heart phantom grew out of his research in the imaging of the cardiovascular system. "Existing heart phantoms don't allow us to standardize our dynamic imaging protocols and imaging data," he explained. That's because existing versions are typically static and only work with one imaging method.

"Commercially available phantoms are also very expensive, so colleagues in preclinical research haven't really considered them," he continued. "With PhantomCOR, we're looking to produce a complete dynamic heart phantom with a controllable pumping system at a more reasonable price."

These 3D printed casts are used to fabricate the heart phantom.

Mentoring Students

Dobrucki advised the students as they tested materials for the heart and developed the electrical and mechanical systems to control the artificial heart.

"Some models are made from hard plastic, which allows you to visualize the heart but doesn't provide the vital information about the function of the heart," said Dobrucki, the former director of the Molecular Imaging Laboratory in the Biomedical Imaging Center. "Ours is unique in that it allows you to study, modify, and visualize the myocardial function."

How does the PhantomCOR concept work? A unique heart is first imaged using x-ray CT or MRI techniques. Next, based on the acquired images, the individual molds are designed, 3D printed, and dynamic heart phantoms are casted with biocompatible materials.

The PhantomCOR team uses hydrogel or silicon for their material and a 3D printer to actually fabricate the replica. They have even developed a novel design for the 3D printed molds that allow them to incorporate physical deformities into the heart phantom. They continue to refine the prototype, eventually looking to be able to incorporate anatomical features specific to the patient, even using ultraviolet light to harden certain areas as a way to simulate infarcted tissue.

Because the material mimics the elasticity of human tissue, it can be used in all three clinically available imaging modalities.

According to Dobrucki, the materials, the design, and the increased capabilities of the PhantomCOR prototype create a variety of applications for the product when it is commercialized.

"In addition to producing phantoms for preclinical researchers who would like to standardize their systems, the PhantomCOR could be an important tool for medical education not only in the training of future physicians but also as a way to expose them to and teach them the engineering fundamentals," said Dobrucki, who also serves as the director of the cardiovascular course for the Carle Illinois College of Medicine.

"Also, it could be especially valuable to clinicians by providing important individualized information that assists them in preparing for procedures and in directing therapy for each patient. This is important as we move toward more personalized medicine."

Hands-On Learning

The PhantomCOR team, all undergraduate and graduate students, are getting plenty of hands-on learning through this project—and not just in bioengineering.

"This is an opportunity for the students that captures the whole process of the development of a new device," Dobrucki said. "Not only are they performing research by testing materials and mechanical systems and by using different imaging modalities, but also they are gaining valuable professional experience by making presentations about their work and by talking with potential investors or sponsors."

Two recent competitions provided some of those opportunities and garnered the PhantomCOR team accolades. They received first place in the "Most Innovative" category at the 2017 Engineering Open House. They also placed third in the 2017 Cozad New Venture competition, which earned them lab space and support from the University of Illinois Research Park for the coming year.

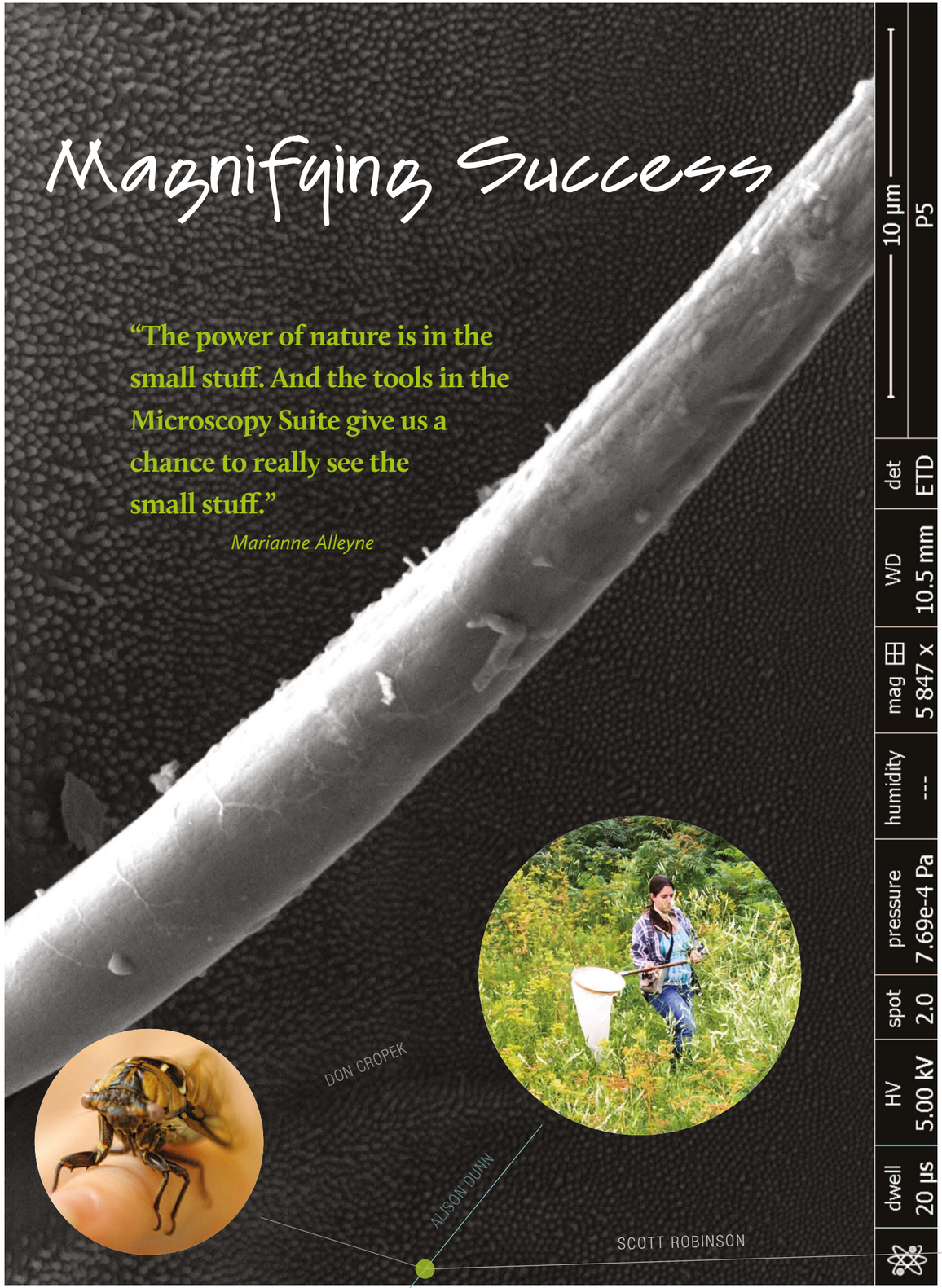
"As potential innovators, it's important for students to have this exposure to the business side of the endeavor and to be able to interact not only with academia but with industry, too," Dobrucki said.

"We envision PhantomCOR as a start-up company that could have a commercially available product within the next five years, so it's important that they have this multifaceted experience."

Magnifying Success

"The power of nature is in the small stuff. And the tools in the Microscopy Suite give us a chance to really see the small stuff."

Marianne Alleyne



"Insects did it first. Can engineers do it better?"

That's the title of Marianne Alleyne's blog, a site where this research scientist in entomology shares her work on bioinspiration. It's a topic she describes as studying "how non-entomologists can be inspired by nature in general, and insects in particular, to create new technological innovations."

The Microscopy Suite at the Beckman Institute—part of the Imaging Technology Group—provides some of the tools that assist Alleyne with that bioinspired work, some of which involves examining cicadas.

Why study that particular summer soundmaker? Because the wings of cicadas have special properties that can inspire innovation in materials development.

"Cicadas have nanoscale structures on their wings that provide favorable reflectivity, which is very important to ensuring the cicadas won't be observed by predators," Alleyne said. "That structure also results in their wings being super-hydrophobic, or super-water-repellant, which also makes them self-cleaning because as water collects on the wings it actually picks up and removes any dirt. Then when the droplets fall, they take the dirt with them. In extreme cases, droplets actually bounce off the wing's surface, possibly even removing heat. There's also research that indicates that these structures could be antimicrobial."

How does this information about cicada wings help us to fabricate materials that have the same beneficial properties? Alleyne's collaboration with Nenad Miljkovic, an assistant professor of mechanical science and engineering, and Don Cropek, a chemist at the U.S. Army Corps of Engineers Construction Engineering Research Laboratory, is investigating that very question.

Currently, chemicals are applied to materials in order to create these benefits, but the ultimate goal, explained Alleyne, "is to have super-water-repellant, heat-dissipating, self-cleaning, reflective, antimicrobial materials without adding chemicals."

To put that bioinspiration into practice requires more research on the wings of different species of cicadas. That's where the Microscopy Suite comes in.

The waxy cones on the wings are about 200 nanometers or billionths of a meter high. In comparison, the average human hair is roughly 100 microns or millionths of a meter wide.

"We need exceptionally high magnification to observe them," Alleyne said. "The scanning electron microscope in the Microscopy Suite helps us to see the difference between the species in these structures. The information we receive from the imaging informs my collaborators' work on materials. Once we fabricate materials, we go back to the electron microscope to be sure that the design looks and functions the same as what we saw in the cicadas."

The structures visible in the Microscopy Suite don't explain everything, Alleyne said. In addition to biology, chemistry also will need to be considered as her work with Miljkovic and Cropek moves forward.

"But we do know that the power of nature is in the small stuff. And the tools in the Microscopy Suite give us a chance to really see the small stuff," she said.

Left: Background photo: High-powered magnification allows researchers to view the structures on cicada wings, like the setae on the wing vein shown here. Bottom photos: Catherine Dana, entomology student, collects cicadas from railroad-side prairies.

Right: From left, Marianne Alleyne, Junho Oh, student in mechanical science and engineering, Nenad Miljkovic, and Catherine Dana, student in entomology, study how nature can inspire technological advancements.

Marianne Alleyne, like many researchers across campus, uses the tools in the Microscopy Suite to further her work, provide opportunities for her students, and expand collaborations. Here, she shares her thoughts about the value the Microscopy Suite adds to her work.

In addition to your bioinspiration work with cicadas, what other ways do you use the Microscopy Suite?

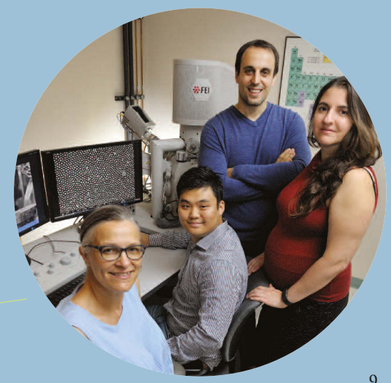
I teach a course in insect physiology that is required for entomology graduate students, and they use electron microscopy to study the cuticle of insects. Scott Robinson, manager of the Microscopy Suite, and Cate Wallace, a microscopist, are exceptional and patient in training the students to use the equipment as they image insects. The Bugscope project, initiated by the Microscopy Suite, also is important to our students' work because it helps them to learn outreach by communicating with students in K-12 and their teachers about the microscopic world of insects.

What about future research?

We anticipate using the Microscopy Suite for a project on click beetles. When these insects are on their backs, they can right themselves 50 percent of the time by using a click mechanism. Basically, they store energy through friction and muscle tightening and then let go and jump up. The friction is created by a peg and a lip, which can only be seen with an electron microscope. As we determine which species we want to work with for this project, we'll use the Microscopy Suite to help us. The engineering application for this work would be to create a small robot that can right itself without using its legs.

How do engineers and biologists benefit from this kind of work?

There's much to be gained when biologists and engineers collaborate, and not just at the faculty level. I teach a class where engineering students and biology students work together on bioinspired projects. The biology students love their science and benefit from this collaboration by learning how to communicate their science better, putting it in a language others can understand, and thinking of applications for the science. Engineering students tell me it's great to look at nature as a way to come up with design solutions. It gives them another tool in their toolbox. They also look at it as an opportunity to design in a better way than nature because nature has certain constraints that engineers don't.



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.

Ana Daugherty
Researches health factors and behaviors that modify changes in brain structure and cognitive ability across the lifespan

Kenneth Hernandez-Burgos
Researches electronic and ionic interactions in redox active polymers

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

Ana: The Beckman Institute has an interna tional reputation for research excellence, and its faculty have produced some of the most influential work on exercise and cognitive aging. My prior work had exclusively considered cardiovascular risk factors in aging, and when I decided to study exercise as a possible protective factor, the Beckman Institute was an obvious fit. The Beckman fellowship is a unique opportu nity to develop an independent research pro gram as a postdoctoral fellow, and it champions multidisciplinary collaboration, which is some thing I ve sought at every stage of my career.

Kenneth: The real question is, Why wouldn t you? When I was still a graduate student, Professor Joaquín Rodríguez López allowed me to present to his group, and I got to visit the university. I was very impressed with the quality of the research and the potential for amazing collaborations. When I came here as his postdoc, I learned more about the Beckman Institute, and I knew I wanted to be part of it because you find illustrious experts in many areas of research who feed ideas to your own research. I find it easy to establish collabora tions here. All the scientists are more than willing to offer their expertise to help you answer a research problem.

2. Who do you collaborate with in your research?

Ana: I work closely with Neal Cohen and Aron Barbey in the Intelligence, Learning, and Plas ticity Group; Ed McAuley in the Cognition, Lifespan Engagement, Aging, and Resilience Group; and Brad Sutton in the Bioimaging Science and Technology Group; and the many postdoctoral fellows and graduate students who make up their outstanding labs. Our work together touches upon topics in memory func tion; metabolic health, exercise, and aging; and advanced neuroimaging methods to study brain microstructure and vasculature. Through recent collaborations with Rachael Rubin, a former Carle Foundation Hospital Beckman Institute Postdoctoral Fellow, I began a new line of research considering many of the same factors I study in brain aging applied to the study of traumatic brain injury. I also work with Carle physicians Graham Huesmann and Ken Aronson on studies conducted as collabo rations between Carle Foundation Hospital and the Beckman Institute.

Kenneth: I spend most of my time in the lab of Joaquín Rodríguez López, an assistant professor of chemistry and member of the Nanoelectronics and Nanomaterials Group, benefiting from his group s expertise in elec trochemistry. In addition, I collaborate with Jeff Moore, professor of chemistry and mem ber of the Autonomous Materials Systems Group. I have the opportunity to provide input into the research done in his lab and to mentor several of his students. His group s expertise in the design and synthesis of new redox active polymers allows me to work with electrochemical characterization. Along with other postdocs in his lab, we explore new ways to tune the electrochemical properties of poly mers by using computational methods. I also collaborate with Autonomous Materials Systems Group member Randy Ewoldt s research group to gain information on the dynamics of polymers in solution by rheology means, and I use equipment in Nanoelect ronics and Nanomaterials Group member Catherine Murphy s lab to learn about the redox active polymers excited states.

3. What has inspired your work here?

Ana: The people I work with at Beckman seem to thrive at the intersection of innovation and rigor. I find this inspiring. Many of the questions that modern psychology and neuroscience, and by extension health care, are contending with demand collaborative work we need the expertise of many different people, not just one. This is the foundation of Beckman, and it is invigorating to conduct my research in this environment.

Kenneth: Since I started my postdoctoral career in the Rodríguez López lab, I have collab orated closely with scientists at Beckman, which motivated me to apply for the Beckman Post doctoral Fellowship. My work at Beckman was inspired by the curiosity of learning about materials properties that have not been studied before and by having the opportunity to work with scientists like Jeff Moore who inspire you to keep working hard every day to become a distinguished scientist.

4. What opportunities has your affiliation with Beckman provided?

Ana: My collaborations at Beckman have opened new lines of research that I hadn t considered before for one, the study of markers of cognitive dysfunction and recov ery following traumatic brain injury, which acts upon the same mechanism of neuro degeneration that I have examined in aging, and studying the injury provides a new win dow into the relationship between brain structure and function. Another line of work I m excited about is using advanced neuro imaging methods to study the microstructure of the hippocampus, a structure that is criti cal to memory function. I am a member of the leading committee for the Hippocampal Subfield Segmentation Group an interna tional collective of over 150 researchers, representing 15 countries, that is dedicated to creating and implementing a harmonized protocol for measuring the subfields, or com ponents, of the hippocampus. My work with this group has underscored for me the impor tance of studying variability in tissue micro structure. With advanced neuroimaging methods available at Beckman, we measured qualities of cell organization within hip pocampal subfields *in vivo* for the first time. The magnetic resonance elastography method has been refined and validated by many peo ple affiliated with Beckman Curtis Johnson, Brad Sutton, Hillary Schwarb and my recent work with them further demonstrates the potential of the method applied to the study of cognitive neuroscience.

Kenneth: First and foremost is the opportunity to discuss science with world class scientists who are more than willing to help me develop as a scientist. Further, the Beckman Postdoctoral Fellowship has afforded me the opportunity to attend interesting presentations and to present my work at the best conferences. Moreover, the independence to pursue aspects of science that I think represent the future, while learning new techniques and skills in the groups that I collaborate with, have been key aspects of my Beckman experience.

The thermal analysis (using a special numerical method developed by AMS over the past few years) of a microvascular material, with parallel wavy microchannels with opposite coolant flow directions.

DAN BODONY

JOHN LAMBROS

Theory MEETS Practice

Phillipe Geubelle marvels at the "beautiful experiments" that his colleagues conduct. As a professor of aerospace engineering and a member of the Autonomous Materials Systems (AMS) Group within the Molecular and Electronic Nanostructures research theme, he theorizes and creates computational models, while others perform the experiments that test his theories and validate his models and optimal designs.

"Direct collaboration with experimentalists has always been part of my research," Geubelle said. "It always adds so much to my work to collaborate with talented scientists who have so much insight and can help us validate the numerical results."

Some of those experimentalists include colleagues in AMS: Nancy Sottos, a professor of materials science and engineering; Scott White, a professor of aerospace engineering; and Jeff Moore, a professor of chemistry. Geubelle has been working with them on self-healing and other multifunctional materials for more than two decades.

Their groundbreaking work focuses on creating new materials that can repair themselves when damaged. It's work that has implications for how composite materials are made, how long they last, and what happens when they are at the end of their useful lives.

"Scott, Nancy, and I started the discussion early on and did a very simple feasibility study on the concept of self-healing materials," Geubelle said. "At the time, we thought the best approach was to use microcapsules that would be embedded in the material. We realized very quickly that to explore this further we would need a top-notch chemist and a multidisciplinary approach. That's when Jeff joined the team. It was also decided that the Beckman Institute was the ideal place to conduct this type of multidisciplinary research."

Geubelle said his role in the self-healing collaboration was "to try to understand how we could achieve an extension of the fatigue life of these materials. Could we actually predict how much longer the structure would survive thanks to this self-healing capability? Could we understand how a crack interacts with one of these microcapsules, whether it is attracted by it or not?"

"I rarely write single-PI proposals because I strongly believe that it's critical to work with experimentalists to get some insight as to what kind of model you should use and then to check how good your model is."

Phillipe Geubelle

Essentially, Geubelle was working to understand how the microstructure of a material affected its performance.

Tangible Results

As the project progressed to other forms of autonomous materials systems, the question became: "Once we understand how the microstructure affects the properties of the material, can we optimize the responsible material by designing the microstructure?"

This emphasis on computational design of materials was motivated by advances made in AMS in the manufacturing of composite materials with complex microvascular systems, basically a system of embedded microchannels, similar to the veins and arteries you find in living systems.

"My role is to come up with numerical methods that allow us to see the impact on the response of these microvascular composites, mostly for active cooling," Geubelle said. "Once we have formulated, implemented, and validated the numerical methods that allow us to quantify the impact of these microchannels on the thermal response of the microvascular materials, we can optimize the configuration of the embedded microchannel network using gradient-based optimization techniques."

One aspect of this materials design work that is particularly satisfying, Geubelle said, is the opportunity to see tangible results of the theoretical and computational work that he does.

"The reason I so enjoy and appreciate working in this collaborative environment is that my colleagues have a unique ability to be able to manufacture what I come up with," Geubelle said. "Whatever I design, these experimentalists can actually make. Their work actually closes the loop because the material system or composite system they make shows experimentally that what we design is indeed better than what we started from."

Science Success

Geubelle believes that the multidisciplinary research focus at Beckman is especially valuable because of the engagement it affords faculty and students.

"The strength of the environment is how it allows chemists to learn from scientists and engineers working in mechanics and materials science and vice versa," Geubelle said. "If you put students with different expertise together, they will influence each other in a way that brings great benefit to each of them and to their fields, which is a great success story for the Beckman Institute. This multidisciplinary environment greatly enhances the education of our students."

He believes the same is true for faculty. "I remember when we started the collaboration on self-healing materials, we had biweekly meetings. When the chemists would talk, we didn't understand a word, and I'm sure they felt the same way. Eventually, you hear them explain their science and you come to learn and gain from that."

That lesson on collaboration continues to inform Geubelle's work.

"I rarely write single-PI proposals because I strongly believe that it's critical to work with experimentalists to get some insight as to what kind of model you should use and then to check how good your model is," he said. "Without the talented scientists at Beckman and across campus, the theoretical and computational work I do would be an intellectual exercise without much application. I know to leave the experiments to the professionals."

IOANNIS CHASIOTIS

ALEX GHOSH

SCOTT WHITE

JEFF MOORE

NANCY SOTTOS

"30 Under 30" News

Lydia Kisley is the inaugural Beckman Brown Interdisciplinary Postdoctoral Fellow, an award named in honor of Arnold Beckman and Theodore Ted Brown, pictured here with Kisley.

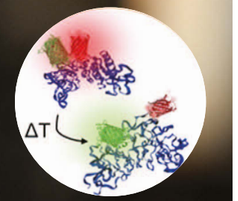
DEBORAH LECKBAND

TED BROWN

MARTIN GRUEBELE

ARNOLD BECKMAN

PAUL BRAUN



Protein folding in a hydrogel.

"At Beckman, working across disciplines is embraced and encouraged, which creates strong and successful collaborations."

Lydia Kisley

Lydia Kisley spends a lot of time poring over scientific literature. But her inclusion in *Forbes* 2017 30 Under 30 issue, provided an opportunity for some lighter reading.

The Beckman Brown Interdisciplinary Postdoctoral Fellow received the *Forbes* recognition as one of 600 of the nation's brightest young entrepreneurs, innovators, and game changers. Her work focuses on developing new microscopies that allow us to examine how biomolecules and materials interact at the nanoscale.

Kisley explains that the research has application in the development of pharmaceuticals, where there is a need to be able to separate the drug molecule that helps cure the disease from the mixture of bacteria cells and other materials that don't.

There is potential in other areas as well. We're examining how proteins in biomolecules interact with surfaces, Kisley said. For instance, when you're placing a manmade material, like a contact lens or a knee replacement, into the body, you want the materials to be compatible with the biomolecules in your body. We're working to develop instrumentation that helps us see the dynamics of the interaction.

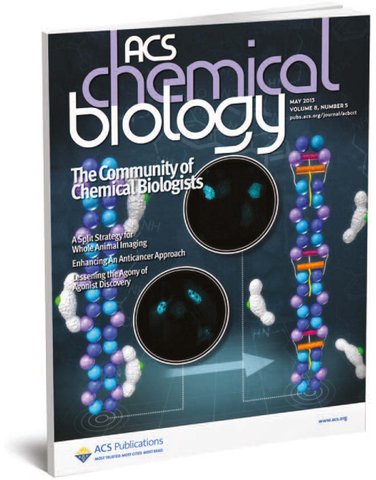
Beckman is the perfect place for this kind of research, she said. My work is very interdisciplinary, and in some scientific communities there are very defined lines. But at Beckman, working across disciplines is embraced and encouraged, which creates strong and successful collaborations.

For Kisley, those collaborations include working with Paul Braun, a professor of materials science and engineering; Martin Gruebele, a professor of chemistry; and Deborah Leckband, a professor of chemical and biomolecular engineering, all members of the Molecular and Electronic Nanostructures research theme.

The value of interdisciplinary endeavors was at the heart of the founding of the Beckman Institute. It also was the impetus for the establishment of the Beckman Brown Interdisciplinary Postdoctoral Fellowship. Named for Arnold and Mabel Beckman and Ted Brown, the founding director of the Beckman Institute, the $5 million gift from the Beckman Foundation annually funds a three year fellowship. Kisley is its first recipient.

It's an honor to be named a Beckman Brown fellow and to receive such generous support, she said. Both men were committed to enhancing research across disciplines, which was really visionary. I also feel privileged to be working on instrumentation at a facility that was founded by someone who was a pioneer in developing instrumentation.

COVERING A LOT OF GROUND



How do you make the cover of *Nature*? *Science*? *Chemical Biology*? It takes two things: an interesting scientific story and a compelling image to help tell it.

The Beckman Institute provides both. With the cadre of talented interdisciplinary researchers from across campus, there is no shortage of leading-edge scientific stories to tell. And with the Visualization Laboratory (Vis Lab), there is no shortage of creativity and technical know-how to design striking images to illustrate those stories.

As Travis Ross, manager of the Vis Lab, tells it, the process starts when a faculty member, a graduate student, or a postdoctoral student contacts him either because they have been selected to submit an image or are entering a competition initiated by a magazine.

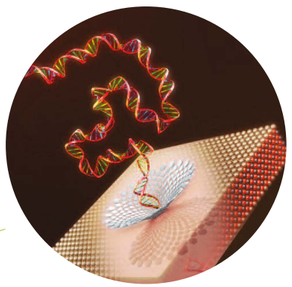
"We'll meet so that the researchers can share their work in enough detail that we can find an effective and strong visual way to quickly communicate the single most important component of their message," Ross said.

First, you have to consider the needs and style considerations of the magazine, Ross explained. "Some are very technical and want a schematic, while others prefer a more dramatic or real-world look. We focus on those things that we know are important both to the magazine and the researcher, and we come up with two or three concepts to present to the researcher."

Ross and his team use the equipment in the Vis Lab to make it happen. It might mean using the various high-speed cameras to get just the right image. Or it might require the use of the lab's 3D rendering capabilities and visual effects. Perhaps scientific visualization, scanning electron microscopy false colorization, or illustration techniques provide the best way to convey the message.

"Sometimes we start with data sets provided by the researcher, and sometimes we create the image from scratch," Ross said. "Sometimes we take hundreds of photos before we come up with just the right one. Other times, our artist might be able to create a traditional hand drawing for an illustrated cover quickly. But whatever we do, the idea is to bring the image—and the concept—to life and deliver it to a large audience."

JOURNAL OF MOLECULAR BIOLOGY



SCIENCE

The Vis Lab has created images for more than 100 journal covers including: at top left, ACS Chemical Biology, *May 2013; at left,* Advanced Materials, *July 20, 2009; at right,* Advanced Materials, *January 15, 2014; and page 17 background,* Journal of Molecular Biology, *January 9, 2014.*

VISUALIZATION LABORATORY

Covering All the Bases, Too

Creating cover story images is just one of the many ways that the Visualization Laboratory serves researchers at the Beckman Institute. Other services include:

- Image analysis
- Animation
- Video production
- Graphics
- Scientific visualization
- 3D object scanning
- 3D modeling
- Ultra high speed video capture and analysis
- Macrophotography
- Macrovideo
- Professional artistic visualization

And the Imaging Technology Group, which includes the Vis Lab as well as the Microscopy Suite, also covers lots of bases across campus, providing services to a wide range of interdisciplinary users in the past year, including those in the fields of:

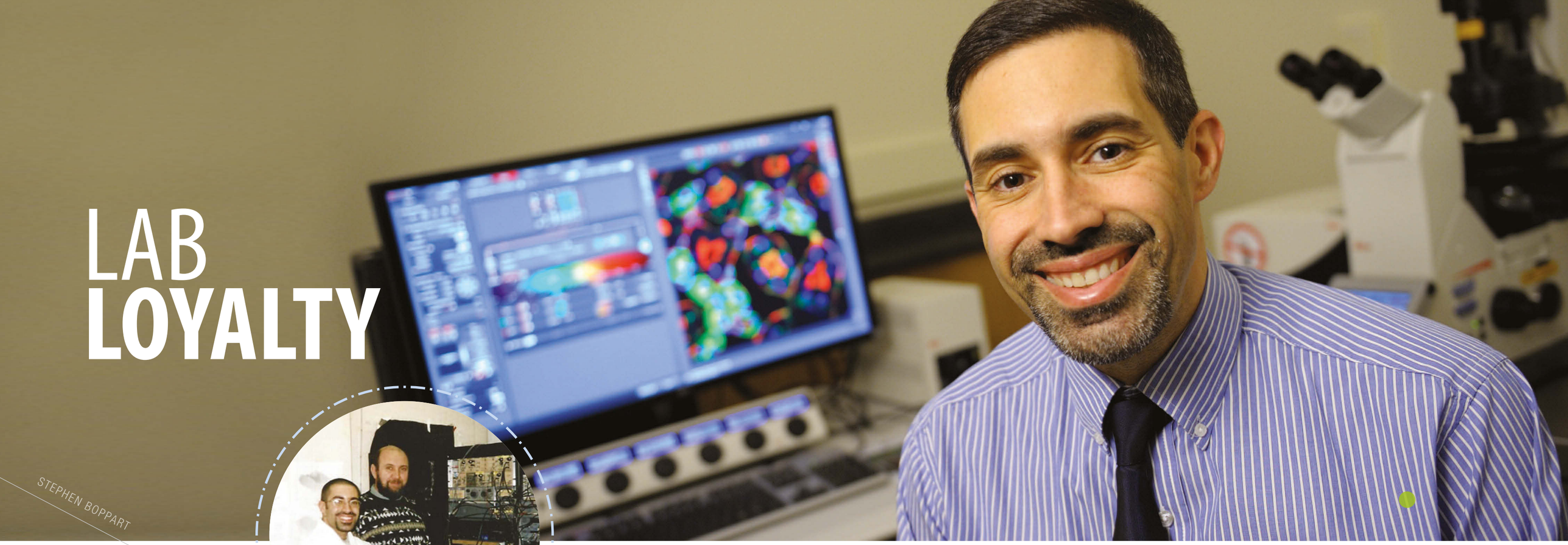
- Aerospace Engineering
- Agricultural & Biological Engineering
- Animal Biology
- Animal Sciences
- Anthropology
- Applied Research Institute
- Architecture
- Bioengineering
- Biochemistry
- Business Administration
- Cell & Developmental Biology
- Chemical & Biomolecular Engineering
- Chemistry
- Civil & Environmental Engineering
- Crop Sciences
- Electrical & Computer Engineering
- Entomology
- Food Science & Human Nutrition
- Genomic Biology
- Geology
- Illinois State Geological Survey
- Integrative Biology
- Kinesiology & Community Health
- Materials Science & Engineering
- Mechanical Science & Engineering
- Microbiology
- Molecular & Cellular Biology
- Molecular & Integrative Physiology
- Neuroscience
- Nuclear, Plasma, & Radiological Engineering
- Nutritional Sciences
- Physics
- Psychology

ADVANCED MATERIALS

BIOPHYSICAL JOURNAL

NATURE

LAB LOYALTY



STEPHEN BOPPART

JUSTIN RHODES

AL FENG

SUSAN SCHANTZ

KARA FEDERMEIER

GRAHAM HUESMANN

Daniel Llano's connections at the Beckman Institute run deep. He was an undergraduate at Illinois studying biology when the building opened in 1989, and several years later he found himself inside that building working in a neuroscience lab while finishing his Ph.D. in molecular and integrative physiology.

More than 15 years after earning that Ph.D. plus an M.D. as part of the College of Medicine's Medical Scholars Program, Llano is back in that same lab. But today he is running it.

The Beckman affiliation began when Llano registered for a class taught by Al Feng, a pioneer in auditory signal processing research and a Beckman faculty member. Llano said the class was one of the most difficult he has ever taken and it took awhile for him to grasp the concepts about the auditory system. Once he did, however, it changed his path.

That path led Llano to the bright confines of Beckman, and a position as a doctoral student in Feng's lab. But the research sent him to a darker workspace as well—deep, pitch-black abandoned limestone mines near Utica, Illinois, where he would round up bats and take them back to the lab.

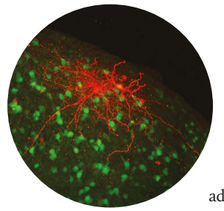
"Our work in Al's lab focused on studying the bats' auditory system and the connection between natural behavior and brain mechanisms."
Daniel Llano

"Bats have an amazing echolocation system," said Llano, an associate professor of molecular and integrative physiology and a member of the Intelligent Systems research theme. "Our work in Al's lab focused on studying the bats' auditory system and the connection between natural behavior and brain mechanisms. The lab I run today is in the same physical space as Al's lab and has a very similar focus, studying the brain's mechanisms of hearing."

But, he explained, there are some differences. Bats are no longer part of the lab's study, so Llano is no longer visiting those dark abandoned mines. But for the most part, the differences are related to the techniques undertaken to study the brain—techniques such as optogenetics, which is a way to activate neurons using light.

"We're more focused on using optical techniques to study the brain's mechanism of hearing and how those mechanisms change during pathological conditions," said Llano, who returned to Beckman in 2010 when Feng retired. "We continue to try to develop newer ways of imaging tissue to create techniques that image brain activation rather than using invasive techniques."

A recent grant for which Llano is the principal investigator will move that initiative forward. A multiphoton microscope will provide "a level of imaging specificity that will allow researchers to interrogate brain circuits in order to modify particular cell types and particular brain structures," Llano explained.



From the Lab to the Clinic

The optical techniques Llano employs play a role in his collaborative work with Beckman colleagues. For instance, a project with Susan Schantz, a professor of comparative biosciences and a member of the Intelligent Systems research theme, uses optical techniques to examine the impact of polychlorinated biphenyl (PCB) toxins in the development of the auditory system.

Llano also is working with Justin Rhodes, an associate professor of psychology and a member of the Intelligent Systems research theme, on a study examining the links between new neuron formation in the brain of aged animals, suggesting links between the muscle development that comes from exercise and higher cognitive function.

In addition to his work in a research lab, Llano is a clinical neurologist. He sees patients once a week at Carle, where he specializes in cognitive disorders. That clinical work gives him an opportunity to help patients, advance his research, and assist other Beckman colleagues with their studies.

"My clinical work focuses on the normal consequences of aging, such as hearing loss and tinnitus, and how that affects the nervous system," Llano said.

In that capacity, he collaborates with Kara Federmeier, a professor of psychology, and Aron Barbey, an associate professor of psychology, both of the Intelligent Systems research theme, helping them recruit patients for their studies.

Continued Connections

As a 2002 graduate of the university's legacy College of Medicine, Llano is enthusiastic about the opportunity to be a part of the new Carle Illinois College of Medicine, where the Beckman connections continue.

He will serve as the associate director for the clinical neuroscience course and will work with Graham Huesmann, a Carle neurologist, a research professor of molecular and integrative physiology, and a member of the Intelligent Systems research theme. Additional faculty of the new college will include other Beckman associates and Carle colleagues as well.

"Many of my rotations as a medical student were at Carle," Llano said. "So some of my mentors while I was a medical student are now my colleagues."

That evolving role from medical student to clinician, from Ph.D. student to professor, and from graduate researcher to principal investigator, all at Illinois, gives Llano a unique perspective.

"I feel fortunate to have had such great mentors, like Al Feng, as a student here," Llano said. "I know how much I benefited from the Beckman vision of interdisciplinary science. Today, we continue to build on that strong infrastructure to provide opportunities for new collaborations and new discoveries."

Above: Daniel Llano, then a graduate student, and Alex Galazyuk, then a postdoctoral researcher, in Al Feng's lab in 1999.

Above: Two neurons recorded simultaneously from the inferior colliculus and filled with a fluorescent dye.

In Tribute to Klaus Schulten

Klaus Schulten, who founded Beckman's Theoretical and Computational Biophysics Group, was a leader in the field of biophysics. He conducted seminal work in the area of dynamic computer simulations, illuminating biological processes and structures in ways that weren't possible before.

Schulten's goal from his start as an original Beckman researcher was to use mathematics and physics to study the natural world through advanced computation.

"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 sys tems work," Schulten said. "That's what makes my life at Beckman so rewarding, because my long dream was finally fulfilled."

Schulten's group created simulations that have pro vided never before seen views of such functions as the chemical structure of the HIV capsid and the first ever simulation of an entire life form, the complete satellite tobacco mosaic virus.

A Swanlund Professor of Physics, Schulten had pro fessional interests in theoretical physics and theoretical biology. His research focused on the structure and func tion of supramolecular systems in the living cell and on the development of non equilibrium statistical mechan ical descriptions and efficient computing tools for struc tural biology.

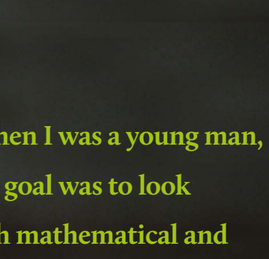
BLUE WATERS SUPERCOMPUTER

NSF CENTER FOR THE PHYSICS OF LIVING CELLS

The genetic material of the HIV virus is encased in multiple structures that hide it from the host immune system. The capsid, in green, protects the virus after it enters a cell and shuttles it to the nucleus, where it completes the process of infection. Graphic by Juan Perilla.

"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. That's what makes my life at Beckman so rewarding, because my long dream was finally fulfilled."

Klaus Schulten



First ever computer simulation of an entire life form the satellite tobacco mosaic virus in a simulated system that also included water and ions with a total of more than one million atoms.

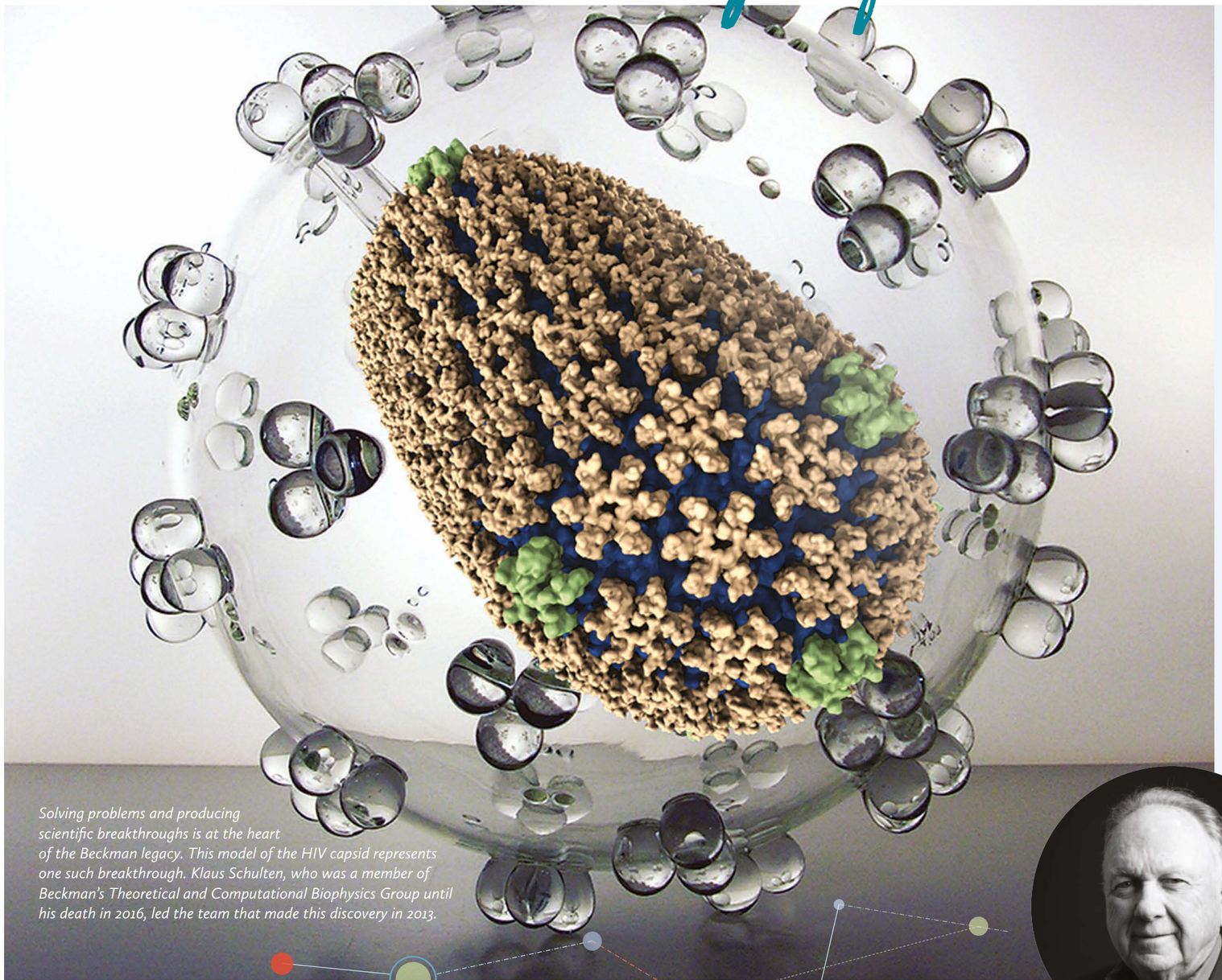
NIH CENTER FOR MACROMOLECULAR MODELING AND BIOINFORMATICS

THEORETICAL AND COMPUTATIONAL BIOPHYSICS GROUP

DEPARTMENT OF PHYSICS

Klaus Schulten, a professor of physics and a Beckman faculty member for nearly 25 years, died in October 2016 after an illness.

Establishing the Beckman *Legacy*



Solving problems and producing scientific breakthroughs is at the heart of the Beckman legacy. This model of the HIV capsid represents one such breakthrough. Klaus Schulten, who was a member of Beckman's Theoretical and Computational Biophysics Group until his death in 2016, led the team that made this discovery in 2013.

Jerry Gallwas is an analytical chemist who spent his career committed to the development of medical device instrumentation for clinical use and the success of Beckman Instruments, which he joined in 1964.

An employee for 30 years, he last served as the director of program management for the company's diagnostic systems group. In that capacity, he established a close friendship with Arnold Beckman. So in the summer of 1976 when Arnold and his wife, Mabel, were considering how best to support scientific endeavor through philanthropy, Arnold shared his vision with Gallwas.

"When the Beckmans made the decision in 1976 to establish a foundation, we discussed their aspirations to support interdisciplinary research in science," said Gallwas. "My daughter and I put them on a plane to Illinois in September of 1978, and that's when they first met Ted Brown." Theodore "Ted" Brown served as founding director of the Beckman Institute, and Brown co-wrote the initial proposal for an interdisciplinary research institute, which incorporated many features and organizational concepts new to academia at that time.

The initial meeting between the Beckmans and Brown and many more over the decade of planning that followed resulted in a burgeoning friendship between the Beckmans and Brown and in the establishment of the Beckman Institute for Advanced Science and Technology at Illinois.

"The legacy of Arnold Beckman and Ted Brown really resides in the interdisciplinary approach they had to solving problems," said Gallwas, a member of the Beckman Foundation from 1995 until his retirement in the fall of 2016.

"Arnold Beckman was a great problem solver," Gallwas said. "He could take theory and apply it. Ted has the same approach. You can see it expressed in his textbook, *Chemistry, The Central Science*, which brings together various disciplines and approaches, and presents them to the student."

That's exactly the kind of thought process that Arnold Beckman employed, continued Gallwas. "When he built a product, it took a mechanical engineer, an electronic engineer, a physicist, and a chemist to bring all the disciplines together to develop an instrument system. He saw the need for the same approach in academia and envisioned the institute as a place where scientists in different disciplines could come together to produce leading scientific breakthroughs and train the next generation of scientists in interdisciplinary research environments."

The Beckman Institute is one of five of those environments. The foundation also established the Beckman Center for Molecular and Genetic Medicine at Stanford University, the Beckman Institute at the California Institute of Technology, the Beckman Laser Institute and Medical Clinic at the University of California Irvine, and the Beckman Research Institute at the City of Hope National Medical Center in Duarte, California.

"The Arnold and Mabel Beckman Foundation is uniquely positioned to support biology and chemistry and has a focus and dedication that few other foundations of its ilk have," Gallwas said. "So many foundations happen because someone has a philanthropic purpose without a real vision and mission. The Beckman Foundation has both."

"So many foundations happen because someone has a philanthropic purpose without a real vision and mission. The Beckman Foundation has both."

Jerry Gallwas
Retired Member, Beckman Foundation Board

Celebrating the Beckman *Spirit*

Arnold Beckman conceived of an academic environment where scientists in different disciplines would collaborate on scientific breakthroughs and train the next generation of scientists. Rohit Bhargava, of the Integrative Imaging research theme, is the kind of scientist whose work Arnold Beckman would celebrate.

So it's fitting that Bhargava is the first recipient of the Beckman Institute Vision and Spirit Award, which recognizes a researcher whose work contributes significantly to advancing the mission of the Beckman Institute. The award honors efforts to foster collaboration in pursuit of bold endeavors that meet short-term research goals and inspire future long-term work.

It's an apt description of Bhargava's work, said Jeff Moore, director of the Beckman Institute.

"He is a visionary researcher whose ideas have resulted in the development of infrared spectroscopic imaging. Instruments developed in his laboratory have provided new means to characterize and define cancer using chemical imaging methods that are leading to the emergence of the field of digital molecular pathology."

Not only does he have a vision for interdisciplinary research, he has a commitment to match.

"With relentless spirit, he has championed the creation of the Cancer Community at Illinois, a universitywide effort dedicated to advancing cancer-related research and scholarship at Illinois," Moore said. "That effort has led to the establishment of the Cancer Center at Illinois, which is bringing together more than 90 faculty members from across campus, and numerous graduate students and postdoctoral researchers, to pursue cancer-related research."

Bhargava's interdisciplinary focus is exemplified by his appointments in bioengineering, chemical and biomolecular engineering, mechanical science and engineering, electrical and computer engineering, and chemistry. He also leads a National Institutes of Health–supported Tissue Microenvironment Training Program based at the Beckman Institute.

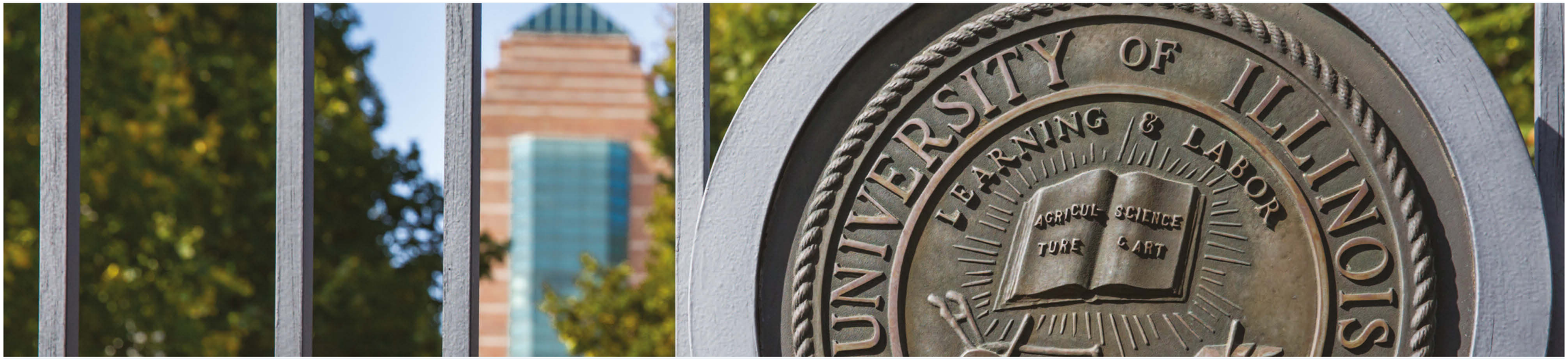
"I am deeply honored and humbled by this award," Bhargava said. "The Beckman Institute has not only helped me attract outstanding students and provided exceptional colleagues and access to world-class facilities, it has provided the inspiration and environment to launch many of our ideas. The Beckman Institute is the 'incubator of ideas' for our campus, and I am deeply grateful to all our members in helping make those dreams a reality."

Arnold Beckman's birthday is April 10, an appropriate day to celebrate the establishment of an award that captures his commitment to furthering interdisciplinary collaboration. The surprise that day was on Rohit Bhargava, the 2017 recipient of the Beckman Vision and Spirit Award.

"The Beckman Institute is the 'incubator of ideas' for our campus, and I am deeply grateful to all our members in helping make those dreams a reality."

Rohit Bhargava

Gateway to *Collaboration*



The east entrance of the Beckman Institute serves as a gateway to interdisciplinary collaboration across the University of Illinois campus.

When the Beckman Institute for Advanced Science and Technology opened its doors in 1989, Stanley Ikenberry was president of the University of Illinois. Twenty years later, he wrote that in many ways the Institute "changed the campus profoundly." Today, that profound influence continues. Other institutes on campus look to the collaborative, interdisciplinary model of the Beckman Institute as they also work to answer the challenging scientific and human questions of today and envision solutions for the problems of tomorrow. That commitment to premier research efforts forms a strong connection among faculty, staff, and students across disciplines and across the University of Illinois campus.

"The Beckman Institute sets an inspiring example of the power of interdisciplinary collaboration, serving as a hub of expertise and inquiry that unites brilliant minds across the university."

Mark Ryan, Executive Director, Prairie Research Institute

"Under Jeff Moore's leadership, the institutional knowledge in Beckman for building large, collaborative research teams has been instrumental in helping the Institute for Sustainability, Energy, and Environment organize and submit its first large *mrxivhmwgmtpmrev' viwievgl kverNvo*

Evan H. DeLucia, Director, Institute for Sustainability, Energy, and Environment

"As leading research institutes at the University of Illinois, both the Beckman Institute and the Carl R. Woese Institute for Genomic Biology have reaped tremendous benefits from a strong interdisciplinary approach to scientific research, and we *gsyrx eqsrk syv kviexiwx* strengths the collaborative nature of our faculty, students, and staff, *fsxl fimxlmr erh fixfiiir xli mrwxmxyxlNvo*

Gene Robinson, Director, Carl R. Woese Institute for Genomic Biology

"OTM receives about 200 invention disclosures from campus every year. Beckman researchers consistently are affiliated with about one-third of those disclosures. In addition, Beckman researchers are affiliated with over 30 start-ups based on Illinois innovations. Start-ups are crucial to innovation commercialization. They bring nascent innovations to a point where they are sellable or licensable."

Steve Wille, Assistant Director, Marketing and Technology Management, Office of Technology Management

"In many respects the Beckman Institute evolved from the scientific and technological strengths and culture of the Urbana-Champaign campus. In other ways, however, it changed the campus profoundly. Interdisciplinary collaboration and the capacity to attract exciting new faculty talent had long been a part of the Illinois tradition, but the Beckman Institute made a profound difference that endures today."

Stanley O. Ikenberry, President Emeritus of the University of Illinois

"The environment at Beckman fosters creative, collaborative thinking in imaging, modeling, materials, and cancer and neuroscience research. For example, the recently awarded $3 million interdisciplinary graduate student training grant funded by the National Science Foundation is representative of how the Beckman Institute unites research groups across the campus. This multi-investigator project will bring neuroscience and engineering students together to provide new insight on how *xli fvemr fisvowo N*

Peter Schiffer, Vice Chancellor for Research

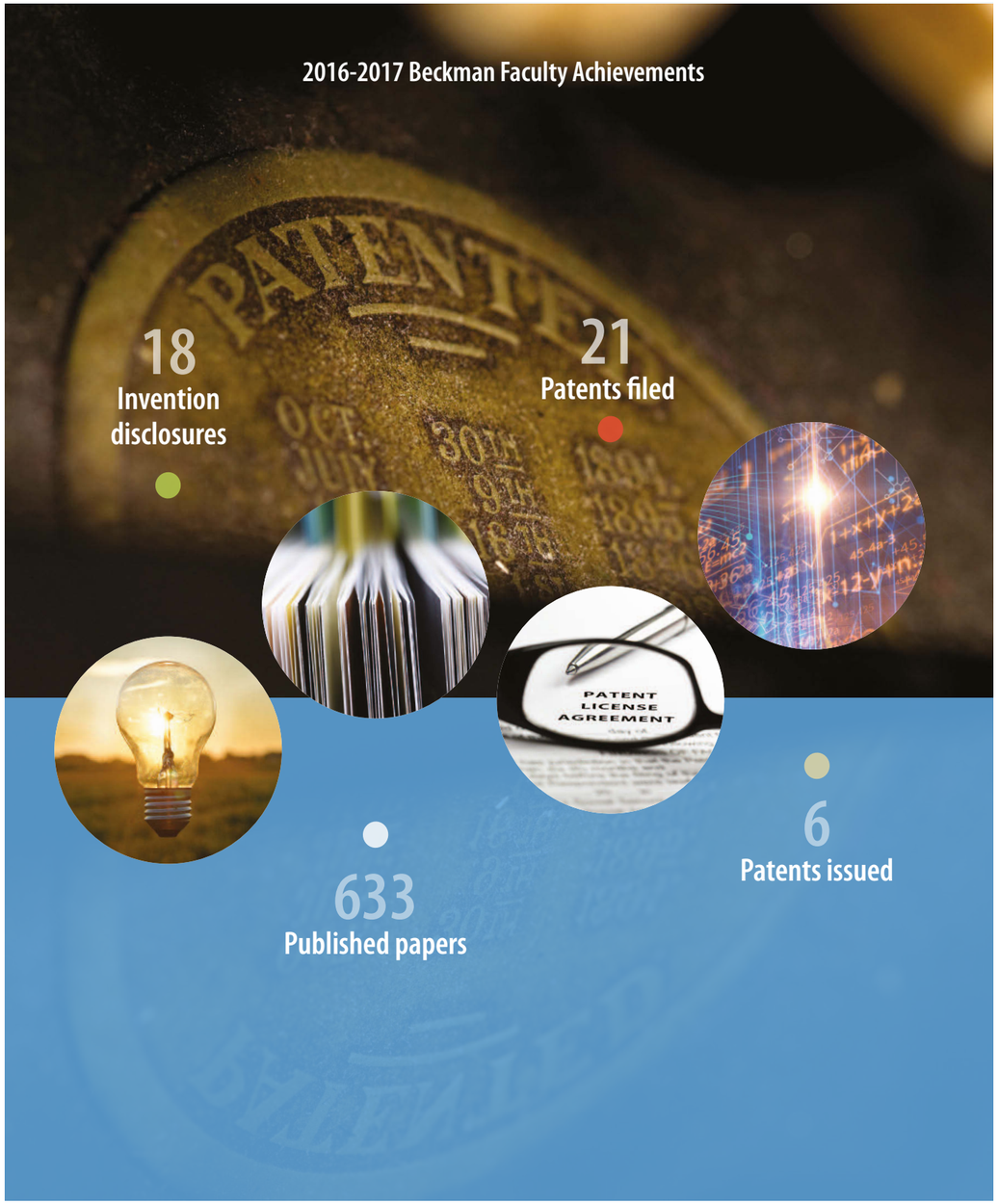
"The stakes of collaboration between STEM fields and the humanities and arts have never been higher. At the Illinois Program for Research in the Humanities, we are pleased to be partnering with Beckman in a set of events in November 2017 called Speculative Futures, which brings writers and creative artists into contact with some of the technological wonders on campus in an attempt to impact imaginative works of the present and the future. This grand experiment is part of what genuinely *xverwjsvqexmzi mrxivhmwgmtpmrev'* culture of the kind that Beckman has long been dedicated to *ryvxyvmrk mw epp efsyxN*

Antoinette Burton, Director, Illinois Program for Research in the Humanities

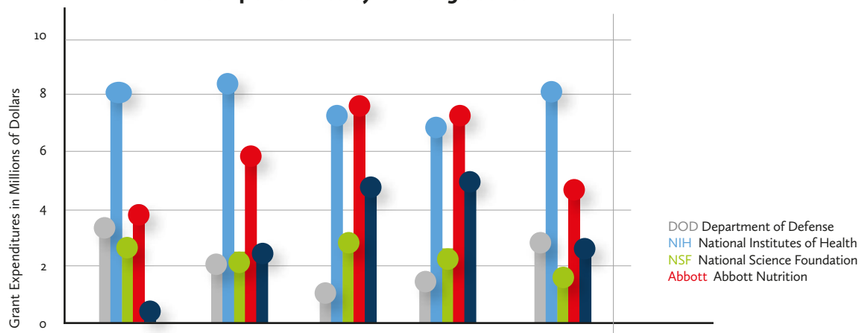
"The impact of the Beckman Institute on interdisciplinary research on campus extends well beyond what happens within its walls. It has been the model for the other institutes, by bringing together world-class talent, surrounding them with the very best facilities and professional staff, and supporting team-based research that redefines the state of the art. The Beckman Institute has in addition been a great partner to the Interdisciplinary Health Sciences Institute in jointly sponsoring the new Cancer *Firxiv- mr tpe'mrk e gvmxmgep vspi* in the success of our Program in Clinical and Translational *Riyvswgmirgi- erh mr fimrk xli* home for many research groups *fisvomrk mr xli liepxl wgmirgiwoN*

Neal Cohen, Director, Interdisciplinary Health Sciences Institute

By the *Numbers*

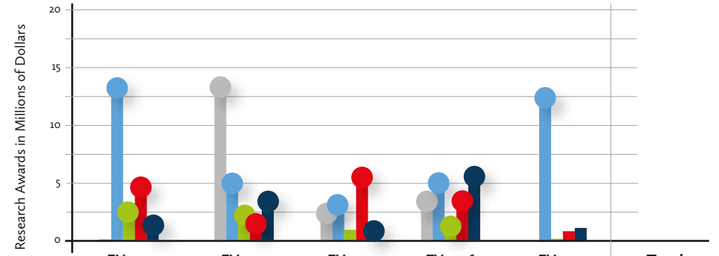


Grant Expenditures by Funding Source[1]



	FY2013	FY2014	FY2015	FY2016	FY2017	Total
DOD	$3,426,205	$2,328,861	$1,490,392	$1,976,766	$3,316,106	$12,538,331
NIH	$8,208,039	$8,718,725	$7,486,994	$7,172,547	$8,209,049	$39,795,354
NSF	$2,565,483	$2,398,696	$2,794,666	$2,425,976	$1,979,136	$12,163,957
Abbott[2]	$4,183,296	$6,249,854	$7,990,755	$7,595,835	$4,939,757	$30,959,498
Other	$690,399	$2,839,996	$5,190,458	$5,367,047	$3,269,903	$17,357,803
Total	**$19,073,422**	**$22,536,132**	**$24,953,265**	**$24,538,172**	**$21,713,952**	**$112,814,943**

Research Awards by Funding Source[3]



	FY2013	FY2014	FY2015	FY2016	FY2017	Total
DOD	$2,317	$14,374,896	$2,909,566	$4,115,529	$-	$21,402,308
NIH	$14,121,116	$5,798,307	$3,442,188	$6,035,109	$13,068,414	$42,465,134
NSF	$3,507,298	$3,012,333	$983,154	$1,970,753	$112,882	$9,586,420
Abbott[2]	$5,272,426	$2,381,765	$6,201,220	$4,237,195	$632,624	$18,725,230
Other	$2,324,885	$4,112,721	$1,632,833	$6,440,233	$824,323	$15,334,995
Total	**$25,228,042**	**$29,680,022**	**$15,168,961**	**$22,798,819**	**$14,638,243**	**$107,514,087**

[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 Agriculture, 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.