Carnegie Mellon University

science connection

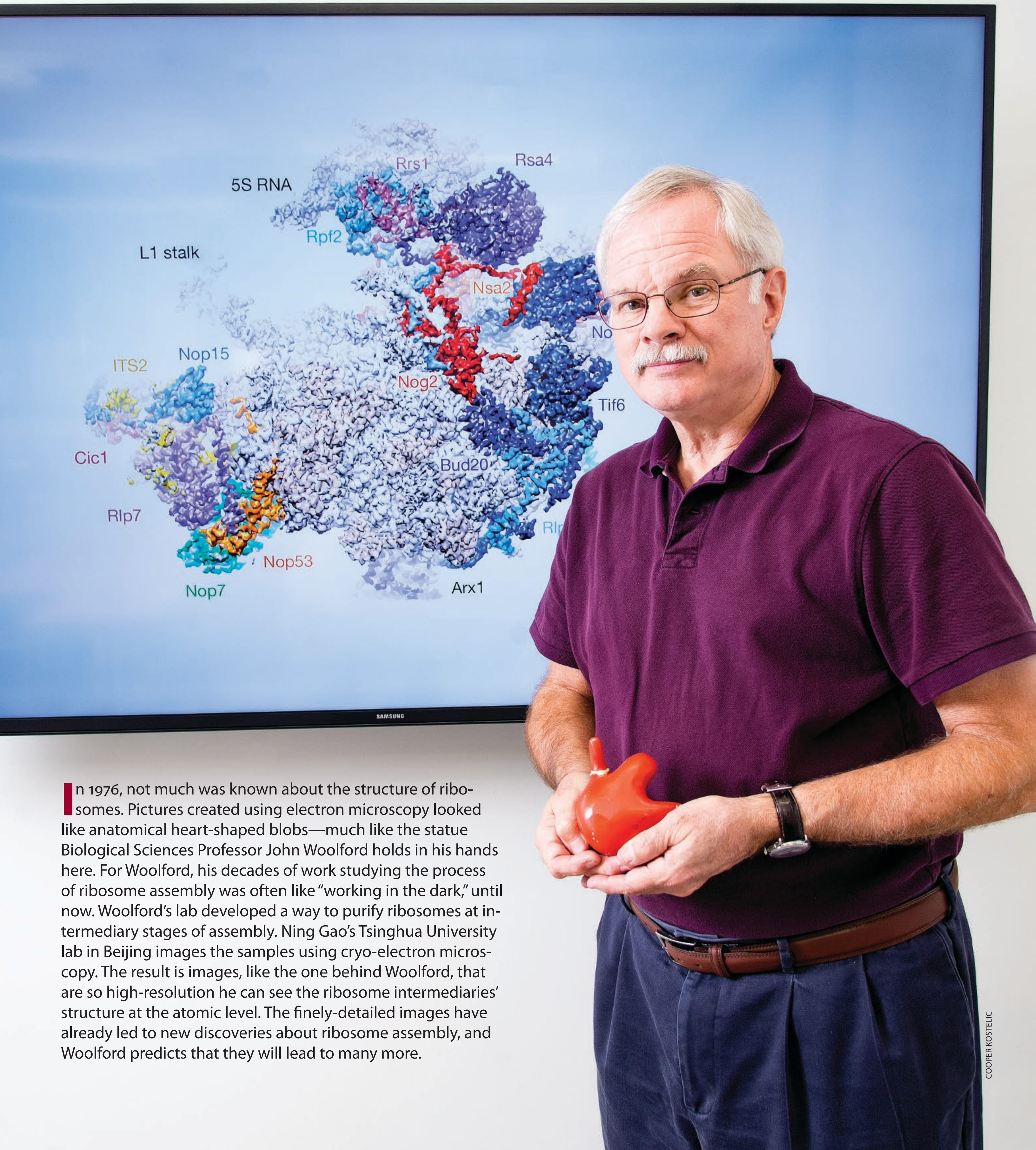
The magazine of the **Mellon College of Science**

Introducing Rebecca Doerge

The new dean of the Mellon College of Science

December 2016, volume 9 number 1

Ribosomes Ready for Their Close-Up



In 1976, not much was known about the structure of ribosomes. Pictures created using electron microscopy looked like anatomical heart-shaped blobs—much like the statue Biological Sciences Professor John Woolford holds in his hands here. For Woolford, his decades of work studying the process of ribosome assembly was often like "working in the dark," until now. Woolford's lab developed a way to purify ribosomes at intermediary stages of assembly. Ning Gao's Tsinghua University lab in Beijing images the samples using cryo-electron microscopy. The result is images, like the one behind Woolford, that are so high-resolution he can see the ribosome intermediaries' structure at the atomic level. The finely-detailed images have already led to new discoveries about ribosome assembly, and Woolford predicts that they will lead to many more.

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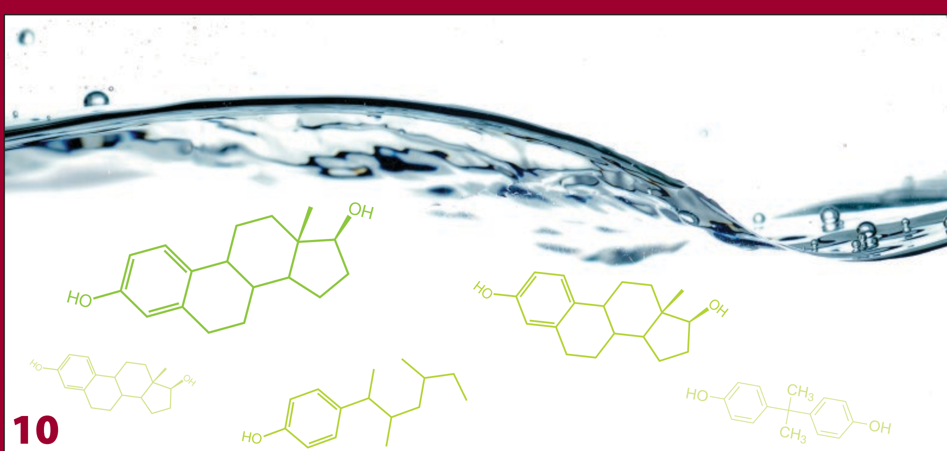
Introducing Rebecca Doerge

The new dean of the Mellon College of Science on choosing CMU and MCS, her interdisciplinary style, and her vision for the college.



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Troubled Waters

Cocktails of micropollutants are found in wastewater, lakes and streams, and drinking water. Carnegie Mellon's Terry Collins has a clean-up solution.

Departments

About the cover: In a ceremony on October 6, Rebecca Doerge was formally installed as dean of the Mellon College of Science (page 6)

After close to six months as dean of the Mellon College of Science, I can say with absolute certainty that this is a college that has many strengths, great potential and limitless possibilities. This issue of Science Connection highlights so many of the things that drew me to MCS and continue to inspire me every day. Our faculty and students are making exciting discoveries in foundational science, including everything from using vast amounts of telescope data to identify the origin of Fast Radio Bursts to developing new fluorescent and optogenetic tools to advance biological and biomedical research (pages 3–5).

Something that impressed me when I first arrived at Carnegie Mellon is that we strive to be problem-solvers. We look to create the next thing that will impact and improve the world. The work at MCS's Institute for Green Science (IGS) exemplifies this ideal. One of the biggest global issues we face is keeping our water clean. Terry Collins and his team at the IGS have created a way to eliminate the cocktails of micropollutants found in wastewater, lakes, streams and our drinking water (page 10). His catalysts break down many of the most persistent micropollutants and have tremendous commercial potential.

It hasn't taken me long to realize that MCS not only moves the world forward with our science—we train the scientists of the future. Our faculty are award-winning educators (page 14) who teach problem-solving approaches that stay with our students throughout their lives, far beyond the classroom (page 15). And our students are remarkable. It's not just my bias when I say that—the national awards they are receiving speak to their achievements (page 18–20).

I look forward to meeting as many alumni as I can. If the four alumni we feature in this issue (page 16–17) are any indication of the caliber of student MCS graduates, I know I will come away even more impressed by the varied and far-reaching ways our alumni are impacting the world.

This issue of Science Connection celebrates some of the things that make MCS such an amazing place, and I'm thrilled to be a part of it. I'm looking forward to working together with all of you to make the college and its alumni, faculty, staff and students soar to even greater heights.

Rebecca W. Doerge
Dean, Mellon College of Science
Professor of Statistics and Biological Sciences

science connection

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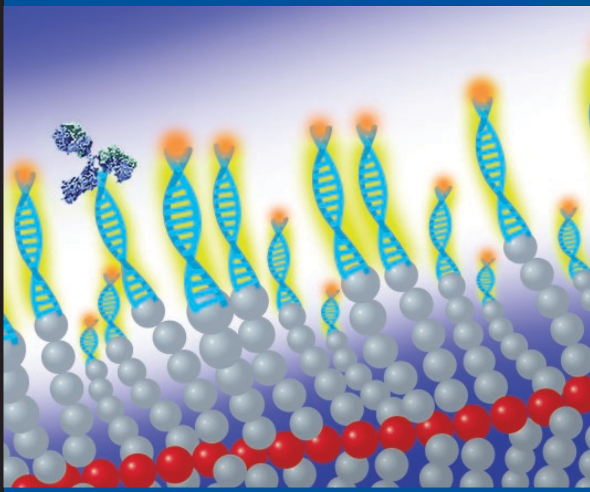
Coming to You From a Galaxy Far, Far Away

Astronomers have been puzzled by Fast Radio Bursts (FRBs), brief yet brilliant eruptions of cosmic radio waves that appear to come from the distant universe. Until now, none of these enigmatic events has revealed more than the slimmest details about how and where it formed. Using highly specialized data-mining software, a team of researchers including Jeffrey Peterson and Hsiu-Hsien Lin searched though 40 terabytes of data from the National Science Foundation's Green Bank Telescope. They flagged more than 6,000 possible FRB signals. Lin, a Physics doctoral student, painstakingly analyzed the data from each of the signals, winnowing the field to one candidate—FRB 10523. The data from FRB 10523 revealed more about an FRB than ever before. The new FRB signal contained both circular and linear polarization data, properties that indicate the orientation of the radio wave. Using this information, the researchers determined that FRB 10523 exhibited Faraday rotation, the corkscrew-like twisting that radio waves acquire by passing through a powerful magnetic field. This and other information provided clues that the burst may have originated inside a highly magnetized region of space, possibly linking it to a recent supernova or the interior of an active star-forming nebula. The discovery helps astronomers get closer to truly understanding the nature of FRBs.

JINGCHUAN YU, BEIJING PLANETARIUM; DEPARTMENT OF CHEMISTRY

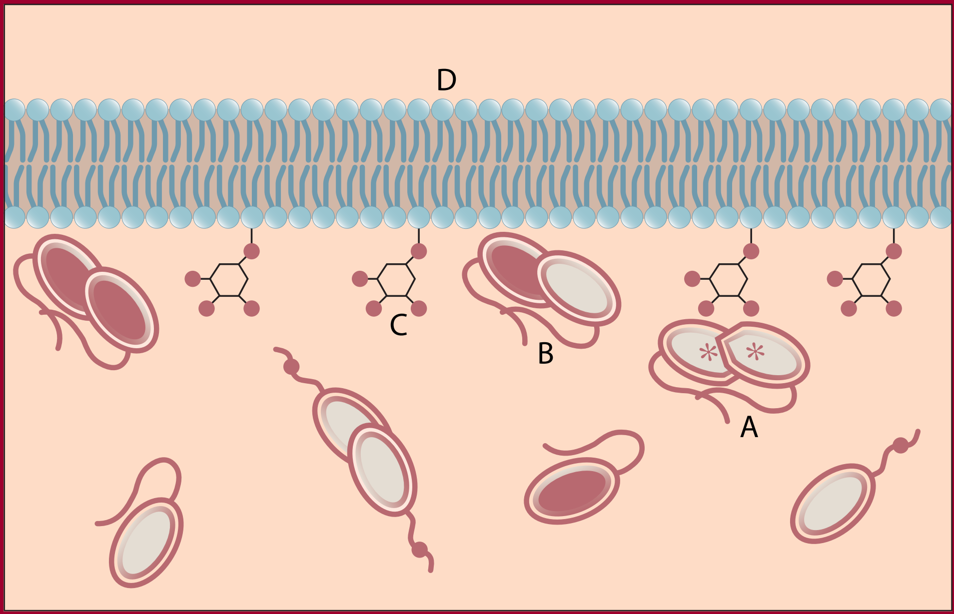


Bristling with Brightness

Fluorescent probes are ubiquitous in the study of biological systems. They allow researchers to see particular cells and proteins. But if a tagged protein of interest is expressed at a low level, the fluorescence can be dim, making the protein difficult to spot using standard imaging techniques. Chemists at Carnegie Mellon have developed a new polymer-based probe that can hold thousands of fluorescent molecules, making it 10 times brighter than current technology. Created by Bruce Armitage, Subha R. Das and Krzysztof Matyjaszewski, the new probe looks like a bottlebrush. It's made up of brush-shaped polymers with side chains that resemble bristles. On the tip of each bristle is a piece of double-stranded DNA, which acts as a scaffolding for special fluorescent molecules that bind only to the inside of DNA's double-stranded structure. This arrangement sequesters the fluorescent molecules on each bristle of the brush, preventing the molecules from quenching and reducing the brightness of the signal. The bottlebrush structure can then be attached to an antibody specific to a protein expressed by the target cell. The design permits researchers to attach different colored dyes to the DNA bristles, allowing them to look for more than one protein at a time.

Structure of Tumor-Suppressing Protein Identified

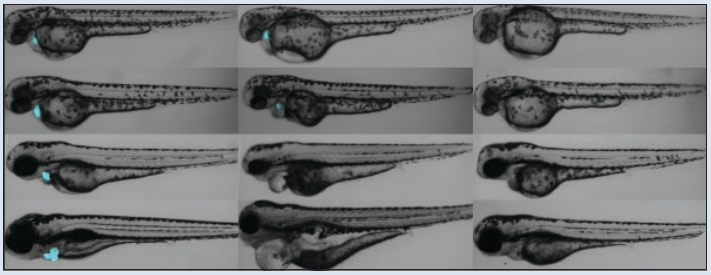
An international group of researchers led by Carnegie Mellon physicists Mathias Lösche and Frank Heinrich have established the structure of an important tumor suppressing protein, PTEN, providing new insights into how the protein regulates cell growth and how mutations in the gene that encodes it can lead to cancer. Phosphatase and tensin homolog (PTEN) is an enzyme at the cell membrane that instigates a complex biochemical reaction that regulates the cell cycle and prevents cells from growing or dividing in an unregulated fashion. Despite PTEN's importance in human physiology and disease, there is a critical lack of understanding of the complex mechanisms that govern its activity. Recently, researchers at Harvard Medical School found that PTEN's tumor suppressing activity becomes elevated when two copies of the protein bind together, forming a dimeric protein. Lösche and colleagues used small-angle X–ray scattering and computer modeling to reveal the dimer's structure. They found that the C-terminal tails of the two proteins may bind the protein bodies in a cross-wise fashion, which makes them more stable. As a result, they can more efficiently interact with the cell membrane, regulate cell growth and suppress tumor formation.



An activated PTEN dimer that contains two non-mutant proteins (A) can transform the functional lipid (C) on the cellular membrane (D) into a chemical form that tunes down cancer predilection. Dimers that contain a mutated protein (B), or PTEN monomers can not transform the functional lipid.

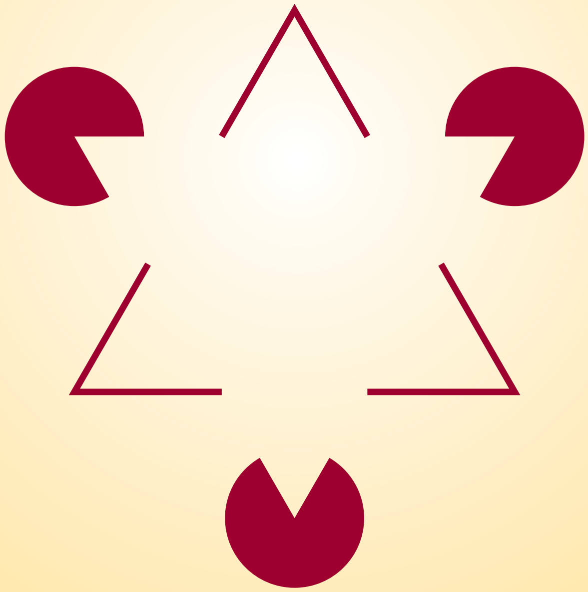
FAP-TAPs Are Powerful New Tool

Researchers led by Marcel Bruchez have re-engineered a fluorescent probe into a powerful optogenetic photosensitizer that can be used to manipulate cells with light. Bruchez and his team at the Molecular Biosensor and Imaging Center started with their fluorescent probes, called fluorogen-activating proteins (FAPs), that are used to monitor protein activity in living cells in real-time. With a little molecular tweaking, the researchers turned the FAPs into more than an imaging tool. They engineered a dye that would not only glow but also produce singlet oxygen—a toxic form of oxygen—when it bound to a FAP and was exposed to light. This FAP-Targeted and Activated PhotoSensitizer approach (FAP-TAP) not only allows researchers to visualize the protein they are targeting but also can be used to selectively inactivate the protein and control a biological function. The technology could help researchers better understand the role certain cells and proteins play in everyday function and disease. Plus, unlike other photosensitizers that required high doses of light at biologically damaging wavelengths, the FAP-TAPs approach uses significantly less light and uses light in the biologically-safe far-red or near-infrared spectra.


Zebrafish larvae expressing FAP in heart cells are treated with a normal fluorogen (left) or the targeted, activated photosensitizer (TAPs, center), then exposed to light and followed for 3 days. Only the TAPs-treated fish show defects associated with loss of cardiac function after photoablation, including loss of cardiac tissues, cardiac edema, and other developmental defects.

STRUCTURE, VOLUME 23, ISSUE 10, 6 OCTOBER 2015, PAGES 1952–1957, DX.DOI.ORG/10.1016/J.STR.2015.07.012; NATURE METHODS 13, 263–268 (2016) DOI:10.1038/NMETH.3735

Neuronal Feedback Could Change What We "See"



Have you ever wondered how optical illusions make you see things that aren't really there? Take the Kanizsa triangle: when you place three Pac-Man-like wedges in the right spot, you see a triangle, even though the edges of the triangle aren't drawn. How does your brain fill in those blanks? According to new research by Carnegie Mellon's Sandra J. Kuhlman, your brain might be reacting to feedback between neurons in your visual system. When we look at an object, information about what we see travels through circuits of neurons beginning in the retina, going through the thalamus and into the brain's visual cortex. There, the information gets processed in multiple stages before it's sent to the prefrontal cortex, where decisions about how to respond to a given stimulus are made. In her study using mouse models, Kuhlman discovered that neurons in the later stage of processing in the visual cortex reverse course and send information back to the first stage of processing, accounting for up to 20 percent of the neural activity present in the first stage. This feedback could change how the neurons in the visual cortex respond to a stimulus and alter the messages being sent to the prefrontal cortex, perhaps allowing our brains to complete the undrawn lines in the Kanizsa triangle.

PSC Bridges Supercomputer Enters Production

The Bridges supercomputing system at the Pittsburgh Supercomputing Center (PSC) opened for production operation in July, following users' successes during early operations. With this latest approval from the National Science Foundation, Bridges is now integrated with other resources in XSEDE, the NSF's national network of supercomputing sites. This transition streamlines use for over 2,300 current Bridges users in a broad range of projects spanning neuroscience, machine learning, biology, social science, physical sciences, engineering and many other fields. In one example of the system's early successes, the PSC Public Health Application Group's Jay DePasse used Bridges to model the possible benefits of flu vaccine choice in Washington D.C., Allegheny County, and Salt Lake City. He used agent-based modeling, in which every person is modeled by a realistic virtual human in the simulation. He tested the results of offering both adults and children a choice between the current injected vaccine and a new nasal mist vaccine. His results suggest that a policy offering vaccine choice would lead to more protection against the virus at lower cost than alternatives such as no choice of vaccine, choice offered to children only, and choice offered to adults only.

A Conversation with Rebecca Doerge the New Dean of the Mellon College of Science

Interview by Amy Pavlak Laird

Statistical bioinformatician Rebecca Doerge joined the Mellon College of Science (MCS) as its seventh dean on Aug 1, 2016. Previously the Trent and Judith Anderson Distinguished Professor of Statistics at Purdue University, Doerge served as Head of Purdue's Department of Statistics from 2010–2015 and oversaw its growth into one of the largest statistics departments in the country. She brings to MCS a career-long commitment to collaborating across disciplinary borders and supporting basic science research. A native of upstate New York, Doerge is a member of the Board of Trustees for the National Institute of Statistical Sciences and the Mathematical Biosciences Institute. She has authored more than 120 scientific articles, published two books and mentored 24 doctoral degree candidates to completion. We sat down with Doerge to discuss why she chose Carnegie Mellon University and MCS, her efforts to cross disciplinary boundaries, and her vision for MCS.

What drew you to Carnegie Mellon and specifically to the Mellon College of Science?

Carnegie Mellon has a great reputation for computing and engineering. The excellence in foundational science at CMU is a well-kept secret that must be exposed, promoted and strengthened. There is huge opportunity to leverage our strengths in analytics and engineering to propel foundational science forward at a faster rate than our peers. We are on an upward trajectory with the new president and the new provost. Plus, it was clear from really early on that the deans of the colleges here are a team that have the best interest of Carnegie Mellon and the students in mind. It was the deans that sealed the deal for me; we are in this together.

Also, when I was interviewing, I learned about how the Mellon College of Science is committed to educating the whole student. That really resonated with me. My hope is for the younger people to change the state of science, for them to be well-balanced and communicative and more integrated into what's important in the world. The new MCS Core Education gets to the heart of this, and it really is a very forward thinking approach to education.

Your undergraduate degree is in theoretical math. Your Ph.D. is in statistics. And you do research that focuses on genetics. How did that happen?

It wasn't planned! I said yes to things that interested me, even though I had no idea how I was going to proceed.

I was an undergraduate at the University of Utah in the '80s during the first phase of the computer science craze. And I thought, there's a future in that. I started out in computer science, and I liked programming, but it just wasn't my thing. But I really liked the math, so I decided to change my degree from computer science to theoretical math. I stayed at the University of Utah and did a master's degree in theoretical math; during that time I took a statistics class. I did well and thought it was interesting. When I realized that I was going to have to get a job, I went to a probabilist, named Simon Tavaré, and he introduced me to a human geneticist. This is 1986–87, right at the start of the human genome project. I ended up joining a human genetics group at the University of Utah Department of Human Genetics.

In a ceremony held on Oct. 6, Rebecca Doerge (pictured here with President Subra Suresh, left, and Provost Farnam Jahanian) was formally installed as dean of the Mellon College of Science. During the ceremony, she received a Quaich, a Scottish drinking vessel that was traditionally used to offer guests a cup of friendship or welcome. Its two-handled design is a symbol of new ventures and mutual trust between the giver and receiver. The ceremony was the first to be held for a CMU dean. Going forward, each dean will be feted similarly.

What was that like, to join a human genetics group as a theoretical mathematician?

I hadn't taken a biology class since seventh grade biology. I had no vocabulary. It was the beginning of interdisciplinary research for me, something that was unheard of at the time. In fact, I would love to know what they really thought about me: a woman in a very male-dominated field, good at math, from New York. I stuck out like a sore thumb. But I liked the research, because it was real. I worked there for a year after finishing my master's. Then I was invited to do a Ph.D. at NC State in statistics and quantitative genetics. That was when I switched from human genetics to agricultural genetics.

Your research now is in the area of statistical bioinformatics. Will you describe your research?

We chase technology and figure out how to design experiments and analyze the data that are collected. Typically, our work is based in genetics, genomics and epigenomics, so the data are DNA- or RNA-based. Our goal is to understand the ultimate function of DNA and epigenomic associations with the genome. Some of what we work on is human cancer. We do proof-of-concept in plants and then spin it off to human applications. We work on real problems that have global impact.

Your research crosses many disciplines, including plant science, human genetics and statistics. How has being interdisciplinary shaped your career?

When I started looking for jobs after my postdoc at Cornell, no one wanted to hire someone who was interdisciplinary. Interdisciplinary research was not cool. At the time (mid-1990s) the trend was to develop deeply in one disciplinary area, and you stayed in it. It was just a function of the time. At Purdue, they actually hired me as an assistant professor with a 25 percent appointment in agronomy (which is the College of Agriculture) and a 75 percent appointment in statistics (in the College of Science). Folklore at Purdue is that I was the first untenured assistant professor that they ever hired jointly.

Do you have any advice for someone who wants to cross a disciplinary boundary, either at their job or in school?

One thing that I had to learn to do is talk across disciplinary boundaries. And to have enough confidence to ask, "What does that mean?" I learned early on that you have to stay at the table. You're not going to learn how to communicate in a disciplinary manner after an hour. It takes dedication and you have to read and you have to ask questions and you have to dig into the literature.

Carnegie Mellon's Provost has said that "science is in our DNA as a university." How do you see MCS's role at the university and, more broadly, in the Pittsburgh region?

Foundational science, thus science, is the basis of all accomplishments at CMU. Whether it is the DNA of the people that create the incredibly vibrant atmosphere, or the fundamentals of biology, chemistry, mathematics and physics that give rise to the computers we use, the materials we rely on, or the theory that supports discovery, it is all based in science.

Pittsburgh is definitely up and coming. With its dozens of universities and colleges, and so much biotech and tech moving in, I think there's huge opportunity here to connect to industry, academics, government, etc. that will not only change Pittsburgh but also position Carnegie Mellon in the middle of all of that.

What are you most looking forward to in your first year as dean of MCS?

One of the fun responsibilities that comes with leading a modern college of science these days is to find out where people shine, where their passion lies and how they want to contribute. And to do that, you have to know people. I'm really looking forward to getting to know our alumni, students, faculty and staff. I think that the Mellon College of Science is really well-positioned to shine, and I can't wait to help us shine brightly.

Dean Rebecca Doerge speaking with Greg Franklin, professor of physics, and Michael Levine, director of the Pittsburgh Supercomputing Center and professor of physics.

What's one thing the MCS community would be surprised to learn about you?

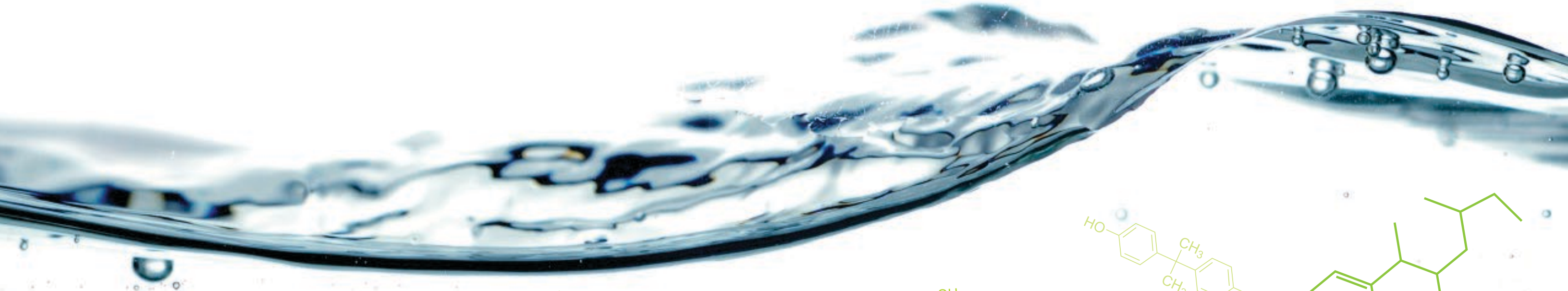
There are two things: First, I have an 8-pound dog named, Mr. BIG. He's terrific! Second, I have an irrational fear of rodents (terrified of mice… dead or alive!).

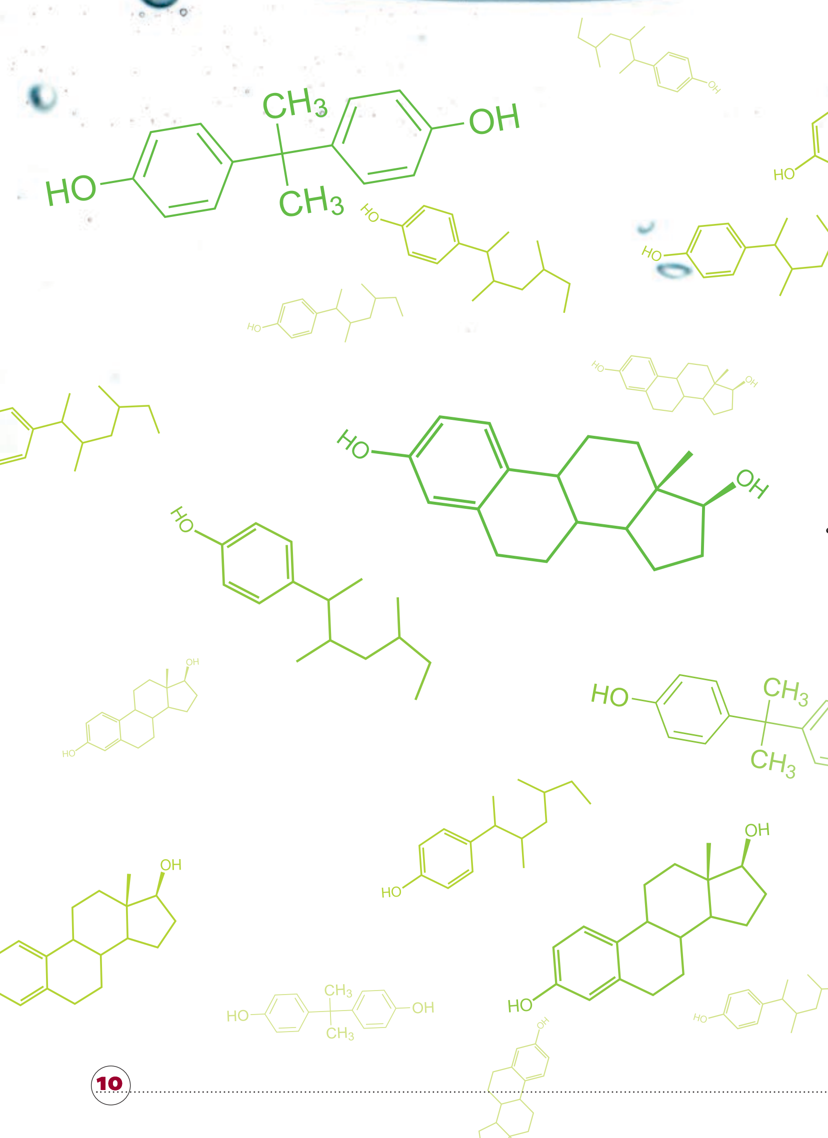
ALL PHOTOS BY CARNEGIE MELLON UNIVERSITY

Troubled Waters

Cocktails of micropollutants are found in wastewater, lakes and streams, and drinking water. Carnegie Mellon's Terry Collins has a clean-up solution.

by Amy Pavlak Laird



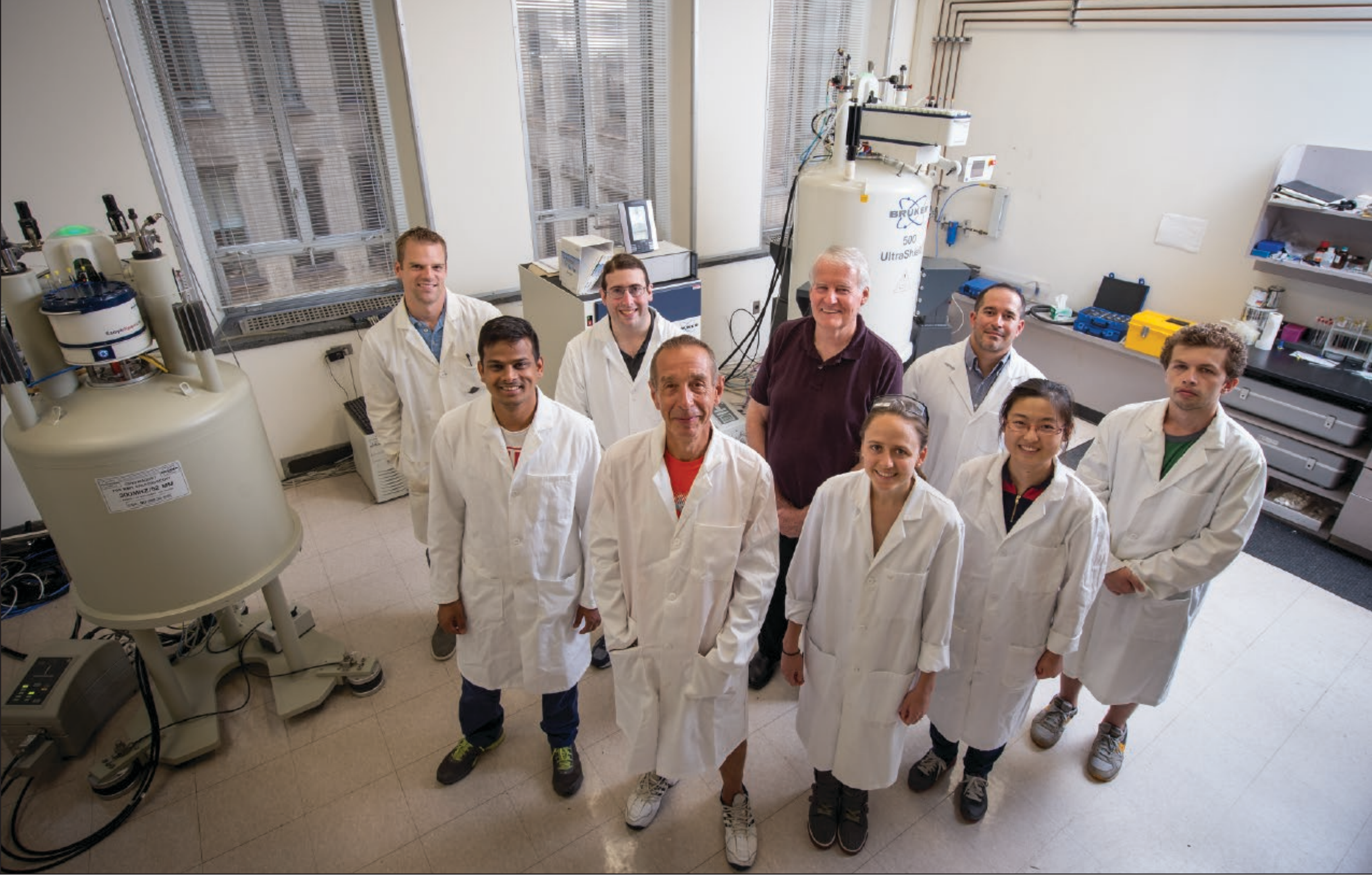


Many of us probably don't give much thought to what we send down the drain. Where does the fancy foaming cleanser we use to wash our faces go? Or the weed killers applied to our lawns and gardens? What happens when we flush the toilet or have run-off after a storm? It all goes down the drain, ending up in wastewater treatment plants.

"The products we use in our homes, the medications we take, the chemicals we spray on crops—every chemical we use—it all ends up in our water at some point," said Terry Collins, the Teresa Heinz Professor of Green Chemistry at Carnegie Mellon.

Many pharmaceuticals, personal care products and household chemicals, not to mention industrial chemicals and pesticides, are "micropollutants"—compounds that produce adverse effects at low doses. These persistent contaminants show up in unexpected places. Human urine contains more than 3,000 compounds, 2,000 of which come from our diets, the drugs we take and the personal care products we use—many were not in the urine of our great-grandparents. Micropollutants cannot be fully eliminated with traditional wastewater treatment methods and wind up getting discharged into local waterways. Some end up returning to us in our drinking water.

Over the last few decades, micropollutants in our water have become an issue of increasing concern worldwide. In 2008, the Associated Press reported that pharmaceutical residues were found in the drinking water of 24 major metropolitan areas across the United States. The U.S. Geological Survey reported in 2000 that 80 percent of the 139 streams it sampled were found to have organic wastewater contaminants and pharmaceuticals, including



From left to right: Matthew Mills, Yogesh Somasundar, Paul Kornbluh, Aleksandr Ryabov, Terry Collins, Genoa Warner, Matthew DeNardo, Liang Tang and Samuel Joyce-Farley

antibiotics and reproductive hormones. In 2016, the EPA reported that atrazine, the second most widely used weed killer in the United States, which often ends up in surface and groundwater, poses chronic health risks to mammals, fish and birds.

Although the concentrations of micropollutants in our water are low, even minute traces affect fish and amphibians. Ethinylestradiol, for example, an artificial estrogen found in widely-used birth control pills, can cause male fish to develop eggs in their testes. Feminized male fish have been discovered in 37 different species in lakes and rivers throughout the world. Perhaps even more worrisome, research on frogs has indicated that mixtures of micropollutants, even at low concentrations, may present environmental hazards that are far greater than those for each individual compound.

"Aquatic animals are indicators of what can happen when hormone control systems get hijacked by synthetic chemicals," Collins added. "We need to get these micropollutants out of our water systems."

Collins and an international team of water treatment scientists and engineers, endocrine disruption experts and membrane developers believe they have the solution.

Collins and his research team in the Institute for Green Science (IGS) in the Mellon College of Science have developed catalysts that, together with hydrogen peroxide, break down many of the most persistent micropollutants. After inventing the first family of catalysts in 1995, the IGS refined them to be effective, affordable, remarkably versatile and easy to use.

TIM KAULEN

Collectively called TAML activators, the catalysts are small molecules that mimic oxidizing enzymes that living things, from bacteria to humans, use as their most potent detoxification strategy. TAMLs react with hydrogen peroxide to degrade persistent micropollutants, including ethinylestradiol, statins, antidepressants, beta-blockers, and NSAID pain relievers.

After creating the catalysts, Collins was quick to realize their promise. "We were taking pollutants that last in the environment for decades and decomposing them catalytically in minutes under ambient conditions," he said. "Very early on, it became crystal clear to me that TAMLs might provide a revolutionary advancement in purifying water that could also provide an answer to micropollutants."

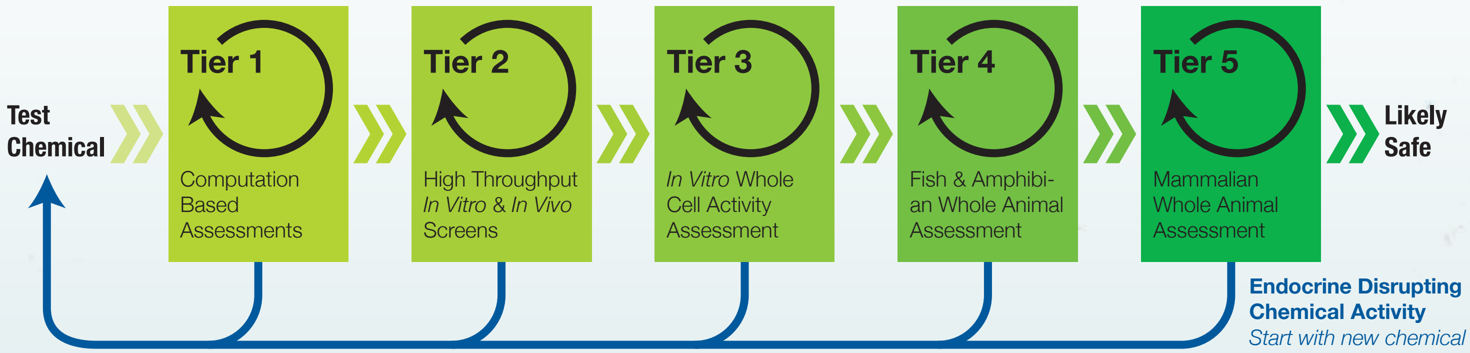
Passing the Green Chemistry Safety Test

"TAML activators are so effective at degrading micropollutants, the only thing that worries me is their potential toxicity," said Collins, an international leader in green chemistry—the design of chemical products and processes that reduce or eliminate the generation of hazardous substances.

To this end, one of green chemistry's key themes is to produce technologies comprised of the same elements nature uses to build all living things. Even though Collins designed TAMLs so that they contain only biochemically common elements, it is still not possible to predict toxicity. Empirical evidence is necessary.

"Before TAML activators could be commercialized for decontaminating water, we needed to be sure that the TAMLs

Tiered Tests for Endocrine Disruption (TiPED)



TiPED helps chemists determine the potential endocrine disrupting activity of a new chemical. The tiers are organized from the simplest and least expensive screens (left) to a whole animal lifetime assessment (right). The lower three tiers detect when chemicals can disturb the normal function of nuclear receptor proteins that the hormones activate to cause gene expression at single-cell levels or in the computer. In the final two tiers, chemical impacts on the full suite of endocrine hormone biochemistry are being assessed simultaneously either in adults, developing organisms, or across multiple generations.

themselves, and their degradation products, weren't endocrine disruptors."

An important public health and environmental concern, endocrine disrupters are synthetic molecules that can mimic and interfere with the function of hormones in the body. A wide range of substances can cause endocrine disruption, including pharmaceuticals, dioxin and dioxin-like compounds, DDT and other pesticides, and plasticizers such as bisphenol A. Endocrine disruption can cause the feminization of fish and other intersex conditions in aquatic species like alligators, turtles and frogs. According to the National Institute of Environmental Health Sciences, some research suggests that these substances are also adversely affecting human health, resulting in reduced fertility and increased incidences or progression of some diseases, including obesity, diabetes, endometriosis and some cancers.

Several years ago, CMU Adjunct Chemistry Professor Pete Myers brought together leaders in endocrine disruption science and green chemistry to develop a testing system that shows scientists how to determine whether a new chemical has any endocrine disrupting activity. Called the Tiered Protocol for Endocrine Disruption (TiPED), the system consists of five tiers of assays that capture the presence of endocrine-related effects (see figure above). So far, multiple TAML safety studies in fish and a test in mice have shown no developmental or adult toxicity. Interestingly, in zebrafish embryo development assays on seven TAML activators, one TAML was found to be quite toxic. Collins eliminated it from water-treatment contention. The toxicity difference between this TAML and others could not be predicted from first principles. "There is simply no way to achieve this design-relevant insight without performing the empirical TiPED assays," Collins asserted.

Ridding Wastewater of Micropollutants

In the last several years, Collins has let TAMLs loose on endocrine-disrupting chemicals, most notably estrogenic compounds in water as these represent some of the most serious threats to the health of aquatic creatures. Collins teamed up with Brunel University London's Susan Jobling and Rak Kanda, who are

ISTOCKPHOTO

world-class experts in aquatic toxicity and wastewater treatment, to test the efficacy and safety of using TAML activators to degrade 17-α-ethinylestradiol (EE2), a synthetic estrogen found in oral contraceptives and a major cause of fish feminization. The research team showed that TAMLs were able to degrade not only EE2 in pure water, but also the early intermediate compounds created as TAMLs degraded EE2, which were also found to be estrogenic.

While the lab results were exciting, Collins was eager to see what TAMLs could do with actual wastewater. The research group took samples of water processed by a municipal wastewater plant in London—water that is known to contain numerous micropollutants like drugs and pesticides—and zeroed in on eleven compounds of high concern to the water treatment industry. The researchers found that TAMLs broke down not only the EE2 but also other estrogenic compounds and various micropollutants in the water.

Through all of these studies, it became clear to Collins that he and his colleagues were inventing a new field of chemistry—catalysis under ultradilute conditions in which the targets are present in vanishingly small concentrations. Currently, one kilogram of TAML catalysts can effectively treat tens of thousands of tons of wastewater in minutes. In 2015, the IGS created a second family of catalysts, "new-TAMLs," that are far more potent than the original "old-TAMLs," making them even more effective and reducing overall cost of scale up.

Competitive Advantages

The safety of the TAML process to date and its proven effectiveness for removing numerous micropollutants from wastewater make it a potentially transformative technology for advanced wastewater treatment. Preliminary studies show that the old-TAML processes are comparable to favored advanced treatment options, such as ozone or activated carbon, but at a much lower cost needed for wide use and potential commercialization. In Switzerland new legislation requires wastewater treatment plants to implement an additional treatment process specifically for the removal of micropollutants. The country is currently adding final-stage ozone or activated carbon processes to about 100 of its 700 municipal wastewater treatment plants at a cost of about $1 billion. This price tag is a hindrance to municipalities and countries around the world that would like to implement such changes to their wastewater treatment systems. According to Brunel's Rak Kanda, "old-TAML plants are estimated to be 3–5 times lower in operating costs, significantly lower in capital costs and 2–3 times lower in energy use compared to ozone plants." Because the new-TAMLs are so much more effective than old-TAMLs, the processes will cost even less; estimates are 10 percent of the cost of ozone treatment.

"When you combine the technical aspects, cost and environmental performances, we now have much better catalysts. And the data are unambiguous," Collins said. "Our innovation provides an effective, affordable, versatile and safe solution for removing micropollutants from water."

What can TAMLs degrade?

Dyes, mold stains, certain pesticides, drugs, explosives residuals, disinfectants, hormones and other endocrine disruptors, phenols including bisphenol A, smelly sulfur compounds, hardy microbes like bacterial spores, and certain hydrocarbons.

ISTOCKPHOTO

University Stars

Eric Grotzinger

Robert E. Doherty Award for Sustained Contributions to Excellence in Education

In his nearly 25 years as associate dean of undergraduate affairs in MCS, Grotzinger has had a direct impact on students and MCS's educational mission. "It is fair to say that there is no part of undergraduate education in MCS that has not been touched by Eric, and is better because of it," Grotzinger's colleagues wrote. Highlights of his tremendous impact include: working to increase the number of women and under-represented students in the college, increasing the retention rate of first-year students in science to an average of 95 percent per year, helping to develop both the SHS and BSA programs, and playing an instrumental part in implementing the new MCS Core Education.

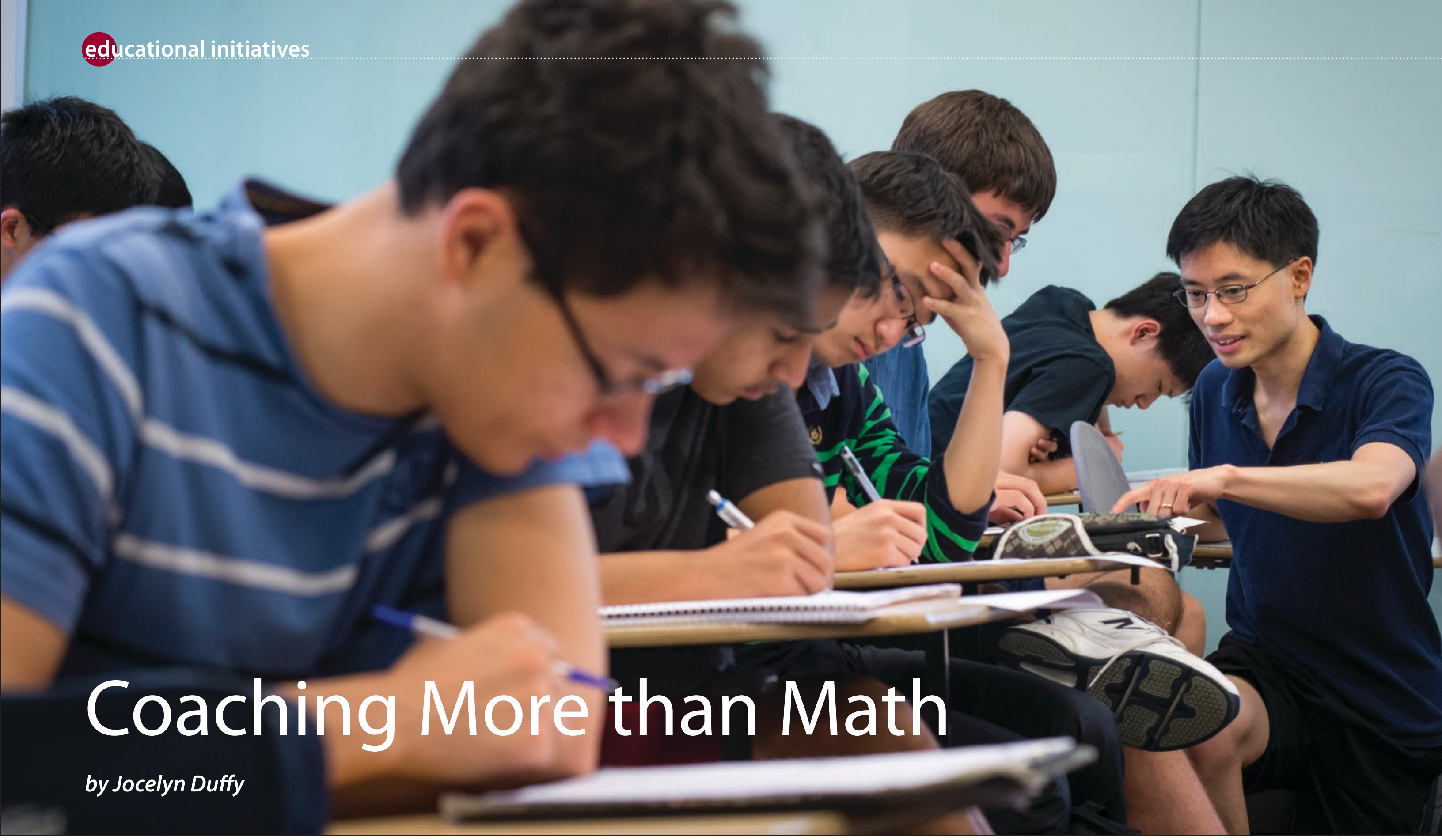
Kunal Ghosh

Award for Outstanding Contributions to Academic Advising and Mentoring

Since Physics Teaching Professor Kunal Ghosh arrived at CMU in 2001, he has remained undeterred on his quest to help students become well-rounded, healthy human beings. For students in any kind of trouble—whether it be academic or personal—he puts every ounce of his energy into helping them. As the primary adviser for every physics major, Ghosh knows and uses every resource the university has to offer to help students. He is proactive, always asking faculty to identify students who have shown any sort of problems and then he seeks those students out. "There is no doubt he has saved large numbers of students' academic careers, and possibly some lives as well," his nominators wrote.

Kunal Ghosh and Eric Grotzinger Receive the University's Highest Advising and Education Awards

TIM KAULEN



Coaching More than Math

by Jocelyn Duffy

Po-Shen Loh (far right) and 2016 U.S. Mathematical Olympiad Summer Program participants.

Po-Shen Loh is a coach who doesn't care if his team wins the game. What matters to him is that each team member wins…in life.

"My philosophy is to focus on the 20- to 30-year trajectory of the students that I work with. Doing this is just part of my DNA," said Loh.

Loh is an associate professor of mathematical sciences at the Mellon College of Science and is a guru in the realm of competitive math. At CMU, he leads the Putnam Seminar, which prepares students for the Mathematical Association of America's (MAA's) Putnam Competition, the premier undergraduate mathematics competition in North America. He is also the coach of the U.S. International Mathematical Olympiad (IMO) Team. While Loh is happy if his students have a 4.0 G.P.A. or win a gold medal, working to achieve those short-term goals isn't what Loh teaches in his classroom.

"I'm often asked why mathematics is relevant. The answer isn't 'to get an A in math class.' Focusing on that makes people fail to see the power of mathematics," Loh said. "The role of mathematics in today's society isn't basic computation, it's to provide a framework for thinking."

Loh provides this framework to his students by focusing less on solving problems and more on problem-solving. He believes that teaching students that there is one "right" answer or leading them to believe that acing a test is their ultimate goal is too high-stakes and too focused on the individual. He says that students really need to learn to work collaboratively and try to find answers to problems using trial-and-error. This shows students that it's okay to make mistakes and that the best way to solve problems is to work in teams—all lessons that can be applied not only to math but to life.

"Dr. Loh gives us students the internal motivation to try, try and try some more when we encounter hard problems," wrote a former Putnam Seminar student. "Wherever life takes us, we will encounter hard problems and it will matter a lot more that we have the strength to try to take them on than it will be for us to know the answers to specific problems."

Loh's students, from the CMU undergraduates in his seminar to the 70 high school students he brings to Pittsburgh for the Mathematical Olympiad Summer Program, have fully embraced his methods. His students can often be found huddling around notebooks, actively debating how to solve a problem.

While his emphasis is on teamwork, Loh also takes time to encourage each student individually, inside and outside class. He regularly eats lunch in Newell Simon Hall, where students are always welcome to join his table and talk about math.

Loh acknowledges that his method of teaching could be seen as unorthodox since it doesn't focus on immediately quantifiable results. In fact, when Loh agreed to take on leadership of the U.S. Mathematical Olympiad team, he told the MAA that he was going to focus on the students' long-term success, and that by doing so, the team would be unlikely to win.

Happily, Loh was wrong. After a 21-year drought, the U.S. IMO team placed first in 2015 and 2016. And for Loh, the wins keep coming. For five years running, Carnegie Mellon has placed in the top 5 in the Putnam Competition. For the last three years, Carnegie Mellon has had the second most number of students scoring in the top ten percent in the Putnam.

Loh looks forward to seeing the real results when his students return to campus for their 20-year reunions. When they return successful and happy, that will be Loh's biggest win.

Alumnae Take the Lead

Njema Frazier Honored at Ebony Power 100 Event

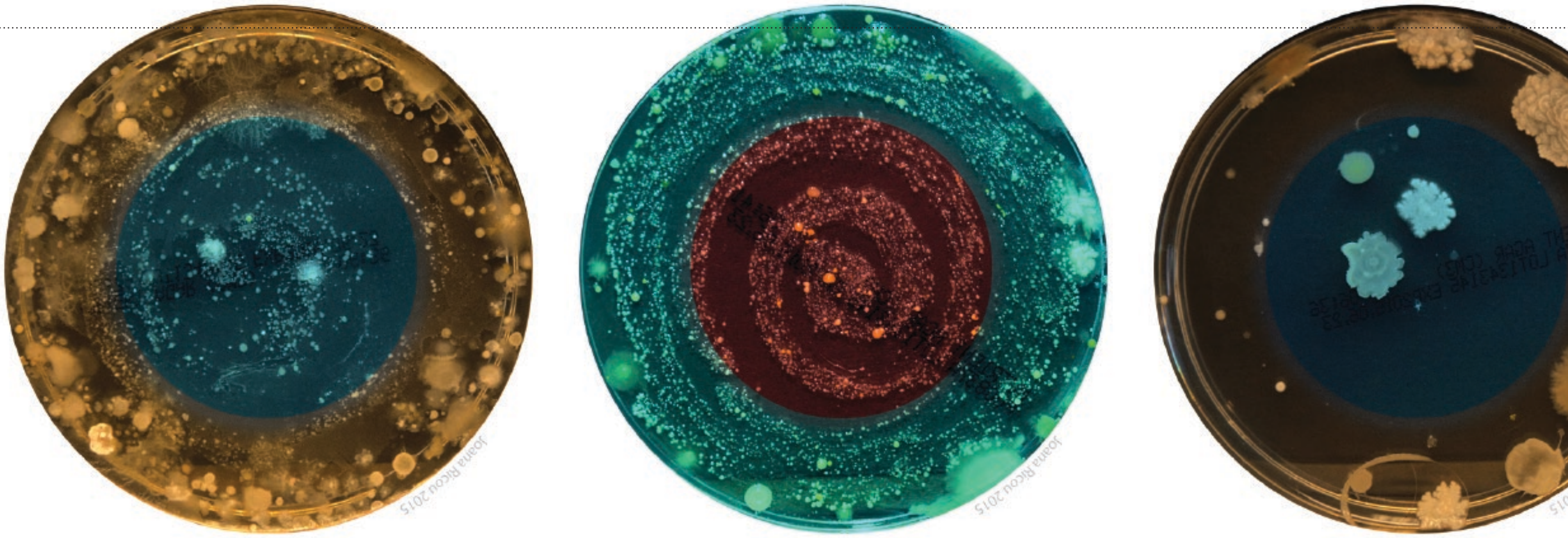
Alumna Njema Frazier walked the red carpet last December at the Ebony Power 100 event in Los Angeles alongside such celebrities as Viola Davis and Drake. But Frazier isn't an actress or a rapper—she's a theoretical nuclear physicist. She was named one of Ebony's Power 100, specifically one of "the 2015 mavericks in medicine and science who literally keep hope alive." Frazier, a 1992 Physics graduate, works for the U.S. Department of Energy in the National Nuclear Security Administration (NNSA) Office of Defense Programs, leading scientific and technical efforts to ensure that the United States maintains a credible nuclear deterrent without nuclear explosive testing. She was recently named Acting Director of NNSA's Office of Inertial Confinement Fusion and High Yield.

In addition to her professional responsibilities, she is committed to promoting STEM education—mentoring students, disseminating information about opportunities in STEM, and starting K-12 programs and initiatives. She is the founder and chief executive officer of Diversity Science, LLC, an expert-based network of scientists and engineers dedicated to broadening participation in STEM fields, and the Co-founder and Chair of the Algebra by 7th Grade (Ab7G) Initiative for students in grades 3 through 7.

General Gina Grosso Appointed to New Role in U.S. Air Force

Three-star general and alumna Gina Grosso is the first woman to hold the post of the U.S. Air Force's Deputy Chief of Staff for Manpower, Personnel, and Services—a position created nearly 50 years ago. In this role, to which she was promoted in October 2015, she's basically the human resources director for the entire Air Force, serving more than 680,000 military and civilian Airmen, not to mention their families. She is responsible for comprehensive plans and policies covering all life cycles of military and civilian personnel management, which includes military and civilian end strength management, education and training, compensation, resource allocation and the worldwide U.S. Air Force services program. General Grosso, who graduated with her B.S. in applied mathematics and industrial management in 1986, is one of only a few dozen female generals in the Air Force.

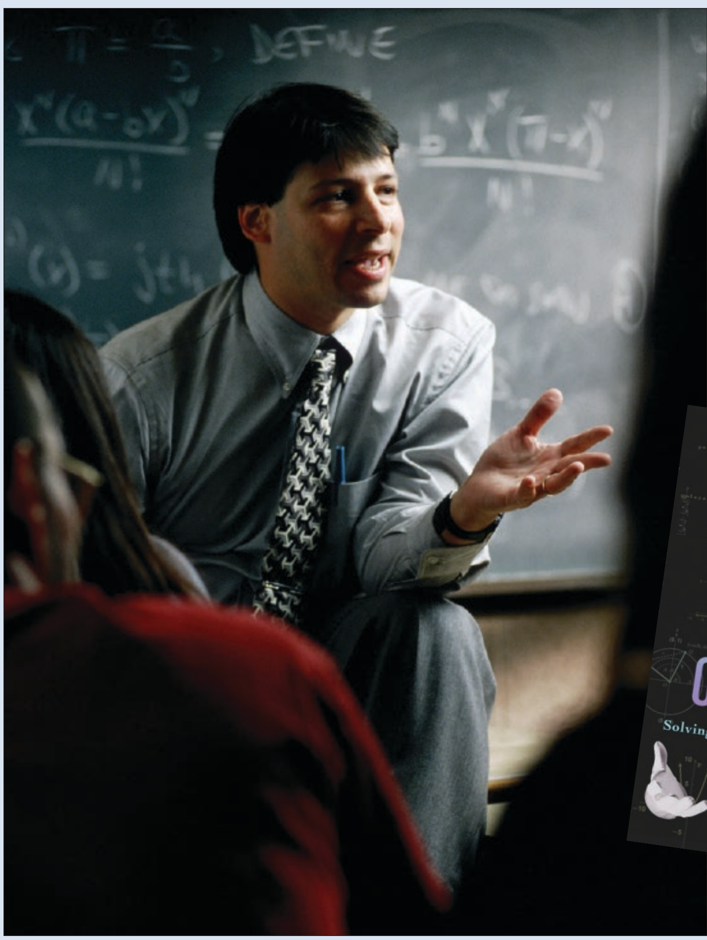
COURTESY OF NJEMA FRAZIER; COURTESY GINA GROSSO

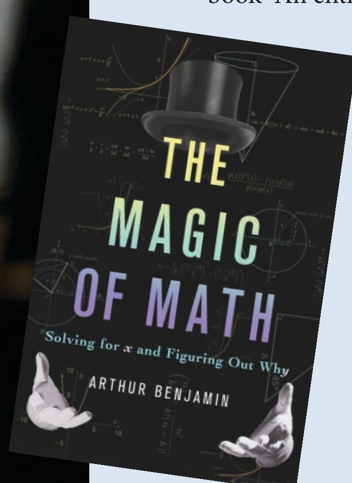


Celine in Cornwall (EP003), UK 2015; Eleri in Cornwall (EP005), UK 2015; Mark in Cornwall (EP018), UK 2015

Navel Gazing

An entire microbial world is living in our belly buttons—and alumna Joana Ricou has been making their portraits. "The Bellybutton Portrait Series is an installation and participatory performance that invites viewers to consider their other selves, the parts of their body which are not human," explains Ricou, a 2004 graduate of the Bachelor of Science and Arts program. Ricou developed the series of portraits as a semi-permanent exhibit for "Invisible You—The Human Microbiome" at the Eden Project in the United Kingdom. Ricou's source material came from volunteers who twirled a sterile swab in their belly buttons during a Strange Science event. The swabs were then swiped across a petri dish, and Ricou waited to see what grew. The result? Microbial portraits that were unique to each person—as unique as a fingerprint.





Demystifying Math for the Masses

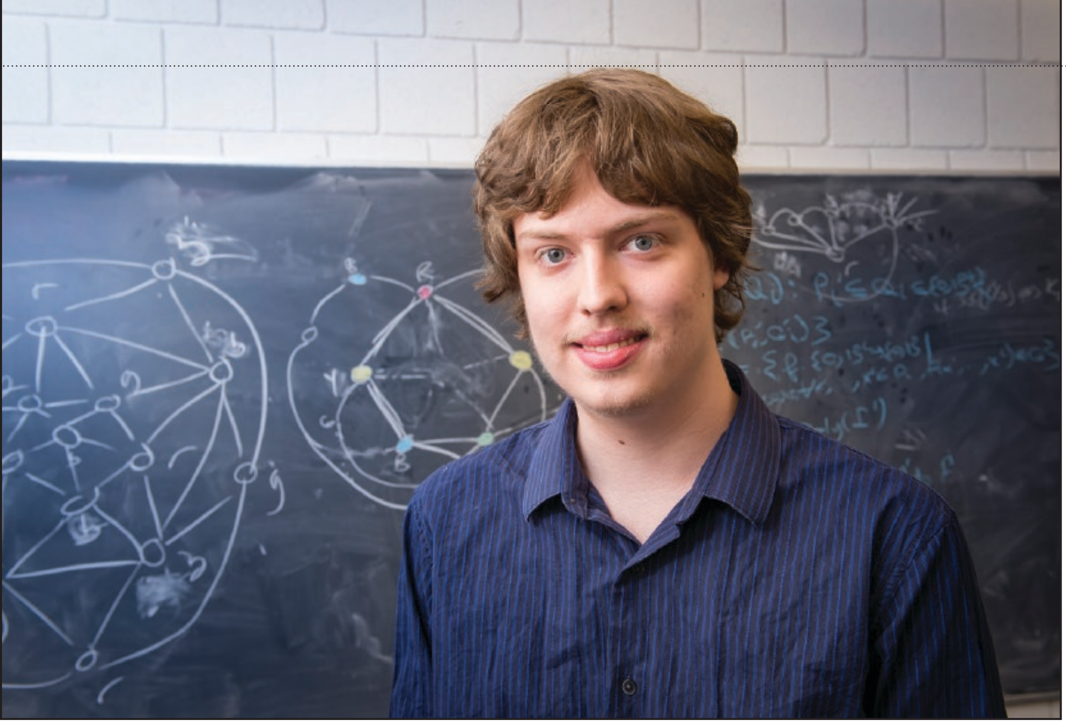
MCS alumnus and world famous "mathemagician" Art Benjamin reveals mystery and adventure in mathematics with his new book, "The Magic of Math: Solving for X and Figuring Out Why." In the book, Benjamin shows how the math we learned in school—from basic counting and arithmetic to algebra, geometry, calculus and beyond—can be easy, intuitive and fun. Kirkus Review called the book "An enthusiastic celebration of the beauty of mathematics," and Bill Nye praises Benjamin for showing readers "how to make nature's numbers dance." A 1983 graduate of the Department of Mathematical Sciences, Benjamin is a mathematics professor at Harvey Mudd College. He has performed his "mathemagics" shows—mixing math and magic to make the subject fun and easy to understand—at thousands of schools, universities, conferences and public venues around the world.

JOANA RICOU , HTTP://MICROBIALART.TUMBLR.COM/; PHOTO COURTESY HARVEY MUDD COLLEGE

Jillian Jaycox Wins Churchill Scholarship

Jillian Jaycox is going the distance. The competitive runner's shoes are pounding the pavement in the United Kingdom, where she's spending a year at the University of Cambridge. The recent biological sciences graduate received a 2016 Churchill Scholarship, one of the most prestigious awards for studying abroad in the United Kingdom. Jaycox is pursuing a Master of Philosophy in Medical Science at Cambridge's Department of Medicine as a member of Ken Smith's research group, which is investigating a new prognostic biomarker for autoimmune diseases. "This work will increase our ability to study and guide treatment for certain autoimmune diseases, such as lupus, which are complex and heterogeneous. Two patients with the same diagnosis can have two very different outcomes, and it is important to understand exactly why this occurs and how we can predict it," Jaycox said. Jaycox is no stranger to this type of research. Working in the lab of University of Pittsburgh Immunology Professor and MCS alumna Sarah Gaffen, Jaycox studied the immune response to bloodstream fungal infections, and co-authored three peer-reviewed journal articles on that work. Following her Churchill experience, Jaycox plans to apply to M.D.-Ph.D. programs and pursue a career as a physician-scientist in immunology.

ALL PHOTOS CARNEGIE MELLON UNIVERSITY



Joshua Brakensiek Wins Goldwater Scholarship

During his first two years at Carnegie Mellon, junior mathematical sciences major Joshua Brakensiek has been busy. He's conducted astrostatistical research with faculty working in statistics and cosmology, and theoretical computer science research with faculty in the School of Computer Science. He flew to Japan to present his theoretical computer science research at the 31st Conference on Computational Complexity. Brakensiek was also a member of the CMU team at the 2015 Mathematical Association of America's William Lowell Putnam Competition, placing among the top 16 of the 4,275 students who took the Putnam test. That's all in addition to carrying a full course load each semester. It's no surprise, then, that Brakensiek was one of 252 college sophomores and juniors nationwide to receive a Barry Goldwater Scholarship to support his pursuit of a research career in mathematics and theoretical computer science.

Clive Newstead Wins Carnegie Mellon's Graduate Student Teaching Award

From left: Amy Burkert, vice provost for education; Clive Newstead; Will Frankenstein (EPP) Graduate Student Service Award; and Farnam Jahanian, provost.

Clive Newstead, a Ph.D. candidate in the Department of Mathematical Sciences and this year's winner of Carnegie Mellon's Graduate Student Teaching Award, is a bit of a legend. Students often attend his recitations even though they aren't assigned to his section, and many of his former students still seek out his help long after they have had him as a TA in class.

Newstead is known for going above and beyond to make sure his students understand complicated and often confusing mathematical concepts. He has a natural ability to explain extremely complex ideas in a way that makes them simple to comprehend. And his passion for math has a profound impact on his students. "His enthusiasm for and love of math reminded me each day why I came to CMU and why I want to continue studying mathematics," wrote first-year student Allison Klenk.

Rebecca Alford Named Hertz Fellow

When she was a child, Rebecca Alford discovered something about herself that would shape her future in more ways than one. She was diagnosed with a rare genetic condition that results in visual impairment, a condition that was a bit of a medical mystery. With time, "I realized that I did not need to wait for other scientists to find the answers. I could find them myself," said Alford, a 2016 chemistry B.S. graduate. While in high school, she created a computational method to classify genetic mutations as disruptive or non-disruptive to the function of membrane proteins. At Carnegie Mellon, she conducted research at Johns Hopkins University, where she helped to develop a new computational method for modeling membrane proteins. Now, she's a Hertz Fellow pursuing her Ph.D. in chemical and biomolecular engineering at Johns Hopkins University. Her ultimate goal is to become a professor and lead her own research group that will build computational tools to explore the connection between genetic sequence, protein structure and function, and disease.

"The Hertz Fellowship will provide me with the creative freedom to do fundamental research in the field, bring my ideas to life, and work toward doing science that will hopefully impact the public," she said.

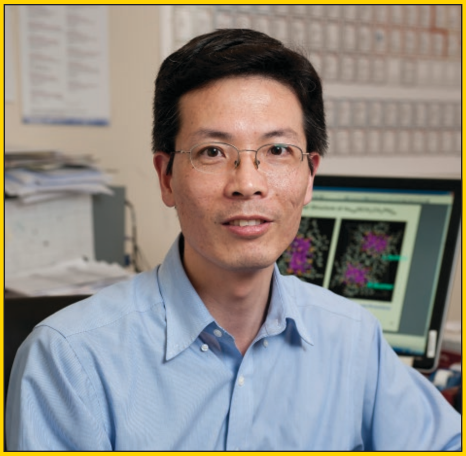
CMU Places Second in 2015 Putnam Math Competition

On Dec. 5, 2015, 4,275 American and Canadian undergraduates from 554 institutions participated in the Mathematical Association of America's 76th William Lowell Putnam Competition, the definitive mathematics competition for undergraduate students in North America. The Carnegie Mellon team—Linus Hamilton, Thomas Swayze and Joshua Brakensiek—placed second. Additionally, 41 CMU students scored among the top 470, the second most of any university. This marks the fifth consecutive year the CMU team has placed among the top five teams, and the third consecutive year in which they had the second most top-ranking students, proving the university is home to many of the nation's best "mathletes."

CARNEGIE MELLON UNIVERSITY

Three Chemistry Professors Named Among World's Most Highly Cited Researchers

CARNEGIE MELLON UNIVERSITY



From left: Neil Donahue, Rongchao Jin and Krzysztof Matyjaszewski

Three members of the chemistry faculty are some of the world's most highly cited researchers in the sciences and social sciences for 2015 and 2016, according to Thomson-Reuters and Clarivate Analytics. Researchers make the list if their research publications were in the top 1 percent of the most cited papers for their subject field and year and indexed in the Web of Science. Neil Donahue, the Thomas Lord Professor of Chemistry and professor of chemical engineering and engineering and public policy, was named among the most cited researchers in the field of geosciences. Chemistry Professor Rongchao Jin and the J.C. Warner University Professor of Natural Sciences Krzysztof Matyjaszewski were named among the most cited researchers in chemistry.

From left: Boris Bukh, Wesley Pegden, Ryan Sullivan and Di Xiao,

COURTESY BORIS BUKH; NICOLE READING; NICOLE READING; CARNEGIE MELLON UNIVERSITY

MCS Faculty Win Early-Career Awards

Four junior faculty members in MCS are shining brightly on the national stage after receiving prestigious early-career awards to support their research and teaching. Mathematician Boris Bukh and atmospheric chemist Ryan Sullivan received Faculty Early Career Development (CAREER) awards from the National Science Foundation. One of the most prestigious awards for young faculty, CAREER awards recognize and support those who exemplify the role of teacher-scholars through their outstanding research and teaching. Mathematician Wesley Pegden was awarded a 2016 Sloan Research Fellowship. He is among 126 early-career scientists and scholars from 52 colleges and universities in the U.S. and Canada to receive the award. Theoretical physicist Di Xiao was named a 2016 Cottrell Scholar. Twenty-four of the nation's top early career scientists received the designation from the Research Corporation for Science Advancement.

New Faculty

Becki Campanaro

Assistant Department Head for Undergraduate Affairs, Assistant Teaching Professor, Biological Sciences

Specialty: Investigated the effects of prenatal nicotine exposure on lung development through directed differentiation of human embryonic stem cells. Advises and mentors students in Biological Sciences, co-teaches several classes including Modern Biology.

Education: Ph.D., Biochemistry, Arizona State University; postdoctoral research, University of Pittsburgh School of Medicine.

Hayden Schaeffer

Assistant Professor, Mathematical Sciences

Specialty: Works on computational methods in applied mathematics with a focus on creating numerical methods for partial differential equations and imaging sciences.

Education: Ph.D., Mathematics, University of California, Los Angeles; postdoctoral research, California Institute of Technology and University of California, Irvine.

Retiring

Thomas Ferguson

Physics Professor Tom Ferguson is retiring after a distinguished 38-year career in experimental high energy particle physics. His research interests lie in understanding the ultimate constituents of matter—their interactions, their number and their properties. He has worked at various colliding beam accelerators, including the Stanford SPEAR accelerator, Cornell's CESR accelerator, and the LEP and LHC accelerators at CERN. Ferguson's research group is a member of the Compact Muon Solenoid (CMS) experiment, which constructed a massive detector for the LHC. In 2014, Ferguson was appointed the co-chairman of the CMS B and Top Physics Publication Committee.

Eric Grotzinger

During his 36 years at CMU, Eric Grotzinger has taught and advised thousands of students and made a difference in countless lives. In 2015, he retired from his post as MCS Associate Dean of Undergraduate Affairs, but still works part-time as a senior advisor to campus affairs. As associate dean, Grotzinger worked to increase the number of women and under-represented students in the college. He helped to develop both the SHS and BSA programs, and he played a key role in implementing the new MCS Core Education. Under his leadership, MCS has increased the retention rate of first-year students in science to an average of 95 percent per year.

Richard Holman

Physics Professor Richard Holman has retired after 28 years with the Department of Physics. His research focuses on the relation between cosmology and particle physics. Over the course of his career, he has published more than 100 articles on early universe cosmology and quantum field theory, and has developed novel formal tools that help researchers better understand how the physics of the early universe impacts the universe we see today. Although retired from Carnegie Mellon, Holman began a new post as dean of computational sciences at the Minerva Schools at the Keck Graduate Institute in 2015.

From left: Joel McManus, Aryn Gittis, Farnam Jahanian and Fred Gilman

Eberly Family Supports Faculty Professorships

Assistant professors Aryn Gittis and Joel McManus received Eberly Family Career Development Professorships in Biological Sciences, allowing them to pursue adventurous paths in their research that might not attract initial funding from other sources.

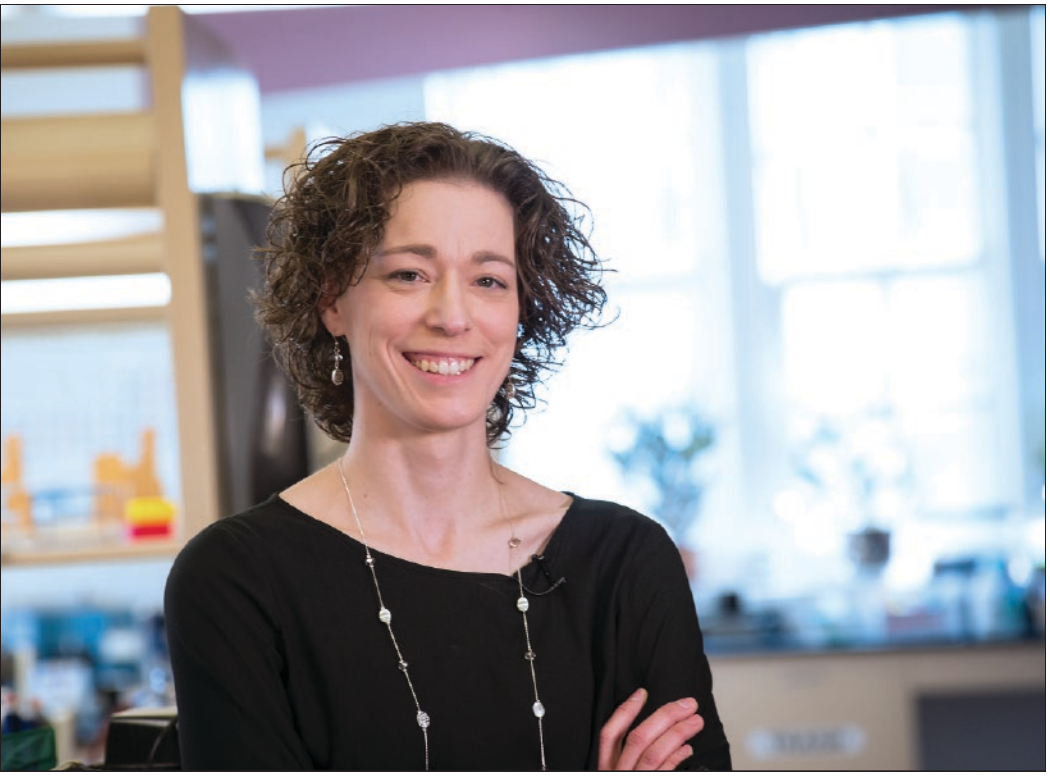
Gittis studies the neural circuitry of the basal ganglia, a brain system involved in movement, learning, motivation and reward. Dysfunction in these circuits is thought to play a role in neurological disorders, such as Parkinson's disease. Gittis' lab uses a variety of techniques to understand how these circuits affect motor control.

McManus studies gene regulatory mechanisms and their evolution. Gene expression involves a host of cellular networks and pathways, differences in which can lead to variation in gene expression and can play a role in health and disease. McManus' lab studies these regulatory networks and investigates the secondary structure of mRNA.

COURTESY BECKI CAMPANARO ; CARNEGIE MELLON UNIVERSITY

New Appointments

Maggie Braun Appointed MCS Associate Dean for Undergraduate Affairs



Maggie Braun's combination of experience and dedication to MCS and its students helped her rise to the top of a pool of candidates from around the world to become the new MCS associate dean for undergraduate affairs. She came to MCS in 2008 and served as the primary academic advisor for all undergraduates in the Department of Biological Sciences, mentoring more than 600 students. In January 2015, Braun was named the director of the MCS Core Education, helping to implement the college's new, multidimensional undergraduate education program. She also has played a key role in developing many new programs within the college and has served on numerous committees, including the groups that developed the MCS Core Education, designed the program outcomes for Biological Sciences undergraduates, established the biological sciences degree program at CMU-Qatar, and created the neuroscience major and minor programs.

Aaron Mitchell Named Head of the Department of Biological Sciences

Noted microbiologist, teacher and Carnegie Mellon alumnus Aaron Mitchell has been named head of the Department of Biological Sciences. After spending 20 years on the faculty at Columbia University, Mitchell returned to his alma mater in 2008. Since then he has served as chair of Biological Sciences' Undergraduate Education Committee and program director of Carnegie Mellon's Howard Hughes Medical Institute Undergraduate Training Program, taught courses in genetics and microbiology, and mentored undergraduate and graduate students in his lab. His research interests focus on the mechanisms by which fungi, particularly the common pathogen *Candida albicans*, respond to their environment and cause infections. Mitchell has won numerous awards and distinctions for his research and teaching.

CARNEGIE MELLON UNIVERSITY; KEN ANDREYO

Faculty, Students Named MCS Education and Research Award Winners

Julius Ashkin Teaching Award: Po-Shen Loh
Po-Shen Loh's constant energy and boundless enthusiasm have garnered him legions of fans. Loh, associate professor of mathematical sciences, is perhaps best known for teaching the Putnam Seminar, an innovative problem-solving class inspired by the annual Putnam exam. Enrollment in the Putnam Seminar has doubled over the past few years, to about 200 students, thanks to Loh. His passion for math has a profound impact on his students, at CMU and beyond. He travels the world giving talks to diverse audiences, and he coaches the U.S. International Mathematical Olympiad team, which finished in first place at the 2015 and 2016 competitions.

Richard Moore Award: Brooke McCartney
Brooke McCartney, associate professor of biological sciences, has made substantial and sustained contributions to the educational mission of MCS. She teaches developmental biology with great skill and has brought many innovative pedagogical approaches to this conceptually challenging course, including a "workshop model" that has students work together in small groups to solve problems based on the lecture. McCartney also has been a major player in providing authentic research experiences for the department's undergraduate students. She played a key role in two summer undergraduate research programs for several years, and her own lab is a powerhouse for productive undergraduate research.

Hugh D. Young Graduate Teaching Award: Clive Newstead
Math graduate student Clive Newstead's students attend his recitations and office hours even if they aren't assigned to his section. He has a gift for explaining complex ideas in ways that make them simple to comprehend, and he's willing to help in any situation.

Guy C. Berry Graduate Research Award: Shadab Alam
Shadab Alam is unlocking the secrets of the Universe. The Physics graduate student uses data from the Sloan Digital Sky Survey III and other large sky surveys to measure the large-scale structure of the universe, which can be used to test models of modified gravity.

Dr. J. Paul Fugassi and Linda E. Monteverde Award: Rebecca Alford
Chemistry major Rebecca Alford's academic achievement and professional promise garnered her this award. She plans to pursue her Ph.D. at Johns Hopkins University, where she will continue building computational tools to deeply explore the connection between genetic sequence, protein structure and function, and disease.

Top: Po-Shen Loh
Center: Brook McCartney
Bottom, from left: Clive Newstead, Rebecca Alford and Shadab Alam

CARNEGIE MELLON UNIVERSITY; CARNEGIE MELLON UNIVERSITY; NICOLE READING; CARNEGIE MELLON UNIVERSITY

In Memoriam: Nobel Prize-Winning Physicist Walter Kohn

Walter Kohn, a former professor at the Carnegie Institute of Technology (CIT), now Carnegie Mellon University, died on April 19. He was 93. Kohn won the Nobel Prize in Chemistry in 1998, sharing the prize with the late John A. Pople, who was also a former member of the Carnegie Mellon faculty. Kohn and Pople were prominent figures in the creation of quantum computational chemistry, a field of study that revolutionized the whole of chemistry by allowing scientists to identify the inner structure of matter. Kohn developed the density-functional theory that simplified the mathematics needed to describe the bonding of atoms, making it possible to study large molecules. In recent years, Kohn had turned his interests towards solar power, producing a documentary titled "The Power of the Sun."

Walter Kohn at the inaugural John A. Pople Lecture in Theoretical and Computational Chemistry, 2009.

By the Numbers
Dean Fred Gilman

9 Years as dean (2007–2016)

38 Faculty hired

15 Early-career awards received by new faculty hires

2250 Degrees conferred

1 Core Education program developed

30,837 Square feet of renovated labs & interactive collaborative spaces

1 State-of-the-art facility to support neurobiology research built

8 MCS Balls attended (student-initiated in 2008)

5 Grandchildren born

Fred Gilman stepped down as dean of MCS on July 31, 2016. He will continue in his role as the Buhl Professor of Theoretical Physics and the director of the McWilliams Center for Cosmology.

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CARNEGIE MELLON UNIVERSITY

Eric Grotzinger Retires

On April 15, the Carnegie Mellon community gathered to celebrate Eric Grotzinger's retirement in true CMU style. If anyone is "Plaid to the Bone," it's Grotzinger. During his 36 years as a faculty member in the Mellon College of Science, he has made numerous and often life-altering contributions to the CMU campus (see pages 14 and 22). And he has been a champion for undergraduate research at MCS. To honor his impact and legacy, the college has established the Eric Grotzinger Endowed Fund for Undergraduate Research. To donate, visit: ***www.cmu.edu/mcs/video/grotzinger.html***

Carnegie Mellon University