Our professors and students are deeply engaged with today’s most pressing societal issues, while at the same time participating in basic scientific research that will lead to great discoveries. Their research extends to every corner of this globe and far into space. How will humanity survive a changing climate? Our scientists are actively working on basic science approaches to understanding the changing climate, mitigating its effects, and creating new ways to harvest and store energy to reduce the change. How will researchers harness and interpret massive data sets? Our new Data Science Initiative will give students the necessary tools to analyze unprecedented amounts of information, as well as provide new insight into the science underlying the data. How do we prepare for the next devastating earthquake? Our geologists are leading the way. How do cells fight cancer? Our mathematicians are helping biologists mine data to discover the clues.

I’m excited about the trend toward more multidisciplinary research. The intersection of departments, as well as with other disciplines across campus, leads researchers to new scientific frontiers and discovery. Centers such as the Berkeley Seismological Lab, the Climate Readiness Institute, and the Berkeley Center for Cosmological Physics provide a framework for finding new paths to answer fundamental questions.

The number of undergraduate “majors” is growing in almost all of our departments — some are even skyrocketing (see page 7 for statistics). In concert with Chancellor Dirks’ Undergraduate Initiative, we are looking for ways to meet demand and improve our students’ experiences.

As an institution, we must also confront the problems in academia that interfere with students’ learning. Our division is poised to tackle problems of sexual harassment and gender inequity head on by creating a framework for finding new paths to answer fundamental questions.

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Thank you for being part of our community and our work. Your support enables our faculty and students to thrive. I hope you enjoy this small sampling of research and education in MPS. I look forward to keeping you up to date on our accomplishments.

Frances W. Hellman
Fall 2015

MESSAGE FROM DEAN FRANCES HELLMAN

As the new dean of the Mathematical & Physical Sciences Division (MPS), I’ve got a bird’s-eye view of the five departments in this division — astronomy, earth and planetary science, math, physics, and statistics — each ranked among the very best in the world. I feel privileged to represent them.

On November 8 Berkeley physicist Kam-Biu Luk and mathematician Ian Agol each won Breakthrough Prizes for their recent discoveries. The Breakthrough Prizes in Physics, Life Sciences and Mathematics were founded in 2012 by notable tech entrepreneur Yuri Milner and his wife, Julia; Sergey Brin of Google; Anne Wojcicki of 23andme; Mark Zuckerberg of Facebook and his wife, Cathy Zhang; and Mark Zuckerberg of Facebook and his wife, Priscilla Chan.

The inspiration for these prizes came when Mr. Milner announced that he would award $3 million apiece to nine theoretical physicists, in the belief that physicists are equal to rock stars and deserve to be treated as such. Over the years, as more sponsors joined, the prizes spread to life sciences and mathematics. The winners each year are chosen by a committee of previous winners and the prizes are given out at a Hollywood-style, star-studded gala in Silicon Valley.

The Breakthrough Prize in Fundamental Physics recognizes major insights into the deepest questions of the Universe. Five different teams received the 2016 award and shared a $3 million prize for “the fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the standard model of particle physics.” UC Berkeley’s Kam-Biu Luk and his colleague, Yifan Wang of the Chinese Academy of Sciences, led the Daya Bay Reactor Neutrino Experiment and accepted the prize on behalf of their team at the event. The physicists won for discovering that neutrinos shift their identities as they travel at nearly the speed of light. Neutrinos were once thought to be massless particles, rarely interacting with the matter around them. However, these experiments have shown that neutrinos actually have a small mass, and that the three types — the electron, muon, and tau neutrinos — morph into one another as they travel through space.

The 2016 Breakthrough Prize in Fundamental Physics continues Berkeley’s great tradition of neutrino physics, which began in many ways with the late Stuart Freedman’s work. His proudest moment came in 2003 when his experiment at KamLAND (an underground neutrino detection facility in Japan) confirmed that different neutrinos have different masses and change from one “flavor” to another while traveling from the sun to Earth. Thanks to his superb work in this area, Freedman became the U.S. spokesperson for KamLAND.

The Breakthrough Prize in Mathematics honors some of the world’s best mathematicians who have contributed to major advances in the field. The $3 million 2016 mathematics prize went to UC Berkeley’s Ian Agol for “sweeping contributions to low dimensional topology and geometric group theory, including work on the solutions of the tameness, virtual Haken and virtual fiber conjectures.” Agol studies the topology and geometry of three-dimensional spaces, such as our own universe, and has won acclaim for solving major conjectures by one of the giants in the field, the late William Thurston, a UC Berkeley alumn.

On November 9 the Breakthrough Prizes were also celebrated on Berkeley’s campus at an extensive and well-attended all-day seminar and dinner sponsored by UC Berkeley, Stanford, UCSF, and the Breakthrough Foundation.

UC Berkeley has the distinction of the most Breakthrough Prize winners to date. Last year, Berkeley structural biologist Jennifer Doudna won the 2015 Breakthrough Prize in the Life Sciences, with her partner Emmanuelle Charpentier, for their revolutionary discovery of a technique, CRISPR-Cas9, that allows scientists to rewrite the genetic material of any organism. Berkeley professor and Nobel laureate Saul Perlmutter and colleagues at other universities won the 2015 Breakthrough Prize in Fundamental Physics for their discovery that the expansion of the universe is accelerating rather than slowing, as had been long assumed.
CREATING AN OPTIMAL EDUCATIONAL CLIMATE

Our ability to excel as scientists and mathematicians requires an inclusive and supportive environment in which to learn, teach, conduct research, and engage in discovery. Recent and well-publicized events have challenged us to look closely at our departments’ and university’s climate for education and research. It is imperative that we address the issue of sexual harassment and all forms of intimidation on Berkeley’s campus. We are determined to bring about positive change. A new, intensive focus on the prevention of sexual, racial, and other kinds of harassment, as well as sexual aggression, will enable us to create an environment that is more conducive to the education and research missions of this university, one that enables all of its participants to thrive.

Most immediately, the MPS division is taking the following steps:

1) Build community by convening a series of meetings with graduate and undergraduate students, faculty, postdocs, and staff to foster a shared understanding about the value of diversity, equity, and inclusivity, and to engage in open and direct discussion of sexual harassment and aggression.

2) Enhance prevention by revisiting the sexual harassment training to better address climate issues and prevention, instead of focusing solely on reporting and compliance.

3) Increase responsiveness by working with the Office for the Prevention of Harassment and Discrimination and the campus administration to improve the process of reporting and communication when offenses occur.

These are the first steps in an important process to effect substantial and meaningful change.

ASTRONOMY

The Gemini Planet Imager (GPI), an instrument the size of a small car mounted on the 8-meter Gemini South telescope in Chile, uses a combination of new technologies, including adaptive optics, to take pictures of Jupiter-like exoplanets next to bright stars. UC Berkeley astronomers are working on the GPI’s international team, and in January 2015 they made an extraordinary discovery. Berkeley postdoctoral fellow Robert De Rosa examined its initial data and saw something large orbiting a young star. He and other researchers realized it was a planet, now named 51 Eridani b. Around 20 million years old as compared to our 4.5-billion-year-old solar system, this planet shows what Jupiter might have looked like in its infancy. “This is exactly the kind of planet we envisioned discovering when we designed GPI,” said James Graham, a UC Berkeley professor of astronomy and the GPI project scientist. “We wanted to find planets that were young so we could figure out the formation process.” The team recently measured the orbital motion of 51 Eridani b, and the results are now published in Astrophysics Journal.

For more, please visit astro.berkeley.edu

FURTHER AND PLANETARY SCIENCE

A Berkeley team recently made international news by uncovering compelling evidence that volcanic activity in India 66 million years ago was accelerated by an asteroid impact in the Yucatan. For years, scientists have argued whether these two events were related and whether they caused the dinosaurs’ extinction. But there hasn’t been enough evidence to answer the questions. This year, Berkeley geophysicist Mark Richards and Paul Renne, director of the Berkeley Geochronology Center, dated lava from the Deccan Traps lava flows in India to find that the volcanoes doubled their output within 50,000 years of the asteroid’s impact. “These dates are smack on what we predicted,” Richards says. And they seem to answer two questions at once: that the Deccan Trap lava flows were too close to the impact to be coincidental, and that both phenomena happened extremely close to the dinosaurs’ demise. While Richards is neutral on what might have killed the dinosaurs, Renne says, “It becomes somewhat artificial to distinguish between [the asteroid and volcanoes] as killing mechanisms: both phenomena were clearly at work at the same time.” What is important to this team is that they have found credible evidence that the lava was triggered by the impact, possibly ending 35 years of debate.

In 2015, Professor-in-Residence and LBNL Climate Division Director Bill Collins launched the Climate Readiness Institute (CRI), a joint effort between campus and Lawrence Berkeley National Laboratory. CRI, an interdisciplinary institute with faculty from many different departments, aims to be a catalyst in bringing academics and students together with practitioners from city, county, and state agencies to address issues of climate change in the Bay Area. Several projects have launched, including the creation of strategies for adapting to long-term sea level rise in the San Francisco Bay and research into land acquisition and ecosystem carbon in coastal California. In June, CRI also convened a who’s who of Bay Area water managers and researchers to address California’s drought. Looking forward to the next few years, CRI will develop more projects that help prepare the Bay Area for the challenges of a changing climate.

For more, please visit eps.berkeley.edu and climatereadiness.org

MATHEMATICS

As research across academic disciplines becomes more deeply interdisciplinary, the Mathematics Department has responded. In 2012 it created Math 10 A-B, a yearlong class for life sciences majors entitled “Methods of Mathematics: Calculus, Statistics, and Combinatorics.” This course has become extremely popular with an unprecedented enrollment this fall of over 700 students. Two large lecture sections are currently running to meet this demand. Mathematics has increasingly become fundamental in tackling biological questions, including modelling and large data collection in DNA sequencing and other aspects of molecular biology, the adaptation of semiconductor technology to biology, and so on. Math 10 is the culmination of years of discussion between Berkeley’s math and biology professors. Designed for relevance to biologists, it does not just add examples from biology to existing coursework, but focuses also on important mathematical and statistical concepts that are increasingly relevant to biology and medicine.

This past year, the Friends of Berkeley Math Fund (FOBM), established by Berkeley alumn Cary Queen Ph.D. ’75, supported graduate student Ralph Morrison. Ralph specializes in tropical geometry, a relatively new branch of algebraic geometry, combinatorial in nature and used in applications such as trade theory, transportation networks, and data analysis of other complex and dynamic systems. Ralph’s goal is to further the understanding of such tropical objects as curves, and to help lift information from the combinatorial world to the more general one of algebraic geometry. He used his FOBM award to attend the American Mathematical Society Summer Institute in Algebraic Geometry at the University of Utah last summer. The conference is held just once every 10 years,
so it was a tremendous opportunity for Ralph to learn more about his field and meet collaborators in related fields. He graduated with his Ph.D. last May and is now a postdoctoral researcher at the KTH Royal Institute of Technology in Stockholm.

For more, please visit math.berkeley.edu.

**PHYSICS**

IGenSpectrum, a student club run by LGBT+-graduate students, faculty, and staff in the Physics Department, recently celebrated its first birthday. The mission of IGenSpectrum is to improve the workplace climate for LGBT+ students and faculty members. Physics chair Steve Boggs is prioritizing issues of diversity and the gender gap in STEM fields, and is excited about the fact that this club has become a home for LGBT+ students looking for support and ways to improve their experience in the department. IGenSpectrum founder Alejandro Ruiz explains, “My success in physics has a lot to do with the fact that I have friends who share my experience, both socially and academically. I want all LGBT+ students to find that support here at Berkeley.”

Quantum mechanics, initially conceived at the turn of the 20th century to describe atoms and light, has shaped our modern world with paradigm-shifting technologies — semiconductors, superconducting magnets, lasers, LEDs, and medical imaging, to name a few. The newly launched Center for Quantum Coherent Science, with its home in Campbell Hall, will bring together a broad range of faculty, postdocs, students, and visitors under the directorship of Professor Irfan Siddiqi. Together, they will look deeply into harnessing quantum coherence and entanglement for a new generation of technological devices while probing the most fundamental of physical questions, once viewed by Einstein, Heisenberg, and others as “thought” experiments. For more, please visit physics.berkeley.edu.

**STATISTICS**

Berkeley’s faculty are at the cutting edge of preparing our students for a data-rich world. Increasing numbers of academic disciplines require the ability to manipulate and interpret large sets of data, in fields as wide-ranging as economics, biology, and geography, and many others. Critical thinking with data is also central to many job opportunities. As a result, a multidisciplinary team established the Berkeley Data Science Education Program, which will build an integrated set of courses and create offerings involving research opportunities, and a minor and major in the field. An introductory course was launched this fall, “Stat 94: Foundations of Data Science.” It is built on three interrelated perspectives: inferential thinking, computational thinking, and real-world relevance. Given data arising from real-world phenomena, how does one analyze that data to understand those phenomena? How does one collect data to answer theoretical questions? In addition to teaching critical concepts and skills in computer programming and statistical inference, the course will involve hands-on analysis of real-world datasets, including economic data, document collections, geographical data, and social networks. It will also delve into social and legal issues surrounding data analysis, including issues of privacy and data ownership.

Private donor funds have made a huge difference in the lives and work of our graduate students. Last year, the Sally & Terry Speed Graduate Support Fund provided financial assistance to Karl Kumbier, a first-year Ph.D. student. Karl is working to characterize gene expression patterns in Drosophila melanogaster (fruit fly) embryos. Drosophila are a widely studied model organism in the biological community, and understanding their developmental patterns helps shed light on biological processes in humans. Karl’s research team aims to reduce the patterns in a database of embryo images into “principal patterns” of co-occurring genes, which will give biologists a more manageable and interpretable dataset, making it easier to identify targets for future experiments. When he entered Berkeley, Karl knew he wanted to find an interdisciplinary project, and his support from the Speed fund gave him the time to do so. In the future, he hopes to enter academia, continue working on interdisciplinary projects, and promote good practices in data science, which is becoming an increasingly popular field. For more, please visit statistics.berkeley.edu.

Degrees Granted 2010–2014

- **Astronomy**
- **Earth & Planetary Science**
- **Mathematics**
- **Physics**
- **Statistics**

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