Carnegie Mellon University

science connection

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

Prepared for What's Next
Alumnus Tom Hu safeguards Americans' health

Coming Full Circle
Marion Oliver provides the same opportunities for CMU-Q students as he did for black students in the '70s

The Long Haul
After 17 years of work, a particle detector moves to its new home

Strength in Numbers
Scientists at Carnegie Mellon are battling biofilms

December 2014, volume 7 number 1

Fueling the Future

Scientists have toiled for decades to devise ways to convert solar energy into a chemical fuel that can be stored, transported, and used when the sun isn't shining. One of the most promising technologies involves using the sun's energy to split water into oxygen and hydrogen and store the resulting hydrogen gas for use as a clean-burning fuel. Since splitting water requires large amounts of energy, chemists employ catalysts that efficiently use energy from light to drive the chemical reactions. Chemistry Professor Stefan Bernhard and his research group are judiciously designing resilient and fast catalysts, a key step toward making the process practical for large-scale applications. Bernhard screens his catalysts, ranging from transition metal complexes to heterocyclic organic materials, using custom-built, high-throughput photoreactors (pictured here).

To run the experiments, graduate student Husain Kagalwala fills vials with water, a photosensitizer molecule to absorb light energy, and the catalyst. A panel of LED lights glowing from below drives the reactions that split the water and liberate hydrogen gas. Transducers capping the vials monitor the pressure of hydrogen gas being produced. The Bernhard lab's goal is to create catalysts that are efficient and long-lasting, characteristics that are essential to developing water-splitting systems that can produce hydrogen gas cheaply enough to compete with fossil fuels.

To learn more about how MCS research like Bernhard's is supporting Carnegie Mellon's university-wide, energy research initiative, please visit the Scott Institute for Energy Innovation's website at *www.cmu.edu/energy/*.

TIM KAULEN

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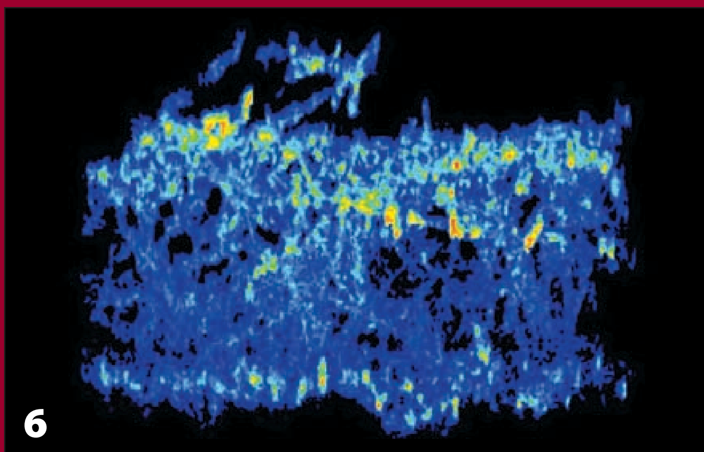


Departments

On the cover: (From left) Fred Lanni, Luisa Hiller and Aaron Mitchell are unraveling the complex structure and biology of biofilms and are developing new strategies to combat those that are dangerous. Photo by Tim Kaulen

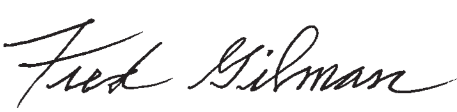
A common thread connects several stories in this issue of Science Connection: teamwork. In our cover story, "Strength in Numbers", you'll read about how faculty in the Department of Biological Sciences and the Institute for Complex Engineered Systems are bringing together their expertise in yeast, bacterial genetics, imaging, and materials science to understand and combat biofilms. Fortified communities made up of tens of thousands of microbes, biofilms are ubiquitous and are responsible for a wide range of chronic infections. By sharing their knowledge and skills, the joint research team is deconstructing these microbial communities and developing strategies to combat those that are dangerous.

Our second feature story showcases Physics Professor Curtis Meyer's 17-year journey to construct and bring online a particle detector at the Jefferson Lab National Accelerator Facility in Virginia. This journey was by no means a solo one. Meyer and his CMU team of faculty, technicians and graduate and undergraduate students, not to mention an international team of collaborators, all played key roles in bringing the detector to life.

I'm also pleased to share with you the story of alumnus Tom Hu, a project officer in the Division of Chemical, Biological, Radiological and Nuclear Countermeasures of the U.S. government. A true team player, Hu leads a network of scientists and policy makers across several federal agencies, including the CDC and DOD, to create medical countermeasures to safeguard the nation's health.

Whether they are working with a lab partner or playing on a sports team, MCS students know the value of teamwork. In this issue we highlight two teams of students who won big at international competitions: the Putnam Exam and the iGEM Competition.

Extraordinary insight and innovation come from people working together. I'm delighted to share with you just a few instances of how teamwork and community have led to great things happening at MCS this past year.



Fred Gilman
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Buhl Professor of Theoretical Physics

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KEN ANDREYO

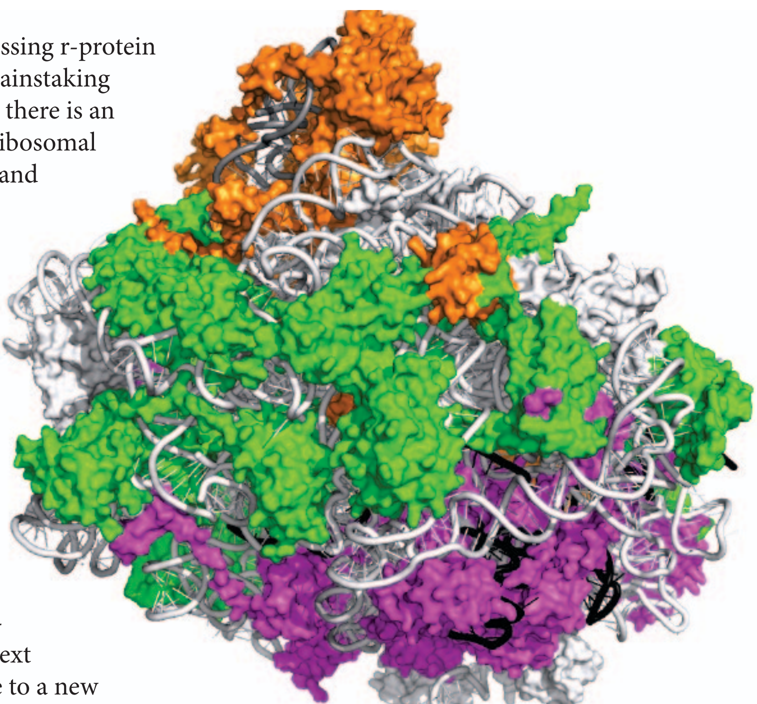
Cosmological Ruler Measures Universe to 1-Percent Accuracy

Relics of sound waves from the early universe are helping cosmologists measure the scale of the universe to an unprecedented level of precision. Called baryon acoustic oscillations (BAO), the relics present themselves as ripples visible in the distribution of galaxies. Cosmologists can use these ripples as a standard ruler to measure the scale of the universe. Working with the Sloan Digital Sky Survey III's Baryon Oscillation Spectroscopic Study (BOSS), Assistant Physics Professor Shirley Ho and postdoc Mariana Vargas-Magaña led a group that measured BAOs in two directions, parallel and perpendicular to the line of sight from the telescope. Because the observed spacing of galaxies is not the same in all directions, measuring the standard ruler in two directions created more stringent constraints, which allowed them to measure the scale of the universe's structure to an accuracy of 1 percent. Being able to do such precision measurements can help cosmologists better understand the expansion history of the universe and reveal vital information about the nature of the dark energy that drives the expansion.

Proper Assembly Required

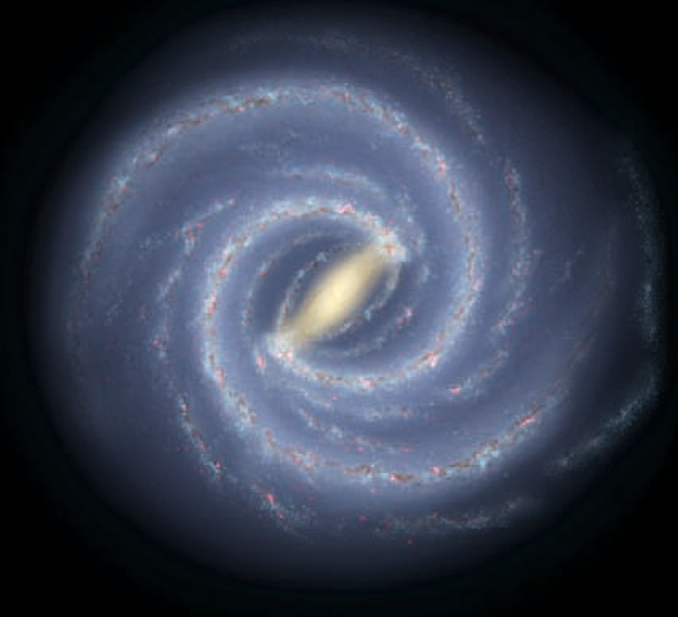
Ribosomes are the cell's protein manufacturing centers. The tiny, complex machines synthesize each and every one of the billions of proteins in a cell. To keep up with protein manufacturing demands, a rapidly growing cell makes as many as 10 million ribosomes during one cell cycle. During ribosome assembly, cells must walk a fine line between speed and accuracy. Errors in ribosome assembly are linked to anemia, cancers and other disorders. Figuring out how living cells assemble ribosomes has been a challenge. Biological Sciences Professor John Woolford and Ph.D. candidate Michael Gamalinda (S'14) have uncovered a key piece of the ribosome assembly puzzle.

Ribosomes are composed of a small subunit and a large subunit. The Woolford lab's research focuses on the large subunit, which is made up of 79 ribosomal proteins (r-proteins) and four ribosomal RNAs (rRNAs). To figure out what roles r-proteins play in large subunit assembly, Gamalinda used genetic tools to deplete 30 different r-proteins, one at a time, and then investigated how the missing r-protein affected assembly. His painstaking work led to a discovery: there is an order to how the large ribosomal subunit is put together, and that order is governed by the binding of r-proteins to specific locations on the rRNA called assembly neighborhoods. In each neighborhood, r-proteins make contact with the rRNA there, increasing and strengthening that contact over time. Once the first neighborhood is stabilized, the next set of r-proteins localize to a new neighborhood and so on—in a specific order—until the mature ribosome is complete. The research, published in *Genes and Development*, provides a new paradigm for large ribosomal subunit assembly.



The sequential assembly of the large ribosomal subunit begins with the assembly neighborhood marked in green, continues with magenta, and finishes with orange.

ZOSIA ROSTOMIAN, LAWRENCE BERKELEY NATIONAL LABORATORY; COURTESY DEPARTMENT OF BIOLOGICAL SCIENCES



Weighing the Milky Way

An international group of physicists, including Assistant Physics Professor Matthew Walker, developed a new, more accurate method for measuring the mass of galaxies. Using this method they found that, contrary to previous measurements, the Milky Way actually has less mass than neighboring galaxy Andromeda. In previous studies, researchers were only able to estimate the masses of the Milky Way and Andromeda based on observations made using their smaller, satellite dwarf galaxies. In the new study, researchers culled previously published data that contained information about the distances between the Milky Way, Andromeda and other close-by galaxies—including those that weren't satellites—that reside in and right outside an area referred to as the Local Group. By studying these galaxies and how they were either moving away from one another due to expansion, or towards one another due to gravity, Walker was able to pinpoint the Local Group's center. Walker and his colleagues then used each galaxy's present location in relationship to the center to calculate the mass of both the ordinary, visible matter and the invisible dark matter throughout both galaxies. Andromeda had twice as much mass as the Milky Way, and in both galaxies 90 percent of their mass was made up of dark matter.

Top: Artist's impression of the Milky Way. Bottom: Andromeda Galaxy.

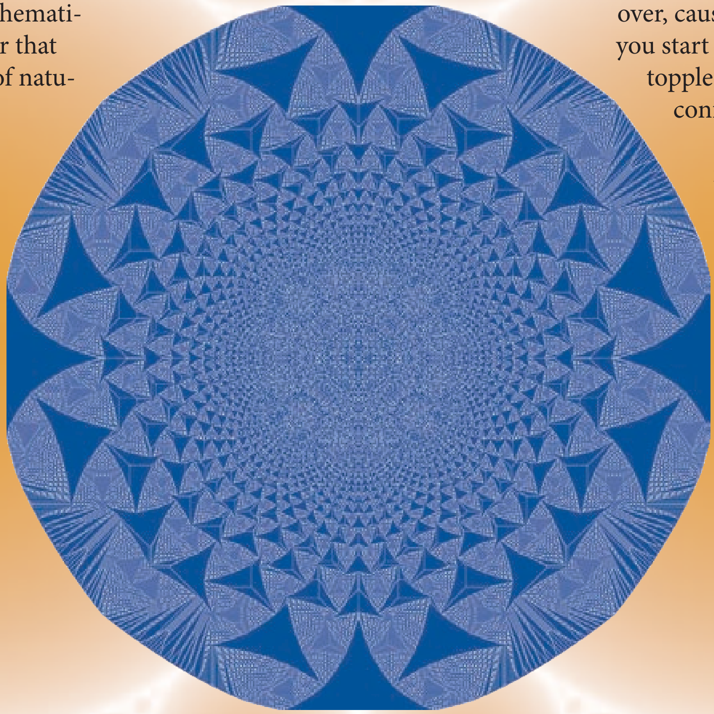
Emissions From Forests Influence Cloud Formation

Clouds play a critical role in Earth's climate, but they are the largest source of uncertainty in present climate models. Much of that uncertainty stems from the complexity of cloud formation. New research from scientists at the CLOUD (Cosmics Leaving OUtdoor Droplets) experiment at CERN, including Chemistry and Chemical Engineering Professor Neil Donahue, sheds light on new-particle formation—the very first step of cloud formation. Cloud droplets form when water vapor in the atmosphere condenses onto tiny particles. CLOUD scientists showed that in the atmosphere emissions from forests are transformed into particles capable of seeding cloud droplets. The team created a typical atmospheric setting inside of an essentially contaminant-free chamber, filled it with sulfur dioxide and pinnanediol (an oxidation product of organic molecules given off by pine trees) and then introduced hydroxyl radicals (the dominant oxidant in Earth's atmosphere). They found that oxidized organic molecules and sulfuric acid cluster together, eventually forming a particle that is able to seed cloud droplets. The scientists incorporated their findings into a global particle formation model and found that the model, with their addition, more accurately matched measurements found in the field.

Playing in the Mathematical Sandbox

Every child who's ever played in a sandbox or on the beach knows a little something about a deep mathematical truth: Pour sand out of a bucket a little at a time, it will build up into a pile. If the pile gets too steep, grains of sand will tumble away from the peak in a mini-avalanche. In 1987 physicists developed a mathematical model inspired by this behavior that captures the statistical properties of natural phenomena as diverse as forest fires, earthquakes and avalanches, which, like the sandpiles on the beach, are the result of sudden changes from gradual buildup. In this model, individual grains of sand even themselves out to a stable organization by continually moving sand away from the steepest areas. Model this on a computer and you get very intricate images that look almost like fractals.

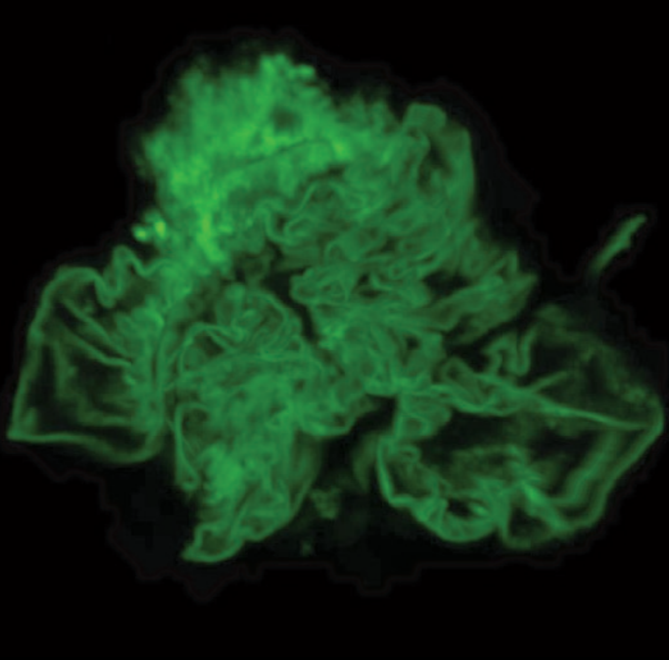
For more than 25 years these crazy, complex pictures (an example is shown here) defied mathematical explanation. New research from Assistant Mathematical Sciences Professor Wes Pegden and alumnus Charles Smart (S'02, CS'02) changes that. Pegden and Smart, an assistant professor of mathematics at Cornell University, set out to explain how a simple rule could produce such incredible complexity. The simple rule is this: Imagine an infinite chessboard. At one of the vertices you place 1,000 grains of sand (or chips). When there are more than four chips at a vertex, they topple, with one chip sliding down each edge to a neighboring vertex. Then a neighboring vertex might spill over, causing a chain reaction. Whether you start with 1,000 chips or 1 billion, they topple and spread out to form the same configuration.



COURTESY WES PEGDEN

By combining their expertise in combinatorics and partial differential equations, Pegden and Smart proved that there is a limit to the toppling process. They also developed a mathematical explanation for why there are triangular shapes in the image and why they're arranged in the way that they are. According to Pegden, having a simple rule that produces complexity is already a mystery. But now they can say a lot about it mathematically.

Researchers Create Self-Assembled Fluorescent Fibers



COURTESY SAADYAH AVERICK

In labs all over the world, scientists use green fluorescent protein (GFP) as a beacon to study a myriad of cellular activities. In a chemistry lab at Carnegie Mellon, chemists have something different in mind for the famous molecule. They are using GFP to create self-assembled protein/polymer nanostructures that are reminiscent of fibers found in living cells. The fibers can act as a structural material to which scientists can attach different payloads for drug delivery and tissue engineering applications. In nature, GFP isn't close to being a structural material, and it doesn't normally bind with other GFP molecules to form fibers. But when the team of chemists, including Professors Krzysztof Matyjaszewski and Tomasz Kowalewski and Ph.D. candidate Saadyah Averick (S'14), modified GFP molecules and linked them together using a process called click chemistry, the GFP molecules began to self-assemble into long fibers. Importantly, the fibers disassembled after being exposed to sound waves, and then reassembled within a few days. Such reversible self-assembly into fibers of this type is unprecedented and holds promise for use in a variety of applications. The work was published in *Angewandte Chemie International Edition*.

Strength in Numbers

by Amy Pavlak

For more than one hundred years scientists have studied microorganisms as individual cells floating in solution. But microbes are much more likely to exist in communities that adhere to surfaces, from rocks in a stream and the enamel of our teeth to medical implants like heart valves and artificial joints. Scientists at Carnegie Mellon are unraveling the complex structure and biology of these microbial cities and are developing new strategies to combat those that are dangerous.

Illustration of a cross-section of a fungal biofilm growing on medical-grade silicone. Illustration based on confocal scanning light microscopy image created by Fred Lanni and Aaron Mitchell.

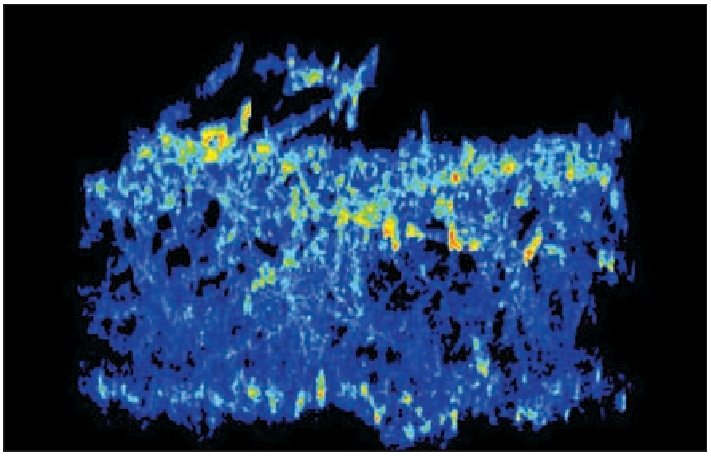
ILLUSTRATION BY NICOLE READING

Fred Lanni carefully removes the postage-stamp-sized piece of silicone from its watery home in the microwell plate. He beckons me to look closely, and I can just barely see what appears to be white fuzz growing on the silicone's surface. It looks innocuous enough, but Lanni assures me that there's much more to the fuzz than the naked eye can see. Images of the fuzz taken with a confocal microscope reveal a thriving microbial city teeming with fungal cells that are layers deep. I was looking at a biofilm, a fortified community of microbes that can grow on nearly any surface—rocks in a stream, a ship's hull, your teeth, a child's middle ear, an artificial hip, or a silicone catheter.

For much of the past century, scientists have studied microbes—single-celled organisms like fungi and bacteria—as free-floating cells that they isolated, cultured and suspended in a liquid. But over the past few decades, microbiologists have begun to appreciate that the majority of microbes live in biofilms. And the need to understand these microbial communities is urgent. Biofilm-based microbes are responsible for a wide range of chronic, difficult-to-treat infections.

Carnegie Mellon Biological Sciences Professor Aaron Mitchell has been studying biofilms for the past 15 years. Four years ago he teamed up with Lanni, an associate professor of biological sciences and an expert in imaging technologies. Their collaboration led to the development of techniques that allow the scientists to image deep inside biofilms, particularly those formed by the fungus *Candida albicans*. *C. albicans* biofilms are commonly found on the surfaces of implanted medical devices such as venous catheters, dentures, and urinary catheters. The biofilms cause stubborn infections that can become nearly impossible to treat with common antimicrobial drugs.

"Microbes living in a biofilm are covered in this slimy stuff called biofilm matrix material, and it has profound biological impact. It can prevent drugs from reaching the microbial cells living deep inside the biofilm," Mitchell said.



Gene expression pattern of two genes (red/yellow and light blue) active in a *C. albicans* biofilm. By locating where in the biofilm certain genes are expressed, Mitchell and colleagues are gaining insight into the genes' function.

Many thousands of microbes can live in this slimy matrix, which provides structure, nutrients and a venue for the cells to communicate with one another.

"Biofilms are as complex as an entire city, and their performance is incredible—they can change their characteristics in order to retain the biofilm in the face of a changing environment. It's just phenomenal," said Alan Russell, the Highmark Distinguished Career Professor and director of Carnegie Mellon's Disruptive Health Technology Institute. Russell's work focuses on designing ways to prevent or disrupt bacterial biofilm growth on certain surfaces such as catheters and teeth. He'll be the first to tell you that it has been a vexing challenge.

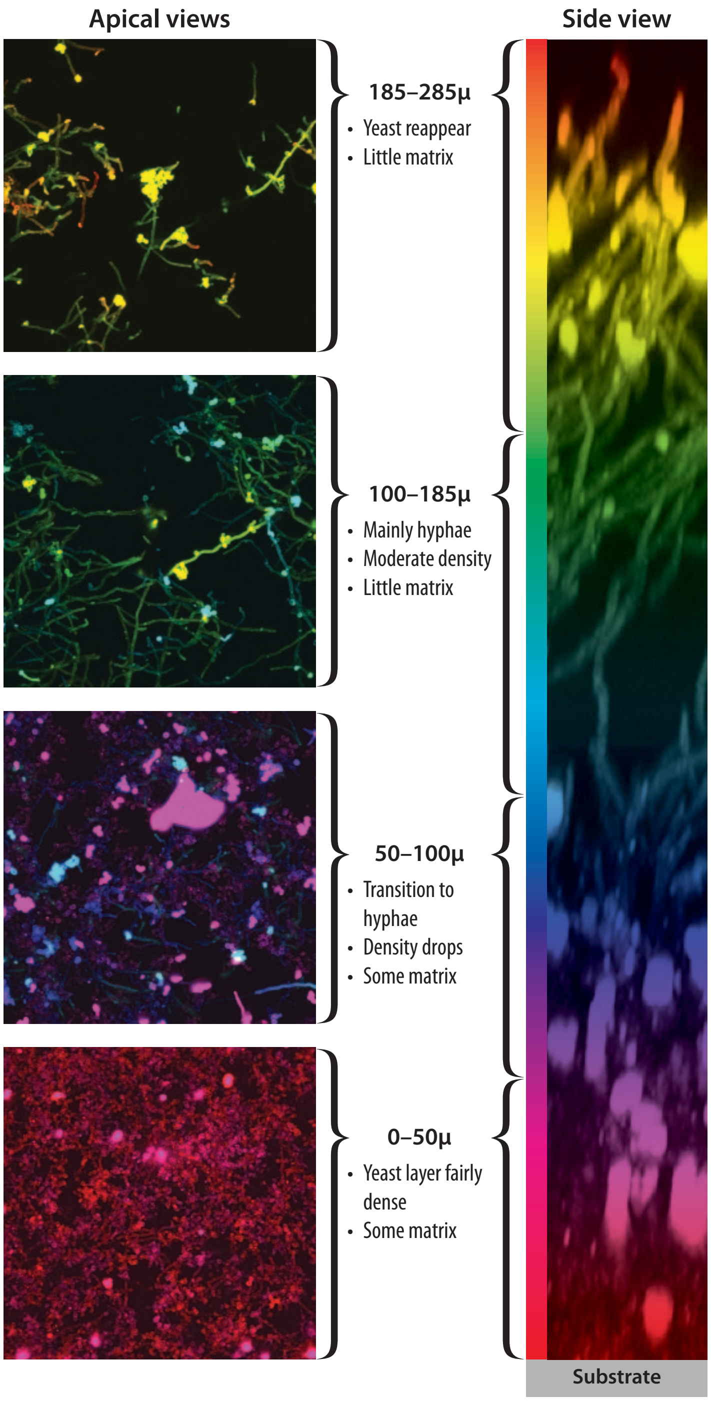
"Bacteria have developed biofilms for a reason," Russell said. "They want to survive and thrive, and they've had a few billion years to figure out how to do it."

Biofilm formation begins when free-floating microbes, such as those in saliva or the air, settle on a surface, grow into a cluster and then stick. The cluster of microbial cells begins producing the gooey extracellular matrix material, providing a protected environment that the microbes control.

To understand the mechanisms by which *C. albicans* biofilms develop and grow, Mitchell and his colleagues compare the gene expression patterns of fungal cells growing in a biofilm to those that are suspended in liquid. It turns out that fungi's living arrangements play a big role in what genes they express.

Working in collaboration with alumnus Vincent Bruno (S'96), an assistant professor at the University of Maryland School of Medicine, the researchers have identified several genes that are more highly expressed in the biofilm cells, including some that are involved in biofilm formation. In their most recent work, the Mitchell lab discovered that a gene called *RHR2* was one of the most highly expressed in fungal biofilm cells relative

COURTESY FRED LANNI AND AARON MITCHELL



Biofilms are made up of many layers of microbes, the composition of which can vary from the top to the bottom.

to free-floating cells. The *RHR2* gene encodes an enzyme that synthesizes glycerol, a small metabolite that is abundant in biofilm cells. When graduate student Jigar Desai (S'14), who works with Lanni and Mitchell, started looking at *RHR2* more closely, he found that glycerol is required for the expression of numerous biofilm-associated genes, including genes responsible for cell-surface adhesion, a key step in biofilm formation.

To test *RHR2*'s role in adhesion, Desai engineered fungal cells that don't have the *RHR2* gene. He then tested the mutant cells' ability to grow on silicone—one of the primary surfaces to which *C. albicans* cells stick, and the main material in many medical implants. Desai found that the fungi without *RHR2* didn't adhere as well to silicone and formed less biofilm than their fully functional counterparts. The promising results prompted Mitchell to send the mutant strain of *RHR2*-deficient fungal cells to David Andes, M.D., a professor in the Departments of Medicine and Medical Microbiology and Immunology at the University of Wisconsin. Andes tested the mutant cells in an animal model of catheter infection. He found that the fungal cells lacking *RHR2* almost completely lose their ability to form a biofilm.

As Mitchell and his team continue to uncover more about *RHR2*, their excitement builds.

"It suggests that metabolic enzymes may have broad regulatory effects on biofilm formation, and that they might be excellent targets for therapeutic development," Mitchell said.

The success of microorganisms living in biofilms depends on their ability to communicate with one another. In bacterial biofilms, the bacteria send chemical signals that allow them to sense each other's presence and respond. These conversations allow the bacteria to take on different tasks from ferrying nutrients and removing wastes to taking up DNA from the biofilm's slimy matrix and using it to modify themselves.

"One thing that is noteworthy about biofilms is that they all have extracellular material. The exact material varies, but there's one constituent that is found in almost every biofilm—extracellular DNA," Mitchell said.

The bacteria that commonly cause middle ear infections in children, *Streptococcus pneumoniae* (pneumococcus for short), like to form biofilms. When in a biofilm mode of growth, these bacteria are up to 1,000 times more resistant to antibiotics. Antibiotic resistance is one of the reasons persistent childhood ear infections are so difficult to treat. Treatment options are further complicated by pneumococcus's skill at taking up extracellular DNA and incorporating it into its own chromosome. This capability allows the bacteria to easily acquire new traits from their neighbors in the biofilm—such as antibiotic resistance and the ability to engage in new interactions with their human host.

Luisa Hiller, assistant professor of biological sciences, studies pneumococcus's remarkable ability to take up extracellular DNA.

COURTESY FRED LANNI AND AARON MITCHELL

From left: Fred Lanni, Luisa Hiller, Aaron Mitchell

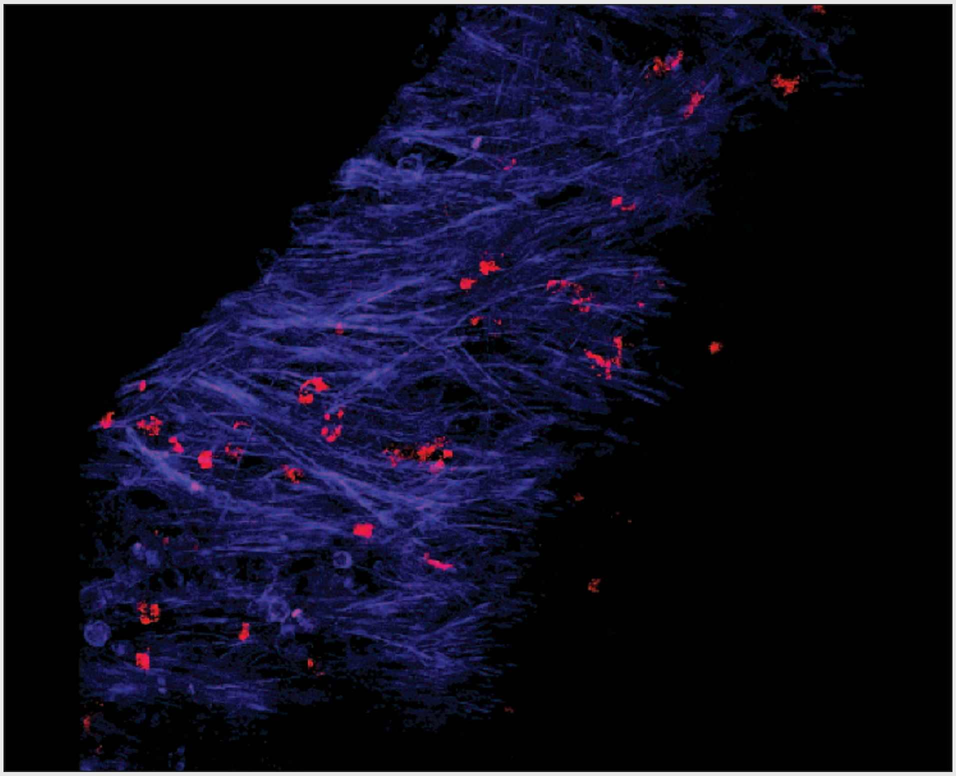
Alan Russell

As a postdoc, she looked at "pneumo" strains isolated from one child with a chronic, biofilm-based ear infection. She found that, over seven months of infection, one of the strains infecting the child acquired about 10 percent of its genome from another strain in the same biofilm. In genome terms, that's equivalent to a mouse becoming a human. The genes the strain picked up provided different features, such as a new bacterial coat.

In recent work in her lab, Hiller has begun digging into the mechanisms that control the extent to which these bacteria take up DNA. Hiller is comparing the entire genomes of different strains of pneumococcus, particularly those that tend to take up a lot of DNA and those that don't. Computational analyses are revealing genomic differences across strains, which can help to zero in on which genes are present in bacteria that are adept or inept at taking in DNA.

Hiller is also interested in how the individual bacterial cells in a biofilm talk to each other. Sometimes the conversations are friendly; other times they are belligerent. Anagha Kadam, a graduate student in Hiller's lab, studies molecules that carry on such conversations. Working with bacterial samples from the ear of a chinchilla, an animal model of ear infection, Kadam looks at the RNA levels inside the bacterial cells. She found that certain molecules, which Hiller calls war molecules, are highly expressed during the infection.

"Pneumo has a lot of molecules that seem to be devoted to warfare, including warfare against slightly different strains of their own species," Hiller explained. She points out that many strains of pneumococcus are present at the same time in a biofilm, so the "hypothesis in the field is that, in times of stress, you kill some neighbors and decrease competition for resources. But you also get their DNA. And that increases the probability of now reaching a new genome that's better adapted."



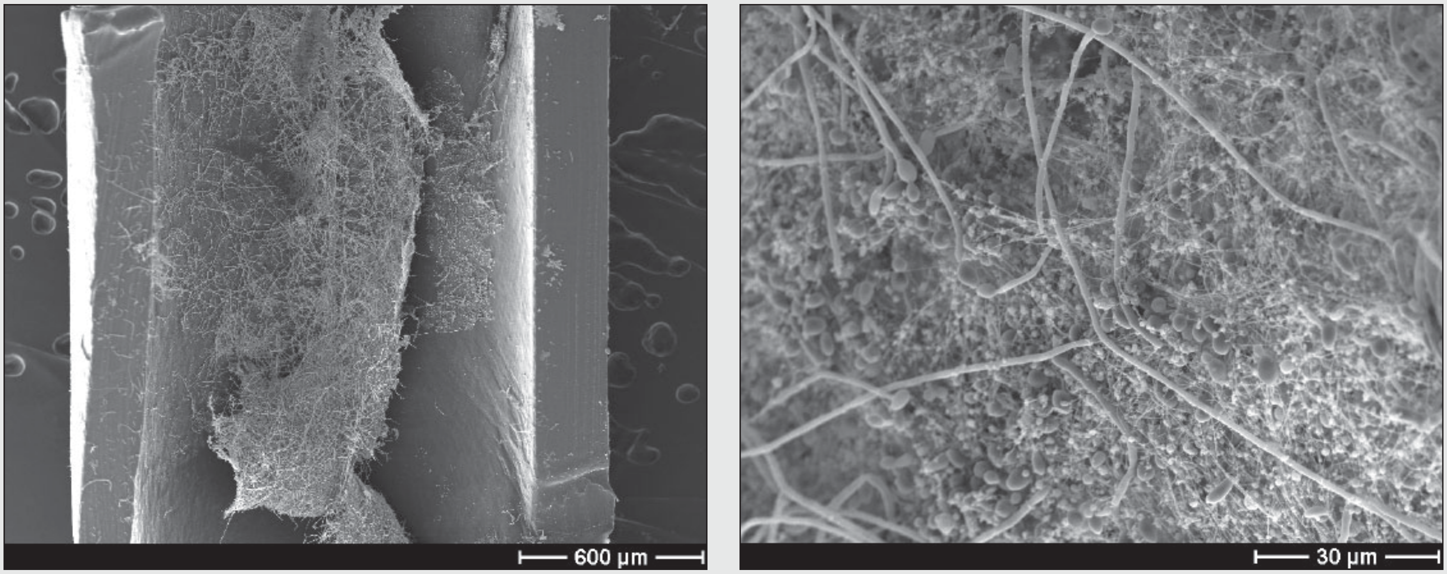
Micrograph of a chronic biofilm infection caused by *Streptococcus pneumoniae* in a chinchilla ear. Blue denotes chinchilla tissue and red denotes bacteria.

As Mitchell and Hiller work to unravel some of the complex behaviors microbes exhibit while living in a biofilm, they also are thinking about ways to kill them—or at least prevent their formation.

"We're definitely interested in how biofilms form and behave. That's kind of the basic science angle," Mitchell said. "We're also working on a project with Fred [Lanni] that is much more applied. In that case we actually don't care how biofilms form or behave. We just care that we can kill them in a broadly useful way."

Hiller, Mitchell and Lanni are taking a cue from a type of cancer treatment known as photodynamic therapy to develop a recyclable anti-biofilm coating for medical devices. This method for treating tumors uses certain dyes that, when hit with light, generate a

TIM KAULEN; CARNEGIE MELLON UNIVERSITY; LAURA NISTICO



Scanning electron microscope image of a *C. albicans* biofilm growing in an intravenous catheter. (Left) 50x magnification. (Right) 1000x magnification, which reveals the biofilm's constituent parts—oval-shaped yeast cells, filamentous hyphae, and stringy extracellular matrix. These experiments were carried out by Mitchell's collaborators, Kaitlin Mitchell and David Andes, at the University of Wisconsin.

toxic form of oxygen called singlet oxygen that kills tumor cells. Lanni reasoned that the same dyes could be used to kill microbes that adhere to surfaces before they have a chance to form a persistent biofilm. The three are developing a coating containing a non-releasable dye, which ultimately could be applied to the surfaces of medical devices like venous catheters, bone pins in extremities or possibly even deeper hardware such as joint implants. Treating the patient externally and locally with deep red light, which penetrates tissues well, would cause the dyes to generate singlet oxygen, killing any microorganisms that had adhered to the medical device. In principle, this could be done chronically to suppress infection during the treatment or healing period.

The research team has performed *in vitro* tests to evaluate the dyes' ability to kill fungi and bacteria, which have proven successful. The next step is to do testing in an animal model.

The method is particularly appealing for a few reasons. Singlet oxygen species have a very short half-life, so they can't diffuse very far away from the dye. This keeps their killing power localized. Additionally, one dye molecule can activate many oxygen molecules and can be hit with light again and again, creating a way to keep the medical implant free of biofilms potentially for the life of the implant.

"You don't want to take out your artificial hip every year or so for a new treatment. You want a lifetime warranty," Mitchell said.

Russell, who works at the interface of chemistry, biology and materials, has taken a different approach to anti-biofilm coatings. He recently developed an aspirin-releasing polymer that coats the inner lumen of urinary catheters. Inspired by the fact that aspirin has the ability to disrupt biofilms, Russell and his team made a polymer that releases aspirin over time. The catheter, which the pharmaceutical company Bayer has patented, reduces biofilm formation by *E. coli* for up to five days under conditions that simulate urine flow.

Russell's group is currently working on a project to coat medical implants with polymers paired with probiotic ("good") bacteria. "The question is: can you create a biofilm that's good? Can we design surfaces that will attract good biofilms versus bad ones?" Russell said.

He maintains that biofilms are a career-sustaining area.

"This is a field where you take three steps forward and two steps back and you keep doing that and you advance yourself. But each time you take a step back, you have to learn why. You have to understand biofilms if you're going to prevent their growth. And that's why CMU has something really interesting, I think. We have a really hard-core depth in the science of biofilms and we have a lot of people on campus who understand how to put biology and chemistry and materials together."

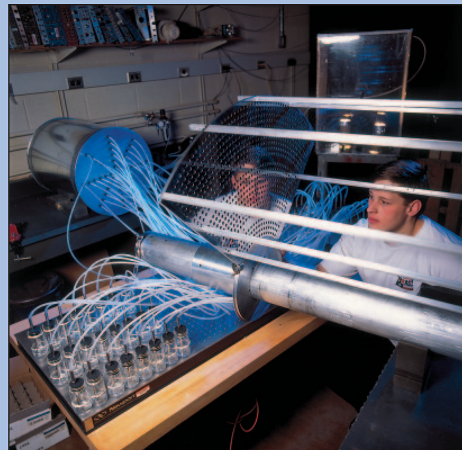
COURTESY AARON MITCHELL

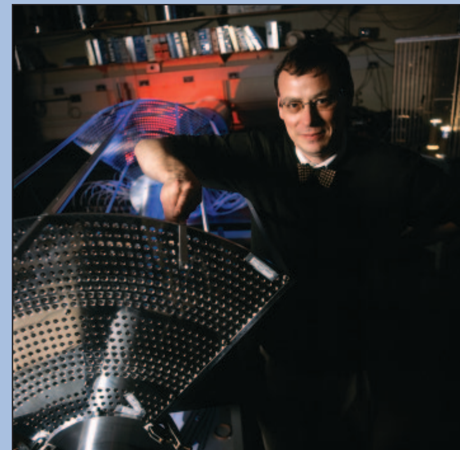
The Long Haul

by Jocelyn Duffy

JEFFERSON LAB PUBLIC RELATIONS

It was almost like sending a child off to college—after 17 years of work, Carnegie Mellon Professor Curtis Meyer watched as the particle detector that he and his colleagues had constructed in Wean Hall was packed up, loaded into a moving van and sent off to its new home, the Jefferson Lab National Accelerator Facility in Newport News, Va. The detector will aid in the search for hybrid mesons, particles that can help us to understand the glue that holds everyday matter together.





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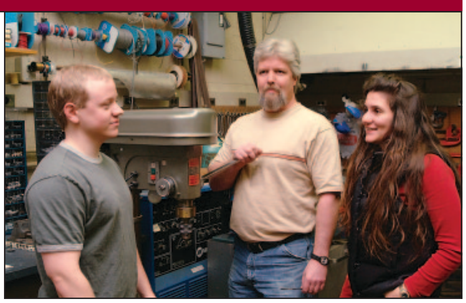


Clockwise from bottom left:

Graduate student Michael Williams, technician Gary Wilkin, and postdoctoral associate Angella Biselli discussing the construction of the Central Drift Chamber (CDC) in the Medium-energy shop in Wean Hall.

Gary Wilkin and graduate student Joe Parker turning out a part for the CDC in the Medium-energy shop in Wean Hall.

Graduate student Zeb Krahn tests gas flow through tubes of the prototype GlueX detector. Uniform gas flow is critical for optimum performance of the detector.

Curtis Meyer, professor of physics and spokesman for the GlueX experiment, with the prototype central tracking device being built and tested at Carnegie Mellon. The central tracking device will be one of 10 major systems making up the final detector to be located in JLab's Hall D.

Previous page: Curtis Meyer standing in front of the completed GlueX detector in the newly constructed experimental Hall D at Jefferson Lab. The green and red cylinder is the GlueX superconducting solenoidal magnet. The CDC is inserted in the far end of the solenoid.

Seventeen years ago, Physics Professor Curtis Meyer and colleagues from an international group of universities and national labs started to plan the GlueX experiment, a project that endeavors to help physicists answer one of the most fundamental questions in physics: how do quarks bind together to form the building blocks of matter?

But as every physicist knows, to study elements of matter as small as quarks, you need one of the largest and most expensive pieces of equipment known to science—a particle accelerator. GlueX is a member of the next generation of experiments to be done with the Continuous Beam Electron Accelerator housed at the Jefferson Lab National Accelerator Facility (JLab) in Newport News, Va. The accelerator became operational in 1994. In 1997, researchers began to think about what would be next for the accelerator. They decided that they'd use the facility to search for hybrid mesons, a theoretical particle that can be used to understand gluons, the particles that bind matter together.

But, in order to accelerate particles at an energy high enough to study the gluons, the scientists knew that the accelerator would have to undergo a significant upgrade. They embarked on a $340M project that would increase the accelerator's energy from 6 billion electron volts (GeV) to 12GeV. As part of the upgrade, they constructed a new experimental building, Hall D, that houses a new, state-of-the-art experiment made up of particle detectors that will capture signals created by subatomic particles. One of the detectors, called the central drift chamber (CDC), was constructed at Carnegie Mellon by Meyer's research group in his Wean Hall lab.

Building such a detector is a precise process that is usually only done at large national laboratory facilities such as Illinois's Fermilab, or California's SLAC National Accelerator Laboratory. Having previously built a similar detector for another project, Meyer's lab is one of only a few at a university with the facilities and expertise to complete such a task.

"Very few places have the infrastructure necessary to build a detector," Meyer said. "We're very fortunate to have the expertise and resources to build this here at Carnegie Mellon."

First, the university constructed a Class 2000 clean room on the 8th floor of Wean Hall that was specially designed to prevent airborne pollutants from entering its protective plastic-walled chamber. Meyer's lab group began to manufacture and assemble the skeleton of the CDC inside the clean room. After the skeleton was completed, they hung it from the ceiling. From 2009 until 2013, at any given time of the day, you could find students and technicians clothed in protective jumpsuits and caps hovering on ladders above or sitting below the CDC, painstakingly installing its delicate pieces.

The CDC consists of a hollow tube surrounded by 3,522 five-foot-long aluminum and plastic tubes. Secured between two plates, the tubes are layered in 28 concentric circles. Gold-plated tungsten wires five times thinner than a human hair are threaded down each tube. In all, it took three miles of wire and countless hours to assemble.

Meyer's group finished the CDC in early 2013, and in November of that year it came time to move it to its home in Virginia.

WINTER 2004: COURTESY DEPARTMENT OF PHYSICS; SUMMER 2004: CARNEGIE MELLON UNIVERSITY

SUMMER 2011

Left: Technician Amy Woodhall (bottom) and CMU undergraduate Maddi Brumbaugh inserting thin-walled straw tubes into the CDC during its construction in the clean room in Wean Hall. Over 3,500 straws were glued into the CDC during its construction.

FALL 2013

Top: Amy Woodhall (behind the CDC), Gary Wilkin and postdoctoral associate Naomi Jarvis inspect the insulation and bubble wrap around the CDC prior to loading it on the transport van. The wheeled cart was specially designed with shock absorbers and the air pressure in the tires was lowered during transport to Jefferson Lab.

Bottom: Gary Wilkin oversees the loading of the CDC into the transport van for transportation to Jefferson Lab. Forklift assistance was provided by the Mechanical Engineering Department.

KEN ANDREYO; COURTESY DEPARTMENT OF PHYSICS

Moving the approximately 400 pound chamber was no easy feat. The detector couldn't withstand any big shocks and needed to be kept at a fairly constant temperature to avoid mechanical stresses. Meyer's group secured a truck that was open to the cab, which allowed them to easily control the temperature. The detector itself was built on a specialized cart equipped with shock absorbers—students had earlier tested the cart by wheeling a prototype around the uneven sidewalks of campus. The research group removed some of the electronics from the detector, and wrapped the detector in bubble wrap. The cart was then wheeled to the Wean Hall loading dock, loaded onto the waiting truck and secured to the corners of the bed.

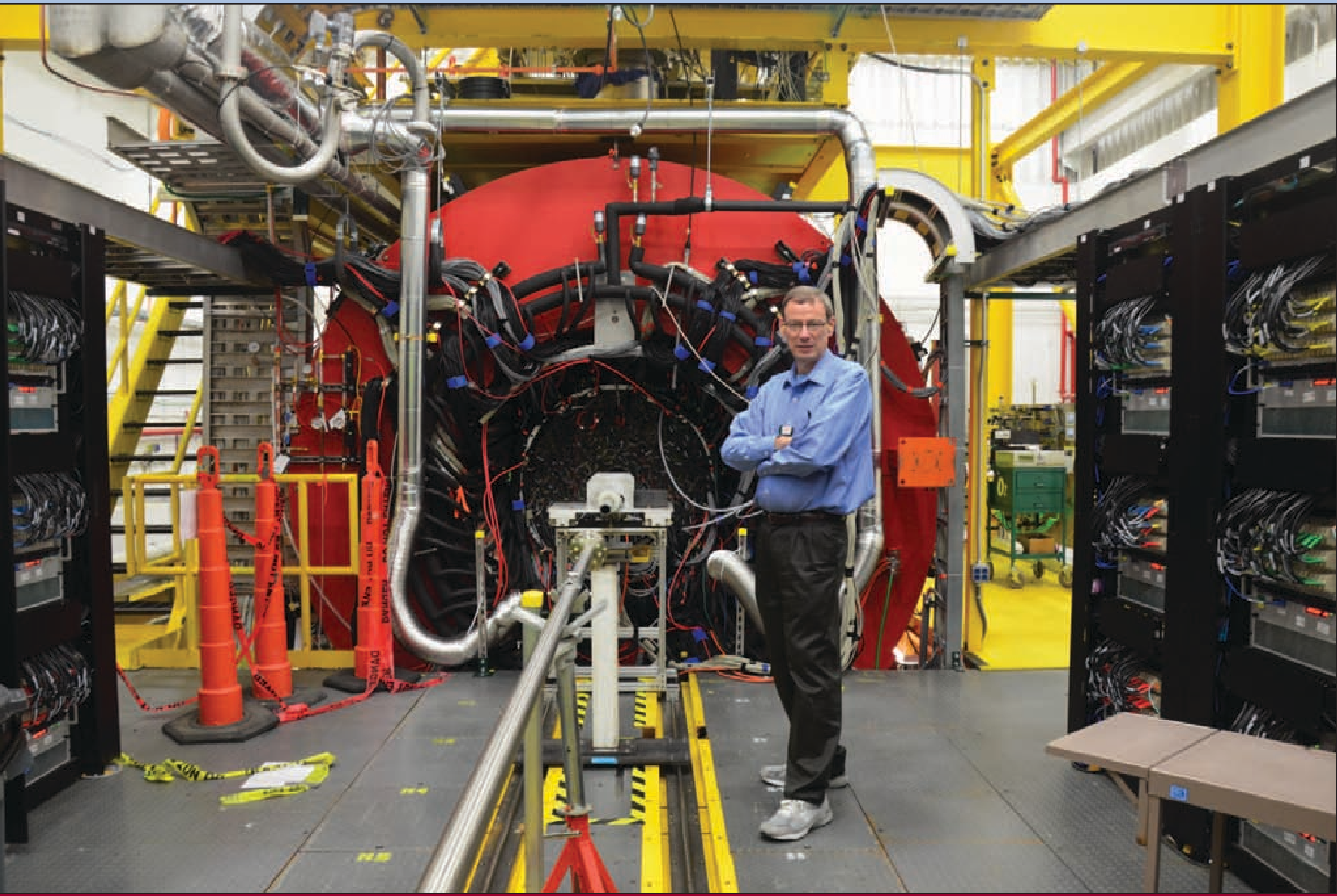
Since the JLab facility wasn't open at night, the truck and detector spent an evening at the house of technician Gary Wilkin. Wilkin helped Meyer deliver another detector 20 years ago, making him the resident expert in moving large-scale physics equipment. The next morning Wilkin and technician Amy Woodhall set off for Virginia. They followed a carefully mapped out 8-hour route to Newport News, specifically avoiding the notoriously busy highways around Washington, D.C. Meyer's postdoctoral researcher and students made a test drive of the route in the weeks before the move to troubleshoot any possible road closures or obstacles that might lie in the way.

The drive went smoothly, and after they arrived at JLab, Wilkin and Woodhall drove the truck into Hall D and unloaded the detector. The detector was installed in early 2014, and the newly upgraded accelerator sent its first beam of photons to Hall D in early November. Images of events recorded in Meyer's CDC gave the researchers the very first indication that the experiment was working. Engineering runs should be completed by mid-2015, and researchers will start doing physics by 2016.

It's then that the GlueX experiment will get underway. Researchers involved with GlueX, including Meyer, hope to find a new type of subatomic particle called a hybrid meson. The particle should reveal pertinent information about gluons.

Gluons bind together quarks, the component parts of protons, neutrons and mesons. Mesons are particles made up of a pair of quarks held together by gluons with no charge. The gluons in hybrid mesons—which have been theorized and hinted at in experiments—are thought to be in an excited state. This gives the mesons unusual, or "exotic," quantum numbers that are a signature of the hybrid particles. Meyer and his collaborators hope that if their detectors find these hybrid mesons, they will be able to derive pertinent information about gluons.

When it's up to speed, the accelerator will use its 12 billion volts of energy to hurl electrons around a ⅞ mile long racetrack. The electrons will be extracted from the track and passed through a thin diamond crystal. High-energy photons—which are the elementary particles of light—will be sent toward a liquid-hydrogen-filled vessel at the center of the CDC. When the photons hit a proton inside the liquid-hydrogen-filled chamber, the collision will produce a variety of subatomic particles that will soar



Curtis Meyer standing on the GlueX Platform in front of the upstream bore of the GlueX solenoidal magnet. The CDC is visible in the bore of the magnet.

JEFFERSON LAB PUBLIC RELATIONS

outward through the detector's tubes, which are filled with argon and carbon dioxide. As the particles fly through the tubes, the gas will ionize and send a charge through the wires at the center of the tubes.

"Each of the tubes will be an individual Geiger counter," Meyer said. "We'll have 3,522 Geiger counters generating information about the particles created by the collision."

The researchers will analyze the trajectory of each particle. Based on the trajectory, they'll be able to calculate the momentum and other characteristics of the particles.

"Previous experiments using photon beams were only able to collect small amounts of data. In GlueX, we will increase the world's statistical data from photon beams by several orders of magnitude," Meyer said. "This will make the detailed study of the physics behind the reactions possible and allow us to see the exotic hybrid mesons—if they exist."

This will mark the first time large amounts of data have been taken from photons. Meyer expects the data set to be in petabytes. While this much data could be daunting, the multi-institutional group working on the JLab experiment has come up with a relatively low-tech way to analyze the information using standard computer video processors. These processors are so small that they can fit 1,024 of them in the space of one hard drive.

"It turns out that graphical processor units can do the types of calculations we need faster than most other processors," Meyer said. "It only works on specific types of problems; luckily ours was one of them."

When the GlueX team begins collecting and analyzing data, they hope to piece together how gluons and quarks interact. They will compare what they learn to current theories, like the theory of quantum chromodynamics.

"We hope to reach a fundamental understanding of how these particles behave. It's going to give us a better idea of how the fundamental pieces of the universe work," said Meyer. "And that's exciting."

Research Driven

Hands-on science sparks Ashley Reeder's passion

by Adam Harring

On a chilly autumn day in Pittsburgh, Ashley Reeder (S'14) made her way out of class a little more swiftly than her classmates. She knew the 61C bus was coming and couldn't afford to miss it. Not because she was done for the day, or was meeting friends for lunch, but because the 61C took her to the Magee-Women's Research Institute where, if timed right, she could fit in a few hours of research before heading back to class.

Beginning the summer after her sophomore year, Reeder worked on a research project with Dr. Melanie Flint, formerly of Magee-Women's Research Institute and the Women's Cancer Research Center, that examined the biological mechanisms underlying how stress hormones affect the efficacy of a common chemotherapy drug, paclitaxel.

"I was really passionate about this research because it reminds you that doctors can't just treat the cancer but must treat the person," said Reeder, a recent Chemistry graduate. "Stress almost inevitably burdens patients who are diagnosed with cancer, and this research exhibits how such stress can have a very quantifiable impact on treatment."

When Reeder came to Carnegie Mellon, she knew that she wanted to be a doctor. And she chose Carnegie Mellon for exactly that reason.

"I wanted to attend a strong research university, to be surrounded by other talented students, and to be located in a city with a strong medical system in place: CMU could offer me all of that."

It also offered her the chance to think about current medical efforts on a more global scale. Reeder joined the CMU chapter of Global Medical Brigades, a student-led organization that conducts mobile medical clinics in under-resourced communities. Reeder spent two spring breaks, one in Honduras and another in Nicaragua, with the group.

"I loved sitting outside the medical clinics we set up—usually in a small school or church—sharing wood-cooked beans with people from the community," said Reeder, who also pursued a Hispanic studies minor in addition to her chemistry major. "I would just talk with them about their life experiences and families in between shifts of patient intake and consultation."

These out-of-class experiences solidified Reeder's desire to become a doctor.

"To experience the appreciation that men and women felt in being given this access to physicians and medicine was so rewarding," Reeder explained.

Currently, Reeder is busy applying to medical schools and working toward her master's degree in biomedical engineering (BME) at CMU. She chose the BME program to become more familiar with developing therapies and technologies so that she may better utilize and integrate them as a physician.

"I think that CMU prepared me for medical school and so much more," Reeder said. "I have such a strong foundation in chemistry and biology, and I feel that will undoubtedly continue to serve me well in medical school and beyond."

NICOLE READING

Prepared for What's Next

Alumnus Tom Hu helps to create medical countermeasures to safeguard Americans' health

by Matthew Moon

Anthrax-laced letters mailed to the White House. A dirty bomb detonated in New York. An Ebola outbreak in Atlanta. These are just a few of the nightmare scenarios that might cross Tom Hu's (S'01) mind and desk on a daily basis. Working across an alphabet soup of federal agencies—the CDC, NIH, FDA, DOD, EPA, DOT, to name a few—Hu leads an interagency network of experts who create medical countermeasures that will prevent the next public health crisis—nature- or man-made.

"It's almost like an insurance policy that you buy just in case something really bad happens," Hu explains. "In our case, the bad thing is a huge anthrax attack or chemical attack or a radiologic or nuclear attack. We have all the necessary tool kits of drugs to take care of those issues."

As a project officer in the Division of Chemical, Biological, Radiological, and Nuclear Countermeasures at the Biomedical Advancement Research and Development Authority at the U.S. Department of Health and Human Services (HHS), Hu's job is to create safeguards for the nation's health. But he's never been one to play it safe in his career. For example, when he started his new job at HHS, Hu didn't have any training in science policy.

"I was very nervous," he recalls. "I had never done it before. But, true to my nature, I said to myself: Oh, that could be interesting. I'll try it out to see how well I do."

That sense of adventure and exploration has served Hu well as he's charted a decidedly unique career path, thanks in large part to the strong network of friends and colleagues he made at CMU.

"Carnegie Mellon created a very good networking base, not only for my career but also for my scientific development."

Born in Taiwan, Hu was a teenager when he moved to Philadelphia with his family. His oldest brother Chih-Kao (S'94, GSIA'97), also a CMU Chemistry Department alumnus, was a source of inspiration to the teenaged Hu.

"When he was in graduate school, I would spend time visiting him during the summer," Hu recalls. "I would talk to him about science, sometimes even visiting the lab and helping him out."

His time helping his brother led Hu to pursue a bachelor's in chemistry with an emphasis in biology at the University of Pittsburgh. Hu continued his education at Carnegie Mellon, earning his M.S. and Ph.D. in chemistry and writing his dissertation on manganese as a potential contrast agent in cardiac magnetic resonance imaging.

Hu credits his time at Carnegie Mellon with providing him the tools necessary to launch his unconventional career path.

"Carnegie Mellon provides a very, very strong analytical base. I think that's the most critical thing. Because with strong critical and analytical thinking skills, you can make a lot of good life and career decisions. It's a good starting point to continue to explore and learn."

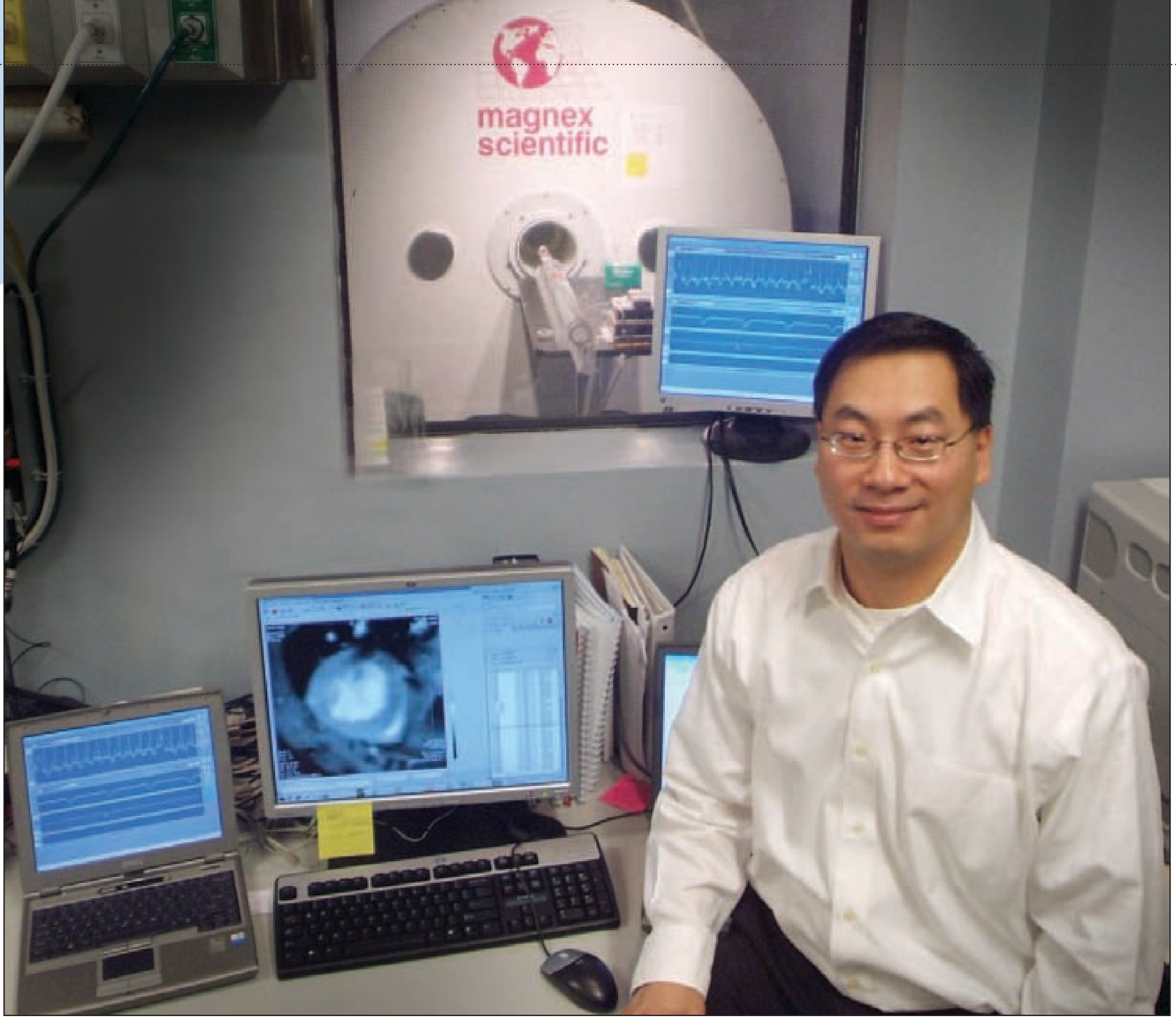
After completing a postdoctoral fellowship at the National Institutes of Health (NIH), Hu joined GlaxoSmithKline, where he worked as a principal scientist in the pharmaceutical giant's Center for Excellence in Drug Development, which was at the forefront of cardiac imaging technology. Faced with the choice between a purely technical career track or one that led to executive leadership positions, Hu decided to earn his MBA to keep his options open.

That decision paid off right before he completed his MBA when he got a call from a friend at NIH.

"She told me 'There's this position that I think is ideal for you. It's an assistant professor position.' I said politely, 'Oh, that's interesting, but I was really hoping to get into business development.'" But when Hu learned that the position would entail starting up a brand new pre-clinical imaging program in the Department

alumni briefs

- **Lisa Alexander** (CMU'12) received a National Defense Science and Engineering Graduate Fellowship, a highly competitive fellowship that provides three years of tuition, a monthly stipend and monetary help with medical insurance.
- Royal DSM, a global life sciences and materials sciences company, awarded **Saadyah Averick** (S'14) the DSM Science and Technology Award, Americas 2014, at the 248th National Meeting and Exposition of the American Chemical Society. The award seeks to recognize and reward outstanding young researchers for innovative research with clear application potential.
- The Bharamara Trust awarded **Padmanabhan Balaram** (S'73) a lifetime achievement award for science. Balaram is a professor in the Molecular Biophysics Unit at the Indian Institute of Science. He also served as the institute's director for nine years.
- **Chris Baldwin** (S'13) and **Jason Rocks** (S'13) received National Science Foundation Graduate Research Fellowships.
- **Kathryn L. Beers** (S'96, '00) was named a fellow of the American Chemical Society. Beers is the leader of the Polymers and Complex Fluids Group in the Materials Science and Engineering Division of the National Institute of Standards and Technology.
- **Eric Dahl** (S'02), a joint Fermilab-Northwestern University physicist, received an Early Career Research Award from the Department of Energy to develop a new style of particle detector for finding dark matter particles.



Tom Hu at the imaging facility he launched at Georgia Regents University's Medical College of Georgia. Hu continues his imaging research and recently published a textbook, "Pharmaco-Imaging in Drug and Biologics Development", with Brian Moyer and Narayan Cheruvu.

GEORGIA REGENTS UNIVERSITY

of Radiology at Georgia Regent University's Medical College of Georgia, he was intrigued. He applied for and got the job.

After only a year, Hu built the Small Animal Imaging Program from the ground up, turning it into a core facility for pre-clinical imaging and basic research that benefits the entire campus. Six years into his tenure at the Medical College of Georgia, Hu received an email from a friend of his, a radiation oncologist at the National Institute of Allergy and Infectious Diseases, who thought Hu would be a perfect fit for a job working on science policy at HHS.

The job was very different from any of the other things Hu had done in his career, but his friend was persuasive.

"Think about how much it would impact folks—on the scale of tens of millions—if you change the policy from the U.S. government perspective," Hu recalls his friend saying. "That's why I went into science policy."

Through all of his career transitions, Hu's most important network—his family—has supported him.

"My wife is extremely supportive. She moved with me five times as I changed career paths," Hu says. Their move to DC has allowed his wife and two children to be closer to his wife's family in Pittsburgh and his brother who lives in New York.

Although busy with his current responsibilities at HHS, Hu makes the time to pass on the lessons he's learned about networking and mentoring to current students—in spring 2012, he participated in the Mellon College of Science's Graduate Career Paths Panel Discussion. "One of the important things I learned is to keep up the network, keep an open mind talking to people, and at the same time share your learned knowledge."

- **Gregory Dewey** (S'74) assumed his role as the eighth president of Albany College of Pharmacy and Health Sciences on July 1, 2014. Prior to his appointment, Dewey served as Provost at the University of La Verne in California, and spent 18 years on the faculty at the University of Denver, including five years as Chair of the Department of Chemistry and Biochemistry.
- **David Huang** (S'12) was selected to participate in the HHMI Medical Research Fellows Program, in which students put their medical studies on hold for one year to conduct intensive, mentored biomedical research.
- The Carnegie Mellon Alumni Association honored **Gregory Polansky** (S'74, TPR'76) with the 2014 Alumni Distinguished Service award. Polansky, Vice President at Dollar Bank, FSB, is a longtime, enthusiastic CMU volunteer. He was former president of the Andrew Carnegie Society and has been a member of the Annual Giving Committee, Alumni Association Board and Board of Trustees.
- The Alfred P. Sloan Foundation awarded **Charles Smart** (S'02, CS'02) a 2014 Sloan Research Fellowship. The assistant professor at Cornell University is one of 20 individuals to receive Sloan Fellowships in Mathematics this year.

Coming Full Circle

Marion Oliver provides the same opportunities for CMU-Q students as he did for black students in the '70s

by Jocelyn Duffy

In 1967, when Marion Oliver came to Carnegie Mellon as a graduate student in mathematics, he probably had no idea that more than 40 years later, he'd find himself working for Carnegie Mellon again, and at a campus some 7,000 miles away from Pittsburgh. Now, as the first-year student advisor at Carnegie Mellon's Qatar campus, Oliver can reflect on dramatic changes he's witnessed in the university, and the world.

Born in Tuscaloosa, Ala., and raised by a single mother in Chattanooga, Tenn., Oliver was a skinny child. Since he wasn't built for sports, he figured that he didn't have many options in life. In the classroom, he excelled at math but thought he wouldn't be able to get into college, let alone pay for an advanced education. Luckily for Oliver, his ninth and tenth grade teachers believed in him.

When Oliver was in the tenth grade his teacher, Lydia McKeldin, paid for him to take an early admissions test for Nashville's Fisk University. Oliver passed, and worked evenings in a clothing store for the next two years to raise enough money for his first year at Fisk. Newly formed federal loan programs allowed Oliver to complete his undergraduate work, and he graduated with a bachelor's degree in mathematics and physics.

In a move that he would never recommend to his current students, Oliver applied to only one graduate school, the Carnegie Institute of Technology. He was drawn to the school because of their program that combined applied and pure mathematics.

COURTESY THE PIPER

During his graduate school years, the university went through a dramatic transformation. CIT became Carnegie Mellon University—Oliver's master's degree in mathematics is from CIT, but his doctoral degree in mathematics is from Carnegie Mellon's Mellon College of Science.

"Between 1969 and 1979, the university changed, in every aspect of its existence," Oliver said.

The country was changing, too. The Civil Rights Act of 1964 had led to more, but still not many, black students pursuing higher education. And race relations in America were still tense.

"I met my thesis advisor, and friend, Mort Gurtin in 1968 at a shelter on the Hill [Pittsburgh's Hill District] when we were preparing care packages for the folks who were having problems getting food after the riots that followed Martin Luther King, Jr.'s assassination," Oliver said.

The uncertainty caused by a changing society trickled into the classroom. Many black students worried that they were ill-prepared to adjust to the rigors of academia, and many white students were skeptical about sharing a classroom with black students. Oliver was the role model that both black and white students needed. He was proof that black students could succeed in Carnegie Mellon's rigorous programs and could be academic equals.

At the end of his doctoral program, Oliver was asked to stay at Carnegie Mellon as an assistant professor of mathematics. He also became deeply involved in the Carnegie Mellon Action Program (CMAP), which provided academic, personal and career development programs and services to minority students. He was named the program's director in 1974.

"CMAP was a life changing opportunity for all involved in it: students, staff and faculty. For the students it gave them an opportunity to acquire the kind of education that could make them major players in business and other areas of our society," Oliver said. "For all those who took advantage of it, it made a difference in their lives."

As the director of CMAP, Oliver and others working in the center established programming and services to help minority students develop and succeed in their academic, personal and professional lives, with the main goal of increasing the graduation rate of minority students attending Carnegie Mellon. To those students, Oliver was an advisor, role model and friend.

Oliver remained at CMU until 1979, leaving to become the Provost and Vice President for Academic Affairs at Millersville University. He would later be named a Vice Dean at the University of Pennsylvania's Wharton School. In both jobs he continued to be a strong example for students.

After 22 years in higher education, Oliver joined the Mobil Oil Corporation in 1990, starting as a recruitment manager and later becoming an international training manager. During this time, he developed a comprehensive training and development strategy in Qatar, and he visited the Middle East a few times each year.

"Doha, Qatar was a very small, one-camel town. There was a Sheraton Hotel, the sand dunes and water," Oliver said.

After his decade-long "sabbatical" with Mobil, Oliver returned to the classroom, teaching quantitative methods at Florida A&M University's business school.

In 2004, Oliver read an article in the Chronicle of Higher Education about Carnegie Mellon's plan to open a campus in Qatar. Oliver sent an email to former Carnegie Mellon Vice President Bill Elliot to see if there was anything he could do to help.

"Some things in life are decided in heaven. Think about it: I had a Ph.D. from CMU in a key subject area for the new campus. I spent five years as a Vice Dean and Director of the Wharton School's undergraduate program and knew a little bit about business education. Finally, I knew the Middle East and what Qatar was like. At Mobil I had evaluated the educational quality of the American School in Doha—I knew what secondary education was like in Qatar, and I was prepared for the challenges that the new campus would face," Oliver said. "How could I not come?"

Elliot recommended Oliver to the founding dean of CMU-Q, Chuck Thorpe. Oliver landed in Qatar in 2004. This time it wasn't just for a visit.

He started by screening applicants for the first incoming class and teaching first-year calculus. He now advises each of the approximately 100 incoming first-year students, and he is having the same dramatic impact on the CMU-Q students that he did on students at the Pittsburgh campus in the '70s.

"CMU-Q is a very special place to work," Oliver said. "We're providing students with the same life-changing opportunities that we did with black students through CMAP in Pittsburgh. If the students really take advantage of what CMU-Q has to offer, they will become very different people who will hopefully change Qatar in significant ways."

This year, Oliver received Carnegie Mellon's Advising Award, becoming the first CMU-Q faculty member to win the university prize. His nomination was supported by students who were part of the CMAP program in the 70s and CMU-Q students of today. Their letters were remarkably similar, stating that Oliver was one of the most important role models they have had in their lives, and they credit their own academic, professional and career success to his advice and teaching.

"Marion's ability to inspire students is as evident today in the Middle East as it was with minority students in Pittsburgh in the '70s. His skill as an advisor and his commitment to our students has spanned more than forty years and two widely different cultures," said Russ Walker, a professor of mathematical sciences who has known Oliver since the two were graduate students at Carnegie Mellon. "He has caused students to achieve more academically than even they believed was possible, and he has inspired them to continue to seek to excel after graduation."

Math Students Finish Second in Putnam Competition

Carnegie Mellon continues to shine brightly at the Mathematical Association of America's William Lowell Putnam Competition, the premier mathematics contest for undergraduate students. This year's second place finish marks the third consecutive year that the CMU team placed among the top five—only 11 other universities have placed in the top five more than twice since 1990.

In the 74th annual competition, 4,113 American and Canadian undergraduates from 557 institutions worked through 12 complex mathematical problems using a combination of creative thinking and concepts taught in college mathematics courses. In classrooms in Scaife Hall, 163 Carnegie Mellon students spent six hours solving the problems. When the results came in more than three months later, 35 of those students scored among the top 10 percent, the second most of any university. Science and Humanities Scholar Linus Hamilton (CMU'16) and mathematical sciences students Thomas Swayze (S'17) and Samuel Zbarsky (S'17) placed among the top 16 students. The second-place ranking reflects the scores of the three students selected to be on the Carnegie Mellon team—Hamilton, Swayze and mathematical sciences major Michael Druggan (S'15).

"Repeated success in the Putnam Competition makes Carnegie Mellon shine like a beacon, showing the extreme talent that gathers here," said Po-Shen Loh, assistant professor of mathematical sciences and the team's coach. "It is our hope that by bringing ambitious students together, they can work with each other to achieve success for themselves, the university and the region."

iGEM Team Wins Best Poster Award

The campus post office is always a hub of activity, with students waiting to pick up a package from an online shopping purchase or a care package from home. At the beginning of summer 2013, five Carnegie Mellon students were waiting in line for something a little different—a kit of standard biological parts. The students were competing in the International Genetically Engineered Machine (iGEM) Competition, and they were ready to get started. Inside their kit were some of the parts that they needed to build a synthetic biological system. Synthetic biology is a field that aims to engineer biological systems to perform functions that do not exist in nature. For the 2013 iGEM competition, the CMU team set out to develop a way to kill bacteria that doesn't involve using antibiotics. Using parts from their toolkit and new parts that they submitted, they designed a bacteria-infecting virus that had a gene for a fluorescent protein called KillerRed that becomes toxic when exposed to light. The *E. coli* cells with their synthetic gene made the KillerRed protein, and then they shone a light on the cells. The bacteria started to die. In October, the team traveled to Toronto to present their work at the North American iGEM Team Competition; other regional competitions were held in Hong Kong; Santiago, Chile; and Lyon, France. Sixty-four teams presented a poster describing their work at the North American regional jamboree. The CMU team's poster titled "Light-Activated Antimicrobial Phage" took home the Best Poster Award.

From left: Coaches Natasa Miskov-Zivanov and Cheryl Telmer, and students Evan Starkweather, Eric Pederson, Benjamin Beltzer, Kathy Bates and Andrew Nadig

student honors

- Mathematical Sciences graduate student **Will Boney** received an NSF Postdoctoral Fellowship.
- Biological Sciences graduate student **Shawn Burton** received the Ruth L. Kirschstein National Research Service Award from the National Institute on Deafness and Other Communication Disorders.
- The Carnegie Science Center in Pittsburgh awarded Chemistry graduate student **Taylor Canady** the University/Post-Secondary Student Award for his outreach work with K-12 students.
- Recent Biological Sciences graduate and tennis player **Katie Cecil** (S'14) received a $7,500 NCAA scholarship, which is given to student-athletes who excel academically and athletically. Cecil also received the 2013 NCAA Division III National Intercollegiate Tennis Association/Arthur Ashe Jr. Award for Leadership and Sportsmanship and the Elite 89 Award for the 2013 NCAA Division III Women's Tennis Championship.
- Physics graduate student **Benjamin Carlson** received a Universities Research Association Visiting Scholar Award to conduct research at the Fermi National Accelerator Laboratory.
- Chemistry graduate student **Anindita (Dia) Das** received a student award from the International Precious Metals Institute, the largest and most well known association focused on precious metals.
- Biological Sciences graduate student **Ezgi Kunttas-Tatli** won The Ralph and Mildred Buchsbaum Prize for Excellence in Photomicrography from the American Microscopical Society.
- Mathematical Sciences graduate student **Andrew Zucker** received an NSF Graduate Research Fellowship.

TIM KAULEN; COURTESY BIOLOGICAL SCIENCES

Faculty News

From left: Nathan Urban, Marcel Bruchez and Neil Donahue

Nathan Urban Named CMU's Interim Provost

Nathan Urban, the Dr. Frederick A. Schwertz Distinguished Professor of Life Sciences, and former head of the Department of Biological Sciences, is serving as Carnegie Mellon's interim provost for a year as the university undertakes a national search to replace Professor Mark Kamlet, who stepped down from his post of provost and executive vice president on June 30, 2014. Urban, a neuroscientist who joined the CMU faculty in 2002 and has led the Department of Biological Sciences since 2010, investigates the molecular, cellular and computational properties of brain networks with a particular focus on the olfactory system. In 2005, Scientific American recognized Urban as one of the nation's top 50 science and technology innovators, and he has received numerous awards. His work has been supported by grants from the National Institute of Mental Health, the National Institute for Deafness and Other Communications Disorders, the Human Frontiers Science Program and the Defense Advanced Research Projects Agency.

Marcel Bruchez Named Director of MBIC

Marcel Bruchez, associate professor of biological sciences and chemistry, has been named the director of CMU's Molecular Biosensor and Imaging Center. He succeeds Alan Waggoner, who led the center since 1999.

Bruchez develops novel fluorescent probes that can be used to view and monitor cell protein activity in living systems. He is currently developing technologies that will allow researchers to study protein synthesis, folding, trafficking, synapse formation and activity in the brains of living subjects.

Bruchez played a key role in developing quantum dots, nanometer-sized particles that can be used to tag proteins and label cells, a technology that was named one of Science Magazine's Top Ten Scientific Innovations of 2003. Bruchez was also named one of the Top 100 Young Innovators by Technology Review Magazine in 2004.

Neil M. Donahue Named Director of Steinbrenner Institute

Carnegie Mellon named Neil Donahue director of its Steinbrenner Institute for Environmental Education and Research, which seeks to change the way the world thinks and acts about the environment. Donahue, a professor of chemistry, chemical engineering, engineering and public policy, and founding director of CMU's Center for Atmospheric Particle Studies, is an internationally recognized expert in atmospheric chemistry and air-quality engineering. He is a member of numerous professional societies, a fellow of the American Geophysical Union, and an editor with several academic journals.

Rachel Mandelbaum Awarded Professorship

Astrophysicist Rachel Mandelbaum has been named the first recipient of the Falco DeBenedetti Career Development Professorship in Physics. Funded by Emma (Falco) DeBenedetti and her family, the professorship supports junior faculty in the Physics Department whose work shows great promise. Mandelbaum, an associate professor of physics and member of the McWilliams Center for Cosmology, studies weak gravitational lensing, a technique that measures the large-scale distribution of ordinary and dark matter in the universe. She conducts her research through many large, international collaborations and holds leadership roles in a number of these projects. In 2011, Mandelbaum was awarded the Annie Jump Cannon Prize from the American Astronomical Society for her contributions to weak gravitational lensing. She received a Department of Energy Early Career Award in 2012 and an Alfred P. Sloan Fellowship in 2013.

Rachel Mandelbaum and MCS Dean Fred Gilman

ALL PHOTOS THIS PAGE: CARNEGIE MELLON UNIVERSITY

New Faculty

From left: DJ Brasier, Clinton Conley, Jason D'Antonio, Raphael Flauger, Hunaid Nulwala and Gizelle Sherwood

COURTESY DJ BRASIER; NICOLE READING; NICOLE READING; CARNEGIE MELLON UNIVERSITY; NICOLE READING; COURTESY GIZELLE SHERWOOD

Daniel (DJ) Brasier

Assistant Teaching Professor, Biological Sciences

Specialty: Studied presynaptic NMDA receptors' role in short- and long-term synaptic plasticity. Coordinates the Intercollege Program in Neuroscience, and teaches a variety of neuroscience courses including the Neurobiology of Disease.

Education: Ph.D., Neurosciences, University of California, San Diego; postdoctoral research, The Salk Institute and University of California, San Francisco.

Clinton Conley

Assistant Professor, Mathematical Sciences

Specialty: Focuses on descriptive set theory, with particular interest in the rich and blossoming study of the relative complexity of equivalence relations on Polish spaces.

Education: Ph.D., Mathematics, University of California, Los Angeles; postdoctoral research, Kurt Gödel Research Center for Mathematical Logic, University of Vienna.

Jason D'Antonio

Assistant Teaching Professor, Biological Sciences

Specialty: Investigated the adaptive role of the androgen receptor in hormone-refractory prostate cancer. Advises and mentors students in CMU's Health Professions Program and is creating a course on Cancer Biology to be introduced Fall 2015.

Education: Ph.D., Cellular and Molecular Pathology, University of Pittsburgh School of Medicine; postdoctoral research, Johns Hopkins School of Medicine.

Raphael Flauger

Assistant Professor, Physics

Specialty: Tackles phenomenological questions in cosmology and particle physics. Explores formal questions in field theory and string theory, or more generally quantum gravity.

Education: Ph.D., Theoretical Physics, University of Texas at Austin; postdoctoral research, Yale University, New York University, and the Institute for Advanced Study.

Hunaid Nulwala

Assistant Research Professor, Chemistry

Specialty: Uses click chemistry concepts to access and manipulate organic materials properties for various energy-related applications including ionic liquids, organic and inorganic polymers.

Education: Ph.D., Chemistry (Materials), University of California, Santa Barbara; postdoctoral research, National Energy Technology Laboratory.

Gizelle A. Sherwood

Assistant Teaching Professor, Chemistry

Speciality: Investigated the effects of aggregation on the photophysics of oligomers related to MEH-PPV and CN-PPV. Primarily lectures and assists in the continuous development of Laboratory 1: An Introduction to Chemical Analysis, and is developing an analytical lab course for non-chemistry majors.

Education: Ph.D., Chemistry, Carnegie Mellon University.

University Launches BrainHub, a Global Neuroscience Research Initiative

At the end of August, Carnegie Mellon President Subra Suresh announced the launch of a new, $75 million dollar, global neuroscience research initiative called BrainHub. The initiative will bring together scientists from many disciplines, including biology, computer science, psychology, statistics and engineering, to conduct research aimed at understanding how brain activity leads to complex behaviors. Faculty involved in BrainHub, including many affiliated with the Mellon College of Science, will develop innovative computational and technological tools for studying the brain and analyzing complex neuroscience data and will conduct research that promises to reveal new insights into topics such as cognition, learning and perception, and brain disorders like autism and Parkinson's disease. Through BrainHub, Carnegie Mellon will collaborate with a global network of partner institutions including Sun Yat-sen University in Guangzhou, China; the Indian Institute of Science in Bangalore; and Oxford University and the University of Warwick, in the U.K.

Marlene Behrmann, Michael Tarr and Nathan Urban visited the White House as part of an Office of Science and Technology Policy event focused on the President's BRAIN (Brain Research through Advancing Innovative Neurotechnologies) Initiative.

Retiring Faculty

Richard Griffiths

Physics Professor Richard Griffiths retired after a distinguished career in space astronomy studying the cosmic evolution of galaxies and massive black holes using Earth-orbiting optical and X-ray telescopes. He planned and used data from several surveys to study the origin of the X-ray background from space, and the nature of star-forming galaxies, active galactic nuclei and ultraluminous X-ray sources. During his career, Griffiths was involved with several international telescope projects. He continues his teaching and research at the University of Hawaii in Hilo where he has access to telescopes on Mauna Kea and where he holds a major NASA research award.

Robert Griffiths

Robert Griffiths, the Otto Stern University Professor of Physics, joined the Carnegie Mellon faculty in 1964. His initial interest in statistical mechanics shifted to quantum foundations in the mid-1980s, and to this was added quantum information and computation in the mid-1990s. Griffiths is a fellow of the American Physical Society and the American Scientific Affiliation, and a member of the National Academy of Sciences and Sigma Xi, the Scientific Research Society.

Jeffrey O. Hollinger

Biological Sciences and Biomedical Engineering Professor Jeffrey O. Hollinger joined the Carnegie Mellon faculty in 2000 after serving 20 years of active duty in the United States Army as a colonel, and seven years as a professor at Oregon Health Sciences University and director of the Northwest Wound Healing Center. At CMU he directed the Bone Tissue Engineering Center, which focuses on understanding the molecular basis for bone formation and wound healing. Hollinger is retiring after a career spent at the forefront of research on bone regeneration using biological factors and biomaterials. He holds several patents and has licensed technology developed in his lab.

Miguel Llinás

Miguel Llinás joined the Chemistry Department in 1976 and was promoted to Professor of Chemistry in 1988. Over the course of his 40-year career he specialized in using NMR spectroscopy and computational methods to investigate protein folding, dynamics and function, ligand-protein interaction, and stochastic ligand docking. One of his research interests was the folding of plasminogen, a molecule released from the liver. Llinás was a visiting professor at universities in the Netherlands, Spain, the United Kingdom and France, and is a member of Argentina's National Academy of Science.

John Nagle

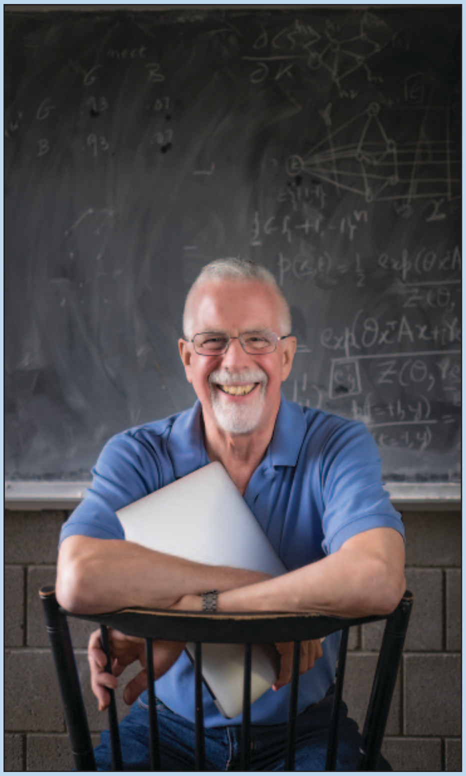
Physics and Biological Sciences Professor John Nagle joined CMU in 1967, and has published highly cited papers in the field of biological physics, specifically in the area of biomembranes. In the 1970s, he developed a theoretical model of the transition of lipid bilayers into their fluid, biologically relevant phase. He then added experimental work, most recently using X-ray scattering to quantify structural properties of model biomembranes. Nagle remains active with a current NIH grant and a research emphasis on membrane mechanics. He and his wife, Research Professor Stephanie Tristram-Nagle, received the Avanti Award in Lipids from the Biophysical Society in 2003 for "significant contributions to both theory and experimental biophysics."

CNAST

DSF Gives CNAST $3M to Continue Research into Synthetic Nucleic Acids

With a $3.1 million gift from the DSF Charitable Foundation, the Center for Nucleic Acids Science and Technology (CNAST) is ramping up its efforts to apply synthetic chemistry solutions to real-world problems, including the diagnosis and treatment of infectious disease, neurodegenerative disorders and cancer. CNAST does extensive research on peptide nucleic acid (PNA), a synthetic analog of DNA and RNA. PNA contains the same nucleobases as natural DNA and RNA, so PNAs have the potential to identify certain gene sequences known to play a role in disease and to block gene function—giving them enormous promise for diagnostics and therapeutics. With the new gift from the DSF Charitable Foundation, CNAST researchers plan to further develop two types of next-generation PNAs: gammaPNA and Janus PNA. For more information, please visit: ***www.cmu.edu/cnast/***

Faculty, Students Named MCS Education and Research Award Winners



Julius Ashkin Teaching Award: Robert Swendsen

Recognizes unusual devotion and effectiveness in teaching undergraduate students

Physics Professor Robert Swendsen's classes often leave students clamoring for more—even though they are some of the hardest they've ever taken. But due to Swendsen's teaching, the classes also are among their favorites. Famous for teaching courses in thermal physics and statistical mechanics, he gives his students every opportunity to succeed. "Looking back on my time at CMU, I can draw a straight and direct line between the teachings and guidance provided by Professor Swendsen and my success after CMU," wrote a former student in a nomination letter. Professor Swendsen's popularity hit new heights recently. He was named one of Pittsburgh's Best Professors by Pittsburgh Magazine in 2014.

From left: Michael Gamalinda, Kelsey Hallinen and Emily Daniels Weiss

Dr. J. Paul Fugassi and Linda E. Monteverde Award: Kelsey Hallinen

Presented to a graduating female senior with the greatest academic achievement and professional promise

While pursuing a B.S. in physics and a minor in history, Kelsey Hallinen carried out numerous research projects at CMU and at the SLAC National Accelerator Laboratory, ranging from measuring the densities of lipid/water mixtures to using Monte Carlo methods to answer various questions in statistical mechanics. Outside of the lab, Hallinen was very involved in the CMU community and beyond as a tutor, RA and camp counselor. She plans to pursue a doctorate in biological physics at the University of Michigan.

Guy C. Berry Graduate Research Award: Michael Gamalinda

Recognizes excellence in research by MCS graduate students

Michael Gamalinda, a Ph.D. candidate in the Department of Biological Sciences, is working to gain a clear picture of how ribosomes assemble. Made of 79 proteins and four RNA molecules, ribosomes translate the information encoded in RNA into proteins. While investigating the functions of more than 30 different ribosomal proteins, Gamalinda discovered how they bind to rRNA as assembly proceeds and how those associations affect binding of other ribosomal proteins and assembly factors as well as the overall structural organization of the assembling ribosome.

Hugh D. Young Graduate Teaching Award: Emily Daniels Weiss

Recognizes effective teaching by graduate students

Whether she is teaching recitations for Organic Chemistry, Intro to Modern Chemistry or Lab IV: Molecular Spectroscopy and Dynamics, Emily Daniels Weiss's passion for teaching shines through. A Ph.D. candidate in the Department of Chemistry, Weiss does everything in her power to help students understand complex topics and keep them engaged with and challenged by the material. "I consider myself lucky to have been her student," wrote a student in support of Weiss's nomination. Weiss has accepted a postdoctoral fellowship with CMU's Eberly Center for Teaching Excellence.

faculty awards and honors

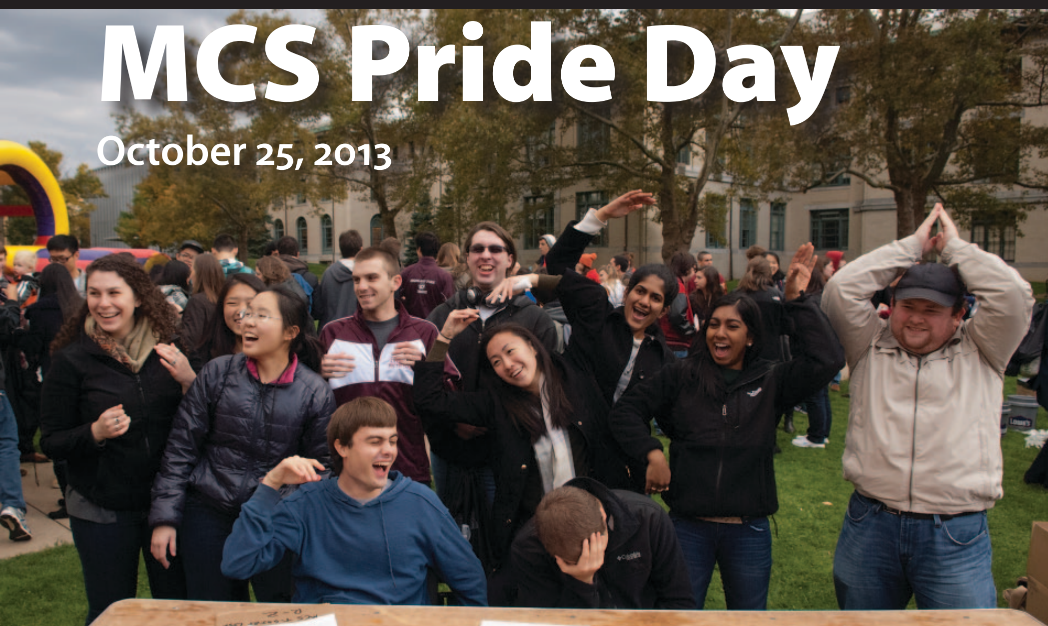
• The American Chemical Society named the Teresa Heinz Professor of Green Chemistry **Terry Collins** a 2013 Fellow. • **Irene Fonseca**, the Mellon College of Science Professor of Mathematics, was one of five CMU professors to receive the elite distinction of University Professor, the highest academic accolade a faculty member can achieve at Carnegie Mellon. • The International Organization of Chinese Physicists and Astronomers has named Assistant Professor of Physics **Shirley Ho** a co-winner of the 2014 Outstanding Young Researcher Award/The Macronix Prize, which is given to young, ethnic Chinese physicists or astronomers working outside of Asia. • Chemistry Professor **Hyung J. Kim** was named a 2013 Korean Academy of Science & Technology Frontier Research Scientist. • Assistant Professor of Mathematical Sciences **Po-Shen Loh** is the national lead coach for the United States team at the International Mathematics Olympiad, a rigorous two-day math competition for high school students held each summer. • The National Academy of Inventors named **Krzysztof Matyjaszewski**, the J.C. Warner University Professor of the Natural Sciences, a 2013 Fellow. • Physics Professor **Robert Swendsen** won the 2014 Aneesur Rahman Prize for Computational Physics from the American Physical Society for "multiple, ground-breaking algorithmic developments in computational statistical physics."

MCS Pride Day

October 25, 2013






Mellon College of Science students often find themselves spending most of their time with other students in their major. The MCS Student Advisory Council aimed to shake things up a bit by organizing and hosting the first annual MCS Pride Day on October 25, 2013. More than 800 people from the MCS community came together from all disciplines, roles, and backgrounds to celebrate their college pride. Undergraduates, graduate students, faculty and staff took over the Mall for the student-led celebration. Whether they were making their own tie-dyed MCS t-shirts or eating liquid nitrogen ice cream, students showed off their MCS pride—and made some new friends outside of their majors in the process.

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CARNEGIE MELLON UNIVERSITY

Victorious Veterans

Bodies in motion tend to stay in motion. That law of physics appropriately rings true for two members of the Physics Department, who enjoyed the distinction of winning Andy Awards and Years of Service citations for their combined 100 years at Carnegie Mellon at the 2014 staff recognition ceremony on Sept. 30. Joe Rudman (right), scientific project administrator, earned the Andy Award for University Citizenship and was celebrated for his 55 years at the university. Chuck Gitzen (left), storeroom manager, received the Andy Award for Dedication and was honored for his 45 years at CMU.

by Bruce Gerson

Carnegie Mellon University