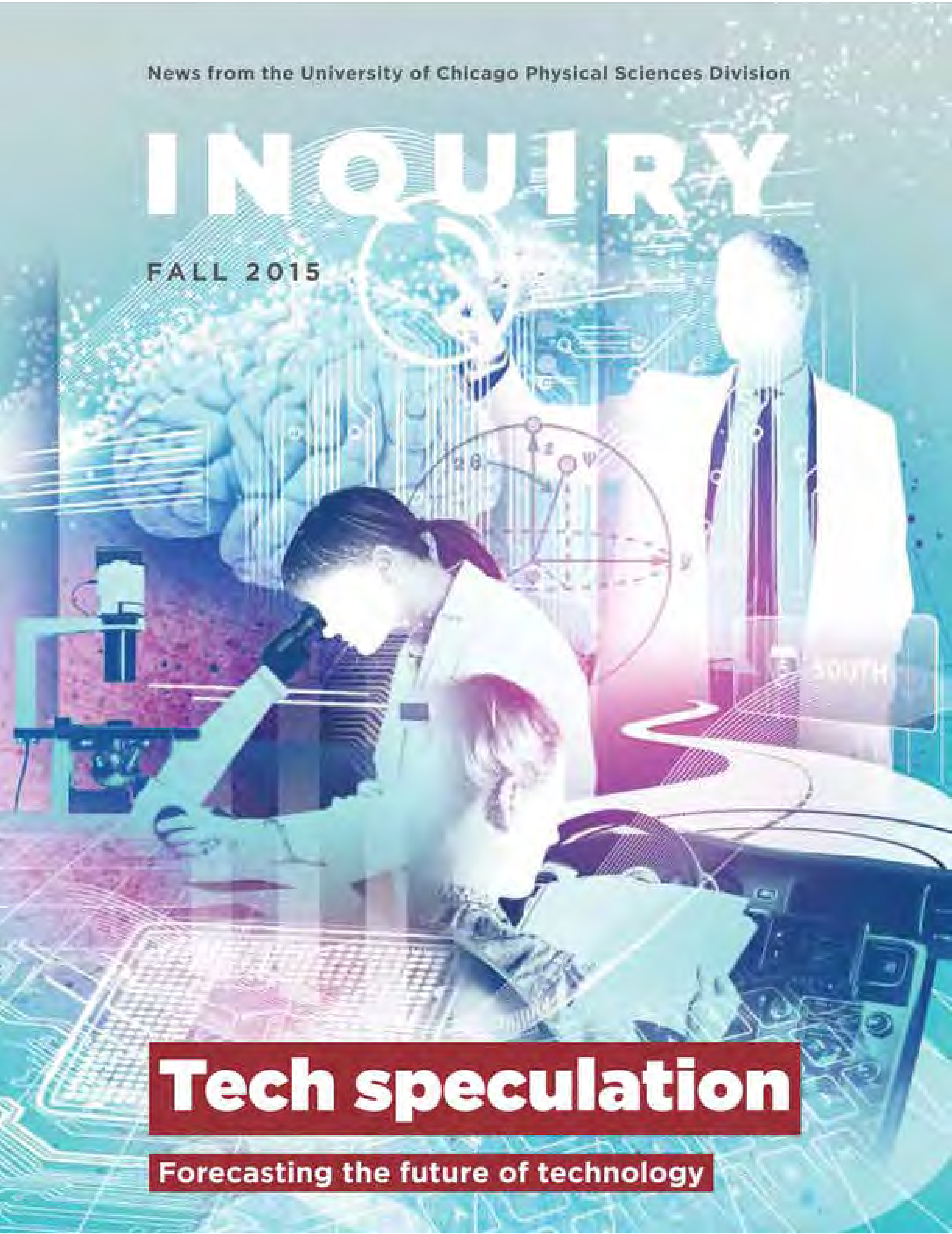
News from the University of Chicago Physical Sciences Division

INQUIRY

FALL 2015



Tech speculation

Forecasting the future of technology

INQUIRY

FALL 2015

Note from the dean

Gained in translation

The University of Chicago has always been an institution built on fundamental research. For over a century, Division of the Physical Sciences researchers have made field-forming, groundbreaking discoveries (page 13), from measuring the charge of an electron in 1909 to helping to discover the Higgs boson in 2012.

Gaining foundational knowledge will always be a priority, but it's also crucial that such research gets translated into practical solutions—sent out into the world to address our most pressing needs.

Collaboration between academic and industrial settings provides an optimal conduit for basic science to reach the masses. The PSD not only recognizes the value of application but actively encourages it.

We foster entrepreneurial spirit by providing science translation assistance. The Innovation Network—a subcommittee of the PSD Visiting Committee that includes alumni, friends of the University, and campus partners—was created to help UChicago innovators navigate the path toward commercialization. In addition to offering their own expertise, members of the network help connect researchers with other alumni who have knowledge and resources relevant to their projects. The network also helps identify outside funding sources.

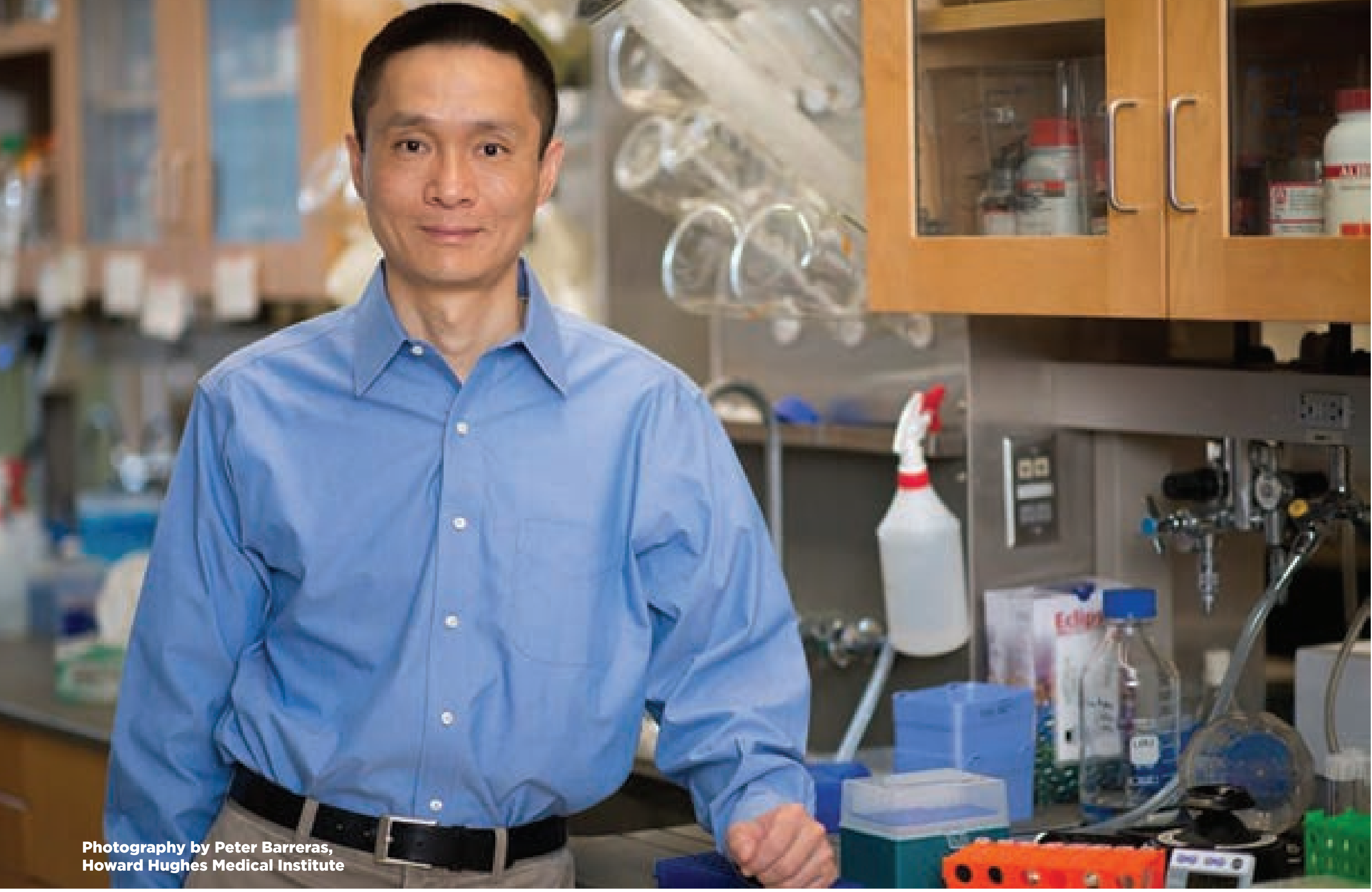
Now in its fifth year, the Innovation Network's outreach efforts have already benefited computer science and mathematics professor Ridgway Scott's FEniCS Project (automated scientific computing software), chemistry professor Dmitri Talapin's novel semiconductor soldering technique, and physics professor Heinrich Jaeger's jamming materials-based robotic gripper.

The PSD has opportunities to advance medicine ("Making a Mark," page 1), IT ("Reliable Source," page 7), and countless other fields. With the support of the Innovation Network, advocacy of the division, and inventive inclinations of PSD scientists, we have the power to improve the human experience, by creating creature comforts, lifesaving procedures, and world-changing technologies.

With all best wishes,

Rocky Kolb

Edward W. "Rocky" Kolb, Dean



Photography by Peter Barreras, Howard Hughes Medical Institute

Chemistry

Making a mark

Chuan He breaks new ground in RNA and DNA epigenetics.

Three billion—the number of base pairs in the human genome—sounds like a huge number. But of those billions of bases, humans appear to have only about 19,000 protein-coding genes. And while that may sound like a large number as well, those genes alone can't account for the vast complexity of a human being with trillions of cells, all with their own identities.

The standard flow of information coded into DNA, transcribed into RNA, and translated into protein provides too small a genetic template to accommodate the diversity of living systems. This discrepancy can be explained in part by epigenetics: changes to gene expression that don't change the underlying DNA sequence.

Epigenetics "is basically a coding process," says Chuan He, the John T. Wilson Distinguished Service Professor in Chemistry. The DNA sequence is a predetermined template, but one with hundreds of millions of spots that can accept chemical flags that alter gene expression. One such template modification is methylation.

Three classes of proteins carry out epigenetic coding: "writer" enzymes that apply tags or marks, "eraser" enzymes that remove the marks, and "reader" proteins that recognize and bind to the marks. This tagging provides an additional genetic coding process, expanding complexity exponentially, and explains, for instance, how cells with identical genome sequences can develop into different cell types. A deeper understanding of epigenetics provides insight into essentially all life on earth.

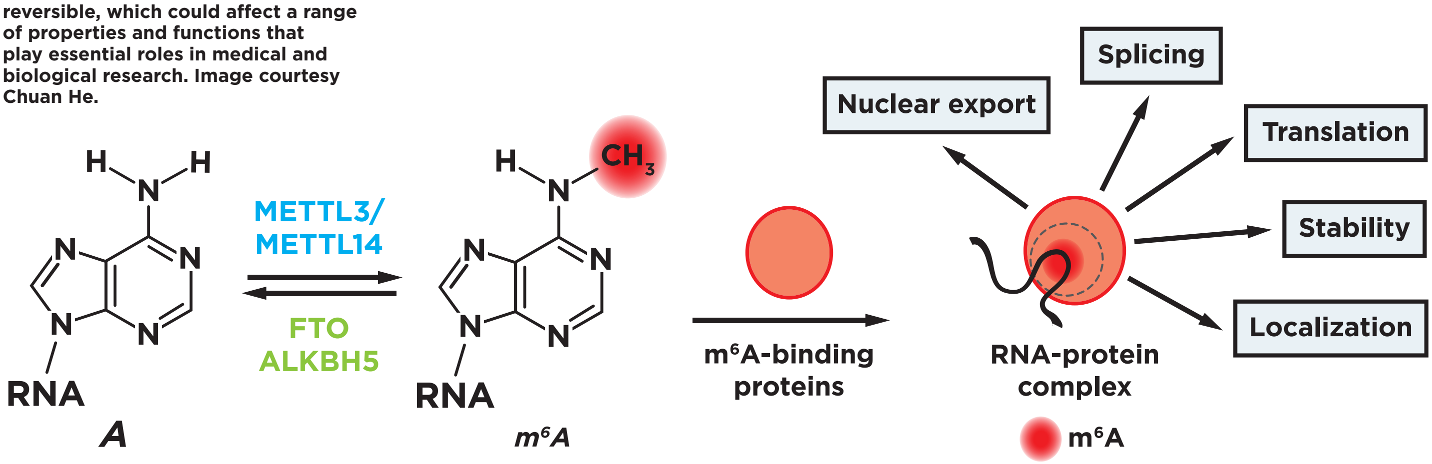
For almost half a century, geneticists have studied DNA methylation. For about three decades, they have been studying the same type of modifications on histones—the proteins around which DNA coils. But until recently, partly for practical and partly for conceptual reasons, no one considered the role RNA might play in epigenetics.

"In the beginning, it was easier to study DNA and histones," says He. "They're much more stable. You can isolate them and perform various analyses." And because RNA has a shorter half-life inside cells, scientists thought it might merely be a template that transfers genetic information from DNA to protein. Yet in the past few decades, as more capable analytic sequencing technology has been invented, researchers have discovered that RNA plays major functional roles in many processes.

He, who joined UChicago in 2002 and now directs the Institute for Biophysical Dynamics and is a Howard Hughes Medical Institute Investigator, came to study RNA via the scenic route. A synthetic chemist

Epigenetics provides an additional genetic coding process, expanding complexity exponentially.

The methylation on messenger RNA that He's team discovered is reversible, which could affect a range of properties and functions that play essential roles in medical and biological research. Image courtesy Chuan He.



who had worked in organic synthesis, he also studied biochemistry; investigated pathogenic bacteria with Olaf Schneewind, the Louis Block Professor in Microbiology; and later collaborated with Tao Pan, professor in biochemistry and molecular biology, on RNA biology.

Researchers have long known about RNA methylation, but they believed it was a static state, playing a minor role. In 2010 He—who had been working on DNA epigenetics—discovered the first RNA demethylase, called FTO, an eraser that removes a methyl group from RNA. His discovery proved that RNA methylation is reversible and thus a dynamic modification. Publishing the research in 2011, He's lab founded the research field of RNA epigenetics.

He's team went on to discover and describe the writer, eraser, and reader proteins involved in RNA methylation. Focusing particularly on the readers, which ultimately affect the cell's biological functions, He is gaining a mechanistic understanding of the methylation pathway, with "the implication that this is going to impact most biological processes." He suspects his lab will have a complete characterization of the reader functions in a couple of years.

The next questions to address are how and why the erasers regulate demethylation and the writers selectively restore the mark. And in the longer term, how these proteins and pathways affect or control cell differentiation, development, and human diseases.

While He is making waves in RNA, he hasn't given up his DNA work. A recent revelation, in fact, links back to his field-making RNA discovery. Scientists know that the DNA base cytosine gets methylated in both multicellular and single-cell organisms alike. (Cytosine methylation is the most thoroughly researched and best understood epigenetic DNA mark.) The DNA base adenine was thought to be methylated only in bacterial cells. However, homologues of the RNA demethylase protein that He's lab discovered remove a methyl group from adenine in multicellular organisms.

With associate professor Laurens Mets in molecular genetics and cell biology, He set off to find methylated DNA adenine in eukaryotes, and they did—in algae, worms, and fruit flies. The discovery led to three *Cell* papers published in April by He's group, a team at Harvard, and a team in China. The DNA mark is also found in mammals, according to as-yet unpublished data.

"This is a completely new mark," says He. "This is new biology emerging." These epigenetic pathways, involving adenine methylation in RNA and DNA in eukaryotes and mammals, play a critical role in innumerable biological processes, and He is providing vital groundwork for advances in medical and life sciences. "We're doing the fundamental research, mapping up the players, the building blocks," says He, "and then others can study immunology, infection, cancer therapy, diabetes, metabolism, neurogenesis, plant biology, developmental biology. You name it, these pathways are involved."
—M.S.

Physical Sciences

Groundwork

PSD facilities keep up with an ever-progressing scientific landscape.

In 1961 faculty members conducting space exploration research, in both the Department of Physics and the Enrico Fermi Institute, were spread across and off campus; physicist John A. Simpson proposed a building to unite them. Completed in 1965, the **Laboratory for Astrophysics and Space Research** (LASR) boasted a foundation and roof designed with future expansion in mind. Simpson knew that research would advance, and such progress requires leading-edge facilities.

Half a century later, Simpson's preparation is paying off. Just as science is built on previously laid groundwork, the University plans to build upon the original design, adding two floors and making extensive internal renovations to LASR over the next two years.

The modernization of LASR comes amid tremendous growth the Division of the Physical Sciences has ushered in over the past decade, notes Dean Rocky Kolb. In 2006 the **Ellen and Melvin Gordon Center for Integrative Science** brought together physical and biological sciences. The **Searle Chemistry Laboratory** was renovated in 2009, and the **Searle Cleanroom and Nanofabrication Facility**—the University's first controlled-environment laboratory for nanoscience research—launched in 2013. This September the **William Eckhardt Research Center** opened, designed for precision science and collaboration between the physical sciences and molecular engineering. LASR is slated to begin construction in November 2015, ultimately serving as the new and improved home to the Fermi Institute and the Kadanoff Center for Theoretical Physics.

"The division's goal is for every unit to have new or renovated facilities by 2022," says Kolb. Now that the Eckhardt Center has opened, **Jones Laboratory**—previously home to PSD administration—will begin renovations and eventually house the Department of Statistics and the division's new undergraduate program in Computation and Applied Mathematics, jointly run by the Departments of Statistics, Mathematics, and Computer Science.

Space made available in **Eckhart Hall** and **Ryerson Physical Laboratory** by the move to Jones will become upgraded instructional and collaborative research spaces for mathematics and computer science, respectively, and the division hopes renovations to **Hinds Laboratory**—the home of the Department of Geophysical Sciences—will also be completed by 2022.

In addition to new construction and adaptive reuse, PSD continues to maintain and upgrade shared core facilities: nuclear magnetic resonance, crystallography, mass spectrometry, a machine shop, an electronics shop, an engineering center, and a graphic arts design and print studio. The PSD invests in the tools its scientists need—one of the most concrete ways the division invests in the scientists themselves. **—M.S.**


This September the William Eckhardt Research Center opened, designed for precision science and collaboration between the physical sciences and molecular engineering.

William Eckhardt Research Center

Stats

- Opened 2015
- 265,000 square feet
- 400+ faculty members, staff, and students
- Department of Astronomy and Astrophysics
- Kavli Institute for Cosmological Physics
- Institute for Molecular Engineering
- PSD and IME deans' suites
- Facilities: Pritzker Nanofabrication Facility, quantum computing labs, nanolithography imaging, astronomy detector labs, soft materials (polymer) labs, immunoengineering labs
- LEED Silver (pursuing)

Spotlight

The Eckhardt Center features natural illumination created by light designer James Carpenter and artwork made in collaboration with the Museum of Science and Industry.

Photography by Tom Rossiter (above); photography by Tom Tian, AB'10

Ecostructure

The University designs new facilities to offer campus researchers the best possible equipment and resources but recognizes its responsibility to the global community as well. Environmental sustainability is a primary concern, and in 2010 the University implemented a sustainable building policy, based on the US Green Building Council's Leadership in Energy and Environmental Design (LEED) certification system. Every new building must comply with these standards.

Photo courtesy Department of Computer Science

"Our computer science department, like most, lives in a building constructed in the '90s," says Kolb. "But their buildings are from the *19*90s, not the *18*90s." Opened in 1894, Ryerson will be modernized, befitting the leading-edge work done by the department's computer scientists.

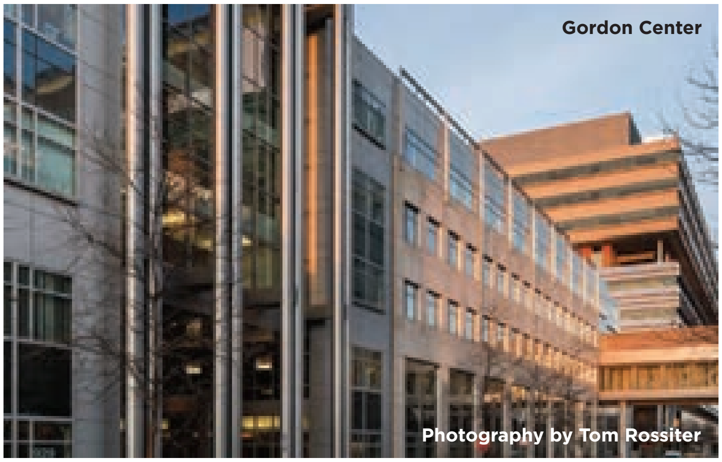
Searle Cleanroom

Shivakumar Bhaskaran, manager of the new clean room in the Searle Chemistry Laboratory building, holds up a three-inch silicon wafer emblazoned with the University of Chicago phoenix. The logo consists of a 50-nanometer-thick layer of gold with a five-nanometer-thick adhesion layer of titanium underneath.

Photo courtesy Shivakumar Bhaskaran

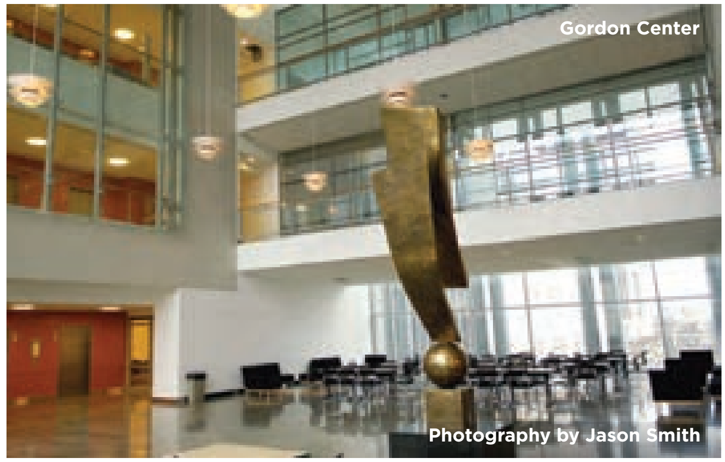
Searle Chemistry Laboratory

Photo courtesy University of Chicago Facilities Services



Gordon Center

Photography by Tom Rossiter



Gordon Center

Photography by Jason Smith

Searle Cleanroom and Nanofabrication Facility

Stats

- Opened 2013
- 2,680 square feet in Searle Chemistry Laboratory
- Class 100/1000 environment (reduces contaminants by 99.99 percent or 99.9 percent, respectively)
- Specialized equipment includes deposition, etching, and lithography tools
- Adjacent biological sample prep area and soft lithography laboratory
- First multiuser clean room on campus; open to entire UChicago research community
- Creates new opportunities for faculty appointments in nanoscience research

Spotlight

Advanced by the semiconductor fabrication industry, the tools inside the clean room are also used to create intricate nanoscale devices.

Searle Chemistry Laboratory

Stats

- Gut renovation 2009, originally constructed in 1968
- 85,000 square feet; four floors plus basement
- UChicago's first LEED Gold research building, with green garden roof
- Department of Chemistry synthetic and theoretical labs, administrative offices
- Computation Institute
- Shared chemical instrumentation facilities for nuclear magnetic resonance spectroscopy, mass spectroscopy, and X-ray diffraction

Spotlight

Laboratory services are modular for potential reconfiguration in response to future scientific needs.

Gordon Center for Integrative Science

Stats

- Opened 2006
- 400,000 square feet
- ~800 senior scientists, researchers, and students
- Institute for Biophysical Dynamics
- Department of Biochemistry and Molecular Biology
- Howard Hughes Medical Institute
- Ben May Department for Cancer Research
- James Franck Institute
- Part of Department of Chemistry
- Specialized equipment includes scanning electron microscope, electron paramagnetic resonance instrument, and time-resolved luminescence spectrometer and microscope

Spotlight

The Gordon Center features walls made from the same Indiana limestone used in the main quad and a colonnade of six-story steel columns acting as a modern interpretation of Cobb Gate, a block and a half east on 57th Street.

THE UNIVERSITY OF CHICAGO CAMPAIGN
INQUIRY & IMPACT

To support PSD initiatives like the Core Facilities Fund, contact Brian Yocum (**773.702.3751**, **byocum@uchicago.edu**) or visit **campaign.uchicago.edu**.

Photo courtesy Department of Computer Science

> "Thirty years ago, programs usually had a thousand lines of code. It was still possible to read through every line and manually validate and correct."
>
> —SHAN LU

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Computer Science

Reliable source

Shan Lu finds your software bugs and kills them.

Say you find a bug in your kitchen. You have three options: leave it be and try to forget about it, put it outside where it won't bother you, or kill it. The same options exist for computer program bugs: ignore the problem, build a work-around, or fix the source code. But what if you have a million bugs? You call a professional, like associate professor Shan Lu. Specializing in computer system robustness and reliability, she eradicates software bugs through program analysis and software engineering.

When she started graduate school at the University of Illinois at Urbana-Champaign, Lu had much less programming experience than many of her peers. "I had a lot of bugs in my programs," says Lu, who joined the University in August 2014. But rather than a liability, her inexperience opened a door. She didn't have an adviser at the time, and a professor who worked on software reliability asked if she'd like to join his group.

Pattern recognition

Understanding, detecting, mitigating, and fixing defects in today's software is much more involved than it once was. "Thirty years ago, programs usually had a thousand lines of code," says Lu. "It was still possible to read through every line and manually validate and correct." Most programs are now too large and complicated to comb through the source code, and they often combine different components. "Software is not built by just one person." So Lu builds programs to find bugs based on patterns and then, if possible, fix them automatically.

A typical project for Lu involves choosing a large, mature, and open-source program and studying its defect database, which contains detailed user reports. She studies discussions between users and developers, patches, and reviews of patches and tries to identify a pattern in the types of mistakes developers make. She uses complex software to provide a large enough sample size to draw statistically significant conclusions.

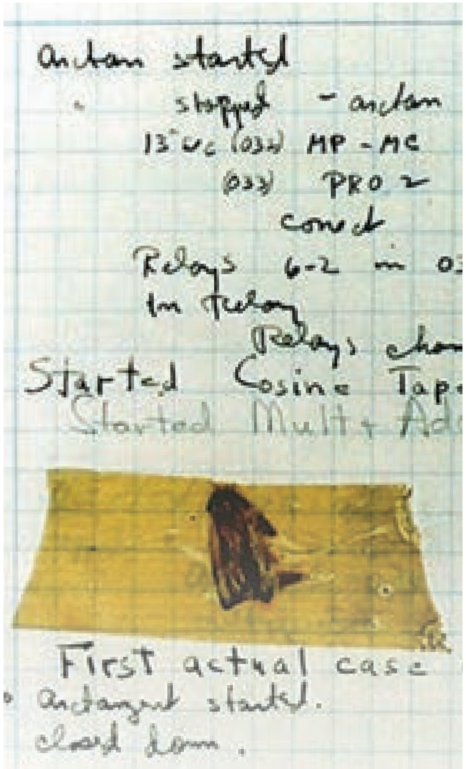
Once Lu generalizes a common problem and identifies a pattern—the most challenging part of the process—she can write a program to search code, identify that pattern, and, depending on the type of bug, automatically fix it. "When you fix a bug," she adds, "you want to make sure you don't introduce new ones."

Lu's group ran one of these programs on 15 widely used Java and C/C++ applications. It found 150 previously undetected performance bugs. Lu submitted the report along with patches to fix the bugs, and 116 were immediately accepted by developers. The software was presented at the International Conference on Software Engineering in May, winning the team a Distinguished Paper Award.

Depending on a digital world

The type of software dependability research Lu conducts affects much of our technologically developed lives, in both trivial and critical ways. Consider your smartphone or smartwatch. If its software is inefficient, your applications can become unresponsive and drain the battery. Now consider the equipment that delivers radiation therapy to cancer patients. A programming error can cause lethal malfunctions—and has, Lu recalls.

Between 1985 and 1987, the Therac-25 radiation therapy machine ran software



In 1947 Harvard's computer lab, run by Grace Hopper, pulled a moth from a malfunctioning Mark II. Though widely cited as the origin of "computer bug," this tale is disputed. For the full story, visit mag.uchicago.edu/reliable-source. Photo courtesy the US Naval Historical Center.

that contained a subtle bug called a race condition, which causes a device to attempt two or more operations at the same time, resulting in the wrong sequence of events. The machine delivered an overdose of radiation; five patients died and many others were injured. Bugs also have caused space rockets to explode (Mariner I, 1962; Ariane 5, 1996) and destroyed pipelines (trans-Siberian gas pipeline, 1982, rumored to have been caused by a CIA-planted bug, leading to the largest non-nuclear explosion in history).

Ivory to computer towers

Because of our dependence on computer systems, academic computer science and industry share a close relationship. Often breakthroughs are directly and immediately applied by corporations. When she was a student, Lu and her adviser developed a tool, filed a patent, and licensed it to Intel. Her adviser created a start-up based on another technique they developed. While she doesn't plan to begin her own company any time soon, she does expect to collaborate with industry.

This melding of academia and entrepreneurship is reflected in recent changes to the computer science department. In 2011 Andrew Chien, previously Intel's vice president of research, joined the department as the William Eckhardt Distinguished Service Professor. While the department maintains its traditional focus on theory, says associate chair Anne Rogers, his appointment marked the beginning of an expansion of faculty members who work under the broad umbrella of systems.

"The field is going to change, and very quickly," says department chair Todd Dupont. Some recent hires come from industry, some from academia, and some have worked in both (see "Science Nonfiction," page 9). The boundaries between the two areas are increasingly fluid, says Rogers, with advances in each driving the other.

This relatively new attention to systems research is part of the reason Lu came to UChicago from an established program at the University of Wisconsin–Madison. "It almost feels like a start-up," she says. "Everyone is energetic, with a 'we're doing this together' feeling." As a relatively junior faculty member, Lu has an opportunity to effect real change.

—M.S.

Cascade effect

The path to gender diversity in computer science.

Andrew Chien, a computer science professor who's helped recruit more systems-focused faculty, has been intent on increasing the department's diversity, making an effort to identify top-flight women in the field and inviting them to visit campus. Sometimes that visit has led to an appointment, as was the case for Shan Lu. In the past year, the department has hired two more women computer scientists—assistant professor Yanjing Li and Diana Franklin, director of computer science education at the Center for Elementary Mathematics and Science Education. Such additions may encourage more women to pursue a field in which they are still underrepresented.

Lu feels surrounded and supported by women colleagues at UChicago, so it takes her a minute to remember ever feeling less at ease. But her years as an undergraduate at the University of Science and Technology of China were difficult. She began her course work with little programming experience—inexperience shared by her three female classmates. The 20 or so male computer science majors seemed to already have programming knowledge. "How can they already know so much," Lu wondered, "and how can I possibly catch up?"

The women banded together, helping each other narrow the gap, while the men moved forward from their head start. She wonders if women are deterred by the disparity in early exposure to computer science.

Now as a professor, she makes a point of assuring her less experienced students—who tend to be women—that although they need to practice programming, they can still do well in her classes. Speed is important, but "there are many other skills that will determine if you're successful," Lu says. "Whether you're organized, determined, or creative. You need to be a good thinker."

As a graduate student 10 years ago, Lu helped her adviser mentor two undergrads through the Distributed Research Experiences for Undergraduates program, sponsored by a woman-focused committee of the Computing Research Association. This summer she became a mentor herself, hosting two women computer science students from different cities for 10 weeks.

Lu's colleague, assistant professor Hank Hoffmann, also hosted women summer researchers through a different program. "We are hoping that a collective effort like this," says Lu, "will contribute to increasing the percentage of women in computer science.

Illustration by Mario Wagner

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Computer Science

Science nonfiction

We asked recently appointed computer scientists what fantastical, futuristic technology they'd like to see invented. Turns out some of their foresights aren't so far off.

Quantum leap
Fred Chong, the Seymour Goodman Professor of Computer Architecture, and computer science lecturer **Matthew Wachs** are eager to see advances in quantum computing. "It's the only technique that may provide exponentially powerful computation," says Chong. Wachs compares it to a genie in a bottle: "Whenever a genie grants you a wish, the obvious strategy is to ask for infinite wishes. The kinds of breakthroughs that quantum computing would make possible would almost be like that."

I, bionic
Associate professor **Shan Lu** and assistant professor **Yanjing Li** would like to see medical technology improved. Li envisions bionic body parts—implantable chips that could restore sight to the blind or speech to the mute. She cites the blood-sugar-monitoring contact lens designed by Google and Novartis. "People are already looking at nonintrusive ways of integrating computer systems into your body, but in the future, it could be another level."

Auto chauffeur
Assistant professors **Ravi Chugh** and **Ariel Feldman** look forward to self-driving cars, "although given recent progress, perhaps that isn't so fantastical any more," says Feldman. Chugh predicts that self-driving cars combined with public transit would lead to safer and more energy- and time-efficient travel. "The economic and social challenges to overcome, however, are probably harder than the technical ones."

Sentient Siri
The technology that assistant professor **Aaron Elmore**, SM'09, most wants developed "has to be the *Star Trek* computer." His vision differs from Apple's Siri and Amazon's Alexa in its ability to contextualize. He wants to have a natural conversation with the computer, where his questions are answered and refined by further discussion.

Transcendence
Assistant professor **Andrew Drucker** hopes for "direct computer/brain interfaces that use the brain's plasticity to intimately link human and machine intelligence," leading to new kinds of virtual experiences and telepathy. He'd be even happier "to see the benefits of existing technologies shared more equitably—for example, to see more of the wealth generated by our computers going to the people who assemble them."

"I know kung fu."
Diana Franklin, director of computer science education at the Center for Elementary Mathematics and Science Education, would like to see "personalized, automated learning systems to support students in all subjects, including math, art, computer science, history, language." Though not exactly *Matrix*-style downloadable education, these would "assist teachers in reaching students with wide variance in background, knowledge, learning styles, and personal interests."

e^x Mathematics

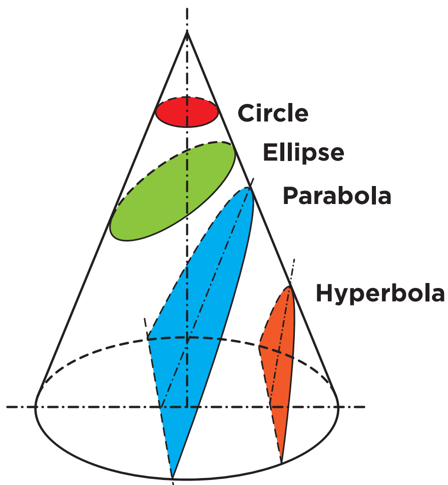
Juggling act

David Eisenbud, SB'66, SM'67, PhD'70, wears a lot of hats. A mathematics professor at the University of California, Berkeley; director of the Mathematical Sciences Research Institute (MSRI); and former president of the American Mathematical Society, he is also an author, musician, and juggler. Eisenbud, who received a 2015 Alumni Association professional achievement award, tells *Inquiry* about algebraic geometry, the first national mathematics festival, and the significance of the number 3264.

How did you first become interested in mathematics?
My father was a theoretical physicist, so it wasn't far to look. He showed me how to solve simultaneous equations, which excited me a lot. When I was about 12, I began announcing that I was going to be a mathematician. I don't know what prompted that exactly. It was the warm contact with my father that started the ball rolling.

Your father started another ball rolling—or flying—right?
He taught me to juggle three balls around the time I went off to college, and I remember practicing while walking around the circular corridor on my floor of Pierce Tower. Later on he and I bought a set of clubs and tried to learn club passing; we made some progress, but not very much. Later I met Joe Buhler—a pro-level juggler, a mathematician from Reed College at the time, and eventually one coauthor on "Juggling Drops and Descents," a paper on the math behind the art form. He was a great teacher, and my juggling took a great leap forward. I still practice a bit and juggle with Joe whenever we're together.

You wrote a graduate-level textbook, *Commutative Algebra with a View Toward Algebraic Geometry* (Springer, 1995). What is commutative algebra and algebraic geometry?
Those are two sides of the same thing. Algebraic geometry started with the Greeks and conic sections. If you think about a slice of a cone, you have a circle, an ellipse, a hyperbola, or a parabola, and those curves can be defined in a plane by a quadratic equation.



The way that people study modern algebraic geometry is to look not at that equation but at the functions on the circle. Let's look at polynomial functions, a function with two variables, like $5x + 7y$. If I apply that to a point on the circle, I get a number. Those functions form what's called a commutative ring—that it's a ring means you can add, subtract, and multiply functions by adding, subtracting, and multiplying their values—which determines the geometric form. Algebraic geometry studies geometric objects, defined by polynomial equations, by studying the functions on those objects.

What fields use algebraic geometry?
String theory is a big application because strings are curves in a sense. It also appears in mathematical biology, robotics and motion planning, and in applications where you have to deal with simple functions or constraints, like optimization.

Who influenced you at UChicago?
I've always been deeply involved in music and joined the Collegium Musicum—a performing group that gave a concert in Bond Chapel every quarter. When I arrived I played the flute and recorder; with them I slowly expanded and played recorder, krummhorn, wooden flute, and eventually viola da gamba. The Collegium Musicum was run at the time by Howard Mayer Brown, a famous musicologist who played the same assortment of instruments as I did. His partner, Roger Weiss, AM'51, PhD'55, a social sciences professor, was a tenor. Brown hosted us at his house, and we became personal friends. I got quite an education from the deep culture of the leaders of the group.

What's been the highlight of your career thus far?
Certainly the fact that I've been director of MSRI in Berkeley now for a total of a dozen years. Last April MSRI hosted the first national mathematics festival in Washington, DC, with an event supporting basic research, several events about mathematics education, and a public festival where 27,000 people came to about 70 events in the Smithsonian museums.

Much of my work with MSRI was made possible by the guidance of my wife, Monika, who's a physician. For example, she was very involved in the design of a new wing we added to the building.

What are you working on now?
I'm making final corrections on a book written with Harvard's Joe Harris. It has a funny title: *3264 & All That: A Second Course in Algebraic Geometry* (Cambridge University Press, forthcoming). The number 3264 references the solution of a classic algebraic geometry problem. "All that" comes from a spoof of English history called *1066 & All That* (W. C. Sellar and R. J. Yeatman), which claims there are only two memorable dates in English history—one of them is the Battle of Hastings. This book *3264* has been a 10-year project. The only way anyone writes another book must be to forget the pain of writing the one before.
—Interviewed by M.S.

Visit **mag.uchicago.edu/eisenbud** for a chance to ask the juggling mathematician a question and win a prize.

Physics

In memoriam

Yoichiro Nambu (1921–2015)

"Yoichiro Nambu is no more," says former student Madhusree Mukerjee, PhD'89, "and with him is gone an era in physics." Nambu, professor emeritus and 2008 Nobel Prize winner, died July 5 of an acute heart attack. He was 94.

The Japan-born physicist is best known for introducing a mathematical model to describe "spontaneous symmetry breaking." Now a cornerstone of the Standard Model of particle physics, this phenomenon helps explain how subatomic particles interact, governed by fundamental forces of nature.

Visit **mag.uchicago.edu/nambu** to learn more about his work, read tributes, and share your own memories of the "gentle genius."

Photo courtesy Special Collections Research Center, University of Chicago Library

Divisional news

ANNOUNCEMENTS

We've moved! The PSD dean's office, the development office, the dean of students, the Kavli Institute for Cosmological Physics, and the Department of Astronomy and Astrophysics now reside in the Eckhardt Center, 5640 South Ellis Avenue. Come visit us and check out UChicago's newest precision science facility.

FACULTY ADDITIONS

John Anderson, SB'08, SM'08
Assistant Professor in Chemistry

Francesco Calegari
Professor in Mathematics

Frederic Chong
Professor in Computer Science

Philipp Heck
Associate Professor (part time) in Geophysical Sciences

Malte Jansen
Assistant Professor in Geophysical Sciences

Edwin Kite
Assistant Professor in Geophysical Sciences

Yanjing Li
Assistant Professor in Computer Science

Arvind Murugan
Assistant Professor in Physics

Sergei Nagaitsev
Professor (part time) in Physics

Charles Smart
Associate Professor in Mathematics

Scott Snyder
Professor in Chemistry

RETIREMENTS

John Frederick
Professor in Geophysical Sciences

Donald Lamb
Robert A. Millikan Distinguished Service Professor in Astronomy and Astrophysics

Gene Mazenko
Professor in Physics

Frank Merritt
Professor in Physics

Robert Soare
Professor in Computer Science and Mathematics

FACULTY AWARD AND HONOR HIGHLIGHTS

László Babai (Computer Science and Mathematics)
Received the 2015 Donald E. Knuth Prize

Elected to the American Academy of Arts and Sciences

John E. Carlstrom (Astronomy and Astrophysics)
Received the 2015 Gruber Prize in Cosmology

Fred Chong (Computer Science)
Named the Seymour Goodman Professor of Computer Architecture

Ravi Chugh (Computer Science)
Awarded Neubauer Faculty Fellowship

Jian Ding (Statistics)
Received an NSF CAREER award

Alex Eskin (Mathematics)
Elected to the National Academy of Sciences

Wendy Freedman (Astronomy and Astrophysics)
Received the R. M. Petrie Prize at the Canadian Astronomical Society

Named the John and Marion Sullivan University Professor

Henry Hoffmann (Computer Science)
Received a Department of Energy Early Career Award

Daniel Holz, SM'94, PhD'98 (Physics)
Received a Quantrell Award for Excellence in Undergraduate Teaching

Richard Jordan (Chemistry)
Named the Paul Snowden Russell Distinguished Service Professor

David Miller, AB'05 (Physics)
Received an NSF CAREER award

Ray Moellering (Chemistry)
Won the 2015 V Scholar Award from the V Foundation for Cancer Research

Angela Olinto (Astronomy and Astrophysics)
Awarded a Faculty Award for Excellence in Graduate Teaching and Mentoring

Norbert Scherer, SB'82 (Chemistry)
Awarded the 2015 Peter Debye Prize from the Edmond Hustinx Foundation

Panagiotis E. Souganidis (Mathematics)
Elected a fellow of SIAM (Society for Industrial and Applied Mathematics)

Andrei Tokmakoff (Chemistry)
Received the 2016 Ahmed Zewail Award in Ultrafast Science and Technology

Yanbin Wang (Senior Scientist, Center for Advanced Radiation Sources)
Named a 2015 American Geophysical Union fellow

Jonathan Weare (Statistics)
Received a Department of Energy Early Career Award

Paul Wiegmann (Physics)
Received a 2015 Simons Fellowship Award

Shmuel Weinberger (Mathematics)
Named the Andrew MacLeish Distinguished Service Professor

Review

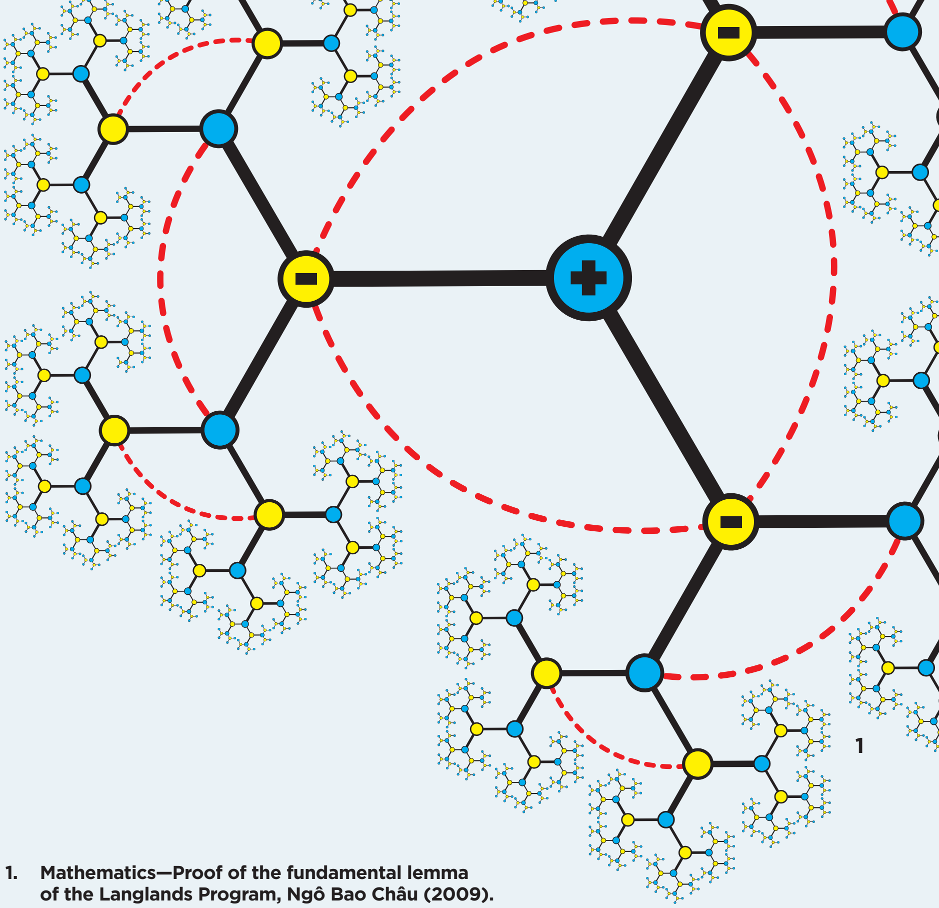
125 years of PSD discovery

In 1890, University of Chicago founder John D. Rockefeller and University president William Rainey Harper created an intellectual culture that led to more than a century of scientific innovation, advancing existing fields of inquiry and creating new ones, like particle cosmology and cosmochemistry. From Yerkes to the Giant Magellan Telescope, UChicago scientists are developing technologies of unprecedented scope, power, and precision; answering some of the universe's most puzzling mysteries; and asking tomorrow's questions today.

This autumn quarter the University celebrates its 125th anniversary with a series of lectures, panels, and events, culminating in the 525th Convocation on December 11, 2015, in Rockefeller Memorial Chapel. The Division of the Physical Sciences joins in this celebration of history, affirmation of its founding principles, and dedication to future progress by noting some of the division's most noteworthy breakthroughs.

To explore more of the University's scientific history, visit Crerar Library's exhibit *A Bold Experiment: The Origins of the Sciences at the University of Chicago*, running through March 31, 2016.

—M.S.



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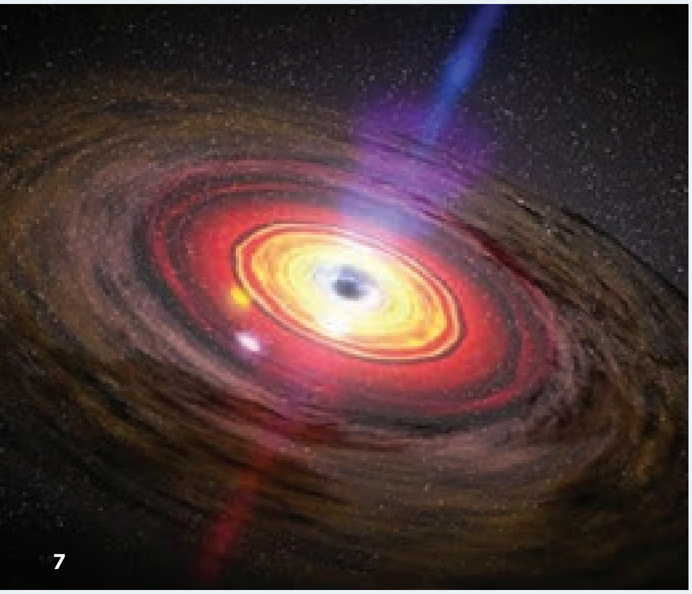
1. Mathematics—Proof of the fundamental lemma of the Langlands Program, Ngô Bao Châu (2009). Graphic courtesy Bill Casselman; adapted by Michael Vendiola.
2. Astronomy and Astrophysics—Yerkes Observatory, George Ellery Hale (1897). Photo courtesy Special Collections Research Center, University of Chicago Library.
3. Physics—First chain reaction, Enrico Fermi (1942). Photography by Robert Kozloff.
4. Computer Science—Grid computing, Ian Foster (1999). Photo courtesy Fermi National Accelerator Laboratory.
5. Astronomy and Astrophysics—Giant Magellan Telescope, Wendy Freedman (2021). Photo courtesy GMTO Corporation.
6. Geophysical Sciences—Fujita Tornado Scale, Tetsuya "Ted" Fujita (1971). Photo courtesy US National Oceanic and Atmospheric Administration.
7. Astronomy and Astrophysics—Black holes proposal, Subrahmanyan Chandrasekhar (1974–83). Illustration courtesy NASA.
8. Chemistry—Carbon-14 dating, Willard F. Libby (1950s). Photography by Maureen Searcy.
9. Physics—Electron charge measurement, Robert Millikan (1909). Photo courtesy *APS Physics*, January 20, 2012.
10. Astronomy and Astrophysics—Expanding universe, Mount Wilson Observatory, Edwin Hubble (1920s). Photography by Andrew Dunn.
11. Physics—Higgs boson discovery, 2000+ US-based physicists, many from UChicago (2012). Image courtesy CERN.



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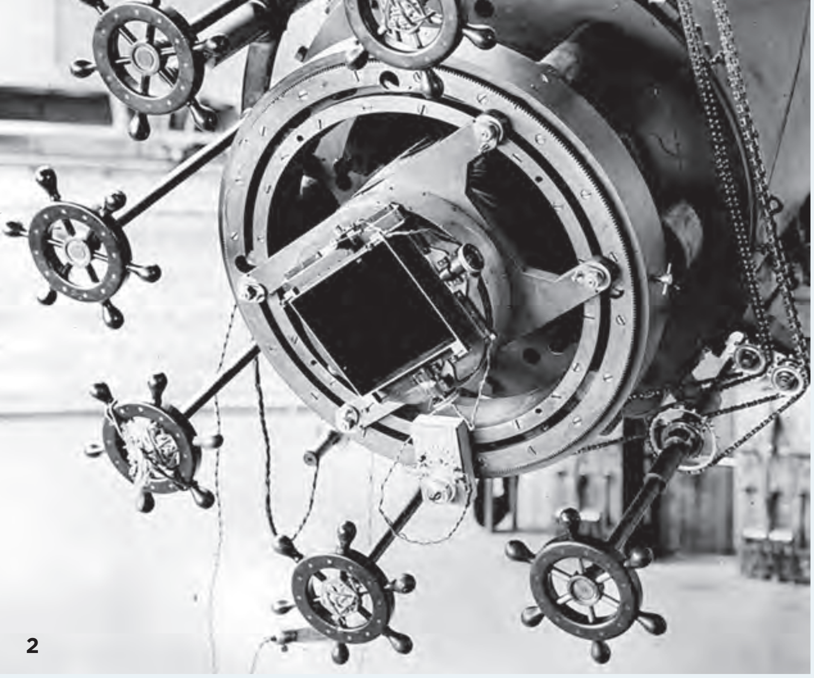
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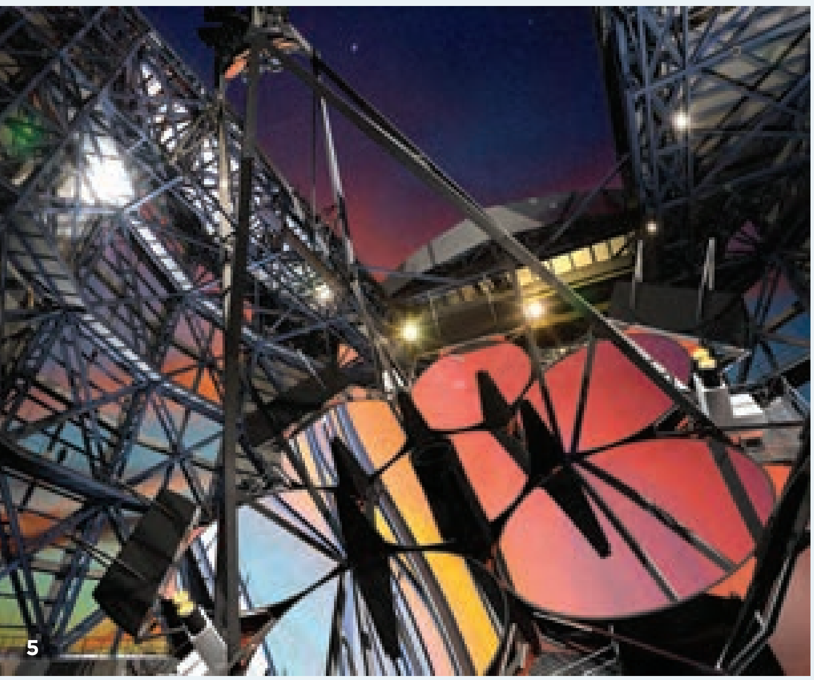
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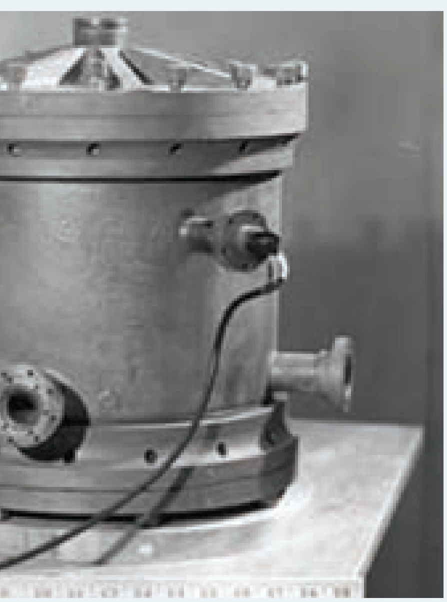


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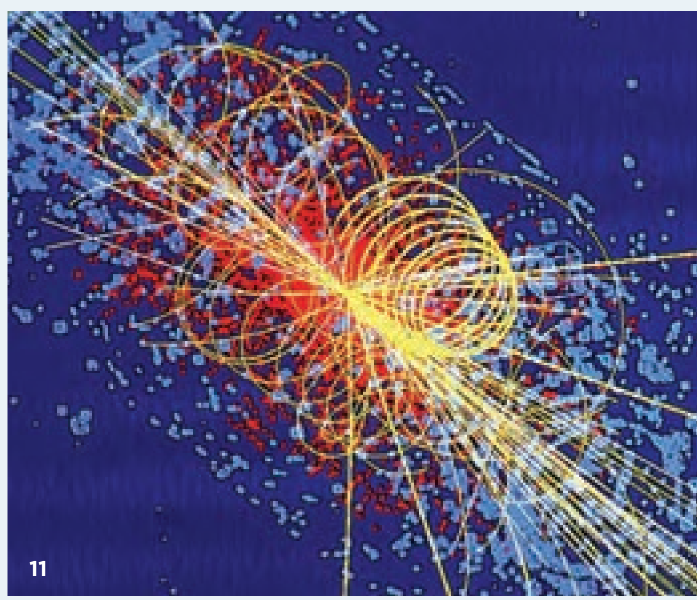
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