

No, it's not the latest Bond girl from the opening titles of the upcoming *Quantum of Solace*. Artist Lynn Aldrich wields a glue gun as she assembles *Pilgrimage: (Through the Wormhole)* via which visitors will travel between two spaces in the gallery.

## RANDOM WALK



## THE ARTS PAGE

The beauty of deep-space astronomy and the inventiveness of contemporary art meet in *OBSERVE*, an exhibition being mounted at the Williamson Gallery at Pasadena's Art Center College of Design in collaboration with Caltech's Spitzer Science Center.

The event, organized by gallery director Stephen Nowlin and infrared astronomer Michelle Thaller, manager of Spitzer's education and public outreach program, features installations by five artists—two with Caltech/JPL connections—as well as a section on the Spitzer Space Telescope and a documentary film.

Lita Albuquerque's video walls turn the astronomers' gaze inward by mapping deep-space images onto a sphere representing Earth. Red lines of light, like string stretched between pushpins, connect sky and ground. As the sphere turns, the parallel lines from pairs of stars above the north and south poles carve out DNA's double helix on its surface.

Lynn Aldrich, an Art Center alum, is contributing the walk-through wormhole seen at left—a physical passage through metaphorical dimensions.

Dan Goods, another Art Center alum now at the Jet Propulsion Lab, is offering a rumination on time and distance. "We think we see the stars as they are right at this moment," he says. "But they're really at vastly different distances, so their light left them at different times in the past. Some of them died long, long ago, and now only exist as starlight." His exhibit features an enormous, Dali-esque wall clock whose hands move backward. As visitors walk through the 34-foot-

deep room, however, they realize that the 12 spheres representing the hours are actually different sizes and different distances away. Speakers on the spheres will play back computer-processed, time-delayed recordings of visitors' voices. "The older the data, the more distorted it will be," says Goods. "They'll be redshifted, if you will, like the stars are talking to you."

George Legrady considers the use of imaging technology in the exploration of outer and inner space, as seen below.

And Daniel Wheeler's installation encourages visitors to explore beyond the visible by feeling for an object hidden inside a wooden cylinder. An infrared camera records their hands' exploration. These images, sent over the Internet to a series of screens on which other cameras are trained, get progressively distorted as they propagate through the gallery.

"When you get artists and scientists working together, you get serendipitous things that none of them intended as each person picks up on what the other is saying," says Thaller. "Every person brings their own set of filters into the conversation, and the result is you get these associations you wouldn't have thought of, and you say, 'Oh, wow, that's really cool!' We talk about things like quantum foam and

## AMERICA'S FIRST LADY OF ROCKETRY

Would you believe that a woman—and a college dropout, no less— invented the propellant that got America's first satellite, Explorer 1, into space? This fall, Theater Arts at Caltech (TACIT) presents the world premiere of *Rocket Girl*, the true story of Mary Sherman Morgan.

The year is 1957. Sputnik is beeping overhead. The Redstone rocket needs a 5 percent power boost to reach orbit. Finding the extra thrust without redesigning the entire system has become the task of the Rocketdyne Corporation, where Mary and her husband, Richard Morgan (BS '49), work. Written by their son, George, *Rocket Girl* is a tale of heroic battles against impossible deadlines, a saga known until now to none but a handful of old men.

Performances are for one weekend only in Ramo Auditorium: November 7 and 8 at 8:00 p.m., and November 9 at 2:00 p.m. **e&s**

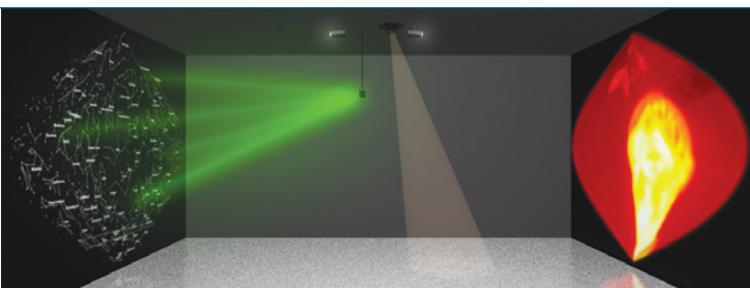
light years without giving it a second thought, and then the artists show us again in a new way just how wonderful the stuff we're working on really is."

This cultural exchange began in August 2007, says Nowlin, noting that science has brought us "a lot of spectacular concepts that torque our everyday perception of reality—black-hole physics, multiple universes, string theories, time distortions—that challenge our human-centered cultural traditions and beliefs." This is "an exhibition about the newly unknown," he says. "Before science we knew everything, because we filled in the

gaps with myths."

Nowlin has previously collaborated with Caltech scientists on *ear(th)*, a sound installation that translated displacement data from the Hector Mine earthquake into notes played on a robotic glockenspiel, and NEURO, a multi-venue exhibit that drew on the resources of Caltech's Center for Neuromorphic Engineering to inspire the work of a half-dozen artists.

OBSERVE opens with a public reception from 6:00 to 10:00 p.m. on Friday, October 10, as part of ArtNight Pasadena, and runs through January 9, 2009. —DS **e&s**



*We Are Stardust*, by George Legrady, projects a map of the deep-space targets of Spitzer's infrared cameras on one gallery wall, on which a beam of green light traces the sequence of Spitzer's observations. On the opposite wall, an infrared camera mounted in the gallery ceiling simultaneously follows the same set of pointing instructions to project thermal images of the people moving through its field of view in the gallery space.

## LOH DOWN ON SCIENCE ON AFN

The Armed Forces Radio Network, which reaches more than 20 million people in 179 countries, will begin offering a little dose of science four times daily, beginning in October. *The Loh Down on Science*, featuring public-radio personality Sandra Tsing Loh (BS '83), already airs on some 90 stations stateside. Each 90-second episode features Loh's patented off-kilter look at some aspect of science or technology. For more information, or to listen to past episodes, visit <http://lohdown.caltech.edu/>. 

## BEAM ON!

Watching the first slug of protons jog their victory lap around the Large Hadron Collider (LHC) was a bit like watching JPL land the Phoenix on Mars: would the nail-biting, brow-furrowing, breath-holding physicists in Mission Control burst into applause as the batch of high-energy particles reached its checkpoint? Or would their stunned silence indicate failure?

For 53 minutes, you couldn't cut this kind of tension with a knife.

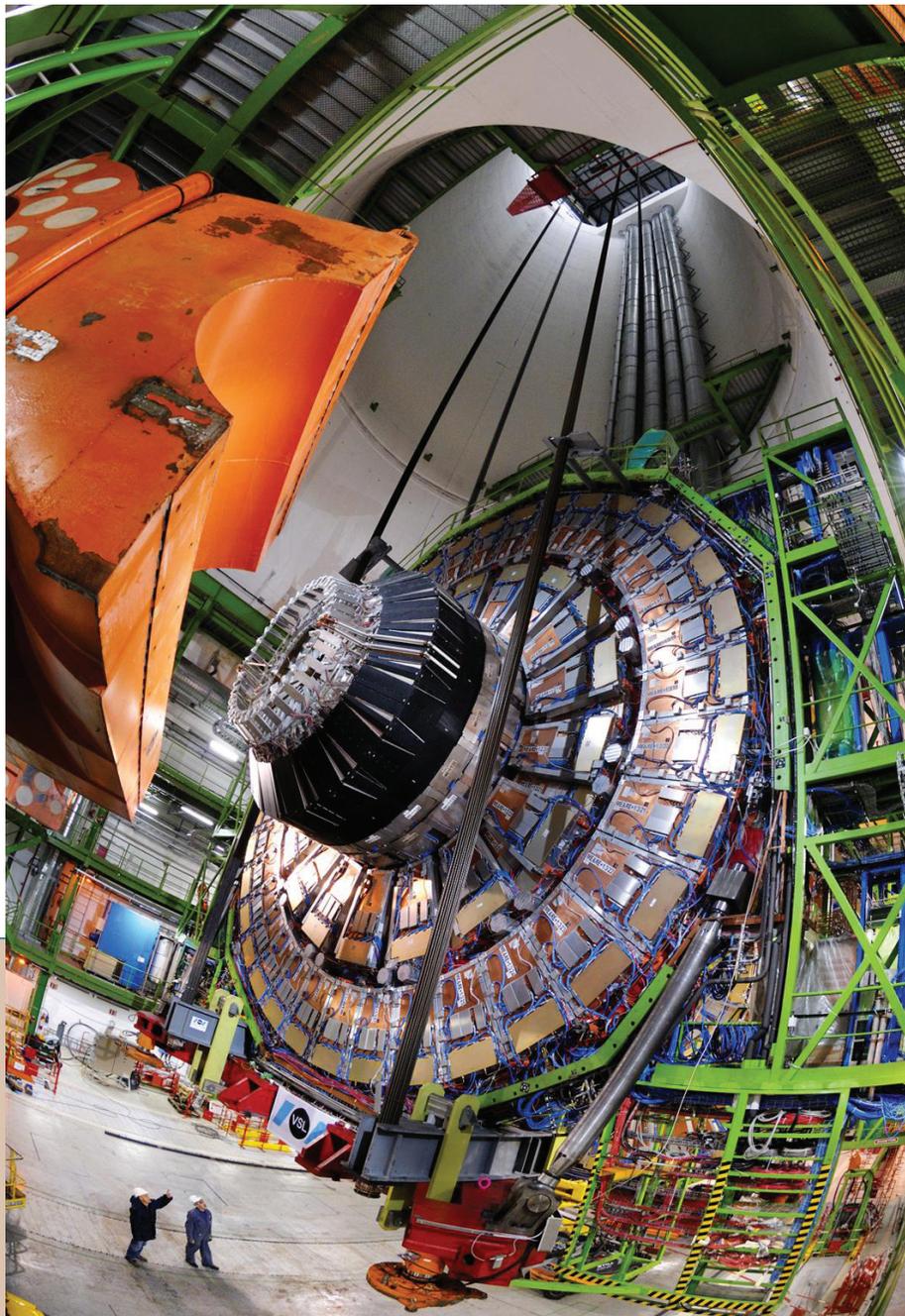
Fortunately for the LHC, it was all cheers at 10:30 a.m. on September 10 near Geneva, Switzerland, where CERN, the European Organization for Nuclear Research, operates the goliath physics experiment. The LHC's beam line, a ring 8.6 kilometers in diameter straddling the Swiss-French border, will recreate the conditions seen during the Big Bang. In the head-on collisions of billions of protons at a time, physicists have their fingers crossed that they will discover new particles, including the famed but as yet undetected Higgs boson.

As the LHC's controllers popped open champagne bottles, some 75 Techers in Pasadena celebrated the beam's first run at a midnight pajama party with pizza and beer, communicating via video conference with

a dozen Caltech physicists in Geneva.

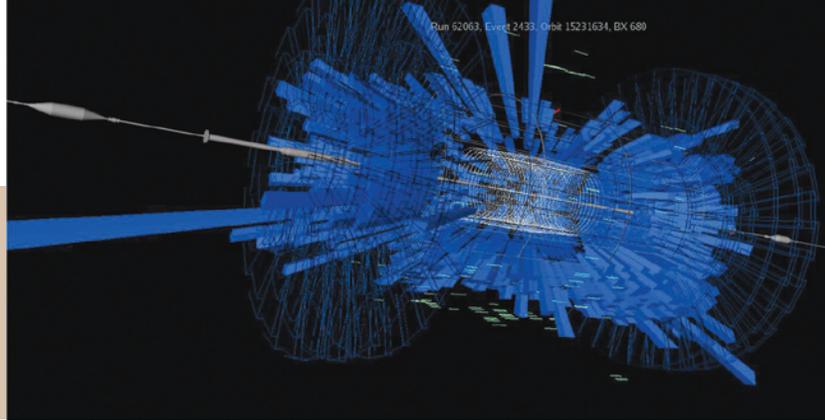
As soon as next month, two beams of protons zipping in opposite directions at 99.999998 percent the speed of light will collide at 10 trillion electron volts (TeV), ramping up to 14 TeV in the spring—about the energy

released by four tons of TNT. At seven times the energy of the Tevatron at Fermilab, now the world's second most powerful accelerator, the LHC will push beyond the limits of what is known in physics as the Standard Model, which has so far described



The cavernous experimental hall that houses the Compact Muon Solenoid detector at CERN lies 100 meters underground and could easily be mistaken for a Bond supervillain's lair—perhaps the secret rocket base in *You Only Live Twice*. The detector's components were assembled on the surface and then lowered down the shaft with centimeters to spare—the first time such an approach has been tried. Here the final component, the 1,430-ton YE+1 end cap, is being mated to the detector on January 9, 2007.

This spray of subatomic particle debris from the proton beam hitting a tungsten block was one of the first images recorded by the Compact Muon Solenoid's detectors.



all the known interactions between particles with high precision.

Some 40 Caltech scientists under Professor of Physics Harvey Newman and Associate Professor of Physics Maria Spiropulu work on the LHC's Compact Muon Solenoid (CMS), one of two experiments searching for the Higgs particle. In anticipation of the terabytes of data soon to come, Newman has also directed a project that bops bits between computers at breakneck speeds—151 gigabits per second, or some 15,000 times faster than the best cable service in California.

Physicists hope the discovery of the Higgs will fill one of the gaping holes in the Standard Model—why do most particles have mass, and why are some particles heavier than others? If the model is correct, it's the interaction between the Higgs and other particles that creates mass. So the Higgs decays much more often into heavier particles, such as the Z or W bosons, than it does into lighter particles such as muons or electrons. If most physicists' hunches are right, the LHC will provide the energy needed to strip a 120–160 billion-electron-volt (GeV) Higgs particle from the wreckage of a proton.

The CMS is the heaviest CERN experiment, packing the weight of the

Eiffel Tower into a volume 400 times smaller. Most of the weight is due to a massive metal coil that generates a 4-tesla magnetic field—enough stored energy in principle to lift the 12,500-ton magnet by 20 meters—which imparts a curve to the path of any charged particles created in the collision. The slower, heavier ones are the most affected—the more momentum a particle has, the straighter its course—allowing the momentum of each individual particle to be calculated by its trajectory through a nested set of detectors. Inside the magnet, a layer of lead tungstate crystals measures the energies of photons and electrons with high resolution, while layers of other materials capture the signatures of hadrons, a class of particles that includes protons, neutrons, and pions. Outside the magnet, another detector tracks muons, which come not only from collisions within the beam line, but from cosmic rays hitting air molecules in the upper atmosphere. Together, the system inventories the flurry of exotic particles from which the exceedingly rare Higgs signature must be plucked.

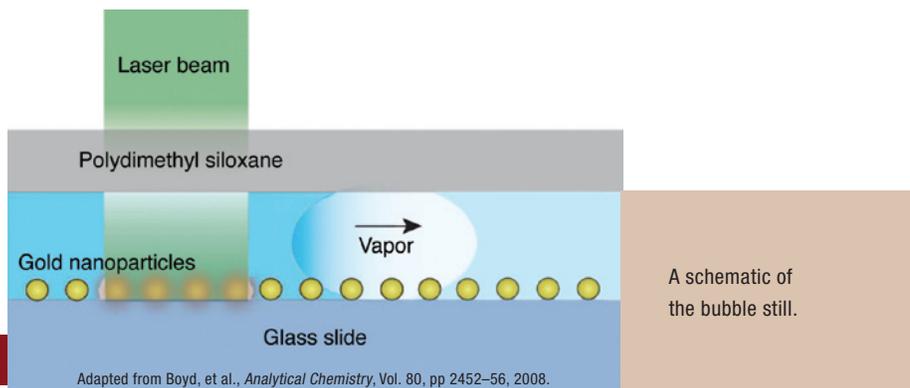
Because the Higgs will be so quick to decay, CMS isn't designed to capture the particle itself. Instead, the physicists will look for a decay of the Higgs into two photons, the massless

carriers of light. Though this is a rare decay mode—only happening once in every ten trillion collisions—its signature should lurk in the crystals that Caltech has spent the last decade and a half perfecting.

Caltech physicists, including grad student Vladlen Timciuc, have analyzed the data from many millions of simulated proton-proton collisions, most of which result in bombardments of photons and pions well documented in other experiments. These simulations are crucial to separating false alarms from the true Higgs. "Yesterday's signal is today's background," says Timciuc, who will be looking through CMS data to find new particles.

CMS, located in Cessy, France, isn't the only station on the LHC hoping to find the Higgs. A competing experiment, ATLAS, takes place on the other side of the ring, on the Swiss side of the border. Though CMS is the better at seeing the two-photon signature of a Higgs decay, there is another possible outcome: one Higgs decaying into two Z bosons, each of which decays into two muons. Both experiments have equal sensitivity to the latter mode, so if one experiment sees it, the other should too. Though both the CMS and the ATLAS teams will race to publish first, Spiropulu

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says it's a friendly competition.

"We cannot play war games," said Spiropulu. "We need each other."

The LHC should start up in earnest on October 21, when the two proton beams will first run into each other. If the Standard Model is right, ATLAS and CMS should see a few Higgs decays a year. But being stood up by the guest of honor would just as exciting. Stephen Hawking recently made a \$100 bet that the Higgs won't show.

"When do you give up on the Higgs?" asks Newman. "There is no other compelling explanation for how mass is generated, and people have gotten used to it."

With no Higgs, it would be back to the chalkboard for theorists. In the quantum world, forces are carried by particles—electromagnetism by photons, the weak force by W and Z bosons, and so on. A particle that supplies mass fits snugly in this framework. But if there's no Higgs, perhaps other particles will pop out of the collisions.

"Whenever you turn on a telescope, you see something new," says Sean Carroll, a senior research associate in physics at Caltech. "It's the same with particle accelerators." —MC 

**Marissa Cevallos (physics '09) is the editor of the California Tech and a member of the women's Ultimate Frisbee team. She reported on LHC's first beam from Geneva, Switzerland, before starting a semester exchange program in Edinburgh, Scotland.**

## A REAL MICROBREWERY

The happy art of distillation has been around for a good 5,000 years or so. But in the future, a household distillery could be essential for your health—and not by making moonshine for medicinal purposes. Caltech researchers have crafted the world's tiniest still to concentrate scant amounts of biomolecules, which could help detect the extremely low-abundance biomarkers that herald some diseases.

"Distillation is a well-established technology. You wouldn't think there'd be many new avenues to develop," comments David Boyd, a lecturer in mechanical engineering at Caltech who grew up in Alabama and is the lead author of a paper describing the work. "But in our approach, you don't need to boil the fluid anymore."

In a still, the vapor from a boiling liquid passes through a condenser, and the chilled condensate collects in a separate pot. If the liquid is a mixture of fluids with different boiling points, like ethyl alcohol in a watery corn mash, the lower-boiling one—the white lightning—will be concentrated in the condensate. Alternatively, boiling off the liquid leaves the heavier molecules behind, concentrating trace chemicals—the biomarkers—in

the still pot. The catch, of course, is that the high heat will turn your precious proteins into so much gravy stock. Boyd and his colleagues have created a microstill that operates at room temperature, and thus could be used as a biomonitor.

The still is a microfluidic chip whose channels are studded with gold nanoparticles. Air bubbles, normally the bane of microfluidic designs, are actually the key to this one's success. Each bubble acts as a tiny still pot. A laser no more powerful than a classroom pointer zaps the gold nanoparticles behind the bubble. The particles quickly transfer the heat to the surrounding fluid, and a little bit of liquid on the bubble wall vaporizes, passes through the bubble, and condenses again on the cooler wall of the bubble's front. "Only the most volatile molecules cross over the bubble. Everything else is left behind," Boyd says. "Typically, air bubbles are a real annoyance, because they pin the flow in the fluid, and are hard to get rid of. We've learned to love them."

The bulk fluid stays at room temperature, preserving the fragile protein molecules intact, because of a unique heating property of gold in its nanoform. The particles absorb green light very strongly, "acting like antennas for visible light," says coauthor David

In the future, a household distillery could be essential for your health—and not by making moonshine for medicinal purposes.

Goodwin, professor of mechanical engineering and applied physics.

In a demonstration experiment, the team dissolved a blue dye in ethanol, then mixed it with water. As the mixture coursed through the microchannels, the color behind each bubble intensified, while the liquid in front of each bubble turned clear.

Moving even beyond clinical diagnostic tools, the ultimate goal is to use this microstill as part of a personal sensor, perhaps even one worn as a patch, to track the level of some substance in one's blood. "Say you are on some prescription whose optimum dose is 10 micrograms per liter of blood," says Boyd. "The still could concentrate that med so another part of the chip could measure it accurately, and automatically control the release of more of it as needed to maintain the activity level."

The paper, whose other authors are James Adleman (MS '04, PhD '08), a graduate student in electrical engineering, and Demitri Psaltis, Caltech's Myers Professor of Electrical Engineering, appeared in the April 1 issue of *Analytical Chemistry*.

—DS/EN 

## THE SOUND OF MOVEMENT

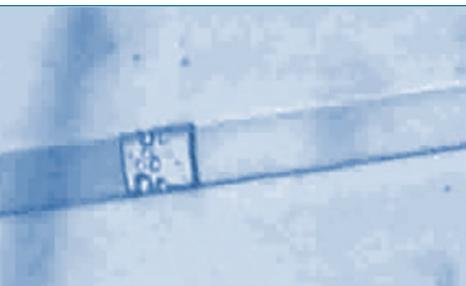
If you see the letters on this page in a rainbow of colors, or if hearing a certain word triggers the taste of cigarette smoke, you are a synesthete—one of perhaps every 100 people whose brains are wired in such a way that stimulating one sense activates another as well. Now, Caltech researchers have discovered a type of synesthesia in which sounds, such as tapping, beeping, or whirring, are heard when things move or flash. Synesthesias that trigger the senses of sight, touch, and taste are well known, but an auditory synesthesia had never been identified before.

Caltech postdoc and lecturer in computation and neural systems Melissa Saenz (BS '98) discovered the phenomenon quite by accident. "While I was running an experiment at the Caltech Brain Imaging Center, a group of students happened to pass by on a tour," explains Saenz, who, along with Christof Koch, the Troendle Professor of Cognitive and Behavioral Biology and professor of computation and neural systems, reports the finding in the August 5 issue of the journal *Current Biology*. "My computer screen was showing dots rapidly expanding out, somewhat like the opening scene of *Star Wars*.

Out of the blue, one of the students asked, 'Does anyone else hear something when you look at that?' After talking to him further, I realized that his experience had all the characteristics of synesthesia: an automatic sensory cross-activation that he had experienced all of his life."

Intrigued, Saenz began to look for others with the same ability. (You can view the video—in a quiet location!—at <http://www.klab.caltech.edu/~saenz/movingdots.html>.) "I queried a few hundred people and three more turned up," she says. "Having that specific example made it easy. It just happens to be quite 'noisy' to the synesthetes, and was a great screening tool. When asked if it made a sound, one of the individuals responded, 'How could it not?' I would have been less successful had I just generally asked, 'Do you hear sounds when you see things move or flash?' because in the real environment, things that move often really do make sounds," like, for example, buzzing bees.

This may be why the phenomenon hadn't been detected before—people with it may not realize that their experience is unusual. "These individuals have an enhanced soundtrack in life,



A microphotograph of the real thing. The channel, 100 millionths of a meter wide, runs sideways; the bubble is the square in the middle. The spheres in the bubble are smaller bubbles—at 10 billionths of a meter in diameter, the gold nanoparticles are invisible at this scale.

# Why don't pregnant women reject their own fetuses, which are packed with antigens from the father that are foreign to the mother?

rather than a dramatically different sensory experience," says Saenz.

The four synesthetes outperformed a control group in recognizing patterns of flashes similar to visual Morse code. Such patterns are normally easier to identify as beeps than flashes, so hearing a sound every time you see a flash should give you an advantage. The subjects watched a series of flashes and then had to guess if a second sequence, played afterward, repeated the same pattern. A similar test was given using sequences of beeps. Both the synesthetes and the control group performed equally well when given beeps, but the synesthetes responded correctly to the flashes more than 75 percent of the time, compared to around 50 percent—the level predicted by chance—in the control group.

Saenz and Koch suspect that as much as 1 percent of the population may experience auditory synesthesia. In fact, they think that the brain may normally transfer visual information to the auditory cortex in order to create a prediction of the associated sound. "At this point, very little is known about how the auditory and visual processing systems of the brain work together," says Saenz, who has begun brain-imaging studies to explore the connection. "Understanding this interaction is important because in normal experience, our senses work together all the time." —KS 

## ENGINEERING IMMUNITY

Caltech scientists are designing living tools that immune-system cells can use to fight disease, thanks to a \$750,000 grant from the Skirball Foundation. The gift will expand the Engineering Immunity program founded by David Baltimore, the Millikan Professor of Biology, and Pamela Bjorkman, the Delbrück Professor of Biology and an investigator with the Howard Hughes Medical Institute.

For nearly 40 years, Baltimore has studied how genetic information gets from viruses into host cells. He codiscovered an enzyme that enables the RNA of certain viruses to make

a DNA copy of its hereditary information—genetically engineering its host. DNA's transcription of information to RNA was well known, but no one knew that RNA could write back. That discovery so altered science that Baltimore and two other researchers won a Nobel Prize.

Engineering Immunity puts viral genetic-engineering capabilities to good use. Researchers in Baltimore's lab are designing highly customized, stripped-down viral molecules containing genetic components that inhibit real viruses and tumors. These molecules can sneak into your body's cells, inserting their protective cargo into the cells' DNA. Engineering Immunity project manager and lead scientist Lili Yang (PhD '04); then-

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## THE OUTER LIMITS

At the very edge of the solar system, Voyager 2 has sailed through the termination shock, where the solar wind abruptly slows as it presses outward against the ions in interstellar space. All of the spacecraft's fields and particles instruments returned data as it crossed the oscillating shock three times in a six-hour period on the night of August 31–September 1, 2007. (At least two other inferred crossings happened during telemetry gaps before and afterward.) A set of papers in the July 3 issue of *Nature* describes the conditions at the encounter, which were quite different from those observed by Voyager 1 in its single crossing four years earlier. The biggest surprise is that the shock is asymmetric—Voyager 1, traveling northward out of the plane of the solar system, crossed it at 14.1 billion kilometers, while southbound Voyager 2 hit it at a distance of a mere 12.6 billion kilometers.

Meanwhile, closer to home, the International Astronomical Union (IAU) has voted to accept Makemake (pronounced mah-kay mah-kay) as the official name for the dwarf planet previously known as Easterbunny. 2005FY9, as it is also known, was discovered by Rosenberg Professor of Planetary Astronomy Michael Brown's team on March, 31, 2005, four days after Easter. IAU rules say that trans-Neptune objects must be named for figures in creation myths; Makemake is the creator of mankind and the god of fertility among the Rapa Nui people of—you guessed it—Easter Island. —DS 

staff member Pin Wang (MS '00, PhD '04), now at USC; and Baltimore recently published a method for designing injectable versions of these molecules that are capable of selecting a specific cell type, such as the cells that kick off immune responses. This vastly reduces the risk, time, and cost involved in previous methods for genetically modifying human cells, which involved removing them, working with them in a laboratory, and then reintroducing them into the body.

Four years ago, the Skirball Foundation provided the project's seed funding. Since then, the program has grown into a massive HIV- and cancer-research effort that extends far beyond Baltimore and Bjorkman's collaboration to include teams at UCLA, USC, and Children's Hospital Los Angeles.

The new grant is intended to do just what the first one did—encourage research seen as too exploratory for most organizations to support. This new money will underwrite three immune-system studies, a breakthrough in any of which could lead to substantial improvements in an array of medical applications.

Yang plans to learn more about T cells—white blood cells central to cellular immunity—by actually watching them in action. She has developed

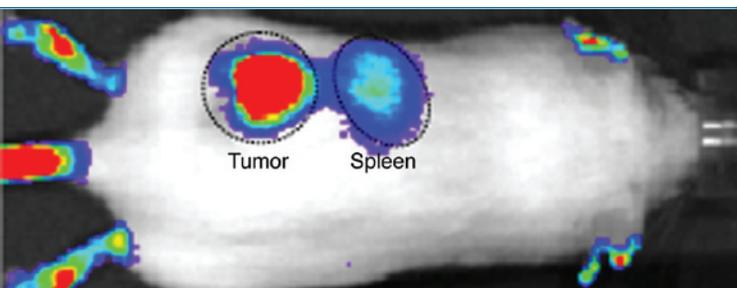
a method for labeling the T cells of interest with a bioluminescent imaging gene, allowing them to be tracked in a live animal in real time. Biologists can now watch how T cells behave when they encounter the friend-or-foe tags known as antigens, when they kill tumor cells, and when they recede after the battle is complete. A wide range of experiments being done in concert with medical imaging under way at UCLA could significantly improve cancer treatments by identifying the critical conditions needed for immunotherapy to work.

Visiting Associate in Biology Daniel Kahn, an obstetrician affiliated with the David Geffen School of Medicine at UCLA, will study some newly recognized types of immune cells that may hold the key to a longstanding mystery: Why don't pregnant women reject their own fetuses, which are packed with antigens from the father that are foreign to the mother? Could pregnancy-specific diseases like preeclampsia result from the immune system going awry? Finding the answers may not only strengthen treatments for pregnancy-specific conditions, but perhaps may improve the long-term success of organ transplants.

Finally, postdoc Ryan O'Connell will tackle RNA molecules called

microRNAs or miRs. Discovered just a few years ago, miRs turn out to be powerful players in the development (or inhibition) of cancer. Three of them, called miR-155, miR-146, and miR-34, have been linked to cancers of the immune system but are also involved in immune-cell development and healthy responses to inflammation. These microRNAs may be able to trigger cells to proliferate, kill themselves, or stop replicating—properties that might be exploited to deal with cells that have run amok and begun growing abnormally.

Engineering Immunity—started by one funder's leap of faith in a speculative line of research—is paying huge dividends. Says Baltimore, "The Skirball grant was the most important grant I ever received. . . . The foundation took a chance in supporting an unproven notion." With that "unproven notion" now going full steam in labs across Southern California, the Skirball Foundation is once again out in front in supporting science in its earliest, most basic stages. —AW 



This bioluminescence image of an anesthetized mouse injected with anti-cancer T cells shows that they gather preferentially in two spots: the spleen, where T cells hang out until mobilized, and the tumor. The red areas have the highest T-cell concentrations. Since this particular cancer, a melanoma, was derived from melanocyte-containing skin cells that display similar antigens, the hairless tail and legs also light up. Losing your melanocytes will cause skin depigmentation; losing a battle to melanoma is fatal.