BECKMAN INSTITUTE
FOR ADVANCED SCIENCE AND TECHNOLOGY

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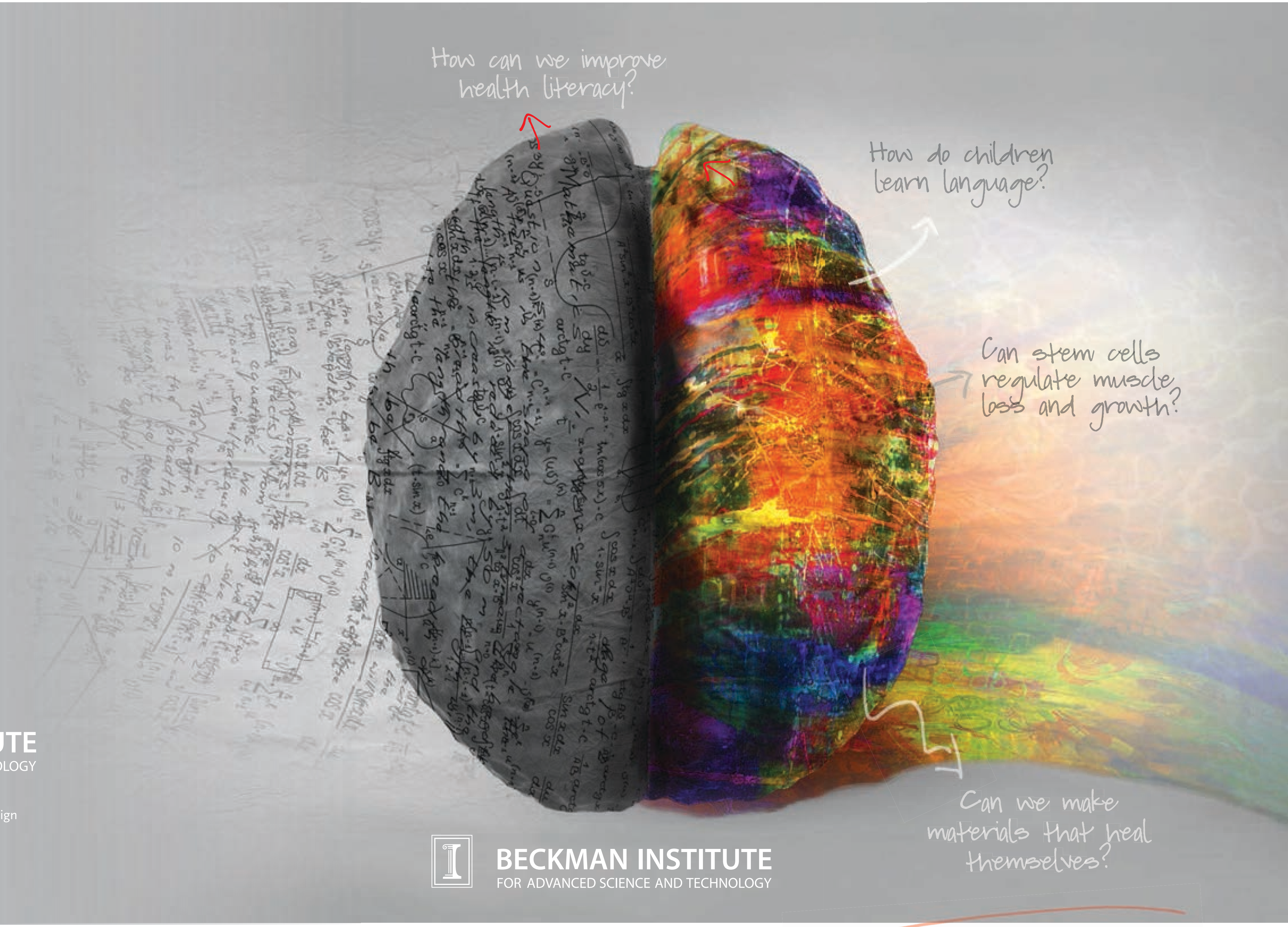
Beckman Institute: Where great minds meet



BECKMAN INSTITUTE
FOR ADVANCED SCIENCE AND TECHNOLOGY

2015–16 Annual Report

Beckman Institute: Where great minds meet

Contents

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Great minds don't always think alike

I was a graduate student at Illinois in June 1988 when my daughter was born at what was then Mercy Hospital. Just across the street from the hospital, the University was erecting a new building—the Beckman Institute. As I saw the structure taking shape, it was obvious that Beckman had the potential to shape much more—namely, a unique interdisciplinary approach to scientific research. And I hoped I'd have an opportunity to be part of that promising initiative as a researcher.

Seven years later, when I was fortunate to become a part-time faculty member at Beckman, it was already established as a premier institute, where collaborations across scientific and technological disciplines were leading to research advances in areas like neuroscience, bioengineering, robotics, materials science, physics, cognitive science, and more.

Today, that reputation for excellence and collaboration continues to grow. The Beckman Institute provides a stimulating, resourceful, and dynamic environment where cutting-edge interdisciplinary research is pursued. As interim director, I am committed to moving the conversation forward on how we build on the exemplary foundation and vision of Arnold and Mabel Beckman and the former directors, and how we position Beckman to be a powerful source for scientific innovation far into the future.

Just like our scientific endeavors at Beckman, creating a framework for the future requires a collaborative approach where all voices make an important contribution. That's what has earned us a prominent position at the center of scientific inquiry and technological advancement and what will ensure that position for the future. It's why we're in the center of the engineering campus, and why we'll play a central role in the University's new medical college.

Thanks to the support of the Beckman Foundation and the University of Illinois, Beckman brings together great minds from many different parts of campus.

And because those great minds bring different perspectives, they don't always think alike. Divergent viewpoints provide a fertile ground for innovation and fruitful collaboration. So we continue to push the frontiers of science. We continue to set the highest expectations. We continue to welcome the best and the brightest as Beckman faculty members and student scholars.

In June 1988, I saw the bricks and mortar as Beckman took shape. It was an impressive sight, but not half as impressive as what goes on inside the building every day. I've been privileged to witness and be a part of that collaborative work for the last two decades. I look forward to a year of carrying that important work forward together.

Jeffrey S. Moore
Interim Director
Beckman Institute for Advanced Science and Technology

Beckman Institute Research Themes

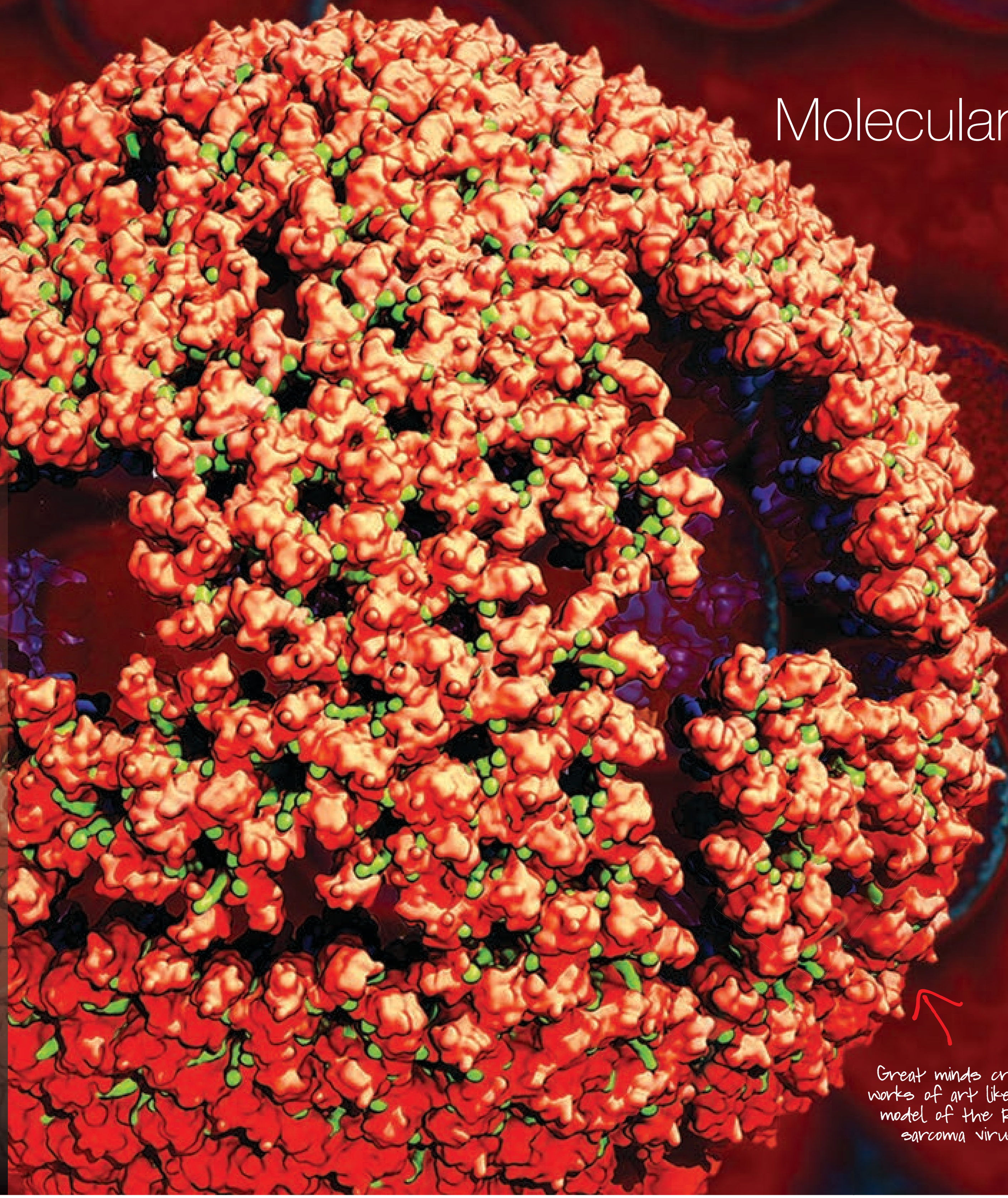
Molecular and Electronic Nanostructures

Integrative Imaging

Human-Computer Intelligent Interaction

Biological Intelligence

Molecular and Electronic Nanostructures (M&ENS)



The M&ENS research theme brings together scientists from disciplines as diverse as biology, engineering, physics, and chemistry, with the goals of both understanding and working with nanoscale structures and processes. M&ENS researchers develop and use computational tools for simulating biological processes and for designing nanosystems, fashioning nanoelectronics for applications in biomedicine and consumer products, and constructing autonomous multifunctional materials systems. The five research groups comprising M&ENS are 3D Micro- and Nanosystems, Autonomous Materials Systems, Computational Multiscale Nanosystems, Nanoelectronics and Nanomaterials, and Theoretical and Computational Biophysics.

Great minds create works of art like this model of the Rous sarcoma virus.

How can we stop the progression of infectious diseases?

Imperfect Intruder

A virus isn't infectious until it has matured. That's why studying an immature virus is so important. It can give us ideas on how to prevent maturity.

Boon Chong Goh, a Ph.D. student working with Klaus Schulten of the Theoretical and Computational Biophysics (TCB) Group, has given us an inside look at one such immature virus.

As you can see on these pages, Goh's model of the Rous sarcoma virus (RSV), which he calls the "Imperfect Intruder," is striking; so, too, are the implications of the computational methodology used to generate it. By offering an atomic-level look at the immature state, this computational model can help researchers understand the molecular mechanisms of virus maturation and how drugs can be designed to stop it.

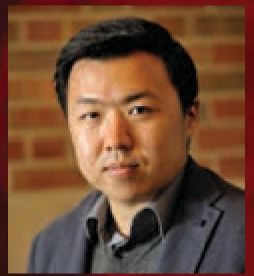
Trial and error in a chemical research lab is one way to understand the world of molecules, said Schulten. "But there is a more systematic way of resolving the molecular world, namely the computational way taken in our RSV study, and one can derive medical treatments from the knowledge reached computationally."

Just how did Goh create this model? He analyzed existing structure data on RSV proteins and developed algorithms to model their atomic structures. He then entered his draft algorithms into sophisticated software programs at Beckman, which performed the calculations, prepared the simulation, analyzed the results, and provided information for Goh to refine his calculations.

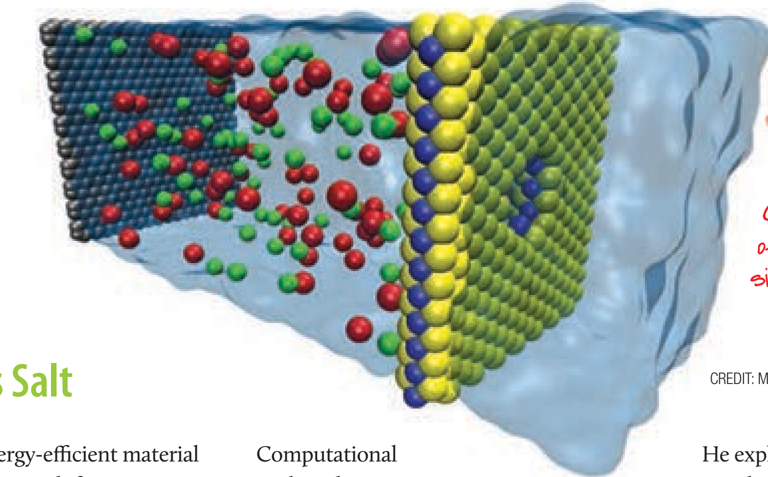
The result was the Imperfect Intruder, which generated both scientific and artistic interest—earning high honors in the Biophysical Society's "Art of Science" image contest and gracing the covers of both the *Journal of Physical Chemistry Letters* and the *Journal of Virology*.

Next up for Goh and the TCB Group? Studying the immature human immunodeficiency virus (HIV), which is similar in structure to RSV.

Klaus Schulten
Physics



Boon Chong Goh
Graduate Student



Computer model of a nanopore in a single-layer sheet of MoS_2.

CREDIT: MOHAMMAD HEIRANIAN

A Discovery That's Worth Its Salt

Narayan Aluru
Mechanical Science and Engineering

How do we solve a growing water crisis?

An energy-efficient material for removing salt from seawater could be a step toward solving the world's water crisis. The material, a nanometer-thick sheet of molybdenum disulfide (MoS_2) riddled with tiny holes called "nanopores," is specifically designed to let high volumes of water through but keep salt and other contaminants out. In fact, a study by University of Illinois researchers found that MoS_2 filtered up to 70 percent more water than other materials.

"Even though we have a lot of water on this planet, there is very little that is drinkable," said **Narayan Aluru**, of the Computational Multiscale Nanosystems Group and the lead researcher on this study. "These materials are efficient in terms of energy usage and fouling [clogging of pores], which are issues that have plagued desalination technology for a long time."

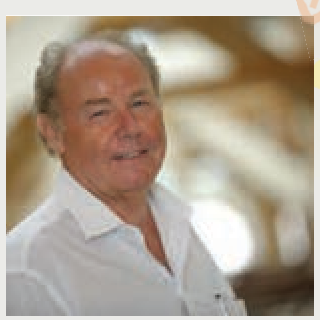
Aluru's group previously studied MoS_2 nanopores as a platform for DNA sequences and decided to explore its properties for water desalination. They found that a single-layer sheet of MoS_2 outperformed its competitors thanks to a combination of thinness, pore geometry, and chemical properties.

He explained that MoS_2 is robust material, so even a thin sheet can withstand the necessary pressures and water volumes. And because it's thin, it requires much less energy, which dramatically reduces operating costs. In addition, creating a pore in the sheet that left an exposed ring of molybdenum around the center of the pore created a nozzle-like shape that actually drew water.

"Finding materials for efficient desalination has been a big issue, and I think this work lays the foundation for next-generation materials," Aluru said.

DNA Paves the Way

What new technology will advance the field of personalized medicine?



Jean-Pierre Leburton
Electrical and Computer Engineering

Fast, inexpensive, and reliable DNA sequencing has the potential to revolutionize medicine, and **Jean-Pierre Leburton**'s work as part of the Nanoelectronics and Nanomaterials Group is focused on exploring a technology that can do just that.

"The use of nanopore membranes represents a promising new technology that could lead to significant advancements in the field of personalized medicine," where treatment is tailored to a person's unique genetic makeup, said Leburton, professor of electrical and computer engineering.

He explained the process: "In typical nanopore sequencing experiments, DNA molecules in an electrolyte are threaded through the pores under an applied voltage. The presence of the DNA nucleotides in these pores, or even bigger objects such as proteins attached to DNA, then causes transient dips in the ionic current. Resolving the magnitude and duration of each dip could enable the identification of individual bases for sequencing DNA molecules, and the detection of proteins indicating DNA methylation that causes cancer."

Using ultra-thin solid-state materials such as graphene or MoS_2 nanoribbons containing a nanopore, Leburton has been able to show that detection and characterization of both double- and single-stranded DNA molecules in a variety of configurations are possible. The single-atom thickness of monolayer graphene and MoS_2 enables the high-resolution scanning of molecules passing through the nanopores. Additionally, like conventional semiconductors, these monolayer materials are electrically active, enabling the electronic control and sensing of biomolecules.

Beckman collaborators joining Leburton in this work include **Klaus Schulten**, professor of physics and a member of the Theoretical and Computational Biophysics Group; **Rashid Bashir**, professor of bioengineering and a member of the 3D Micro- and Nanosystems Group; and **Lav Varshney**, assistant professor of electrical and computer engineering and a member of the Image Formation and Processing Group.

Better disease prevention and treatment starts with better information, and nanotechnology-based approaches have the potential to provide genetic information needed to tailor medicine to each patient with precision.

Packing Some Power

How can we build better mobile technologies?

Joe Lyding
Electrical and Computer Engineering

Paul Braun
Materials Science and Engineering

Electrical systems are the heart of many of today's products—machinery, mobile electronics, construction equipment, aircraft, and electric cars, for instance. And heat can be hard on the heart. That's why it's so important to find ways to help protect that heart while optimizing what it can do.

The Power Optimization for Electro-Thermal Systems (POETS) center at the University of Illinois will be focusing on just that—solving the thermal and electrical challenges surrounding mobile electronics and vehicle design as a single system.

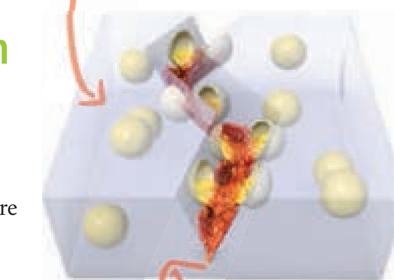
POETS is an $18.5 million engineering research center supported by the National Science Foundation. A truly collaborative endeavor, POETS has more than a dozen partners around the world working together to pack more power into less space for mobile technologies. These partners will build novel 3D thermal cooling circuitry, next-generation power converters, and algorithms for smart power management.

Beckman researchers are among those leading the POETS effort, which has three interdisciplinary thrusts: optimization and control; system design and analysis; and materials and fabrication. **Paul Braun**, professor of materials science and engineering and a member of the 3D Micro- and Nanosystems Group, and **Joe Lyding**, professor of electrical and computer engineering and a member of the Nanoelectronics and Nanomaterials Group, serve key roles in the center, with responsibilities for the third thrust—materials and fabrication.

A modular, academic test bed will facilitate communication between thrusts, while practical test beds from power levels of 1 kilowatt to 1 megawatt will provide stronger proof-of-concept technologies.

An Illuminating Approach to Damage Detection

How can we detect damage to structures when we can't see it?



CREDIT: ALEX JEREZ OF THE IMAGING TECHNOLOGY GROUP

When damage occurs, microcapsules rupture and release materials that react with the coating to change color.

After an accident, damage to your car may be obvious—a broken taillight, a dented fender, a flat tire. However, there could be additional damage to the polymeric material in that car that isn't visible to the eye but could compromise the safety of its passengers. The same is true for large, polymer-coated steel structures, like ships and bridges, where even the tiniest of cracks can lead to damage that can have catastrophic consequences.

Researchers in the Autonomous Materials Systems Group are developing an illuminating approach to damage detection. And it starts with microcapsules.

The work of Beckman Postdoctoral Fellow **Maxwell Robb**, Postdoctoral Research Associate **Wenle Li**, and that conducted by **Jeffrey Moore**, professor of chemistry, **Nancy Sottos**, professor of materials science and engineering, and **Scott White**, professor of aerospace engineering, has led to new discoveries, including simple and effective ways to detect microscopic damage.

"We've developed microcapsules that are colorless and nonfluorescent when intact," said Robb, the winner of the American Chemical Society's 2016 Henkel Award for Outstanding Graduate Research in Polymer Chemistry. "We can embed them into materials, and when damage occurs the microcapsules will release their payload and become fluorescent, indicating that repair is needed."

In the case of a new polymer coating, a color change identifies the damage. Even a crack as small as 10 micrometers will initiate the bursting of the microcapsules. "We want to target damage at its earliest stage to prevent further damage, improve safety and reliability, and reduce life cycle costs associated with regular maintenance and inspection," said Li. He explained that the light yellow pH-sensitive indicator that is released reacts chemically with the epoxy matrix and changes to bright red. The larger the crack, the greater the amount of indicator, and the more pronounced the color change.

A next step would be to incorporate the self-reporting ability into a self-healing plastic. The initial color change would indicate the presence of a crack, and a secondary color change would indicate the damage had healed. "The long-term vision is to devise multichannel, reversible indications, allowing the materials to self-report damage and healing for multiple cycles," said Li.

Maxwell Robb
Beckman Postdoctoral Fellow

Wenle Li
Postdoctoral Research Associate

Damage Control

GROUNDBREAKING WORK FOCUSES ON INNOVATION IN SELF-HEALING MATERIALS

Materials, like people, undergo an aging process. The wings of an aircraft and the blades of a wind turbine work hard, battle the elements, and suffer a variety of stressors. But a team of Beckman collaborators is doing damage control—creating a vision of healthy aging for those wings and blades plus a lot of other materials made with polymers.

It's an engineering and materials science process that resembles a biological one—focusing on self-healing, regeneration, and longevity.

"Nature shows us what is possible," said **Jeffrey Moore**, Murchison-Mallory Professor of Chemistry. "We're inspired by what she presents. The question is: Can we capture it in a useful and meaningful way?"

The progress made by the pioneering team of Moore and **Scott White**, professor of aerospace engineering, and **Nancy Sottos**, professor of materials science and engineering, all of the Autonomous Materials Systems Group, indicates that the answer is "yes."

For more than 15 years, the group has been focused on the creation of new materials that display autonomous functionality. Moore, also a professor of materials science and the interim director of the Beckman Institute, explained the concept.

What is autonomous functionality?

"'Autonomous' means without human intervention. We want the damage to be the trigger that promotes repair. We want there to be a built-in functionality whereby the materials are actually managing their own well-being without anyone going in and initiating a fix or even knowing there is a need for one."

And what they've discovered in this groundbreaking work on the lifecycle of polymers could lead to significant changes in how composite materials are made, how long they last, and what happens when they are at the end of their useful life.

Chemistry in the Wild

Moore described the healthy aging of materials this way: "Live long, be fit, die fast, and leave no mess behind." Self-healing is one important step that takes its cue from biology.

"Our team has developed several approaches, depending on the kind of damage we are trying to repair," said Moore. "If there is a loss of mass from a bullet hole or chipped coating, for example, we have to provide a conduit to feedstock that can serve as a replacement for what was lost. Our vascular system provides an example of how to approach that."

Here's how it can work: damage triggers two previously isolated vascular channels to empty their contents, setting in motion a chemical process. That might come in the form of a gel that moves into the damaged area, stiffens, and eventually hardens.

The process requires the right communication, the right healing material, the right timing, and the right placement. All of this together "requires us to have some new tricks up our sleeve," said Moore. "It's more of chemistry in the wild than in a flask because we aren't talking about a controlled environment. When you're repairing damage, you have to consider all of these functional issues and then add in exposure to wind, humidity, gravity, and other factors."

It's a complicated problem with tentacles that reach across scientific disciplines.

Team Science

If chemical bonds are what hold molecules together, collaboration is the glue that binds discovery. And that's exactly where Beckman shines, said Moore. In fact, his work with the Autonomous Materials Systems Group has translated into building strong collaborations on other fronts.

One such project is Moore's involvement with the Joint Center for Energy Storage Research (JCESR). This initiative is a partnership between 14 organizations, including national laboratories, universities, and industry, all of which are working to transform transportation and the electricity grid with next-generation energy technology. **Joaquin Rodriguez-Lopez,** assistant professor of chemistry, is another Beckman faculty member involvd in the project.

Moore, who is leading the effort in developing prototype pilot batteries for grid storage, explained that the JCESR project has a 5/5/5 goal: develop five times the energy density at one-fifth the cost within five years. "It's about making cheaper, more compact batteries through better chemistry," he said. And doing it with sprint-like speed.

It's also about collaboration, which Moore said is all about working hard and building trust. "What I've learned about team science from my collaborations at Beckman has been very beneficial in my work with JCESR. It's taught me what it takes to recognize problems in the collaboration when they arise and how to resolve them to move solutions forward. The most important part of the collaboration isn't necessarily the investigators talking but the students and postdocs at the bench solving the problems."

The size of the JCESR project, supported by taxpayers with $25 million per year, and the distant nature of the participants make the effort unique. "At Beckman, we're built specifically so encounters between collaborators are frequent and often spontaneous. Although we don't have that luxury with the JCESR project, with participants at locations all over the country, I work to take the Beckman model of collaboration in team science and apply it to this large-scale project," said Moore.

Disruptive Change

Where will these collaborations lead?

While the JCESR initiative is nearing the end of its first five-year cycle, Moore predicts that components of the various collaborations will continue as these important energy needs persist and solutions take shape.

The work by Moore, White, and Sottos in the area of self-healing polymers is likely to have very tangible benefits even sooner. Moore said a first product, a coating that protects against corrosion, could be on the market in less than two years.

"I'm excited that we are in the early development of what could be disruptive change in how composite materials are manufactured," he said. "This will be a strong focus for manufacturers for the future."

What are the best ways to prepare the next generation of researchers?

Jamila Hedhli, graduate research assistant, mentors Hannah Bauer, junior at Iowa State University, as part of a recent Research Experience for Undergraduates program at Beckman.

Integrative Imaging (IntIm)

The IntIm research theme brings together people and technologies to create advances in imaging science that have real-world impacts in both research and clinical settings. Research in this theme includes working to design and engineer new imaging instruments and methods, optimizing current techniques, and conducting scientific research that relies on imaging. The two research groups comprising IntIm are the Bioacoustics Research Laboratory and the Bioimaging Science and Technology Group.

Opening Doors to Discovery

When you have great minds and great tools, you have a lot to share—especially with aspiring researchers. As a host institution for the "Discoveries in Bioimaging" Research Experiences for Undergraduates (REU) program, Beckman researchers share their expertise and open doors to the next generation of scientists.

The program, funded by the National Science Foundation, has brought 10 undergraduates from universities across the United States and Puerto Rico to Beckman each of the past two summers. After a weeklong boot camp featuring lectures and discussions with leading researchers from labs across campus, the undergrads worked on diverse bioimaging projects under the guidance of graduate student mentors.

In 2016, students had opportunities to learn about specific imaging modalities from infrared spectroscopy to magnetic resonance imaging to bioluminescence imaging. They each were assigned to an ongoing project, which ranged from examining the effect of adipose-derived stem cells on angiogenesis to building a classification system for cancerous tissue samples.

The Illinois program is led by Stephen Boppart, professor of electrical and computer engineering, bioengineering, and medicine, and a member of the Bioimaging Science and Technology Group, and Andrew Smith, professor of bioengineering. It is supported by several other Beckman researchers.

"Beckman's reputation as a leader in bioimaging provides inspiration to the students and encourages them to consider graduate school in the field," said Marina Marjanovic, associate director of the Center for Optical Molecular Imaging and coordinator of the REU program. "Our REU program is dedicated to inspiring and training undergraduates in STEM fields through a summer experience in bioimaging research," said Marjanovic. "The unifying link between bioscience, discovery, and bioimaging is an inspirational centerpiece for this site at the University of Illinois."

Bettering Brain Health

Curtis Johnson
Research Scientist

A collaboration between Beckman researchers and physicians at Carle Foundation Hospital offers potential for patients with epilepsy.

It begins with a new way to monitor and measure the stiffness of soft tissue. The technology, called magnetic resonance elastography (MRE), was developed at Mayo Clinic to detect hardening of the liver. Beckman researchers saw the accuracy of MRE and its noninvasive nature as a promising tool for evaluating brain tissue without a biopsy. So they developed brain MRE applications and, together with Carle, are using MRE to examine the brains of patients with mesial temporal lobe epilepsy.

The Beckman-Carle team includes **Brad Sutton**, associate professor of bioengineering and a member of the Bioimaging Science and Technology Group, **Curtis Johnson**, now assistant professor at the University of Delaware, and **Graham Huesmann**, a Carle neurologist, a research assistant professor of molecular and integrative physiology, and a member of the NeuroTech Group.

"This type of epilepsy becomes increasingly resistant to medication," said Huesmann. "Over time, with accumulated damage added to the side effects of some of the medications, patients become incapable of forming new memories. They can't work, they can't drive. The disease destroys their lives."

Using MRE, damaged, or stiff, tissue can be identified, and that's crucial to understanding potential treatments.

"Stiffness is becoming this sensitive measure that's reflecting the cumulative damage or changes to the tissue over time," said Sutton. "We learn a lot about progression and how to stage a patient's treatment based on what the stiffnesses look like. Mechanical properties are a new piece of information that we wouldn't have gotten out of the brain images in the past, so we're really interested in what that means about the status of the tissue and how it's related to other measures that we already get, like blood flow and function."

Graham Huesmann
Molecular and Integrative Physiology

Brad Sutton
Bioengineering

How can we improve treatment for patients with epilepsy?

How can we improve the accuracy of cancer diagnoses?

Diagnostic Precision

Tomasz P. Wrobel
Beckman Postdoctoral Fellow

Chemical changes in tissue provide important information about disease progression, which, in turn, inform diagnosis and treatment. But studying those changes means being able to see them.

Technology developed at Beckman and work being done by **Tomasz P. Wrobel**, a Beckman Postdoctoral Fellow, is advancing that visualization. Together with **Rohit Bhargava**, professor of bioengineering, and **Scott Carney**, professor of electrical engineering, both of the Bioimaging Science and Technology Group, Wrobel is using infrared imaging to obtain information about chemical composition. A machine-learning algorithm uses that information to provide a diagnosis.

This process provides insight into how a disease changes. "Currently, we are looking at cancer," said Wrobel. "Cancer, when it develops, changes not only the morphology of the tissue but also the chemical composition. Thanks to Bhargava, we created a proper model for how much changes throughout the disease. We can say whether its grade 2, grade 3, or grade 4 cancer."

Now, they can also do this work in a spatial matter, explained Wrobel. Previously that involved a spectroscopic approach, where single-point measurement was normally used. With this new technology, Wrobel can create images of chemical composition distribution, which allows the researchers to create a visual margin of error.

This has important implications for the cancer community, especially surgeons.

"It's difficult for a surgeon to determine which tissues are still cancerous," said Wrobel. "Should they take it out or leave it? Our system can measure the tissue and say if it's healthy or not. In certain cases, this can be extremely crucial, especially if you think about brain cancer where every little millimeter removed is important."

Front and Center

How can we tell how molecules, cells, and tissues react to drug treatments? A new industry-supported center located at Beckman has the potential to provide answers.

The GSK Center for Optical Molecular Imaging is a partnership between GlaxoSmithKline and Beckman's Biophotonics Imaging Laboratory. **Stephen Boppart**, professor of electrical and computer engineering, bioengineering, and medicine, and a member of the Bioimaging Science and Technology Group, is the University director of the center, which is initially investigating skin health by developing advanced optical molecular imaging technologies. And that could be just the beginning.

"GSK approached my group a couple of years ago because of its interest in using novel optical techniques and tools to track drugs in the skin," said Boppart, whose lab has developed numerous optical imaging technologies for diagnosing diseases. "One of the big questions with drugs is where do they go and what effect do they have? There really is no regular way of tracking that at the molecular and cellular level in living tissue, especially with new drugs."

Optical molecular imaging could be a game changer, not just for tracking reactions to drug treatments but for diagnosing and treating disease.

"Molecular changes happen very early," said Boppart. "Getting a look at how the molecules are changing earlier will help with treatment."

What might this technology look like in the future? Hopefully, much smaller.

"Someday, we will give handheld units to doctors in the clinic," said Boppart. "So when they apply a drug to a patient, they can track it to make sure enough is there and that the drug is working."

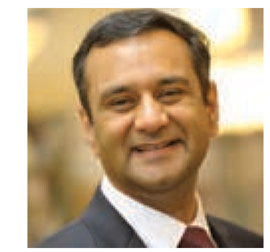
Stephen Boppart
Electrical and Computer Engineering
Bioengineering
Medicine

How can we assess the health of a cell?

How can we advance drug treatments for cancer?

Small Particles, Big Difference

Dipanjan Pan
Bioengineering



Rohit Bhargava
Bioengineering

Nanotechnology has led to a variety of homing, imaging, and therapeutic agents that hold promise for advancing biomedicine, specifically leading to new imaging techniques, targeted and guided therapy, sensing, cellular labeling, bio-separation, and gene therapy.

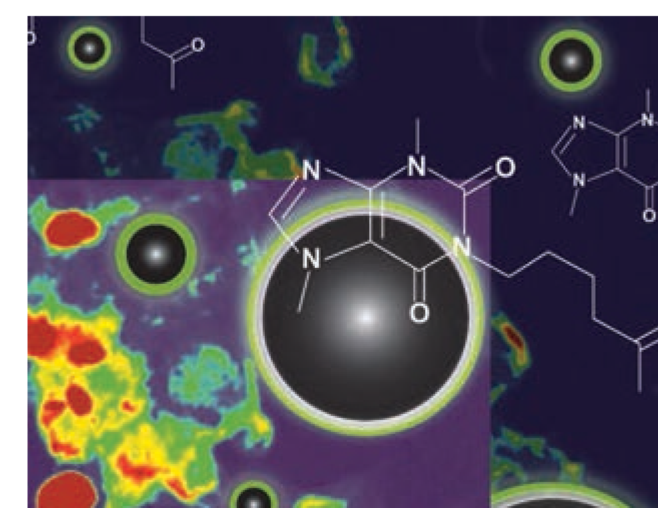
But there are limitations to continued advancement as more multifunctional nanoparticles with increasingly specific functions are designed. That's because adding functionality requires additional steps and costs and creates uncertain effects and unknown regulatory obstacles.

Members of the Bioimaging Science and Technology Group are investigating how to tackle those challenges to enable continued discovery of nanomedicine solutions.

Dipanjan Pan, assistant professor of bioengineering, and **Rohit Bhargava**, professor of bioengineering, are examining how multifunctional nanoparticles can be used beneficially, manufactured in a cost-effective manner, and can meet regulatory standards.

One solution they propose is the design of a next-generation particle that introduces a carefully selected single functional molecule to serve multiple purposes. Their preliminary research with beta-carotene-decorated carbon nanoparticles indicates that these particles can serve multiple functions where cancer cells can be targeted, measured, and regressed.

It's an important step toward advancing cancer treatment and a part of their ongoing work to track nanoparticles once they are internalized within the cell through the use of vibrational spectroscopy and chemical imaging.



CREDIT: PRABUDDHA MUKHERJEE AND DIPANJAN PAN

A look at synchronized tracking of drug and luminescent carbon spheres using vibrational spectroscopy.

Flexing Our Muscle

RESEARCHERS TEAM UP TO STUDY STEM CELLS AND MUSCLE REJUVENATION

You're working hard to stay in shape—it helps your spirit, your body, and your mind. The bad news is that, as you age, your muscles do too. Despite your best intentions, there's no guarantee that you can maintain that hard-earned muscle mass over time. The good news is that Beckman researcher Marni Boppart is on the job, examining why muscle loss occurs and looking for ways to rejuvenate muscle.

"They say that you cannot completely prevent loss of muscle mass and strength over the lifespan, but with resistance training you can reduce the rate of loss," said **Marni Boppart**, associate professor of kinesiology and community health and member of the Bioimaging Science and Technology Group.

An exercise physiologist, Boppart examines the underlying factors for muscle growth and how exercise affects it. She joined the University of Illinois in 2007 and has worked with researchers at the Beckman Institute who have pioneered studies on healthy aging, such as **Art Kramer**, **Ed McAuley**, and **Neal Cohen**.

In the Molecular Muscle Physiology Laboratory, Boppart continues this tradition, taking a look at whether stem cells can regulate muscle loss and growth.

"We have an interest in understanding how muscle responds to exercise and which cellular components contribute to the increase in repair and growth with exercise," she said. "But the primary goal of our lab really is to have some understanding of how we can rejuvenate the aged muscle to prevent the physical disability that occurs with age and to increase quality of life in general as well."

The work couldn't be more timely.

"We are on the brink of an explosion in the population of individuals over the age of 65. Many individuals will lose, on average, the last 15 years of their life to disability, likely in a residential facility. That loss of independence is tough for anyone. But there is a larger societal issue here: How can we care for so many disabled aged individuals? The numbers are unsustainable given the framework for health care that currently exists."

Strong Training

While studying molecular, cellular, and developmental biology as an undergraduate at the University of New Hampshire, Boppart joined the Air Force ROTC and graduated as top cadet and corps commander. Her first position out of college was as an office and aerospace physiologist, where she trained aircrew members about the hazards of the high-altitude environment, including hypoxia and G forces. However, teaching about the core principles of physiology left her with more questions about human performance and resilience to stress.

"While we know that regular physical activity is important to preserve health and prevent disease, we still know very little about the molecular and cellular events that take place in muscle, bone, and the brain that account for these beneficial outcomes."

Her early research during graduate school at Boston University allowed her to work with researchers at Harvard Medical School to identify intracellular signaling pathways activated by exercise in human skeletal muscle. They published the first series of papers that described changes that could occur in muscle in response to exercise.

Boppart's research at Illinois continues to answer questions related to how muscles can decline or improve.

"There are two possibilities: there's this loss of the ability for the myofiber [single muscle cells] to sense stress, but there's also a theory that there are stem cells, stromal stem cells, in the tissue environment outside the fiber that strongly regulate that process of growth," said Boppart.

Doing the Heavy Lifting

Boppart and her colleagues at Illinois have been working on trying to rejuvenate the skeletal muscle of aged mice using the stromal (also known as mesenchymal) stem cells. Early work showed that even the most potent young stem cells became dysfunctional and were ineffective in aged skeletal muscle following transplantation.

How do you exercise stem cells?

However, if the researchers "exercise" the stem cells by mechanically straining them prior to injection, they can preserve cellular function and subsequently improve nerve structure and muscle strength in aged mice.

The cells release various factors —growth, neurotrophic, and immunologic—that can enhance the growth process within the muscle fiber and, once released in the circulatory system, can also impact the brain. Boppart's work with **Justin Rhodes**, professor of psychology and member of the NeuroTech Group, has observed new neuron formation in the brain of aged animals, suggesting links between muscle and higher cognitive function.

Beckman has been the ideal place for Boppart and Rhodes to join forces in their investigations.

"This is the merging of two areas: someone who is an exercise physiologist with the tools to manipulate the muscles and study how exercise affects muscle physiology, and someone who is interested in the effects of exercise on the brain," said Rhodes. "I don't have the tools or knowledge to know how to stimulate or contract the muscles—that's all her area. But she wouldn't have been able to determine what her manipulations are doing in the brain without my contribution, so there's two completely different sort of fields that are merged together to produce work that we couldn't do independently, but something that could have quite a big impact."

Exercise the Options

Both researchers are interested in exploring this concept further.

"So many questions remain," said Boppart. "Which stem cell type is most effective, where should the source be obtained (fat appears to be a popular candidate), how should the cells be handled prior to transplantation, and, of course, what are the potential negative outcomes associated with each?

"I don't believe that stem cell therapy can or ever will replace the benefits of physical activity for achieving optimal health and wellness. But, it will be increasingly important to take advantage of what we learn about the body's response to exercise to help those who can't."

What are the long-term effects of pediatric concussions?

The HCII research theme has a mission that both utilizes and develops advanced technology, while also pursuing a greater understanding of the human side of the human-machine interface. The three research groups comprising HCII include Artificial Intelligence, Human Perception and Performance, and Image Formation and Processing. HCII researchers work in areas as diverse as language acquisition, computer vision and signal processing, human brain function and cognition, robotics, and speech and hearing science and technology.

Human-Computer Intelligent Interaction (HCII)

Thinking Ahead

Charles Hillman
Kinesiology and Community Health

With millions of children in the United States participating in athletic activities, pediatric concussions and their long-term effects continue to be a concern for physicians, parents, and researchers, including Charles Hillman, professor of kinesiology and community health, and R. Davis Moore, who earned his Ph.D. in biobehavioral kinesiology from the University of Illinois.

Their work, published recently in the *International Journal of Psychophysiology*, studied the consequences of such injuries for pre-adolescent children.

"Our data indicate that children who sustain a concussion demonstrate deficits in brain function and cognitive performance approximately two years after injury, relative to others their age who do not have a history of mild traumatic brain injury," said Hillman, of the Human Perception and Performance Group.

The study included 30 8- to 10-year-old children who participated in athletics. Half the children had no history of concussion, and the other half had suffered a sports-related concussion two years prior to the study.

Through cognitive assessments and analysis of brain signals during the cognitive tests, Hillman and Moore found that children with a history of concussion performed worse on tests of working memory, attention, and impulse control. They also found that those who were the youngest when injured had the largest cognitive deficits.

"These data are an important first step toward understanding sustained changes in brain function and cognition that occur following childhood concussion," Hillman said. "Our study suggests the need to find ways to improve cognitive and brain health following a head injury, in an effort to improve lifelong brain health and effective functioning."

Can physical activity reduce chemotherapy-related cognition?

Movement Matters

As more women survive breast cancer, there is more data showing the impact of the chemotherapy treatments they received, including alterations in white matter lesion volume in the brain and deficits in cognitive functioning, such as reduced verbal ability, impaired decision making, and faulty short-term memory. Many survivors deal with these impairments long after treatment ends.

A study by Beckman researchers finds that moderate physical activity may help reduce the treatment-related risks associated with breast cancer.

The research was conducted by Bioimaging Science and Technology Group member **Brad Sutton**, associate professor of bioengineering; Human Perception and Performance Group members **Ed McAuley**, professor of kinesiology and community health, and **Art Kramer**, professor of psychology; and Gillian Cooke, a research development specialist with the Interdisciplinary Health Sciences Initiative at Illinois.

A group of 58 women participated in the study—30 were breast cancer survivors who had surgery, chemotherapy, radiation, or a combination of interventions, and 28 had no cancer diagnosis. Using physical activity trackers, cognitive tests, and MRI scans, the research team measured how physical activity levels impacted memory attention, comprehension, and other cognitive tasks, as well as how it impacted the structure of the brain, specifically white matter. They found that those who were more active had fewer white matter lesions.

"Our novel findings suggest that continued physical activity might be particularly important in breast cancer survivors as brain structure significantly predicted cognitive function via mediation of physical activity," said Kramer. "Continually active lifestyles may help reduce the treatment-related vulnerabilities associated with breast cancer, including reduced white matter integrity and cognitive impairment. Collectively, these findings suggest that physical activity plays an important role in both brain structure and function, warranting further investigation in larger physical activity intervention studies."

Figure of Speech

If you speak English, or any other language prevalent in first-world nations, the automatic speech recognition (ASR) program on your phone will likely be able to understand any question you ask. But for those who speak "low-resource" languages, which account for more than 99 percent of the world's languages, current ASR programs won't help answer your questions.

Preethi Jyothi, a Beckman Postdoctoral Fellow, is looking for ways to tackle that problem so that ASR software can be developed for any language spoken anywhere in the world.

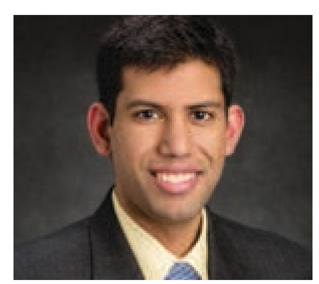
That starts with finding ways to provide large amounts of speech transcriptions—a key component for building ASR software—and to do it well. Jyothi, along with **Mark Hasegawa-Johnson**, professor of electrical and computer engineering and a member of the Artificial Intelligence Group, and **Lav Varshney**, assistant professor of electrical and computer engineering and a member of the Image Formation and Processing Group, have taken on that task.

When a target language is not yet on the Internet, it may be impossible to recruit native speakers as transcribers, therefore Jyothi and her colleagues have created a method called "mismatched crowdsourcing" that taps into the perception of people who don't speak the language. They are investigating how to best select a set of transcribers with different native languages in order to ensure adequate coverage of the sounds of target languages.

A recent transcription project, using mismatched crowdsourcing, has proved promising. It focused on seven languages: Arabic, Cantonese, Dutch, Hungarian, Mandarin, Swahili, and Urdu.

"We were able to get significant improvements on a speech recognition system for the languages," said Jyothi. "The system started with data that was not for that particular language, and then we adapted those systems using these transcriptions."

Preethi Jyothi
Beckman Postdoctoral Fellow



Lav Varshney
Electrical and Computer Engineering

How can we improve speech recognition software?

How can we advance artificial intelligence?

The Image Formation and Processing Group's artificial intelligence algorithms successfully recognize occluded and blurred moving objects from video.

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Winning Ways

Who is better and faster at distinguishing objects—man or machine? While recent advances in computer vision, image processing, and artificial intelligence might give the edge to the machine, it still takes humans to design the machine's programs.

The ImageNet Large Scale Visual Recognition Challenge pits teams of researchers at academic, government, and corporate labs against each other to develop programs to classify and detect objects. The Image Formation and Processing team of Beckman graduate students was the top U.S. finisher and the third-place overall finisher in the video category of the global competition.

Thomas Huang, professor of electrical and computer engineering and a member of the Image Formation and Processing Group, is a founding figure in computer vision and image processing. His graduate students—**Honghui Shi**, **Pooya Khorrami**, **Tom Le Paine**, and **Wei Han**—led the winning effort.

For the competition, teams had to create models to learn to detect objects from approximately 4,000 videos. Since videos tend to include a larger variety of poses, motion blur, and occlusion, it is a challenging task. But the small Beckman team was up to it—and as they continue to refine their work, they are seeing even more accurate results.

"This is an interesting time for artificial intelligence," Le Paine said. "Now we have machine models which can recognize objects in pictures more accurately than humans. This challenge helps drive research throughout the computer vision and artificial intelligence community."

Read Between the Lines

You pick up a book, a magazine, a newspaper and just start reading. You've done it for so long, you don't even have to think about how you do it. It's simple; it's second nature.

But **Brennan Payne**, a Beckman postdoctoral researcher and a member of the Cognitive Neuroscience Group, says reading is actually "amazingly complex."

Studying that complexity is the focus of his research. It began with his collaboration with **Elizabeth Stine-Morrow**, professor of educational psychology and a member of the Human Perception and Performance Group, and it continues with research in the Cognition and Brain Laboratory with **Kara Federmeier**, professor of psychology and a member of the Cognitive Neuroscience Group.

His work focuses on what cognitive factors and mechanisms allow us to read with such perceived ease and what happens when it is no longer easy. Payne measures the mechanisms that support language processing by logging volunteer readers' brain activity, reaction times, memory performance, comprehension, and eye movements.

"What we found is that if we have people listen to a short story and then ask them to recall the gist of this story, the ability to do that after a minor delay declines by about 60 percent from the age of 65 to 95," said Payne. "We want to figure out what causes these declines and if there are pathways available to change these trajectories."

These results led Payne to design a home-based working memory training program that older adults could complete on iPads for the three-week training period for the study, instead of having to come into the lab for tests. The participants read sentences for plausibility, categorized words, and decided if strings of letters were words or not. The iPads stored the results.

At the end of three weeks, memory performance improved from 30 to 100 percent, doubling some participants' memory span. Training also led to improvements in sentence memory and comprehension.

Brennan Payne
Postdoctoral Researcher

How can we stop memory declines in older adults?

What is health literacy?

A Healthy Prescription

BECKMAN RESEARCHERS EXAMINE HOW COMPREHENSION AND MEMORY IMPACT SELF-CARE

Electronic health record portals should make it easy and convenient for patients to view the important information in their medical records. But having access to the information and understanding how to use it are two different things. That's especially true for older adults, whose increased health care needs can coincide with age-related declines in cognitive abilities, such as working memory and attention. It's a reality that motivates Daniel Morrow in his work on health literacy.

"Health literacy is an umbrella term for specific abilities involving comprehension and memory capacity," said **Daniel Morrow**, professor of educational psychology. "As we get older, we're more likely to suffer from chronic illnesses, like diabetes, hypertension, and cardiovascular disease, that require us to monitor symptoms, take blood pressure, or remember medications. At the same time, we're facing processing constraints that come with aging, like less working memory capacity. This can make self-care very challenging."

That certainly could be the case for the one in four adults over 65 years old who take five medications every day. In fact, cognitive decline may be partly responsible for the statistics that indicate that half of those older adults may not be taking their medications correctly, which can reduce the efficacy of their treatment or even threaten their safety.

But there is good news, explained Morrow. "While we find that working memory declines with age, knowledge tends to sustain or increase with age. So the hope is that as you have more experience with your illness, you develop expertise. Knowledge can compensate for the constraints of memory."

Finger on the Pulse

A recent study by Morrow and his collaborators bears this out. Together with **Elizabeth Stine-Morrow**, a professor of educational psychology and member of the Human Perception and Performance Group, Jessie Chin, a former Beckman graduate fellow who earned a Ph.D. in educational psychology, and Elise Duwe, an M.D./Ph.D. student, Morrow assessed 75 older adults as part of a project working on developing a process/knowledge model of health literacy.

First, participants were given a common measure of health literacy that required them to read health-related passages, such as those from a patient consent form. Then, they were given the passages again with words missing and asked to choose from four words to fill in the blank. It may be a simple test, but it is a strong predictor of many health behaviors and outcomes, explained Morrow. They also completed measures of processing capacity, such as working memory capacity and knowledge about language (through vocabulary tests) and about health (specifically, hypertension).

In addition, the 75 participants, all of whom suffered from hypertension, read passages about self-care specific to their illness and then were questioned about what they remembered.

"We found that people who did better on health literacy measures recalled more from the passages," said Morrow. "Moreover, this relationship was explained by the processing capacity and knowledge measures, suggesting that those participants with better health literacy could better remember the passages because their comprehension was supported by higher levels of processing capacity and knowledge. We also found that those with more knowledge had higher levels of recall regardless of their level of processing capacity.

"If you're knowledgeable, you can understand more efficiently even if you don't have the same working memory capacity that you used to. This fits with theories of comprehension and our process/knowledge model, and it helps provide a general framework about how we might help older adults make decisions on ways to ensure the most effective self-care."

Vital Signs

Morrow's current project, which focuses on those patient health care portals, builds on that framework.

"The technology has the potential to revolutionize patient-centered care, providing information that can allow us to be more effective in taking care of ourselves," said Morrow. "But the downside is that the people who would benefit the most don't have the health literacy to use a system that isn't well designed. Unfortunately, that's the case for many electronic medical records systems."

For instance, patients can log in to their portal to retrieve cholesterol test results, but the numbers alone leave many older adults scratching their heads. "Many systems are more of a repository of information rather than a tool to engage patients," he explained. "The goal is to improve the way numerical information is presented to patients in these portals."

How does he plan to do that? The first step is to leverage the abilities that patients do have and use that to improve the messages provided by the portal.

"The most effective way for a patient to understand numerical information is to talk with his or her provider," said Morrow. "Patients really just want to know the bottom line about what their numbers mean—are their numbers increasing or decreasing, what it means for their risk, and what they can do about it. That brings up the question: Can we make the portal a little more like having a conversation?"

The Right Medicine

That's where the second step comes in—engaging the collaborative power of other Beckman researchers. For this project, the team includes **Mark Hasegawa-Johnson**, a professor of electrical and computer engineering and a member of the Artificial Intelligence Group, and **Thomas Huang**, a professor of electrical and computer engineering and a member of the Image Formation and Processing Group. William Schuh, chief medical information officer at Carle Foundation Hospital, is also part of the team.

Together, they're focusing on ways to make the information in the portal more usable—and that means more engaging. The modes range from the simple—a number line that is color coded in red, yellow, or green to indicate risk levels, or emoticons, like smiley or frowning faces, that quickly and easily portray your health status—to the more complex, like a computer agent (or an "avatar" as Huang and Hasegawa-Johnson call it) that is programmed to talk to you about your test results. While it wouldn't substitute for time with a physician, it could provide the kind of conversational experience that promotes comprehension in between visits with a provider.

"What we're doing is trying to emulate in a portal environment some of the dynamics of face-to-face communication," said Morrow. "We're examining what could be the best way to design the computer agent to make it interactive and effective so patients can use it to make good decisions. We're just scratching the surface of this promising idea."

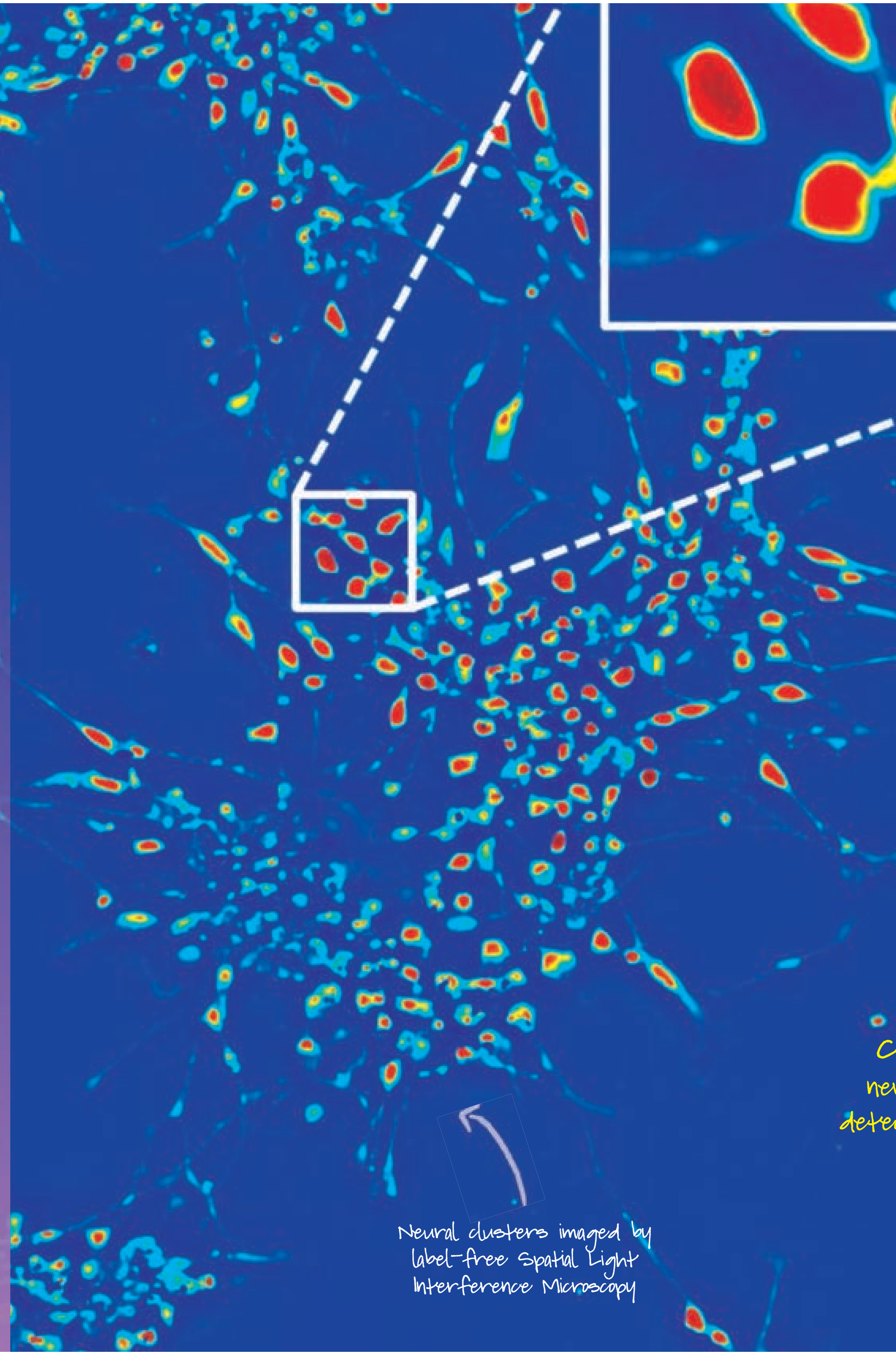
Conversation promotes comprehension.

Biological Intelligence

(BioIntel)

100 µm

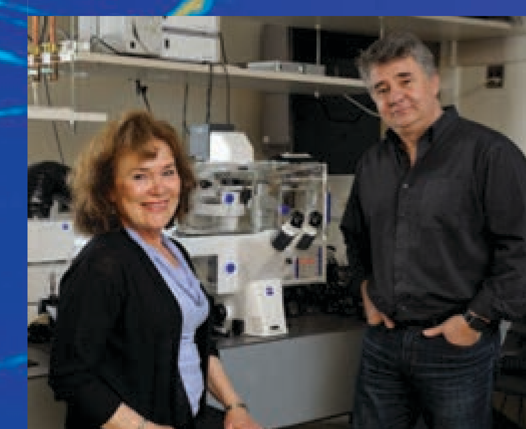
The BioIntel research theme is comprehensive in scope as researchers seek to understand the brain, cognition, and behavior from the molecular and cellular levels to higher expressions of intelligence like memory and attention, and human behavior. The three research groups comprising BioIntel are Cognitive Science, Cognitive Neuroscience, and NeuroTech.



Neural clusters imaged by label-free Spatial Light Interference Microscopy

CREDIT: DR. MUSTAFA MIR, QUANTITATIVE LIGHT IMAGING LABORATORY

Martha Gillette
Cell and Developmental Biology



Gabriel Popescu
Electrical and Computer Engineering

Can we develop a new technology to detect cell activation?

Turn On Neurons

How do you compute how far to throw a baseball or how best to navigate an obstacle course? How do you remember the sound of your mother's voice or the how it feels to walk on a sandy beach? Of course, it's all the work of your brain.

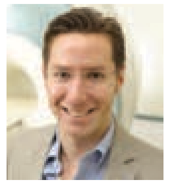
Fast signals in neurons play a central role in intercellular communication. These dynamic changes are the basis of the most simple to the most profound functions of the brain. The signals are generated through ion channels on the plasma membrane, when the membrane potential increases and surpasses the threshold.

This subtle and rapid event occurs in milliseconds, which makes it extremely difficult to detect without an expensive electrophysiology system. These systems also require a highly precise control and are limited to single-point measurements. It is challenging to do wide-field imaging of these cells in action because of the required imaging speed and sensitivity.

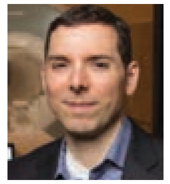
But research being conducted at Beckman is making it easier. Martha Gillette, professor of cell and developmental biology and member of the NeuroTech Group, and Gabriel Popescu, associate professor of electrical and computer engineering and member of the Bioimaging Science and Technology Group, are developing a quantitative phase imaging microscopy system for non-contact measurement of neuronal activation. This technology will be the first label-free, non-contact method for detecting cell activation.

Little is known about the dynamic behavior of fast signals in neurons, but noninvasive technologies like this that allow quantification provide the promise for learning more.

Picture This



Joachim Operskalski
Graduate Student



Aron Barbey
Psychology

Is a pictograph worth a thousand words? When it comes to helping people evaluate their medical risks, it just may be.

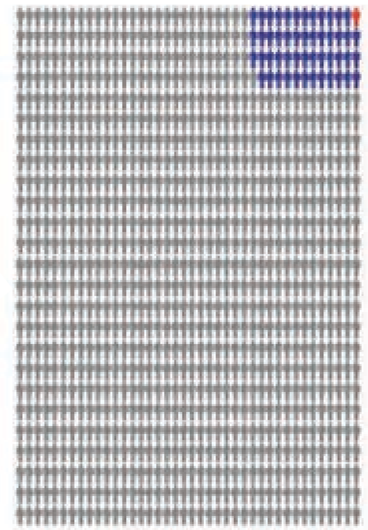
"Decades of psychology research converge on the finding that people have a difficult time thinking clearly about probabilities and percentages, regardless of their educational level or ability to reason about other topics," said **Joachim Operskalski**, a graduate student in the Decision Neuroscience Lab. "In the context of modern medicine, this can have serious consequences when the relative risks of aggressive treatment and more conservative approaches must be weighed against one another."

Research conducted by Operskalski and **Aron Barbey**, associate professor of psychology and a member of the Cognitive Neuroscience Group, explores risk literacy in medical decision making. Their work outlines several steps to communicating effectively about risk by framing it in terms of frequencies rather than probabilities.

They use this example. Imagine you are asked to interpret a positive result on a screening test for a condition that afflicts 0.1 percent of the population. You are told the test is 99 percent sensitive (meaning, it misses the disease 1 percent of the time) and has a 5 percent false-positive rate. Most people judge the chance of the positive result being accurate at somewhere between 95 and 99 percent, which is incorrect. The correct answer becomes apparent, however, when the problem is framed in terms of how often the diagnosis occurs out of a meaningful denominator: 50 people out of 1,000 test positive, but just one person out of 1,000 actually has the disease. Visual representations of conditional probability, as in the pictographic format shown here, facilitate the correct inference even beyond the use of a meaningful denominator.

"By understanding the psychology and neuroscience of uncertainty, we hope to reveal the source of our cognitive limitations while also discovering ways to teach and communicate effectively about matters of risk and uncertainty, so that we can overcome our limitations together," said Operskalski.

Probability is easier to understand when presented visually



How do people evaluate risk when making medical decisions?

PCBs and Brain Development

Susan Schantz
Comparative Biosciences

Renee Sadowski
Beckman Postdoctoral Fellow

Even when an environmental contaminant has been banned, it can continue to have lingering long-term effects on human health.

Renee Sadowski, a Beckman Postdoctoral Fellow, conducts research on how one such toxicant, polychlorinated biphenyls (PCBs), impacts brain development into adulthood. PCBs are found in fish in the Great Lakes and the Fox River in Wisconsin.

"PCBs, even though they were banned in the 1970s, are very persistent," said Sadowski. "They're not easily broken down, so they get in the fat and can stay there for decades. There are certain populations of people who eat a lot of fish and have higher body burden of PCBs."

She explains that her collaborative research with NeuroTech Group members **Susan Schantz**, professor of comparative biosciences, and **Dan Llano**, assistant professor of molecular and integrative physiology, studies how such toxicants may impact the brain development of children whose parents have that higher body burden.

Here's how Sadowski's experiment works. For four weeks before female rats become pregnant and continuing during gestation and lactation, they are fed a solution that mimics the mixture of PCBs in walleye fish from the Fox River. After the pups are grown, they are tested for changes in brain function.

Findings show that when inhibition in the brain is blocked by using a drug, the PCB-exposed rats had greater activation, suggesting an imbalance of inhibition and excitation.

"Activational and inhibitory processes in the adult auditory cortex, a brain area important for hearing function, was disrupted in developmentally PCB-exposed rats," said Sadowski. "These changes may contribute to the increased seizures and impaired hearing that we've seen previously in these animals."

How do chemicals impact brain function?

How can we reduce the impact of emotional challenges?

Driven to Distraction

You're at your kitchen table working on your taxes, when you hear emergency sirens from your open window. How easy is it to get back to calculating your return? How different would your level of distraction be if instead of a fire truck you heard the music from a nearby ice cream truck?

Research conducted by **Alexandru Iordan**, a graduate student in neuroscience, and **Florin Dolcos**, assistant professor of psychology and a member of the Cognitive Neuroscience Group, has investigated how the brain responds to negative and positive distractions during cognitive tasks.

In their study, participants were shown a series of images of people's faces and were asked to hold them in mind for a few seconds. After a short delay, they were asked to indicate if they had seen specific faces or not. During the delay, the participants were shown a mixture of negative, positive, and neutral pictures; the negative and positive pictures were selected to elicit similarly intense responses. Using the fMRI technology at the Biomedical Imaging Center, the researchers recorded brain responses to evaluate which parts of the brain were activated when the distracting images were shown.

Dolcos and Iordan found that both positive and negative pictures affected the brain, but positive distractions were linked to increased performance compared to negative distraction.

"The main result is that the positive distractions do not interfere with working memory performance," said Iordan. "In fact, they actually help compared to the negative distractions, even though they may produce equally intense emotional responses."

Why is this true? "Positive stimuli are usually less imperative than the negative ones, because the immediate costs of not paying attention to them are typically smaller," said Dolcos. "One may be able to survive longer without food, but will have to respond quickly in the face of imminent danger." Consistent with this idea, the study also found that positive distracters interfered less with activity in brain regions involved in working memory and actually increased activity in brain areas associated with emotion control.

It's work like this from Beckman researchers that has implications for understanding clinical conditions and improving emotional health.

Alexandru Iordan
Graduate Student

Florin Dolcos
Psychology

Communication Connections

Diane Beck
Psychology

How do different areas of the brain communicate with each other?

Diane Beck, **Monica Fabiani**, and **Gabriele Gratton**, all professors of psychology and members of the Cognitive Neuroscience Group, are collaborating with researchers across the country and the world to discover answers to that question. Together with former Beckman Postdoctoral Fellow Nate Parks, now a faculty member at the University of Arkansas, and Evelina Tapia, now a lead user experience researcher at ChaiOne, as well as Chiara Mazzi and Silvia Savazzi, research associates at the University of Verona, and Mazzi and Savazzi's former colleague **Ramisha Knight**, now a Beckman postdoctoral research associate, the team is using a new approach to determine how signals in one area of the brain move to other areas.

In their most recent collaboration, they used transcranial magnetic stimulation (TMS) to stimulate the posterior parietal cortex and then used event-related optical signal (EROS) technology to record brain activity. EROS, which was invented by Gratton and Fabiani, can pinpoint activity in the brain within millimeters and milliseconds. The combination of these methods allows investigators to ascertain that excitation of one part of the brain causes activity a few milliseconds later in another part of the brain, an indication that these areas are functionally connected.

What their team discovered is that there is in fact a connection of this type between activity in the parietal cortex, which is related to directing attention to particular stimuli, and activity in the visual cortex, which processes visual information. And the connection is quick—it happens in just 20 to 40 milliseconds, said Gratton.

While others have speculated that this is true, the group's groundbreaking work using TMS and EROS provides evidence of the causal nature of this connectivity.

"This is promising because it allows us to see the brain as a network that communicates," said Fabiani. "It's a tool that can provide information about how the communication occurs and about the dimensions of wiring and timing that can help us make maps of connectivity across larger areas of the brain. There's a lot of exciting work ahead of us."

Are areas of the brain functionally connected?

Strong Language

RESEARCH PROVIDES INSIGHTS INTO HOW CHILDREN ASSIGN MEANING TO WORDS AND SENTENCES

While most two-year-olds can recognize a range of nouns, such as the words that identify their parents, their siblings, and their favorite toys or foods, you certainly wouldn't expect them to be able to grasp more advanced grammar—especially concepts like transitive and intransitive verbs. But Cynthia Fisher's research gives us reason to rethink that assumption.

What is syntactic bootstrapping?

Her work focuses on language acquisition, specifically how very young children interpret words and sentences. While conventional wisdom says that knowing the meaning of each word is central to that task, **Cynthia Fisher** says sentence structure, or syntax, plays a primary role as well—even for those as young as 15 months old.

"The language we learn is not just words but a formal system of combining the finite set of words or expressions for our own purposes as a way to say new things," said Fisher, professor of psychology and linguistics, and a member of the Cognitive Science Group. "It's the grammar that allows us to make new combinations and figure out an unlimited set of sentences."

"One of the questions I'm most interested in is: 'How is it possible that the structures of sentences affect how very young children interpret their meaning even before they have learned much about the grammar of their language?'"

Syntax Facts

The answer to that question begins with an understanding of "syntactic bootstrapping," the theory that young learners use their preliminary knowledge of syntax to infer the meaning of words. This idea was developed in 1985 by Lila Gleitman, Fisher's graduate advisor at the University of Pennsylvania, and has informed Fisher's work since she wrote her dissertation.

The idea is that once toddlers know a handful of nouns, like "Mommy," "baby," and "cup," for instance, "they have a tiny bit of structure that can be used as building blocks for more structure," said Fisher. "A simple set of nouns is sufficient to learn new things about the language," such as identifying verbs.

"To study the learners' sensitivity to syntax, we use invented verbs, like 'pilking' or 'kradding,'" said Fisher. "Simple syntactic cues, like how many nouns occur in the sentence, help babies determine meaning. A sentence with two nouns, for instance, tells the learner that the sentence's meaning involves two participants."

Use invented verbs.

Some Words About Verbs

How does Fisher test the theory when the children are too young to express their knowledge in speech?

She explains it this way. "Imagine a 16-month-old is sitting in front of a television with two video 'windows.' One video shows a two-participant event, such as a box, bumping another box along. The other shows the action of one participant, perhaps a ball jumping up and down. While watching these two events, the child hears an invented verb—either transitive, with a direct object, like 'Mommy is pilking the baby,' or intransitive, without a direct object, like 'Mommy is pilking.' We videotape the kids and track their eye gaze, coding which video they're looking at. What we find is that the children who hear the transitive verb look longer at the two-participant event than the kids who hear the intransitive verb do."

A Beckman collaboration is advancing this work on "baby knowledge of syntax." **Dan Roth**, professor of computer science and a member of the Artificial Intelligence Group, is a pioneer in the use of advanced machine learning methods in natural language processing. With current postdoctoral research associate Christos Christodoulopoulos, Roth and Fisher have developed a computational model that allows for further experimentation as well as refinement of the syntactic bootstrapping theory.

The model, called BabySRL (SRL for Semantic Role Labeling), verifies that it is possible for very young children to begin learning sentence-level semantics, and to identify verbs, once they can identify a small number of nouns.

Future work with the model will test how the theory can be extended to more complex sentence structures.

Fisher's expertise in language acquisition and infant cognition has also added to other Beckman collaborations, including research being conducted by psychology professors **Gabriele Gratton** and **Monica Fabiani** of the Cognitive Neuroscience Group. The team is exploring how a technology that Gratton and Fabiani have developed for studying brain function, the event-related optical signal (EROS) technology, can be used to measure the brain activity of infants during learning tasks.

Making Sense of Sentences

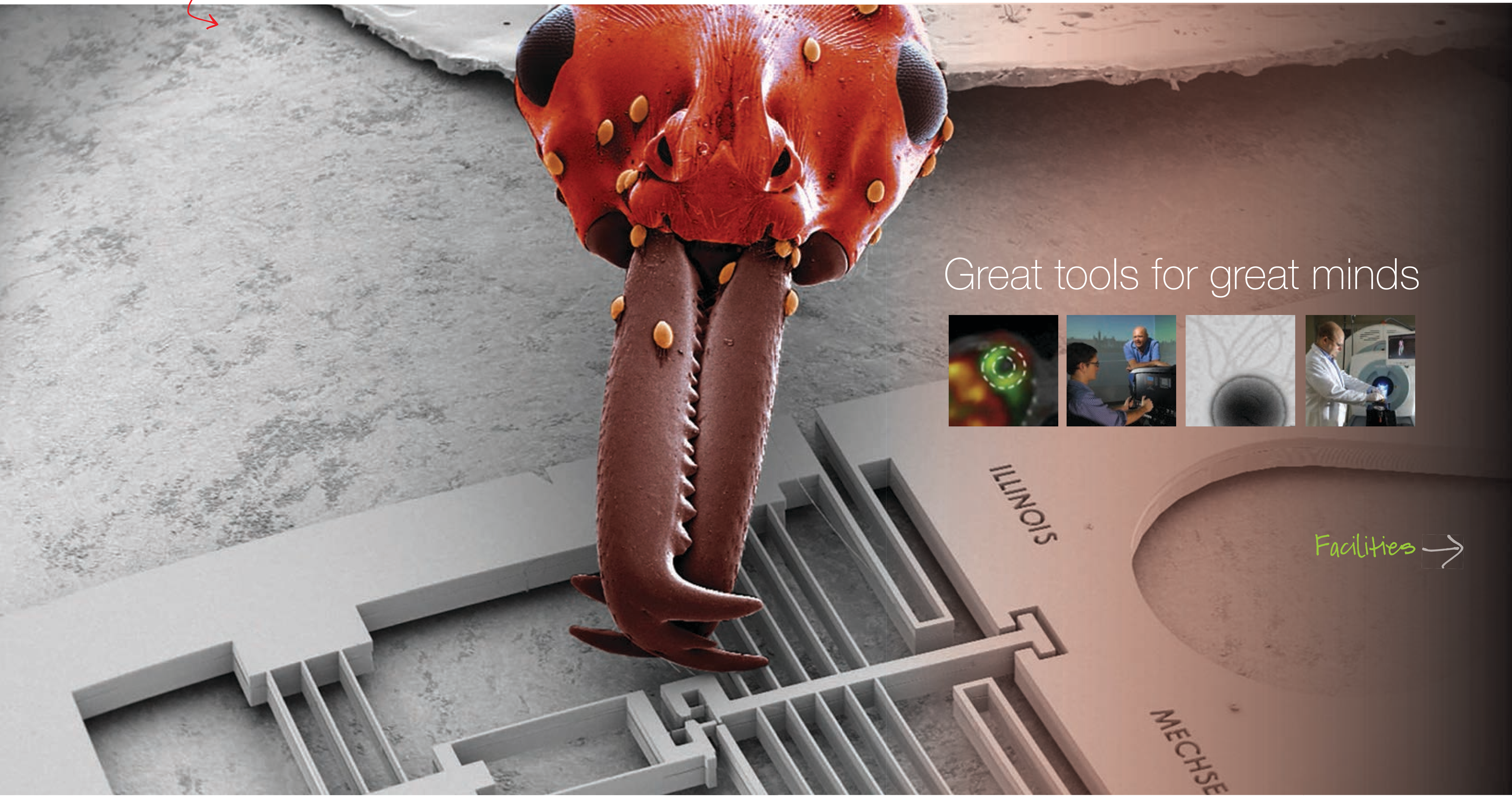
Collaborations beyond Beckman involve whether the theory of syntactic bootstrapping applies best to English or holds up equally well in other languages. Kyong-sun Jin, who earned a Ph.D. in psychology from Illinois, is examining that question in her research as a postdoctoral fellow at Yonsei University.

Fisher says Korean is an excellent choice for testing the theory because it is one of several languages in which speakers can drop nouns from sentences. Results from the same methods of video testing and eye-gaze monitoring used in Fisher's lab in the United States indicate that "despite the many differences between languages, there are more similarities in the kinds of information that input sentences provide than you might expect," said Fisher.

Whatever the language, the research continues to provide insights into how children assign meaning to words and sentences.

"It's an exciting notion that the structure of sentences can be intrinsically meaningful to young children, helping to push them into new interpretations and new learning about the grammar," said Fisher. "There is a relationship between structure and meaning, and that's something that even very young children can discover."

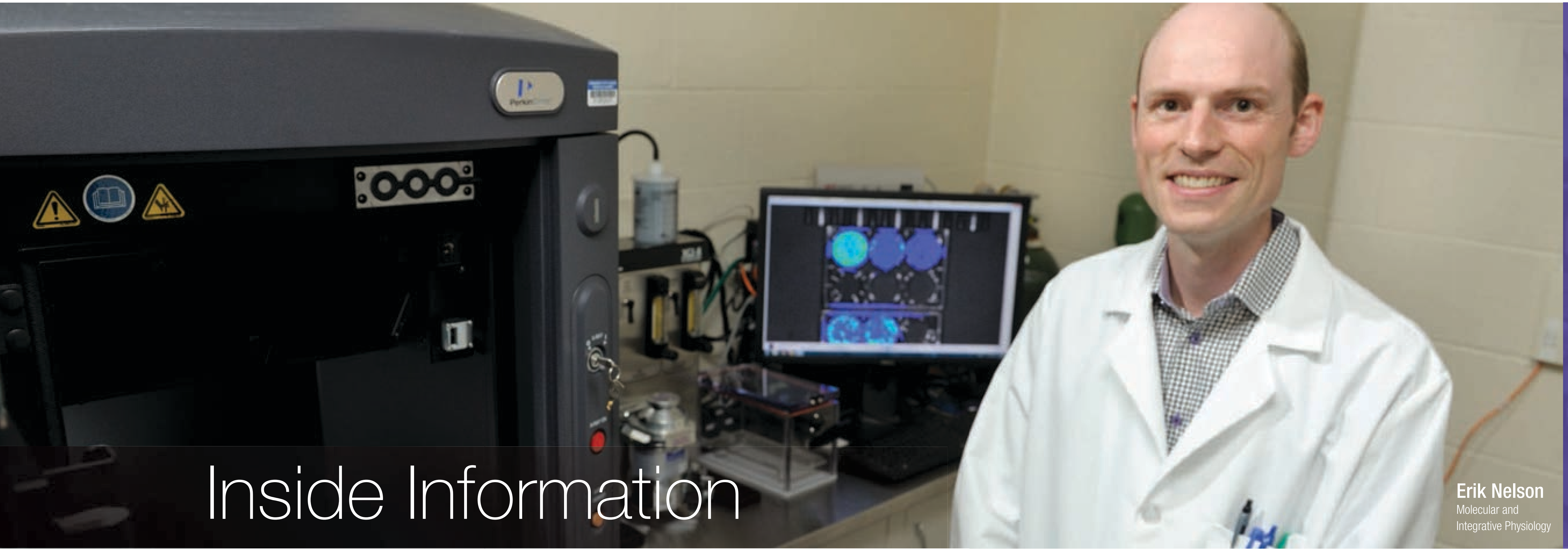
Using an environmental scanning microscope in the Microscopy Suite, Mohamed Elhebeary, a graduate student in mechanical science and engineering, was able to photograph micromachines built in his lab.



Great tools for great minds

Facilities →

CREDIT: THIS IMAGE, TAKEN BY MOHAMED ELHEBEARY, WON THIRD PLACE IN THE IMAGE OF RESEARCH CONTEST SPONSORED BY THE GRADUATE COLLEGE AT THE UNIVERSITY OF ILLINOIS.



Inside Information

Erik Nelson
Molecular and Integrative Physiology

What labs are within BIC?

Magnetic Resonance Imaging
Ultrasound Imaging
Molecular Imaging

What equipment can you find at BIC?

3 Tesla MRI scanners
Varian 600 MHz small-bore scanner
MicroPET/SPECT/CT scanner
PerkinElmer IVIS Spectrum CT live-animal imaging system
Visual Sonics Vevo 2100 scanner
Siemens Antares system

BIOMEDICAL IMAGING CENTER PROVIDES A TOOL THAT IMAGES SMALL ANIMALS IN REAL-TIME

You know that high cholesterol levels can cause problems in your arteries, leading to heart disease, a heart attack, or a stroke. But are you aware of other effects of cholesterol, including impact on tumor progression in certain cancers?

Using a new tool in the Molecular Imaging Laboratory (MIL), Erik Nelson, assistant professor of molecular and integrative physiology, studies how cholesterol affects tumor progression in breast cancer.

"There's pretty strong clinical data showing that breast cancer patients who have either elevated circulating levels of cholesterol in their diet or elevated circulating levels of cholesterol have a poor prognosis for the progression of the disease," said Nelson. "Cholesterol can also be a risk factor for the onset of disease."

The MIL, part of the Biomedical Imaging Center at Beckman, recently acquired a PerkinElmer IVIS Spectrum CT live-animal imaging system. Collective cross-campus contributions from the Office of the Vice-Chancellor for Research, Beckman Institute, several colleges, departments, and individual principal investigators made the purchase possible. The IVIS system is the only *in vivo* small animal dedicated imaging system on the market that supports both 3D optical and x-ray computed tomography (CT), which allows for both functional and anatomical imaging.

"This is an imaging machine that allows you to detect bioluminescence or fluorescence, and the real advantage of it is you can image small animals while they are still alive, in real-time, and you can image luminescence or fluorescence throughout their entire body," explained Nelson. "It's a really good way of tracking, in my field for example, whether your cancer is growing, or whether it's spreading to different organs."

On Track

Nelson is studying how statins, drugs that limit the production of cholesterol, such as Lipitor or Crestor, can be used as either a treatment or as a way to prevent cancer metastasis. His research is funded by the National Cancer Institute.

"A machine like the IVIS is great because otherwise we'd have no way to track our cells or track how fast the cells are growing until necropsy [after the animals are humanely euthanized]," said Nelson. "The only alternative to the IVIS is basically to do terminal assays, and that makes it impossible to track the same tumor growth through time."

The IVIS allows the researchers to examine the cells as they grow and spread. Using the CT scanner on top of the IVIS scan provides for a 3D image, which can give more detail as to the exact location of the cancer cells.

"For a lot of my work, we're looking at metastasis to the bone, so we can see exactly if these cancer cells are on top or inside the bone," said Nelson.

Multipurpose System

The IVIS system complements other non-invasive *in vivo* imaging tools within MIL such as positron emission tomography (PET) and single photon emission computed tomography (SPECT) scanners.

"The IVIS provides our users with an outstanding imaging tool using integrated optical and X-ray microCT technology," said Iwona Dobrucka, senior research scientist. "Not only can we detect fluorescence and bioluminescence with an excellent sensitivity, but we can also use x-ray imaging in order to locate optical signals in relation to animal anatomy. Through interfacing the IVIS system with existing nuclear imaging scanners such as PET and SPECT, we became a unique, highly specialized facility, which allows for multimodal noninvasive monitoring of living organisms. Such multipurpose systems are in use only in the best cancer research facilities, so we're glad that we can provide this service to our users."

BIC traces its heritage to the Biomedical Magnetic Resonance Laboratory founded in 1985 by Paul Lauterbur, who won the Nobel Prize in Medicine in 2003 for his discoveries in magnetic resonance, which led to the development of modern MRI.

Running Start

Ivy Hernandez
Undergraduate Researcher

What are the capabilities of the Microscopy Suite?

- Live-cell microscopy
- Micro-, bio-micro-, and nano-x-ray-CT
- White light/laser fluorescence microscopy
- Scanned probe microscopy
- Electron microscopy
- Sample preparation
- Other analytical instrumentation

CAN EXERCISE REPAIR DAMAGE DONE BY EARLY EXPOSURE TO ALCOHOL?

In the third trimester of a pregnancy, prenatal alcohol exposure can hinder brain development greatly. The influence of this exposure is known to be long term, and possibly detrimental to brain function as an adult. Using tools in the Microscopy Suite, researchers have been analyzing these developmental complications.

Gillian Hamilton, Beckman Postdoctoral Fellow, is leading a project studying these impacts and whether exercise can ameliorate the long-term damage usually associated with alcohol exposure early in life.

Justin Rhodes, associate professor of psychology and a member of the NeuroTech Group, oversees the project with Hamilton. Ivy Hernandez, an undergraduate researcher in the lab, is using tools in the Microscopy Suite to analyze the results.

"We know that high doses of alcohol during pregnancy cause long-term damage," said Rhodes. "This experiment is trying to see if exercise could recover some of the known damage."

Using an animal model, the researchers compared brain development with early alcohol exposure to brain development in a control group. Half of the subjects within each of the two groups were introduced to voluntary aerobic exercise in the form of running wheels and half were not.

The experiment allowed the researchers to measure how aerobic exercise may be used as a preventative method for fetal alcohol-related disorders.

Different behavioral tests were used to analyze motor coordination, memory, and higher cognitive functioning. These tests target brain functions such as working memory, behavioral inhibition, and learning retention.

Seeing Cells

Using the stereology workstation in the Microscopy Suite, researchers can examine the brain tissue and see the cells affected by alcohol exposure early on. Hamilton's team, which is specifically examining the cerebellum and prefrontal cortex because those areas are known to be sensitive to alcohol exposure in the early stages of development, is able to look at these cells and quantify the effects of exercise on them.

The stereology workstation, which includes the StereoInvestigator and Neurolucida, is almost exclusively used for studies in neuroscience.

"The most frequently used version of the StereoInvestigator software superimposes randomly positioned counting frames on the region of the brain under study," said Scott Robinson, manager of the Microscopy Suite.

"With the StereoInvestigator, we're able to zoom in and count the cells," said Hernandez. "It allows us to measure the thickness and the overall volume of the tissue."

Ease and Accuracy

Though Rhodes and Hamilton designed the project, Hernandez is involved in the entire process.

"When I first started using the microscope, the Microscopy Suite staff was very hands on, showing me how to do the analysis and use the software," said Hernandez. "[The microscope] is easy to handle, you just have to learn all the techniques and tools. You can really see the tissue clearly, and it really diminishes the work you have to do."

Being able to correctly analyze the tissue provides more accurate results for the project. Specifically, it allows the group to collect unbiased estimates of total number of cells and total volume of specific brain regions of interest.

Rhodes and Hamilton hope to continue their research in this area. "Another really interesting question is about the dangers of moderate levels of drinking during pregnancy," said Rhodes. They will continue looking at developmental changes related to moderate drinking behavior in the future.

The Microscopy Suite and the Visualization Laboratory (featured on the following page) are part of the Imaging Technology Group, which offers a wide array of microscopy- and spectroscopy-related instrumentation and sophisticated image-processing capabilities, including comprehensive graphics assistance, for scientific research. Professional staff train and assist users, and trained users then have access to the Imaging Technology Group facilities 24 hours a day, seven days a week. In a given year, the Imaging Technology Group will serve hundreds of students, faculty, and staff from 68 departments across the University of Illinois campus, in addition to researchers from industry and from other universities across the world.

What's next? How does moderate drinking during pregnancy impact developmental changes in offspring?

Iwona Jasiuk
Mechanical Science and Engineering

Martin Ostoja-Starzewski
Mechanical Science and Engineering

Visualizing Success

What services does the Visualization Lab provide?

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

DISCOVERIES OF MATERIAL IMPORTANCE ARE EXPLORED IN THE VISUALIZATION LABORATORY

An aircraft must be able to withstand lightning strikes, and metals used in the outer body of a plane provide that protection. But what if there were more lightweight materials that could dissipate the electric charge of lightning the way their metal counterparts can? The fuel efficiency, extended flight range, and other benefits associated with lighter materials could be a boon for the aerospace industry.

Researchers at Beckman are examining the potential of polymer composites to be that lightweight solution. And state-of-the-art tools in Beckman's Visualization Lab (Vis Lab) are aiding them in that work.

Martin Ostoja-Starzewski, professor of mechanical science and engineering and a member of the Bioimaging Science and Technology Group, and Pouyan Karimi, a Ph.D. student in mechanical science and engineering, are leading this research. **Iwona Jasiuk**, professor of mechanical science and engineering and a member of the 3D Micro- and Nanosystems Group, is a collaborator on the project. She explained that the development of such polymers begins by infusing them with conductive materials and then testing their shielding effectiveness—that is, performing simulations to determine the material's ability to disperse electromagnetic waves.

Jasiuk said the Vis Lab's resources, including 3D scanning, 3D modeling, and scientific visualization, have informed their work. The graphics, animation, and video production services available at the Vis Lab have helped bring that work to life.

This research on shielding effectiveness is part of the work undertaken by the Center for Novel High Voltage-High Temperature Materials and Structures, an initiative of the Industry/University Cooperative Research Centers Program (I/UCRC). This partnership, supported by the National Science Foundation, focuses on enabling industrially relevant, pre-competitive research. Jasiuk is the University of Illinois site director for this partnership.

"My research involves characterization of materials, both biological materials, such as bone, and synthetic materials, such as ceramics, metals, polymers, and composites," said Jasiuk. "Several of our projects require high-computational resources and software, which the Vis Lab provides."

Material Impact

One of those projects, led by graduate research assistant Diab Abueidda, involves the examination of novel foam geometries, where corners have been mathematically architected to be smooth. Jasiuk explained that "the software in the Vis Lab allows us to model the material so changes can be made to improve its mechanical and electrical properties."

Another project being done for the I/UCRC focuses on the manufacturing of novel polymer and nanocomposite foams to create more lightweight, absorbent, and attractive materials. Potential future applications could include insulation or impact protection, for instance, as materials that provide reinforcement in car doors. The idea for the new material is to start with a polymer and use a novel technique to create a foam. The Vis Lab assists in the development of the material by providing tools that allow Jasiuk and collaborator Mete Bakir, a graduate student in mechanical science and engineering, to visualize the foams and determine how processing affects their structure, pore size, and porosity.

And Jasiuk's work on developing materials that have high resistance to impact doesn't stop there. Her research with Srikanth Raviprasad, a graduate student in aerospace engineering, has a biological inspiration. "As we look for ways to protect infrastructure, such as transformers, from harm, we can look at examples from nature, like turtle shells, that provide good impact-resistance properties," said Jasiuk. "With that inspiration, we are currently designing materials and doing computation using the Vis Lab. This fall we will be doing experiments to validate our computations."

Bone Health

In addition to her work with synthetic materials, Jasiuk and her collaborators, Fereshteh Sabet and Siyuan Pang, both Ph.D. students in mechanical science and engineering, study biological materials. Their two current projects focus on bone.

Sabet is examining the elastic response of trabecular bone, the spongy tissue at the end of long bones that absorbs impact. She uses the technology at the Vis Lab to get precise 3D models of the animal bone. The digital image correlation capabilities available allow her to assemble and record new positions. By understanding the mechanical problems of trabecular bone, predictions can be made about whole bone, which can be especially relevant to the wrist and hip fractures associated with osteoporosis.

Pang's research focuses on the second type of bone tissue, cortical bone. Her goal is to understand bone fractures by measuring acoustic signal emissions. Information obtained through this work provides data on how age influences the structure of bone. Again, the Vis Lab is instrumental in supporting such work, explained Jasiuk.

"The resources provided by the Vis Lab has great value in moving our work forward," she said. "We're fortunate to have access to these kinds of tools for the research itself. Plus, there are additional resources, like graphics services, that provide the professional images we need for publishing our work, so others can learn from it and build on it."

Taking Off

Naira Hovakimyan
Mechanical Science and Engineering

What technology does the Illinois Simulator Laboratory provide?

CAVE
Flight simulator
Driving simulator
Motion capture suite
Cube
ImmersaDesks

ILLINOIS SIMULATOR LAB CONDUCTS RESEARCH ON A HIGHER PLANE

Self-driving automobiles are, according to some, the wave of the future. But recent accidents have ignited the debate over the safety of the automated control system in the vehicle.

Of course, cars are the not the only mode of transportation that can rely on automated controls. Researchers at the Beckman Institute have been using the flight simulator at the Illinois Simulator Laboratory (ISL) to examine automated control systems on airplanes.

Since 2009, **Alex Kirlik**, professor of computer science, and **Naira Hovakimyan**, professor of mechanical science and engineering, have been working on automation control and human situation awareness. Both Kirlik and Hovakimyan are members of the Human Perception and Performance Group and have been using the flight simulator at the ISL to conduct their research.

Their project, Engineering Safety-Critical Cyber-Physical-Human Systems, involves creating novel techniques for coupling humans with automated control systems. Collaborators on this work include Lui Sha, professor of computer science, and Carolyn Beck, associate professor of industrial and systems engineering.

The goal of the project is to exceed the previous levels of safety achieved solely by skilled human operators or by autonomous systems alone. The group is considering how human interaction is impacted by the systems and the best way to weave human skills and computers together to provide the highest level of safety.

According to Kirlik, the automation and human interaction need to go hand-in-hand.

"We'd like to identify how we can leverage the human strengths to compensate for the automation's deficiencies and automation strengths for human deficiencies," he said. "Many methods for automated control systems in cars or planes take the human out of the loop. In flight control automation, pilots need to be involved to avoid distraction and to maintain situation awareness."

Flight Control

At the ISL, Kirlik and Hovakimyan can observe how actual pilots deal with failure and how automation and human interaction work together to provide flight control.

"In our first round of experimentation, we used pilots that were flight instructors," said Kirlik. The aircraft used in the flight simulator is similar to a 767, and the pilots who usually fly those planes are very senior pilots. Throughout different testing stages, their team utilized 18 pilots in central Illinois to test using the tools in the ISL.

Kirlik and his team programmed scenarios into the simulator to best assess how their test pilots use the simulation interface.

"We created challenging and surprising scenarios for the flight crews to stress test them," said Kirlik.

Some of the biggest challenges pilots face because of automation include loss of situation awareness, skill decline, and the ability to jump back into the control loop when necessary. To combat these, the pilot needs to understand what the automation is doing.

!

"The engineers and programmers of the ISL develop these systems to become reconfigurable research environments for individual sponsored projects or basic research," said Hank Kaczmarski, director of the ISL.

Safety is an essential part of flight control technology, and the flight simulator provides a way to safely test these applications.

"The ISL has written specific software for generating potential real-world scenarios and gathering biometric data from subjects tested in the simulator, so researchers can test novel assumptions related to the challenges of increasingly complex human-computer interactions with real-world flight and driving interfaces before those challenges lead to fatalities," said Kaczmarski.

Piloting New Displays

The researchers have created new types of displays and visualizations that will allow a pilot to understand and see the behavior of the automated controls, preparing him or her to aid in flight control if needed.

"We started developing an additional display that could guide the pilot on safety envelopes, so that the pilot would be fully informed of the autopilot's actions in taking care of failures," said Hovakimyan.

Communication is essential between the automation control and the pilot control.

"In any type of relationship between two agents, coordination is improved with better communication," Kirlik said. "We're trying to reveal more of the automation's behavior and even its rationale for what it's doing and communicate that to the pilot who's trying to be a team player with the automation now, rather than going to sleep and hoping that nothing goes wrong."

By repurposing the automation to keep the pilot in the loop, the pilot's control panels can display all the actions that the automated system is performing, rather than alerting the pilot to take over during a control failure situation.

As the pilot is given the ability to oversee and direct the automation's hardware and software, an additional layer of safety will lead to better aircraft control and situation awareness.

Hovakimyan and Kirlik hope to see their research applied to other disciplines.

"We intend to continue to work to modify our approach based on empirical lessons learned, said Kirlik, who presented at the recent Coalition for National Science Funding Exhibition in Washington, D.C "The impact we hope is beyond airplanes. It could be robotic surgery, highways and cars, that type of thing."

Applications beyond flight?

By the numbers

(administrative and support staff)

On any given day you'll find many of our 1426 personnel collaborating in the spacious Beckman atrium—a place where great minds meet.

237 faculty members

49 visiting scholars

46 administrative staff members

340 undergrads

498 graduate students

1426 personnel in total

78 postdoctoral research associates

16 Beckman Institute Postdoctoral Fellows

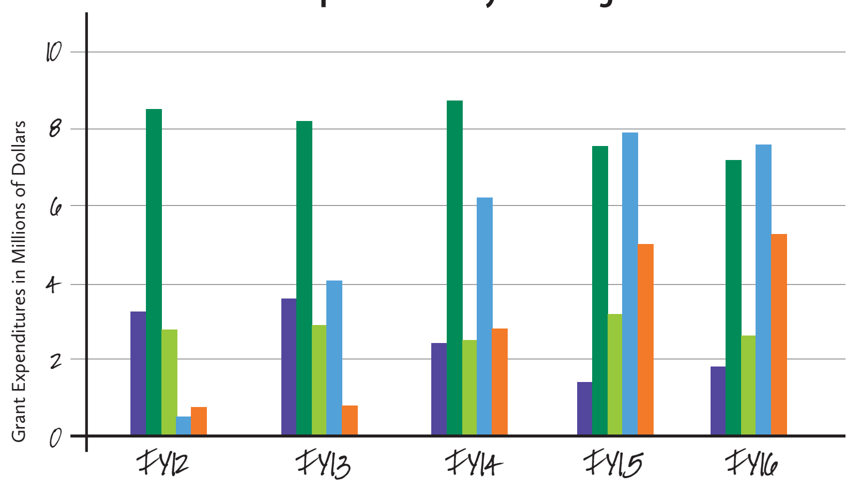
6 Beckman Institute Graduate Fellows

22 research staff members in Beckman facilities

134 research staff members in research themes

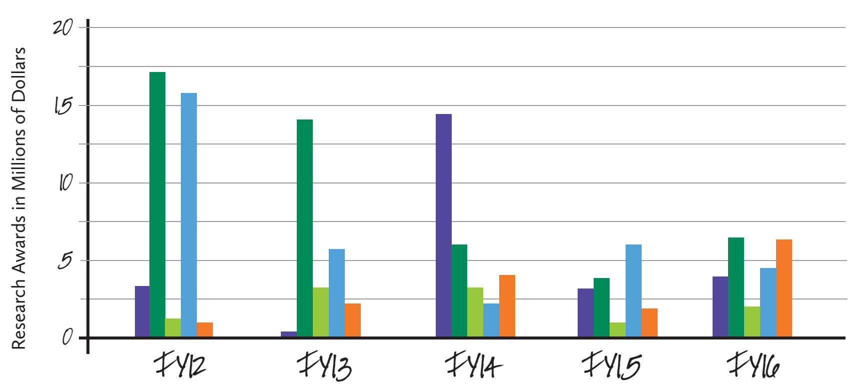
Awards and Expenditures

Grant Expenditures by Funding Source[1]



	FY12	FY13	FY14	FY15	FY16
DOD	$3,200,338	$3,426,205	$2,328,861	$1,490,392	$1,976,766
NIH	$8,665,427	$8,208,039	$8,718,725	$7,486,994	$7,172,547
NSF	$2,482,559	$2,565,483	$2,398,696	$2,794,666	$2,425,976
Abbott[2]	$484,248	$4,183,296	$6,249,854	$7,990,755	$7,595,835
Other	$575,790	$690,399	$2,839,996	$5,190,458	$5,367,047
Total	**$15,408,362**	**$19,073,422**	**$22,536,132**	**$24,953,265**	**$24,538,172**

Research Awards by Funding Source[3]



	FY12	FY13	FY14	FY15	FY16
DOD	$3,107,121	$2,317	$14,374,896	$2,909,566	$4,115,529
NIH	$17,245,588	$14,121,116	$5,798,307	$3,442,188	$6,035,109
NSF	$876,173	$3,507,298	$3,012,333	$983,154	$1,970,753
Abbott[2]	$15,246,982	$5,272,426	$2,381,765	$6,201,220	$4,237,195
Other	$757,369	$2,324,885	$4,112,721	$1,632,833	$6,440,233
Total	**$37,233,233**	**$25,228,042**	**$29,680,022**	**$15,168,961**	**$22,798,819**

DOD Department of Defense
NIH National Institutes of Health
NSF National Science Foundation
Abbott Abbott Nutrition

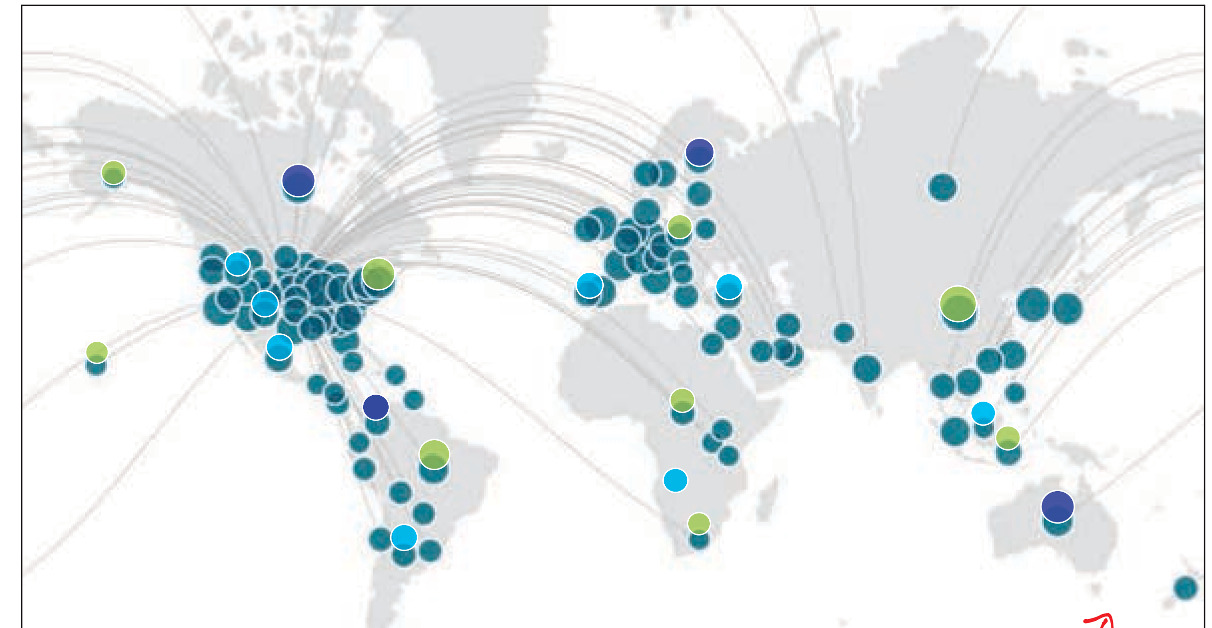
[1] In addition to those sources itemized in the chart, funding for the Beckman Institute is received from the following sources:
a) The state of Illinois to the University of Illinois and allocated through individual departments: Faculty Salaries
b) The state of Illinois to the Beckman Institute: Administration 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 multi-year 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.

Global Impact

Beckman Collaborations—Beyond the Institute

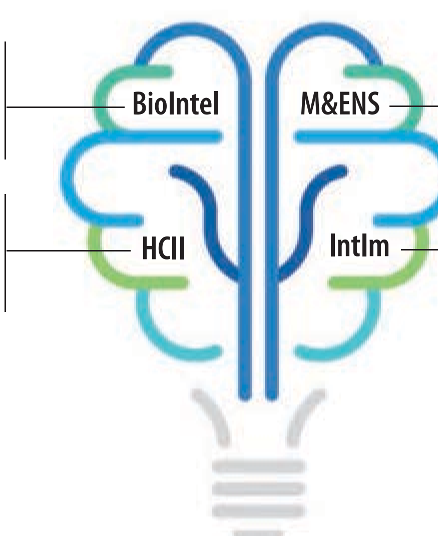


Credit: © 2016 Elsevier B.V. (modified)

Beckman collaborations reach across the world.

Impact on the field

Patents, Publications, and Grants FY2016



BioIntel
Patents issued: **1**
Patents pending: **1**
Publications: **159**
10 Grants: **$5,067,438**

M&ENS
Patents issued: **6**
Patents pending: **14**
Publications: **437**
6 Grants: **$5,014,766**

HCII
Patents issued: **1**
Patents pending: **2**
Publications: **152**
7 Grants: **$2,691,126**

IntIm
Patents issued: **5**
Patents pending: **9**
Publications: **268**
11 Grants: **$9,628,479**