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Nanomachination

Table of Contents

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Special EFFECTS

by Anna Lynn Spitzer

If it's true that good things come in small packages, absolute greatness is encased within the tiny world of nanotechnology.

So small it is not visible to the human eye – or even an optical microscope – nanotechnology is seeding new ideas in healthcare, communications, energy and manufacturing. In fact, along with its slightly larger relative, microtechnology, it is poised to impact every facet of daily life.

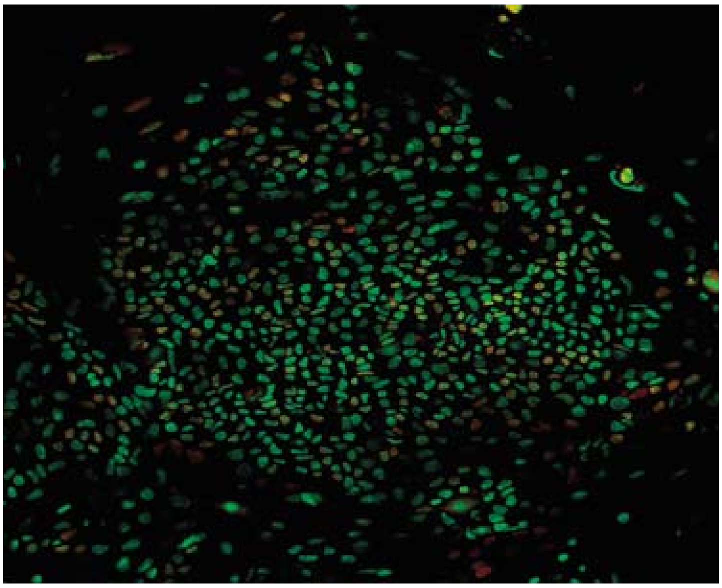
It's hard to conceive just how tiny this scale really is. Greek for "dwarf," nano means one-billionth; a nanometer is the equivalent of one-billionth of a meter, smaller than the wavelength of visible light. A centimeter – less than half an inch – contains 10 million of them, while one million fit on the head of a pin. A single strand of human hair is 80,000-100,000 nanometers wide.

Yet, scientists are creating materials and building tiny structures smaller than 100 nanometers out of atoms and molecules. "Atoms are like Legos; they are the building blocks that make up the universe," says Peter Burke, UC Irvine professor of electrical engineering and computer science. "The periodic table lists 100 or so different kinds of atoms … and it's up to mankind to assemble those into materials and structures."

In this tiny realm, however, nothing is as expected. The properties of elements often change, along with the rules of physics, challenging science even further.

At the nanoscale, insulating materials can become semiconductors. Melting points, boiling points, colors and density can change. Solids may become liquids, and liquids that flow easily at the macroscale become too sticky to move.

(continued, page 2)



Human embryonic stem cells have been grown on nanostructures. Scientists think these structures may help prolong cell life.

Surprisingly, even the color of gold is not sacrosanct. When examined with a spectrometer, a nano chunk of gold can be either red or green, depending on its exact size.

"Properties that you would predict based on classical physics no longer are true at the nanoscale," explains physics and astronomy associate professor Phil Collins. "As you shrink and shrink and shrink, you reach the realm of quantum physics, and all these properties change."

Science has already harnessed this phenomenon to improve consumer products. White zinc oxide particles that block sunlight become transparent at the nanoscale, making possible clear sunscreens. Nanoparticles that repel liquid become stain-resistant clothing fibers, while aluminum silicate nanoparticles improve scratch-resistant materials for eyeglass lenses and car bumpers. There are even antibacterial bandages made with nanoparticles of silver, which block the cellular respiration of microbes.

Now, the challenge is to evolve this understanding into areas that can help humankind by detecting disease, producing fuel, identifying toxins and delivering medicine directly into a human cell. "I think of nanotechnology as a 100-year-long revolution and we're only in the first decade," says Collins, whose research focuses on nanosensors to detect toxic substances. "Our suntan lotion is now transparent, but that hasn't changed the world."

"As you shrink and shrink and shrink, you reach the realm of quantum physics, and all these properties change."

Physicist Richard Feynman first presented the concept to scientists in 1959. In a speech to the American Physical Society, he explained why directly manipulating individual atoms could one day be possible.

The word "nanotechnology" was coined 15 years later by Tokyo Science University professor Norio Taniguchi and popularized by Eric Drexler in a 1986 book. It appears, however, that the science itself predates the concept by hundreds of years.

Stained glass in European cathedrals dating back to the sixth century contain nanoparticles of gold chloride and other metal oxides and chlorides. "They didn't have microscopes and they didn't know what they were creating … but people have always played with different materials by trial and error," Collins says. "They knew if they followed a certain recipe they could create a piece of glass that was green [or red or purple]. There are a lot of really interesting examples showing that nano goes way back in history."

But it wasn't viable as a science until the 1980s, when a new breed of microscopes allowed scientists to "see" atoms and molecules in a way that wasn't possible previously. The scanning tunneling microscope, which won the Nobel Prize in 1986, and its successor, the atomic force microscope, which images, measures and manipulates matter at the nanoscale, opened the field to scientific inquiry (see pg. 20).

The past decade has seen a jumpstart in nanotechnology research. In 2000, then-President Bill Clinton announced the National Nanotechnology Initiative, and federal spending on nanotechnology research since has totaled approximately $1 billion a year. In announcing the initiative, Clinton referenced scenarios that now are well on their way to reality. "Just imagine," he said, "materials with 10 times the strength of steel and only a fraction of the weight; shrinking all the information at the Library of Congress into a device the size of a sugar cube; detecting cancerous tumors that are only a few cells in size."

> "They didn't have microscopes . . . but people have always played with different materials by trial and error."

UCI researchers have moved beyond imagination. Engineering professors Peter Burke and Marc Madou grow carbon nanotubes, cylinders of carbon atoms that can conduct electricity and serve as transistors; they are stronger than steel and six times lighter. Physics professor Zuzanna Siwy creates nanopores, artificial systems that mimic the behavior of biological systems.

Engineering professor Albert Yee is using a nanoimprinting process on polymers to create nanomaterials for sensing, monitoring and diagnosing; and Dr. Edward Nelson, associate professor of medicine, is building micropallet arrays that can trap and identify individual cells, possibly leading to personalized cancer treatments.

Even scientists immersed in the field can't fully predict the promise of nanotechnology. What they do know is that it provides a better understanding of atoms and molecules, as well as the tools with which to reproduce cellular processes with artificial materials.

"Biology is the world's best nanotechnology," says Collins. "We just don't know how it works."

Case in point: bomb-sniffing dogs. "We can't make sensors today that perform better than a dog. We know it's possible, that there's some combination of biology, chemistry and proteins that allows for a signal to be detected and reported. We'd like to figure that out so we could build it into a device."

Consider abalone, which synthesizes proteins to build, layer by layer, its remarkably strong rainbow-hued shells;

(continued, page 4)

nanotechnology TIMELINE

(courtesy of nano.gov, the National Nanotechnology Initiative)

4th century

The Lycurgus Cup (Rome) is an example of dichroic glass; colloidal gold and silver in the glass allow it to look opaque green when lit from outside but translucent red when light shines through the inside.

6th-15th century

Vibrant stained glass windows in European cathedrals owe their rich colors to nanoparticles of gold chloride and other metal oxides and chlorides.

1936

Invention of the field emission microscope allows near-atomic-resolution images of materials.

1959

Richard Feynman of the California Institute of Technology gives the first lecture on technology and engineering at the atomic scale, "There's Plenty of Room at the Bottom," at an American Physical Society meeting.

1974

Tokyo Science University professor Norio Taniguchi coins the term nanotechnology to describe precision machining of materials to within atomic-scale dimensional tolerances.

1981

Invention of the scanning tunneling microscope allows scientists to create direct spatial images of individual atoms for the first time.

1986

The atomic force microscope is invented, giving scientists the ability to view, measure and manipulate materials down to fractions of a nanometer in size.

1999-early 2000s

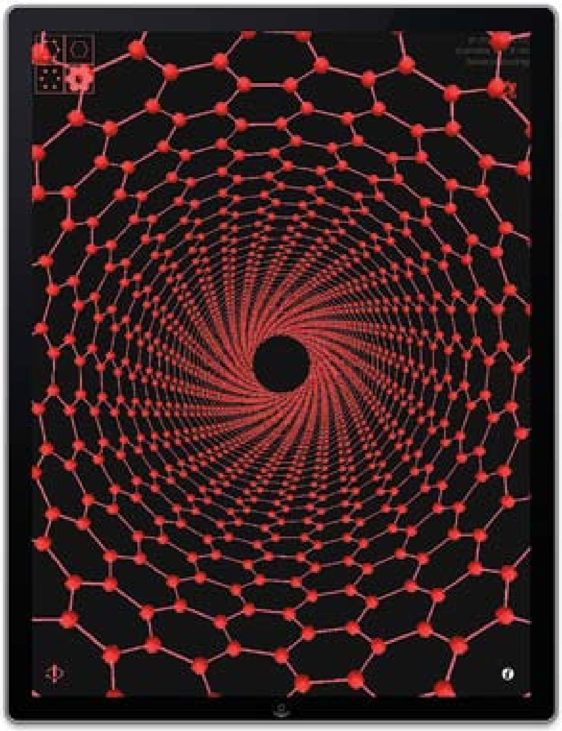
Consumer products making use of nanotechnology begin appearing in the marketplace.

2000

President Clinton launches the National Nanotechnology Initiative (NNI) to coordinate federal R&D efforts and promote U.S. competitiveness in nanotechnology. Congress funded the NNI for the first time in FY2001.

2010

A silicon tip measuring only a few nanometers at its apex chisels away material from a substrate to create a complete nanoscale 3D relief map of the world 1/1000 the size of a grain of salt.



Carbon nanotubes (top) and graphene are materials of choice in nanotechnology. Unlike other materials, which start losing conductivity as they shrink, carbon's conductivity actually improves.

and sand dollars, which use special proteins to construct their radial-patterned skeletons. "These are techniques that nature developed over millennia to achieve its goals," Collins says. "And we're just now starting to realize what a great toolbox that is."

Because those processes happen on a molecular level, Collins believes that nanotechnology holds the answers. "Biology shows us that it's possible and there are no rules of physics that make it impossible."

Ultra-sensitive nanosensors can do the same job as bomb-sniffing canines. Why? Because devices that are only the size of a molecule can easily detect the presence of another molecule that comes into contact with it.

"At the nanoscale, I can start with a one-molecule system and add a molecule to it. Now I've [approximately] doubled the size – a big effect that's easy to detect," explains Collins. "With a larger system – say, a million times bigger – the addition of one more molecule is a tiny fractional change that's just not big enough to be detectable."

This very high surface-area-to-bulk ratio allows precise measurement of single molecules, which can lead to easy identification of foreign substances.

Using electrically charged hollow carbon nanowires called nanotubes, Collins builds circuits designed for exposure to air or liquid. These chemical and biological sensors can accurately sense the presence of foreign molecules – airborne Anthrax for example, or blood-borne toxins in very low concentrations.

Mechanical and aerospace engineering professor Marc Madou makes polymer nanowires using a technique called electrospinning, and then converts them to carbon. Less expensive than standard methods, electrospinning formerly produced randomly placed, uncontrolled fibers. Madou and his team developed a way to control placement of the wires, a crucial step in manufacturing optical and electronic devices. "We can connect point A to point B, write a pattern or write names with the wires," he says.

They are also suspending these wires between two posts and hanging DNA or proteins on them, creating what Madou calls "washcloth sensors." Because the wires have so much surface area, they are especially sensitive and can detect electrical activity caused by molecules binding to the substances. This allows scientists to inexpensively identify DNA and proteins.

Peter Burke also grows carbon nanotubes, as well as graphene, sheets of graphite one atom thick.

In 2004, Burke's lab synthesized the world's longest electrically conducting nanotube. Four-tenths of a centimeter long, it was 10 times the length of any previously created. Today, Burke's nanotubes grow to almost three centimeters, an achievement that proves it's possible to build atomic-scale structures.

Collins, who grows these carbon nanotubes to build tiny circuits, says it's the versatility of the material that makes it so intriguing. Unlike other elements, copper and aluminum for instance, which start losing their conductivity as they shrink to the nanoscale, carbon actually improves. Electronically, nanotubes serve as switches and wires. Mechanically, they're ultra-strong fibers, and they have interesting optical properties as well.

Burke uses these materials to make electronics, including analog transistors and antennas for radio-frequency devices used in wireless communications. Based on their electronic properties, carbon nanotubes and graphene are particularly well-suited for analog applications, which have different technical requirements than digital applications. Burke spun off this research into a startup company, RF Nano, in 2005.

He currently directs a Multidisciplinary University Research Initiative project aimed at discovering how fast electric signals and light waves can propagate across a nanowire. The $5 million Department of Defense grant also involves researchers at seven other universities, and will impact the future of information storage, lithography and communications.

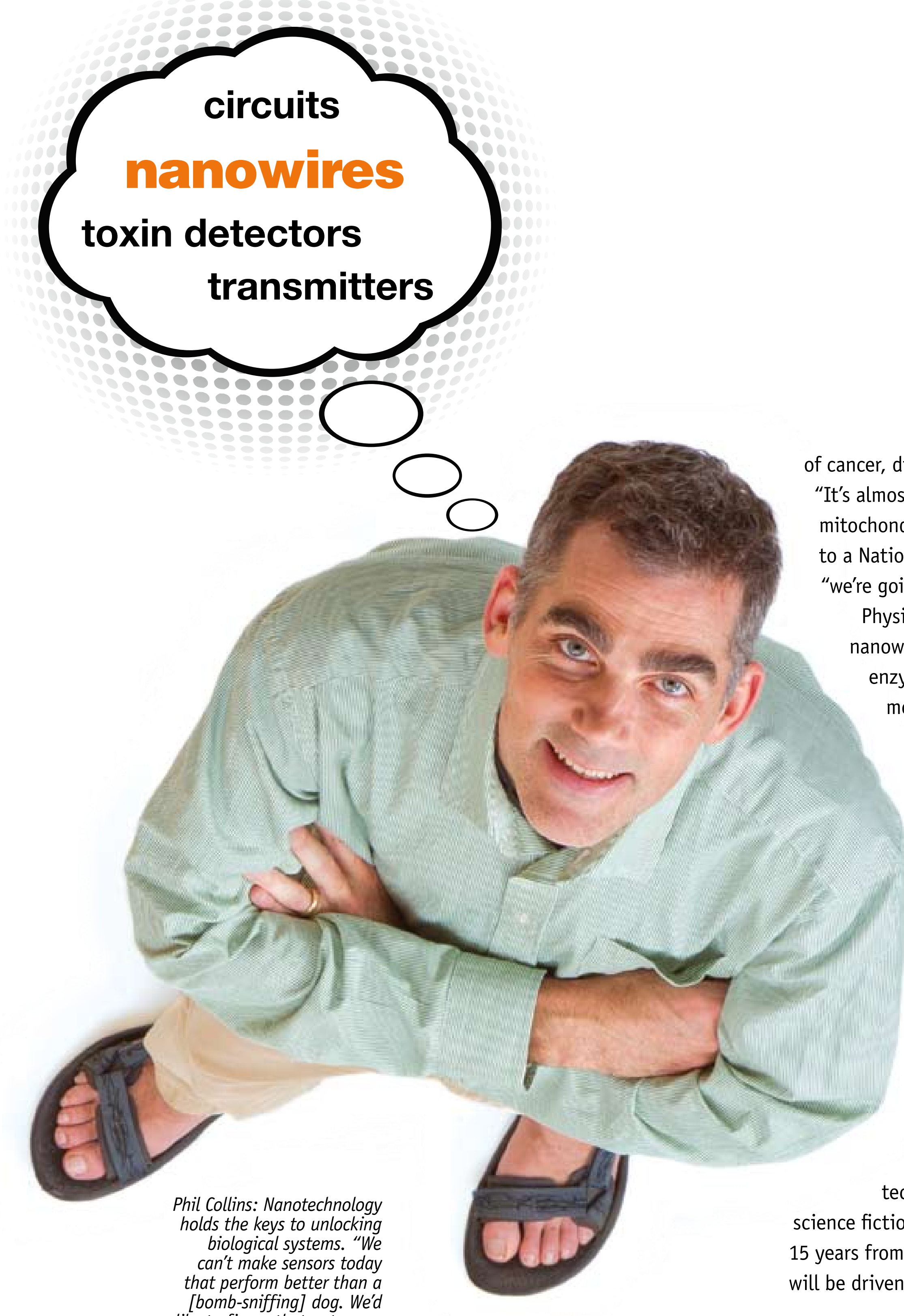
Eventually it could make possible even smaller nano-antennas and ultimately, nanoradios small enough to fit into a human cell. These tiny electronics could serve as glaucoma or blood pressure monitors, cancer detectors and wireless interfaces to the brain. "Right now people are building radios a millimeter by a millimeter by a millimeter," Burke says. "But I think you could make one that's a micron by a micron by a micron, which is the size of a single living cell."

He's also using nanotubes and graphene to probe the sub-cellular organelles that comprise mitochondria. Known as "cellular power plants," mitochondria play an important role in the body's metabolism, informing stem cell biology and the progression

(continued, page 6)

Peter Burke: A radio small enough to fit into a human cell could serve as an interface to the brain, as a glaucoma or blood pressure monitor, or as a cancer detector. "I think you could make one that's a micron by a micron by a micron, which is the size of a human cell."

Opposite: Dr. Edward Nelson (far right) uses the Hiperwall to magnify his micropallet arrays; he discusses results with INRF's Jake Hes and Mo Kebaili.



Phil Collins: Nanotechnology holds the keys to unlocking biological systems. "We can't make sensors today that perform better than a [bomb-sniffing] dog. We'd like to figure out so we could build it into a device."

of cancer, diabetes and other diseases. "It's almost impossible to interrogate mitochondria," Burke says. But thanks to a National Cancer Institute grant, "we're going after it with guns blazing."

Physicist Collins also uses nanowires to probe proteins and enzymes, examining individual molecules. How does the protein receptor on a cancer cell act? What molecules is it binding to and when does the binding occur? The answers could yield transmitters implanted in the human body that send out information from cells or even nanorobots capable of identifying and destroying cancerous cells.

Science fiction? "Absolutely," Collins says. "But almost all great technologies came out of science fiction. Medicine will be different 15 years from now and much of the change will be driven by nanotechnology."

"Biology is the world's best nanotechnology."

Tumor immunologist and physician Dr. Edward Nelson would agree; he uses micropallet arrays designed by engineers G.P. Li and Mark Bachman to characterize cell populations in tumors. The device actually measures about 1 inch by ½ inch, but it contains 40,000-50,000 individual plastic blocks just large enough for single cells obtained from a biopsy to land on and stick to.

Each type of cell in the tumor expresses different types of molecules on its surface. By adding antibodies, each of which naturally attaches in different combinations to these expressed molecules, Nelson can identify what type of cells they are – endothelial progenitor cells, which make blood vessels; cancer stem cells, which are thought to be the origin of tumors; or subsets of the tumor cells themselves.

His team developed a methodology to connect each antibody to a specific colored nanocrystal, allowing easier identification of the tumor cells after the antibodies attach. “We’re hopeful that using this micropallet array and the nanocrystals across a broad spectrum will allow us to understand or predict the biology of a tumor before we start to treat it,” he says. “We think the cellular profile of a tumor before we do anything to it can give us insight as to what that tumor is most likely to respond to.”

Nelson is almost ready to test the device in a clinical study. He’s also in the formative stages of an effort to construct nano-instruments that can probe cells undergoing chemotherapy treatment. Rather than waiting six weeks to see if tumors respond to specific treatments – the current methodology – this instrument could monitor changes in the cells in real time. “If you don’t see what you want to see, you have the opportunity to change the treatment earlier, and you can limit side effects and toxicity to the patients,” he says.

Monitoring individual cells can also lead to improved healing techniques by replicating biological processes with pharmaceuticals. One day, we might even send into the body tiny nanoparticle-protected cages containing drugs that would only release their contents when they arrive at the right cellular “address.”

“The recurrent theme here is to make everything work better,” Nelson says. “If we’re smart about it we can reduce the toxicity and enhance the efficacy of drugs.”

“Medicine will be different 15 years from now and much of the change will be driven by nanotechnology.”

The human body contains billions of nanopores, tiny holes with diameters one-millionth of a human hair, in the fatty lipid membranes surrounding our cells. These nanometer-sized pores control the ions that pass into and out of each cell. The rhythm of a heartbeat is due to calcium channels, which only allow calcium ions and water to pass. Similarly, kidneys have aqua pores to keep out salt and pH, allowing only water to pass through. Zuzanna Siwy, associate professor of physics & astronomy, calls these “the best desalination units ever created,” – a thousand times more efficient than manmade units.

Human nanopores have various structures and functions. “They are very complicated and multifunctional. These little holes that nature developed allow a controlled and beautiful way of cuing the transfer of ions in and out of the cell,” Siwy says. She and her colleagues are attempting to replicate this unique behavior, using polymers and silicon nitride.

The work involves building tiny nanostructure pores, then chemically modifying them by putting certain groups of molecules on the pore walls. These “decorated” nanopores begin fulfilling certain functions, relying on the attraction and repulsion of positively and negatively charged particles. Negatively charged membranes allow only positively charged molecules to pass through and reject negatively charged species, and

(continued, page 8)

nanotubes

Their unusual properties make carbon nanotubes and graphene the materials of choice in nanotechnology research. Because of the way their carbon atoms are arranged, these materials have extraordinary thermal conductivity as well as unique mechanical and electrical properties.

Graphene, a sheet of graphite one atom thick, can be made in large quantities. It can be patterned, like silicon.

Nanotubes are rolled sheets of graphene that are most often chemically synthesized by other processes, including:

- Carbon arc discharge, which leaves a carbon soot of graphite electrodes;
- Laser ablation, in which a pulsed laser vaporizes graphite; and
- Chemical vapor deposition, in which carbon gas and other gases are added to a heated substrate.

Most of these processes take place in a vacuum or at atmospheric pressure.

The angle at which the sheet of graphite is rolled and the radius of the nanotube determine its properties.

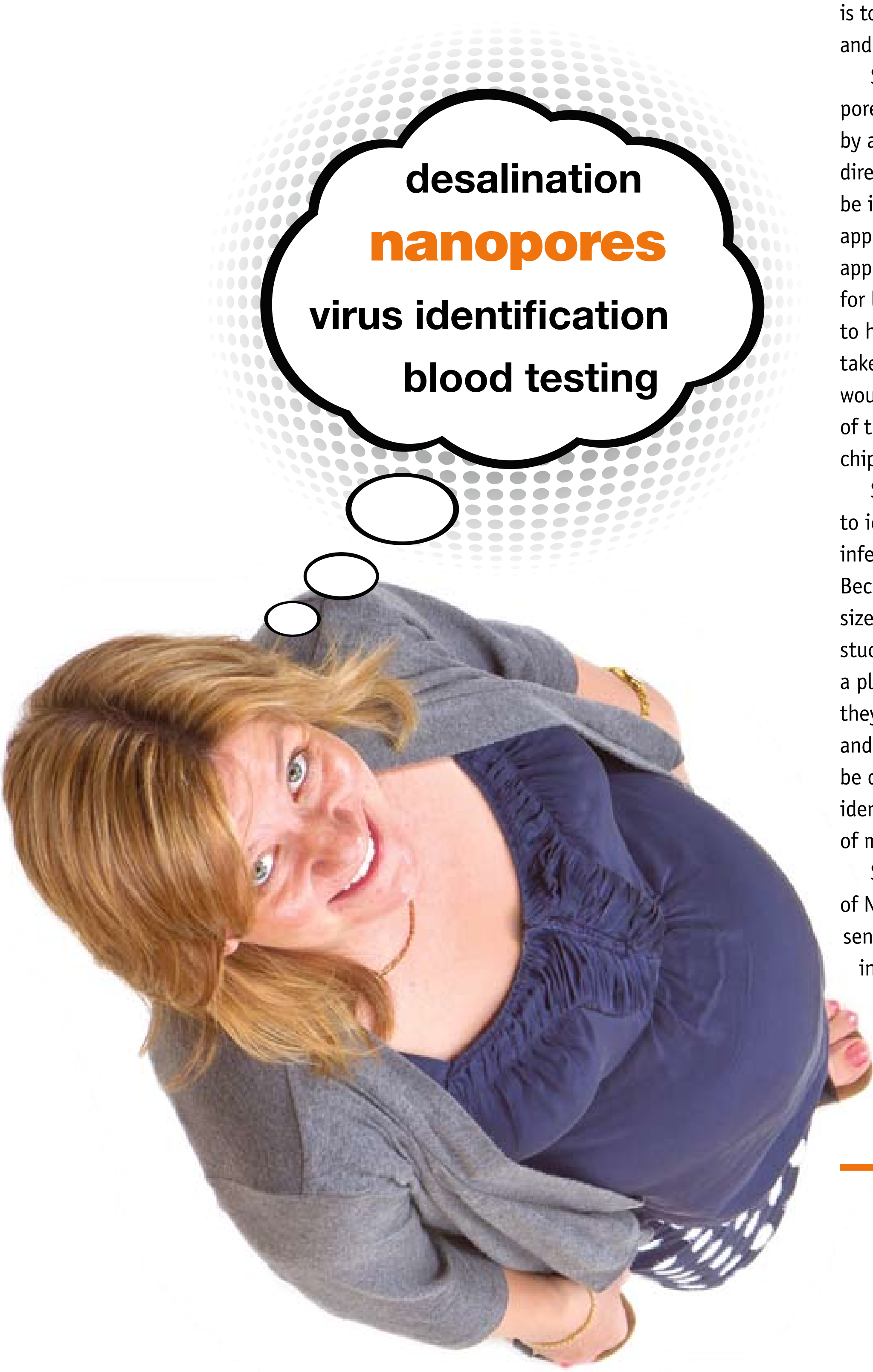
These diagrams depict carbon nanotubes that were rolled from a sheet of graphene, but at different angles. Thus, the carbon atoms are aligned differently and the nanotubes have different properties.

vice-versa. The ultimate goal, says Siwy, is to learn how to manipulate molecules and ions in a solution.

She also has created uni-directional pores, which mimic human nanopores by allowing the ions to pass in one direction only. The technology could be implemented in a lab-on-a-chip application for testing blood. "I'm appalled at the volume of blood required for lab tests," she says. "It would be nice to have a little chip, where they would take a little bit of your blood, and there would be ways to redirect different parts of the blood onto different parts of the chip for testing."

Siwy also can use the nanodevices to identify viruses, diseases and other infectious agents at an early stage. Because most viruses are comparable in size to the nanopore's opening, they get stuck temporarily, quickly developing a plaque that's easily detected. And they carry a charge – some negative and some positive – so their signal can be detected, allowing researchers to identify their size and shape in a matter of minutes.

Siwy and colleagues at the University of Nevada/Reno are developing a sensor that detects Anthrax bacteria in blood using a nanopore decorated with molecules that bind with the bacteria's shell. When the shell subsequently sheds into the blood sample, researchers can quickly detect it.



Zuzanna Siwy: Uni-directional nanopores can mimic those in humans and could be used in lab-on-a-chip applications. "I'm appalled at the volume of blood [currently] required for a lab test."

"These little holes that nature developed allow a controlled and beautiful way of cuing the transfer of ions in and out of the cell."

How do you build something you can't see? One way is with a tool called a nanoimprinter, which uses heat and pressure to mold polymers. A master mold is created when a computer-designed pattern is stamped onto a variety of substrates, including

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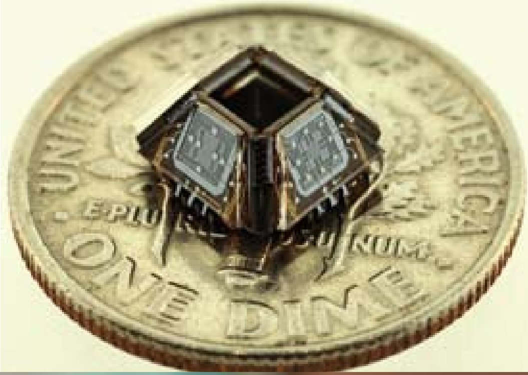
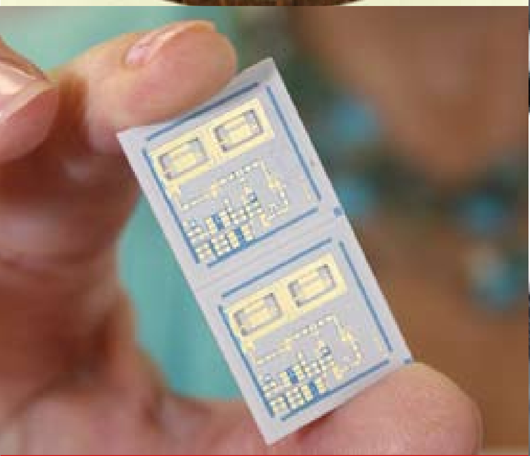
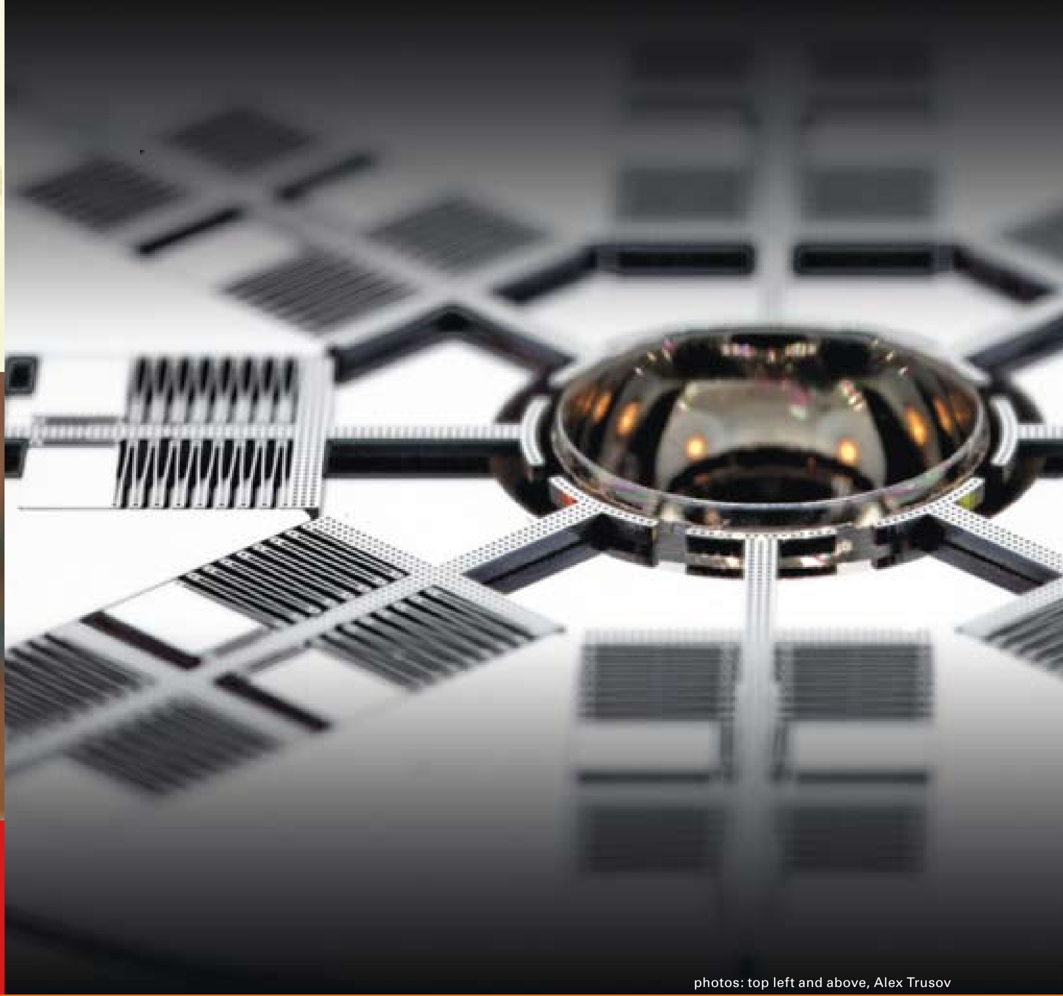






photos: top left and above, Alex Trusov

MINIATURIZED MACHINES

They are minuscule but mighty. They're MEMS: Micro-Electro-Mechanical Systems, and they're revolutionizing technology.

Already in commercial products, including automotive airbags, cell phones, inkjet printers and projector display systems, they are also quickly becoming crucial in military technology.

MEMS components are just 1-100 micrometers (also known as microns). Considering there are 25,400 microns in an inch, the largest components are smaller than four-thousands of an inch. The devices themselves usually range from 20 microns to a few millimeters.

UCI engineering professor Andrei Shkel is bringing the latest MEMS technology to the U.S. Department of Defense as manager for DARPA's Microtechnology for Positioning, Navigation and Timing (micro-PNT) Program.

Under his direction, researchers are developing self-contained chip-scale inertial navigation and precision guidance systems. These tools will reduce dependence on GPS and other external signals, which are easily jammed or intentionally misdirected. "GPS is a great technology but we're becoming too dependent on it. [Finding an alternative] is critical for military systems," Shkel says.

His team is using MEMS systems, including gyroscopes, atomic clocks and three-dimensional accelerometers, to develop devices the size of an apple seed, which can be imbedded into military technology.

"The current technology has no path to miniaturization because components are built and then basically glued together," Shkel explains. In contrast, his researchers are developing a complete inertia system in a parallel manufacturing process; all components are made, assembled on a substrate and folded into a two-millimeter-square device. Shkel expects to have a prototype by late 2013.

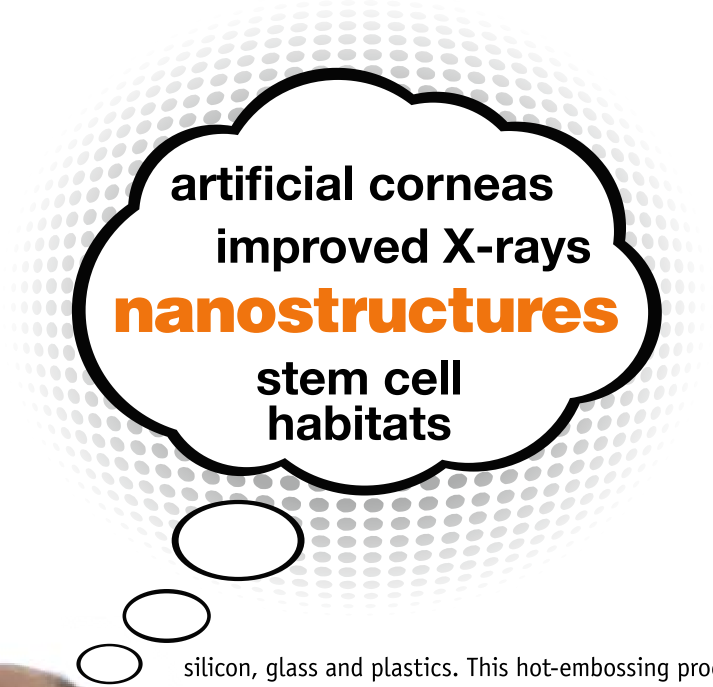
MEMS technology has advanced significantly in the last 40 years. In the late 1960s, an IBM engineer began experimenting with mechanical devices that could be miniaturized and fabricated just like the electrical devices in integrated circuits.

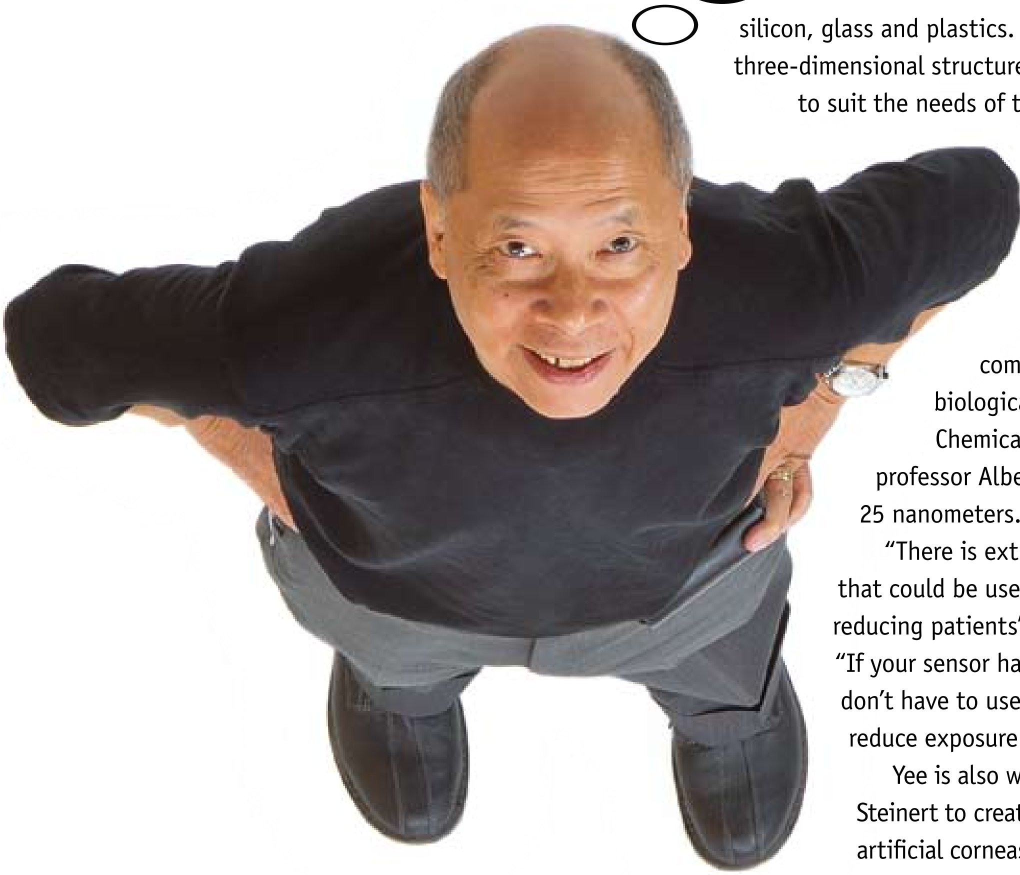
These early mechanisms were etched into silicon, a process known as bulk micromachining. They were successful as tiny machines but were difficult to integrate into other products.

In the mid-80s, however, scientists created surface micromachining, a technique that allowed them to deposit materials onto the silicon in layers. Now, they can laminate one layer on top of others, eliminating technical problems inherent in the earlier process and making it even easier to incorporate MEMS into a wide range of electronic applications.

Today, the tiny chips are made from non-conventional materials like plastics, ceramics, glass, poly-diamonds and other polymers.

"MEMS is benefiting from new material, new processes and new devices," says G.P. Li, director of UCI's Integrated Nanosystems Research Facility. "Our devices can perform better, have better flexibility and eventually, can be cheaper."





silicon, glass and plastics. This hot-embossing process can create three-dimensional structures on the substrate, which are refined to suit the needs of the researcher by subsequent addition or removal processes. Along the way, researchers assess their progress through an electron microscope.

These minuscule structures can be used for many purposes, including nanocircuits or other electronic components, and as tools to understand biological, chemical and mechanical processes. Chemical engineering and materials science professor Albert Yee has built nanostructures as small as 25 nanometers.

"There is extraordinary sensitivity in these materials," that could be used in a number of ways, he says, including reducing patients' exposure to radiation such as X-ray. "If your sensor has the highest degree of sensitivity, you don't have to use large amounts of X-ray. Not only will you reduce exposure but you'll get higher-resolution images."

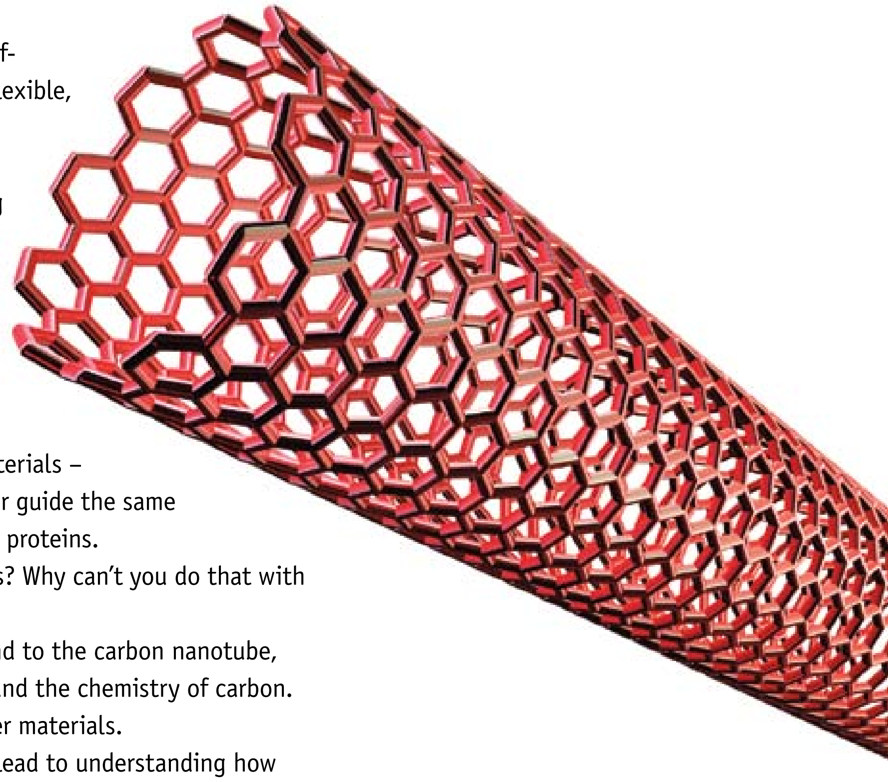
Yee is also working with UCI ophthalmologist Roger Steinert to create a nanotextured material for improving artificial corneas. Again, nature provides the template, known as the lotus effect. Lotus leaves repel water due to nanostructures on their surface, and Yee wants to replicate that in a surface that can also repel bacteria and proteins. "With nanotechnology you can engineer an artificial cornea to more resemble a human cornea and it can be more easily integrated into the eye," he says.

Albert Yee: Nanotextured materials, which could be engineered to repel water, bacteria and proteins, may lead to improved artificial corneas. "You can engineer [it] to more resemble a human cornea."

"Imagine . . . a nanomachine that can build a nanomachine."

Imagine electronic clothing or a flexible tablet computer as thin as a newspaper page. Peter Burke's lab is experimenting with printed circuits on flexible substrates, using ink made from nanotubes. The nanotubes are grown in bulk, then dissolved in a solution, where they are chemically purified, making them 99 percent semiconducting. When the solution dries, the result is a nanotube "mat" of surprisingly high-quality strands with good network properties.

These circuits can be printed onto a variety of materials – paper, plastic, even clothing – and could contain integrated solar cells for self-charging. "Instead of your iPad being solid, it could be flexible, with a full-color display and a solar cell. And it would be cheap to make … about $1," Burke says.



He has an additional dream for nanotechnology: using biological principles to synthesize artificial products, an emerging field called synthetic biology. Implausible as it may sound, these concepts could be used to construct large-scale items like buildings, planes and cars from nanosized materials.

It's a long shot, he admits, but eventually, nanotechnology researchers hope to synthesize other materials – even artificial ones – with atomic precision, using as their guide the same biological principles that direct the synthesis of DNA and proteins.

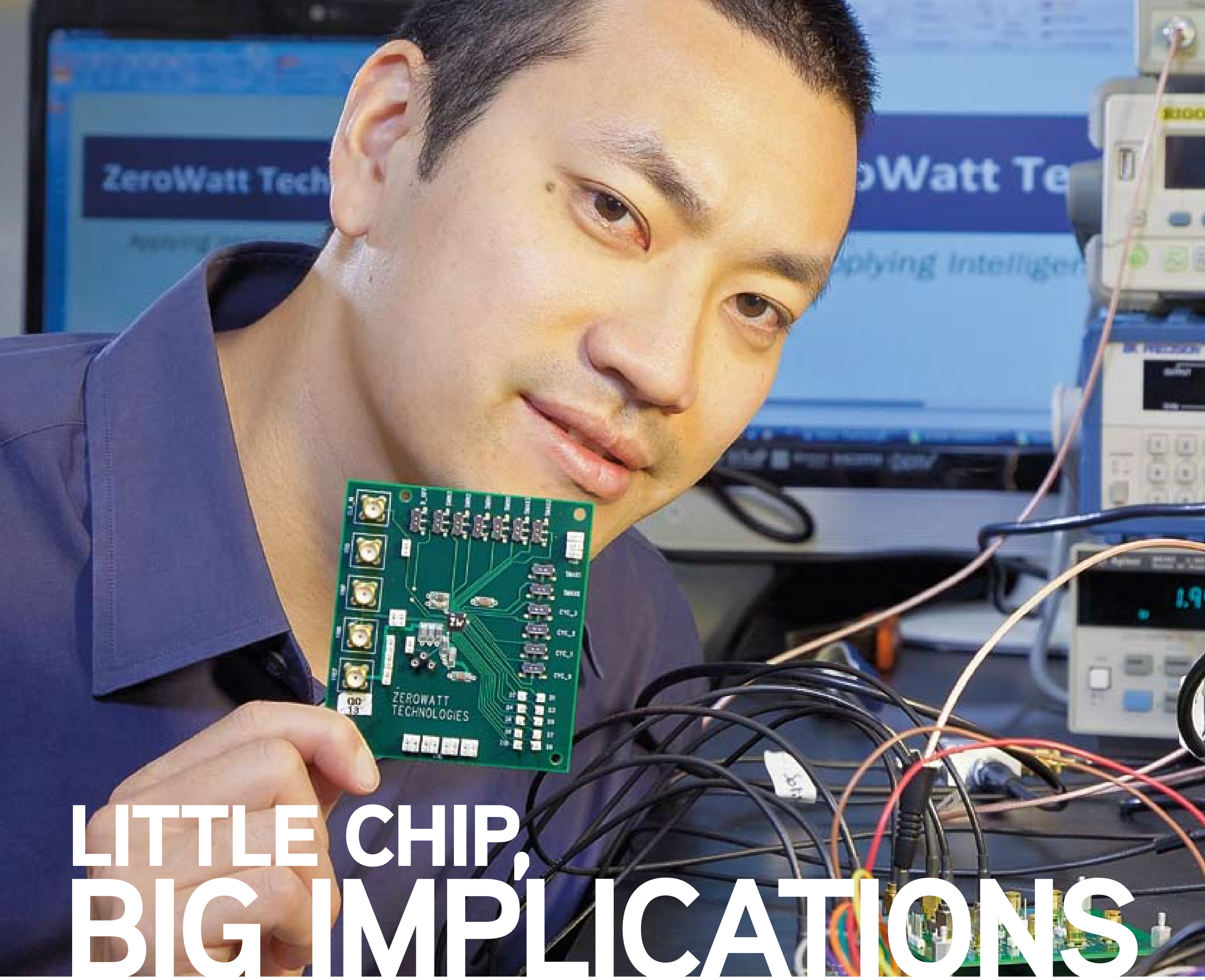
"Why does it have to be limited to DNA or amino acids? Why can't you do that with anything?"

Burke has begun by identifying which amino acids bind to the carbon nanotube, a good starting point because scientists already understand the chemistry of carbon. These advances could one day allow the synthesis of other materials.

"We've established the fundamental science that will lead to understanding how proteins and nanotubes interact at the molecular level," he says. His goal is designing a nanotube synthase that would get the ball rolling.

"Imagine … a nanomachine that can build a nanomachine," he muses.

It's a long, slow process, says Phil Collins. "Nanotechnology is still very much about inventing the tools to be able to do the science to uncover the rules so that you can someday build something useful. It's a continuous process that's moving along slowly. But there's promise these things are possible."



LITTLE CHIP, BIG IMPLICATIONS

Calit2 UC Irvine techportal PRIMER

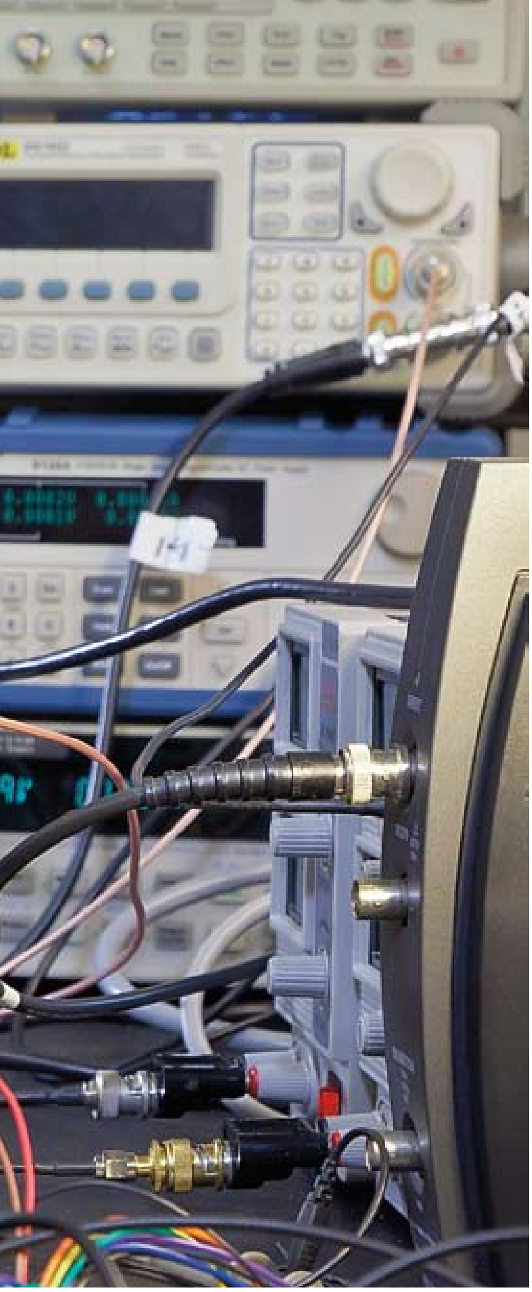
by Lori Brandt

You might say they "zeroed" in on a groundbreaking idea.

It was November 2008, and engineering doctoral student Fred Tzeng was brainstorming research projects with his advisor, Payam Heydari, UC Irvine professor of electrical engineering. After much discussion, they conceived of a concept – a way to more intelligently convert analog signals (sound, light, heat, motion) to the digital format required by modern electronics, using 10 times less power than the current conversion process.

If it worked, their low-power analog-to-digital converter (ADC) technology would extend battery life, enhance functionality and lower the cost of portable electronics. Potential applications ranged from automobiles, airplanes, industrial machinery, medical devices and sensors, to satellites, CD players, scanners and cell phones.

After a couple of failed attempts, Tzeng and Heydari eventually configured a simulation that showed promise. With the help of UCI's Office of Technology Alliances, they applied for the first of three patents, and the seed of their business was planted. ZeroWatt Technologies went on to win first place in the 2009 Business Plan Competition at the UCI Paul Merage School of Business.



Startup ZeroWatt offers a technology breakthrough with vast market potential.

The new company incorporated and applied for grants from NASA, the U.S. Navy and the National Science Foundation. It was the latter that gave them a Small Business Innovation Research (SBIR) grant of $150,000, which allowed Tzeng to quit his two part-time jobs and work full time on ZeroWatt. To take the fledgling company to the next level, they needed a place to set up shop, so they turned to Calit2's TechPortal, a technology/business incubator for startup companies based on, or using, UC-licensed technology.

"The TechPortal offered a good price, good support and excellent networking opportunities," including introductions to local business people, lawyers, investors and tech-business executives, says Tzeng, now ZeroWatt's chief technology officer (pictured).

ZeroWatt is TechPortal's third tenant. In February 2011, they moved into their 150-square-foot lab on Calit2's second floor, joining BiMaple Inc. and Shrink Nanotechnologies Inc. A fourth startup, Tear Diagno, is a more recent addition.

For now, ZeroWatt is pursuing prospective partners in the semiconductor manufacturing business, primarily micro-controller suppliers. But they are also prepared to meet with venture capitalists who might be interested in investing. The important thing is to continue making steady progress. They've applied for the second phase of the NSF SBIR grant to fund development while they raise capital from other sources.

Heydari, ZeroWatt's chief science advisor, is not new to the process of technology transfer; the Office of Technology Alliances has named him one of 10 outstanding innovators at the university. With five patents secured and five more pending, Heydari has built a number of novel integrated-circuit systems that have ended up in surveillance and medical applications.

But this is his first startup business. "The TechPortal has been a great place for us to get established and give demonstrations to potential partners," he says.

Today, three years after Tzeng and Heydari conceived the technology, ZeroWatt has two employees. Tzeng was joined earlier this year by Vipul Mehta, a former Western Digital executive and co-founder of Aristos Logic, a chip company that was sold to a larger Silicon Valley company. Mehta joined ZeroWatt as president and CEO.

Tzeng and Mehta have been demonstrating the company's third-generation prototype, which uses their patent-pending intelligent analog compression engine, or ACE. They've shown the chip to six potential strategic partners.

"There is a big market for our technology, so the challenge is where to start. We want to go where we can make the biggest difference," explains Tzeng.

Those markets include:

- Medical and healthcare (ultrasound and cardiac devices and hearing aids);
- Automotive (sensors, instrumentation, hybrid vehicles);
- Communications (broadband, local networks);
- Computers (audio, video, wireless);
- Consumer (mobile phones, audio and video players);
- Defense and military (sensors, satellites);
- Industrial (production machinery, measurement devices, sensors).

"We are exploring business models and staying open to possibilities," Tzeng says. "At the same time, we need to maintain momentum and eventually move out of startup mode."

Mehta is optimistic. "This is a compelling, game-changing technology that provides real benefits to a broad range of applications. It constitutes a powerful building block that partner companies can integrate into their own products and offers breakthrough solutions spanning multiple markets. Everyone we've shared the technology with has been very impressed."

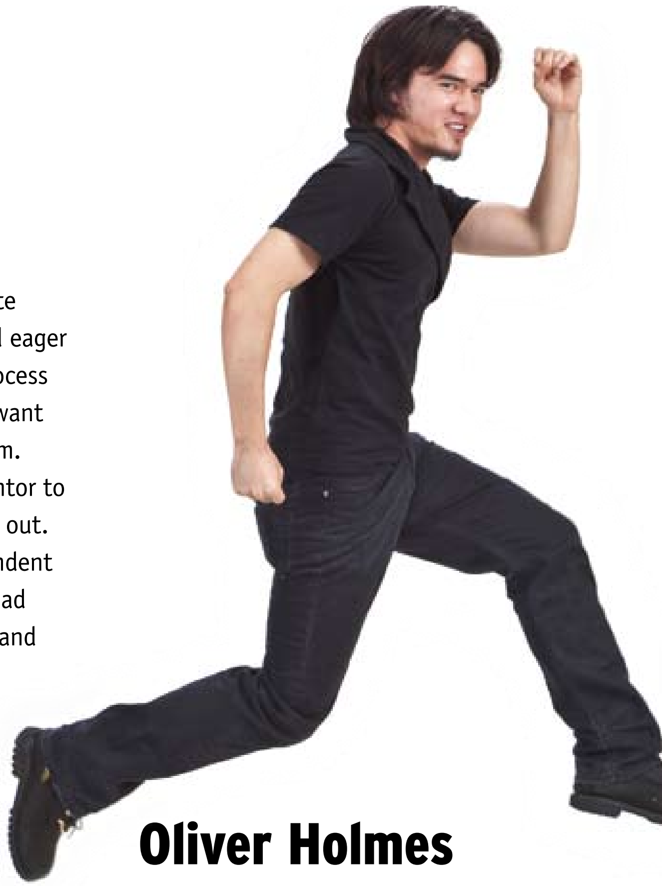
SURF-IT

Editor's Note: This summer marked the seventh year for Calit2's undergraduate research program. Eleven talented students share their experiences, recounting the challenges and rewards of conducting hands-on research and offering insights for incoming Fellows.

– compiled by Shellie Nazarenus

Huy Nghiem

After three years of undergraduate classes, I'd felt quite restless and eager to familiarize myself with the process of conducting research, which I want to continue in a graduate program. Initially, I was expecting my mentor to hand me my list of tasks to carry out. I did not expect to be as independent as I was through the summer. I had a lot more freedom in proposing and committing to what I wanted to accomplish. This proved to be both a blessing and a challenge. There has been a feeling of frustration in not knowing for certain if my decisions are correct. Transitioning from being dependent to taking initiative has been a challenging but rewarding process. It is a feeling of elation to look back at what I have accomplished. To actually see my working database products makes me feel proud and confident because it is proof of my maturity as a researcher. My advice to future SURF-IT Fellows is every time you face a problem, just remember: "This too shall pass."



Oliver Holmes

It's rewarding to know that I'm doing research on a part of popular culture and game studies that hasn't been done before. What we're looking at has only recently gotten big so it hasn't been fully looked into yet. We are studying how and why people make their own contributions to existing works, specifically video games, and what influences them. Linking concepts, like situated design and meta-gaming, to the creation of custom levels is building upon works in related fields and expanding the net of our knowledge on the subject. The goal is to write a 10-page paper for the Conference on Human-Computer Interaction. Because of the novel nature of my project, my research can be the foundation of future, perhaps more influential, research and development to come. My advice for prospective SURF-IT participants is to be ready for a lot of work. For me, there have been no flashes of inspiration, just steady incremental progress building upon prior research and dutiful collection of data.

Jeffrey Tse

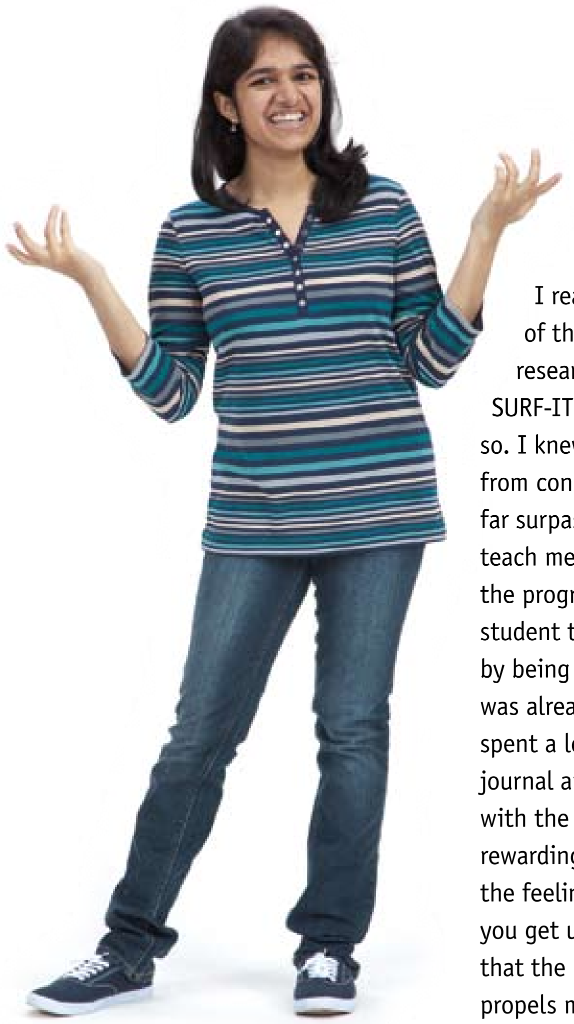
The program provided me with the opportunity to engage in a challenging new multidisciplinary research project while becoming involved in various discussions and seminars. Through these different experiences, I have improved my thinking and speaking capabilities. My project goal was to develop a smartphone application that integrates both medical sensors and a 3D avatar for facilitating healthcare applications and consultation between patient and doctors in remote regions. By the end of the summer, I met this goal by designing a simple yet functional version of this application. Because there is a considerable amount of research that can be conducted within this field, I am determined to continue telemedicine-oriented research under my mentor. In 10 years, I see myself pursuing a medical/technology career although I am still unsure what I will be doing. The best advice for next year's SURF-IT participants is to stay positive and think, work, and expect only the best. They should never be afraid to speak up and ask questions because everyone involved in the program is there to help you learn and grow as a person.

Luke Heidbrink

I expected the program to be more individualized, but the actual environment fostered interaction among the Fellows. It also proved to be an excellent program for experiencing some of the typical challenges and expectations of a research position. My "Eureka!" moments came whenever something finally ran correctly after days or weeks of errors. One example: I was tasked with finding a 3D game engine that would run on our Android tablets so we could demonstrate controlling a game with custom hardware built in the lab. After spending the whole day trying to understand very low-level computer programming, I was ready to give up and go home defeated. Having vowed that it was my last try, I pressed the run button and the game engine appeared, working perfectly. I went home ecstatic! When you start SURF-IT, you will probably feel like you have no idea what you are doing. In my experience, that's how everyone feels. Therefore, don't be afraid of not knowing how to do the tasks you are given. Experiment with new methods, be quick to learn and persevere when you hit roadblocks.

Kiruthika Paulvannan

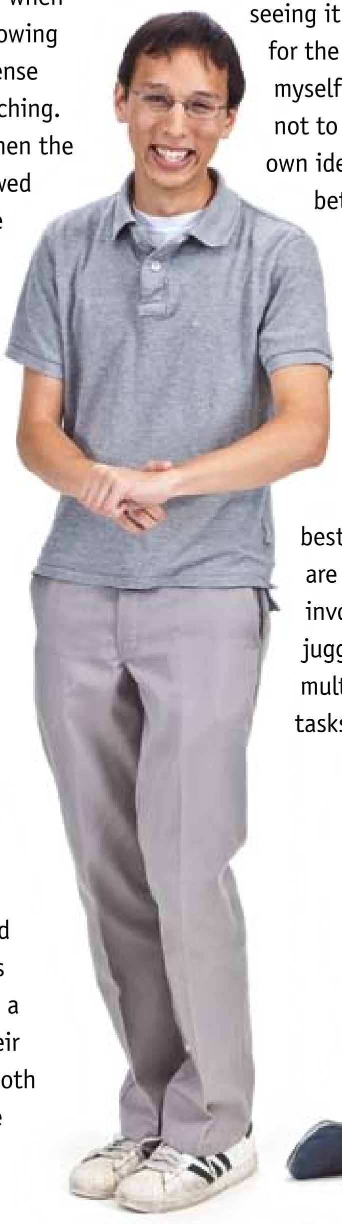
I've always been interested in ways to make learning both fun and effective. Initially, my task was to help create interactive media that would enable English language learners to better understand science concepts. A few bumps along the way prevented us from having the right tools to actually carry through the intended project. On the bright side, while transcribing focus group interviews I got a better understanding of the hardships of English language learners and teachers, as well as a better look at the Teaching Artist Project and the benefits it provided for the students. As a result, my goal has shifted more towards understanding how the arts, especially vocal music, can improve language acquisition. Based on my experience, the advice I would give new Fellows is to really think about what you want to do with your project. It's also very good to be flexible. If something unexpected gets thrown your way, take it in a positive light. I didn't get to work with innovative technology like some of my peers did, but at the end of the program, I was able to find something I am absolutely thrilled with the thought of working on. It takes a little bit of time and a little bit of thought, and you can turn any situation in your favor.



Sara Bangloria

The most difficult part of my research was dealing with the rapid rate at which information changes in the world of social media. Throughout my project, the companies I was researching continuously altered their social media strategies and Google Plus emerged as a player in social networking. As a result, I had to learn to cope with working in a very fluid environment. In previous research, I had merely scratched the surface of the topics I was studying. SURF-IT enabled me to fully immerse myself and learn many of the nitty-gritty details that I otherwise would have been unable to explore. We were able to evaluate the social media policies of a diverse set of companies and determine what elements are important to a company, depending on its business goals and strategies. I would advise future participants to carefully utilize all the time they have because it passes by in the blink of an eye. I wish summer was longer, just so I could have had more weeks to do research.

Andrew Karman



I really wanted to take advantage of the fact that I was attending a research institution and I thought SURF-IT would be a great way of doing so. I knew that the lessons learned from conducting actual research would far surpass anything a classroom could teach me. The most difficult aspect of the program was transitioning from student to researcher. I felt intimidated by being immersed into a project that was already years in development. I spent a lot of nights up late reading journal articles to familiarize myself with the research project. The most rewarding aspect of the program is the feeling of satisfaction when you get useful results. Knowing that the data is making sense propels me to keep researching. There was one incident when the timing protocol was followed incorrectly and an enzyme was left incubating for an extended period of time. We decided to continue and test anyway to see how it compared to previously collected data. Surprisingly, this led to better results and consequently the protocol was updated with the new incubation time. In the past weeks I've learned that success is built upon a collection of failures and that it is simply part of the learning process. New Fellows should be prepared to spend well over 40-plus hours if they want to gain a solid understanding of their research projects. Being both diligent and patient is the best advice I can give.

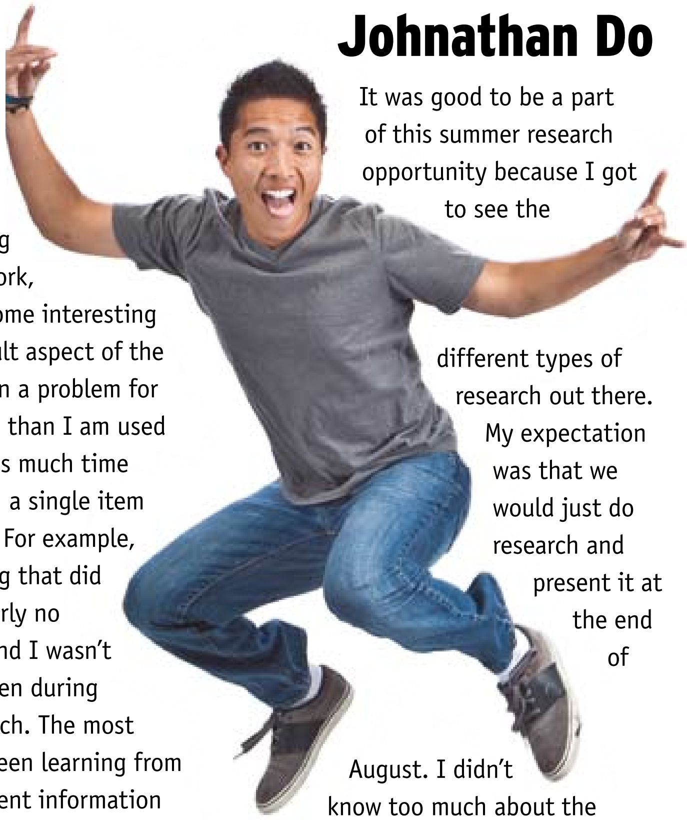
Rachel Ulgado

I chose to participate in SURF-IT because it was the perfect opportunity to really bring together what I have been learning from my anthropology and informatics disciplines; it was an opportunity that allowed me to do hands-on work outside of the classroom, working much more closely with faculty and graduate students, which I had never done before. The most rewarding part of the project was seeing the progress of the work I helped do, developing a prototype of our application that we could test and then seeing it used by teachers. My goals for the summer were to involve myself as much as possible and not to be afraid of suggesting my own ideas, as well as to develop a better understanding of the research process. I believe I surpassed those goals and I will continue to work with my mentors. I would advise incoming Fellows to stay open-minded – these projects require a lot of work, and it's best to realize early that they are likely to involve juggling multiple tasks.

David Ho

I was introduced to the program at a UROP info session during my second year at UCI. I wanted to do something more outside of classwork, and the program had some interesting topics. The most difficult aspect of the program was working on a problem for longer amounts of time than I am used to. I have not spent this much time in sequence working on a single item during the school year. For example, there was this one thing that did not want to work properly no matter what we tried and I wasn't expecting that to happen during the course of my research. The most rewarding aspect has been learning from my mentor how to present information in a structured and coherent way. In 10 years, I hope to be doing something useful in the field of wireless networks or telecommunications. For future SURF-IT participants, I would advise spending as much time as possible in the lab or in proximity of the research group members. Not being able to ask questions is usually the bottleneck of being stuck on a problem. The next tip is when you are accepted into the program make sure to know what tools you will be working with and get familiar with them quickly. The most important advice is to get along well with the people you work with.

Johnathan Do



It was good to be a part of this summer research opportunity because I got to see the different types of research out there. My expectation was that we would just do research and present it at the end of August. I didn't know too much about the Tuesday meetings, but those were amazing! I did not expect to really get to know the other SURF-IT students, and I am so glad that I have met them and plan to keep in touch for years to come. My goal for the summer was to help my professor as much as I could. I believe I did achieve that goal because he called me the other day and thanked me for my work. Now I just want to continue with the project; hopefully we will be able to learn more about the development of the brain. My advice to future program participants is that when doing research you will encounter times of distress and failure, but you will also encounter relief and success. Do not give up because it's worth it. Enjoy life, but don't waste time.

Kier Groulx

This was my first time doing any sort of quantitative, hands-on research, and it was quite fun to experience. I came in with a blank slate and an open mind, not knowing what to expect. My personal goal was to obtain some hands-on experience with research and to see what people were intent on discovering through research, all while furthering my own skills in computer science and interpersonal relations. It was especially challenging to deal with the various unexpected difficulties, such as hardware failures or bugs in the code which wouldn't come undone for days. There were definitely some questions brought up during my research – namely, "Why has no one thought to develop this before?" It was rewarding after working at length on a single problem to eventually solve it and see the application burst to life. My advice to students new to research can be summed up in one word: "Persevere!" The research may seem daunting at first, but if you keep applying yourself, you will eventually make great progress.

Drop by Drop

by Anna Lynn Spitzer

Microtechnology and nanotechnology differ in scale, but nowhere do they converge as seamlessly as in the ultra-small channels on a microfluidic chip.

Often referred to as a lab on a chip, microfluidics is the science of manipulating, mixing, metering and analyzing minute volumes – from microliters to picoliters – of fluid or gas on the surface of a chip. "It's like taking a lab bench with beakers and mixers and all the other equipment, and shrinking it down," says Gisela Lin, development manager at UCI's Micro/Nano Fluidics Fundamentals Focus Center (MF3).

Founded in 2006 and funded by $12.5 million from DARPA and 10 corporate partners, MF3 unites 20 researchers from 12 universities with the goal of advancing microfluidic research and developing potential applications.

"In the past, everyone was just developing their own technologies, and there was not a lot of cooperation or collaboration," Abe Lee, MF3 director, says. "Part of MF3's function is to connect industry with academia."

Today, the center works closely with local companies and with Lawrence Livermore National Laboratory and the NASA Ames Research Center.

"It's a new way of thinking for microfluidics," Lin says. "A lot of people understand it but they don't actually do it, whereas at MF3, we're actually trying to do it."

"A lot of people understand it but they don't actually do it, whereas at MF3, we're actually trying to do it."

Microfluidic chips are used to create biologic or chemical reactions at the micro- and nanoscale. But liquids and gases take on different properties at those scales. "At the microscale, water gets thicker and stickier," Lin explains, and at the nanoscale it's even more pronounced.

So creating the necessary reactions on a chip requires constructing devices that direct molecules towards each other in an efficient way. Pumps, valves and nozzles move the liquid or gas through

Mechanical and aerospace engineering professor Marc Madou is making microfluidic devices on compact discs – the same size and shape as music CDs and from the same polycarbonate plastic but with features carved in (pictured, left). As the CD spins, the liquid moves through the channels and its components separate into different areas. From a raw blood sample, DNA can be isolated, amplified and detected.

Madou also is investigating the use of the CDs for water quality control. It works the same way, he says, “only we’re detecting pathogens in wastewater instead of in the body.”

Below: Lisa Flanagan (left) discusses her microfluidic chip design with MF3’s Gisela Lin and Abe Lee. She uses microfluidics to evaluate the reaction of neural stem cells to an electric field, a technique called dielectrophoresis.

“If we didn’t have micro- and nanotechnologies, these chips would be the size of a desk.”

the chip’s channels, forcing molecules to mix and react with each other. Those reactions produce results that can be quantified by electrical signals, color changes, weight changes or other indicators.

MF3 is focused on medical diagnostics - creating inexpensive, disposable, automated chips for testing blood, water and other fluids. By building the microfluidics on low-cost materials like plastic, paper and printed circuit boards, these point-of-care diagnostics can be used easily in Third World countries or by the military. Additionally, chips created on printed circuit boards are ready to interface with cell phones or tablet computers, enabling field-based test results to be transmitted to doctors’ offices, military clinics or laboratories.

Lin foresees the strips being sterilized and packaged, similar to bandages, and readily available. Chips no larger than postage stamps might one day conduct multiple assays from a single drop of blood and could be manufactured for about one cent.

“If we didn’t have micro- and nanotechnologies, these chips would be the size of a desk,” she says.

Microfluidics also might unlock treatments for Alzheimer’s, Parkinson’s, multiple sclerosis and other neurodegenerative diseases.

Neurology assistant professor Lisa Flanagan is using microfluidic devices to try to determine the pathways used by neural stem cells as they become progenitor cells. These progenitors differentiate into three specific types: neurons, astrocytes and oligodendrocytes, each of which have precise functions in the brain and spinal cord.

In some illness or injury situations, the body needs astrocytes; in others, oligodendrocytes or neurons are the answer. Transplanting the differentiated cells themselves hasn’t worked; the mature cells end up dying. So scientists want to try transplanting progenitor cells and let them differentiate once they’re in the body.

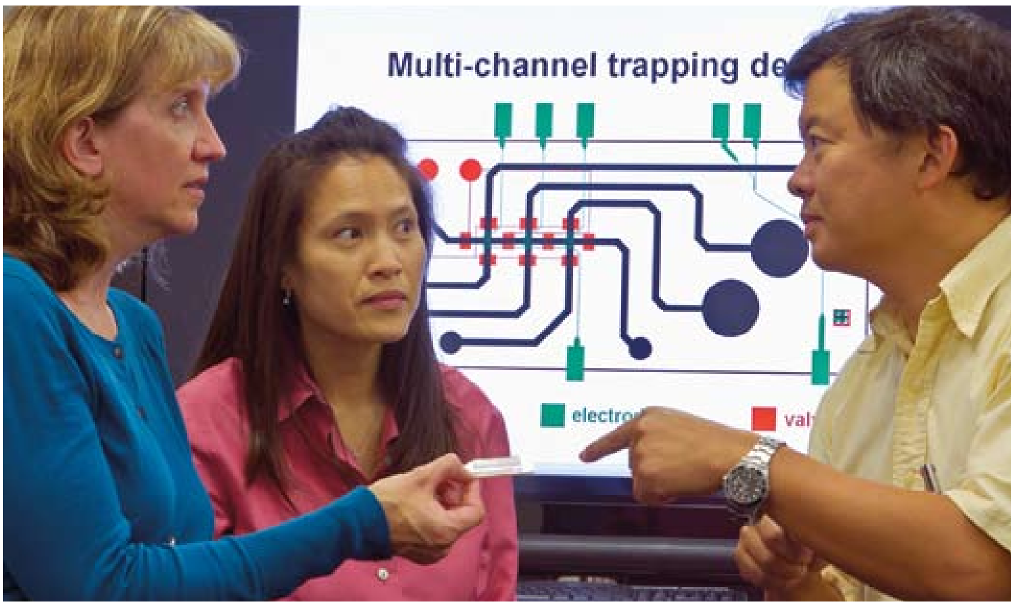
But they can’t tell how the undifferentiated neural stem cells become progenitor cells that will produce what they want. The problem, says Flanagan, is a lack of identifying information. “We’re really behind [other fields] in terms of having markers to pull out the cells we’re interested in studying to understand more about their biology,” she says.

After much trial and error, she and Abe Lee found a way to evaluate the reaction of neural stem cells to an electric field on a microfluidic chip and separate the cells accordingly – a technique called dielectrophoresis.

“Our ultimate goal is to isolate these cells and then use traditional biological techniques to determine the differences between the progenitor cells,” she says. “We can start to understand the cells’ lineage tree. … and get a better handle on what kinds of cells are the right ones to transplant for certain kinds of diseases and injuries.”

Abe Lee sees the technology’s progress in the marketplace. “All the major diagnostic companies either have micro-fabbed components or microfluidic channels in their products already or they’re building these as we speak,” he says.

And the future? “Microfluidics hasn’t changed the world yet, but it’s changing it drop by drop.”



Instrumental BREAKTHROUGH

by Anna Lynn Spitzer

Science is only as advanced as its instruments. Nanotechnology may be hundreds of years old but its progress would have stalled long ago without microscopes that allow scientists to image and manipulate materials they can't see.

Kumar Wickramasinghe developed the vibrating mode AFM when he was at IBM. He and his group also introduced silicon tips, which allow imaging without damaging the material; the AFM Jet for rapid molecule sorting and delivery; and other probes that measure heat, light and magnetism on a nanometer scale.

One of those tools is the atomic force microscope (AFM) invented in 1986, which gathered information by tracking the surface with a very sharp mechanical probe.

The vibrating mode AFM – today's instrument of choice for probing nanostructures – was introduced in 1987 by UCI electrical engineering and computer science professor H. Kumar Wickramasinghe, who at the time was managing nanoscience and technology research at IBM's T. J. Watson Research Center.

"All the structures that people were building in those days were within the resolution limits of an optical microscope," Wickramasinghe says. "But it was very clear to me that with time and miniaturization, everything would get smaller and smaller, and soon … we would need something different."

The Calit2 Microscopy Center features a 3D scanning electron microscope/focused ion beam (pictured), an atomic force microscope and a micro system analyzer, also known as a vibrometer. Three new tools are scheduled to arrive in the lab soon, courtesy of UCI's Office of Research.

"Major state-of-the-art instrumentation is an extremely important component of the infrastructure necessary to support modern science and engineering research," says John Hemminger, vice chancellor for research, adding that Calit2's emphasis on interdisciplinary research makes it the right home for the new equipment.

"Calit2 activities cut across all the major schools at UCI, and also involve the local high-tech community. It is the perfect organization to develop and manage this infrastructure."

As time has told, he couldn't have been more correct.

Today, Wickramasinghe studies living cell cultures, using the AFM Jet to extract messenger RNA, a process that could benefit cancer research, stem cell research and diagnostics. The device, which can pick up molecules, transport them and deposit them elsewhere, allows him to penetrate the cell membrane, "just like a little needle," and pull RNA onto the probe.

"I want to see what's happening in that cell, what chemical changes are going on," he says. "The more we can learn about the chemistry of what is going on at the single cell level, the more tools we have to try to combat disease and infection."

He's also developing tools that can measure the vibrations of single molecules and capture those images. This will allow him to characterize the behavior of molecules – in essence, image their specific "fingerprints" – and see them in action, "like watching a movie."

That's a new capability, which if successful could provide a tutorial on catalysis and other biological processes.

"That would be big," he says. "We could understand how to make energy from sunlight; leaves do it all the time."

"It was very clear to me that with time and miniaturization, everything would get smaller and smaller, and soon . . . we would need something different."

Microscopes are just one instrument in the miniaturized-technology toolbox.

Equally important is the sophisticated equipment contained in Calit2's Bio-Organic Nanofabrication (BiON) facility and Integrated Nanosystems Research Facility (INRF). Both contain Class 10-1000 clean room areas and are open to the campus and the larger community on a recharge basis. A few dozen UCI faculty members use the facilities regularly, as do about 30 companies.

INRF caters to MEMS, micromachining and the semiconductor industry; BiON equipment is reserved for biomedical devices and other biological applications.

Mo Kebaili is one of three process engineers who provide fabrication services in the facilities and advise companies how best to approach their projects. "Based on our users' applications, we have the ability to do whatever processes they need," he says.

The fabrication process for MEMS devices starts with a pattern created by a computer-assisted design program. This pattern is transferred via photolithography onto a plate, creating a mask. After a photo-resist material is applied to a substrate – glass, silicon or polymer – the pattern is transferred onto the substrate.

What happens next depends on the final application of the device; material either is added to the substrate or it is removed, creating a mold.

"There are a lot of different ways to put down or remove materials from your substrate," says Jake Hes, who manages the facilities. Material deposition methods include sputtering, e-beam evaporation, thermal evaporation and electroplating.

Wet-etch processes use acids or alkaline solutions to remove materials, and laser ablation is also used to carve material away from the mold. Each process is done on a dedicated machine determined by the material of choice and the device's final application. "The end result might be the same, but based on the application, one machine might be more suitable than another," Hes says.

After the mold is fabricated, it is used as a master to emboss the final pattern onto a polymer material, using heat and pressure. Microfluidic chips are usually made from PMMA, PDMS, polystyrene or other acrylic-based polymers. They can also be made from printed circuit boards, or in some cases, paper.

MEMS devices, which were once exclusively silicon, are now built with metals, polymers and glass-fiber printed circuit boards – materials that are cheaper than silicon and offer improved functionality.

Kebaili compares the labs in INRF and BiON to a kitchen: "There are different appliances and tools. Based on what you're trying to cook, you need to use different pieces of equipment."

"Depending on what the requirements are, we can advise users on the best way to accomplish their objectives," adds Hes. "We can help put all the pieces of the puzzle together."

by Stuart Ross

Scaling Up

Nano, micro, macro: Calit2 offers support to projects of all sizes

Peter Burke (Electrical Engineering and Computer Science) recently earned an award that will establish Calit2 as a leader in nano-spectroscopy. A **Defense University Research Instrumentation Program** grant for **$144,000** will enable his team to develop a new kind of atomic force microscope (AFM) that combines two relatively new extensions of AFM technology. The first is AFM microwave microscopy, which provides measurements of materials' electromagnetic properties with nanoscale resolution, and the second is an AFM that can trace the topography of biological molecules in liquid, rendering a more realistic visualization of their behavior. Combining these two approaches will yield greater resolution and more realistic answers.

Mark Bachman (Electrical Engineering and Computer Science) leads a contract team that earned a **$137,000** award from **Samsung Telecommunications America** to further improve the design of a micro-level switched capacitor they developed last year. Switched capacitors are important because they control the frequency response of telecommunications equipment. Micro-electro-mechanical (MEMS) devices are advantageous in size and performance, but are usually restricted to low-power environments because close spaces and fragile materials cannot function properly under high voltages or currents. The team's previously developed MEMS switched capacitor, also supported by Samsung, could operate at power levels up to 40W, four times the previous state-of-the-art. Their device had good performance in other respects and required only low power for switching. The follow-on contract will improve the design for manufacturing and marketing.

Calit2's newest research center, the **California Plug Load Research Center**, was awarded **$1 million** by the **California Energy Commission** to study ways to increase energy efficiency in electronic devices and appliances. The initial focus is set-top boxes, which consume more energy than most other home appliances. The award also provides for future research projects and outreach efforts that promote energy efficiency.

The **National Science Foundation** has awarded **$373,000** to a UCI team led by **Sharad Mehrotra** (Computer Science) to support continued research in the theory and practice of building sensor-based systems. The "I-Sensorium" comprises equipment and software for sensing, computation and information storage. I-Sensorium consists of three major components: a shared experimental laboratory in Bren Hall, a live testbed instrumenting three UCI buildings (including the Calit2 Building), and a state-of-the-art storage and computational infrastructure that can support continuous streams of data from diverse sensors. The software will provide a high-level programming environment, allowing many researchers to participate, and facilitating interactions with industry-sponsored projects and educational outreach efforts.

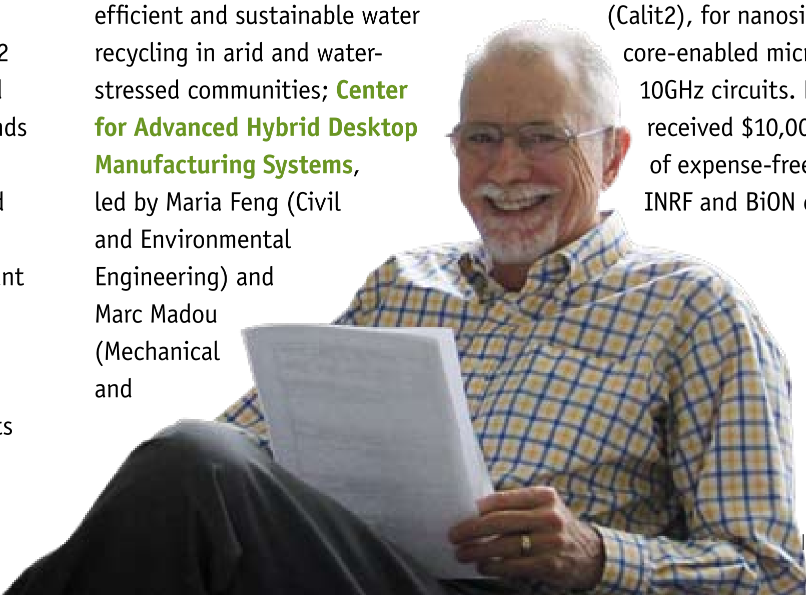
The MEDLINE database maintained by the **National Library of Medicine** has more than 18 million publication entries and is used for 2 million-plus searches daily. So faster, more fruitful and intuitive searches would benefit many. The Library awarded Calit2 affiliate **Chen Li** (Computer Science) **$366,000** to investigate new techniques for improving the search methods. His team will: improve techniques for search-as-you-type data exploration, displaying search results as the user types keywords; improve techniques for accommodating typographical errors or misspellings; and enable automatic incorporation of synonymous terms. The team has already developed a pilot version of the system and the Library of Medicine now wants to see the system developed more fully.

Liane Brouillette (Education) won a **$1 million** award from the **California Postsecondary Education Commission** that extends the "Teaching Artist Project" administered by Calit2 in 2007. That project covered grades K-2 in a portion of the San Diego Unified School District, and this award extends the research to grades 3-5. The key insight is that exercises in dance and drama can help students learn basic physical and social concepts important for learning academic subjects later; the research is conducted to verify and specify the effects, thought to be particularly important for students who are not native English speakers.

The grant is specifically for teacher professional development; specialized teaching artists assist and train the regular classroom teachers, and Web-based videos provide lesson samples that teachers statewide can watch for their own training. Each teacher participates for three years.

Calit2 was instrumental in seed funding multidisciplinary campus research projects. The second annual **Large-Scale Interdisciplinary Research Ignition Initiative** yielded four winners this year, each awarded $36,000. Sponsored by Calit2, and the UC Irvine engineering and computer sciences schools, the grants stimulate development of comprehensive, externally funded research. This year's winners include: **The Science and Technology Center for Integrated Microfluidic Systems for Biochemical Sensing**, led by Abe Lee (Biomedical Engineering), which is developing low-cost bio-sensing and analysis platforms; **Environmental, Engineering and Human Dimensions of Low-Energy Treatment Technologies for Recycling of Runoff in Southern California and Melbourne, Australia**, an international effort led by 11 UCI professors to investigate energy-efficient and sustainable water recycling in arid and water-stressed communities; **Center for Advanced Hybrid Desktop Manufacturing Systems**, led by Maria Feng (Civil and Environmental Engineering) and Marc Madou (Mechanical and Aerospace Engineering), whose goal is to bring advanced manufacturing practices and education back to the U.S.; and **BREATHE – Better Resource Environment for AsThma HEalth**, led by Yunan Chen and Alfred Kobsa (Informatics), Jill Berg and Jung-Ah Lee (Nursing) and research scientist Walt Scacchi, which aims to develop a game-based eHealth environment prototype for asthma self-management.

Calit2 partnered with UCI's Integrated Nanosystems Research Facility to fund five projects last summer through another seeding competition focused on clean room research. Those winners included: **Peter Burke**, who is growing graphene for fabricating nanodevices; **Mark Bachman** and **John Longhurst** (Medicine), for microelectrode arrays for minimally invasive acupuncture; **Elliot Hui** and **Steven George** (Biomedical Engineering), for tumor micro-environments in colon cancer; **Lizhi Sun** (Civil and Environmental Engineering) and **Lorenzo Valdevit** (Mechanical and Aerospace Engineering), who are developing dielectric nanocomposites for flexible bioelectronics systems; and **Chen Tsai** (Electrical Engineering and Computer Science) and **Arthur Zhang** (Calit2), for nanosized magnetic core-enabled micro inductors for 10GHz circuits. Each project received $10,000 and 40 hours of expense-free access to the INRF and BiON clean rooms.



No matter the size or scope, Stu Ross is happy to be of service.

[Bits and Bytes]

by Shellie Nazarenus

Taking IT to the Max

It was a definitive performance for a group of telematic artists who have been collaborating for several years. Last May, they were able to impress not one – but two audiences – courtesy of an ultra-high-speed bandwidth connection between the Calit2 buildings at UCI and UCSD. The jazz improvisation, TeleMotions, featured trombonist Michael Dessen, in Irvine, in concert with Mark Dresser on bass and pianist Myra Melford. The bandwidth, coupled with crystal-clear, high-fidelity sound enabled Dessen's image to be projected onto a large screen between Melford and Dresser in San Diego, while their representations were beamed into the Irvine venue. "It went really well," Dessen said. "The delay was far less than ever before and the quality was incredibly sharp. That was a huge advance for us since video latency and quality has always been one of our big technical challenges." Active Space media performance technology developed by UCI's intermedia artist John Crawford provided a real-time improvised response to the music in visual form, treating both audiences simultaneously to stunning projected video interpretations.

Incubating Energy Efficiency

Those wanting to know more about how to do business with utilities participated in a statewide symposium at Calit2 in May. The Technology Resource Incubator Outreach (TRIO) program is a collaborative effort by California Investor Owned Utilities (IOUs) designed to nurture new technologies from universities, entrepreneurs and investor firms through outreach activities. The symposium helped participants gain the necessary perspective and tools to work with the IOUs, which include Southern California Edison, San Diego Gas and Electric, Southern California Gas Company and Pacific Gas & Electric. The day-long event consisted of a mix of presentations, panel discussions and networking sessions. The session opened with Calit2 Irvine Director G.P. Li explaining the institute's energy research and technology transfer efforts.

Learning from Experience

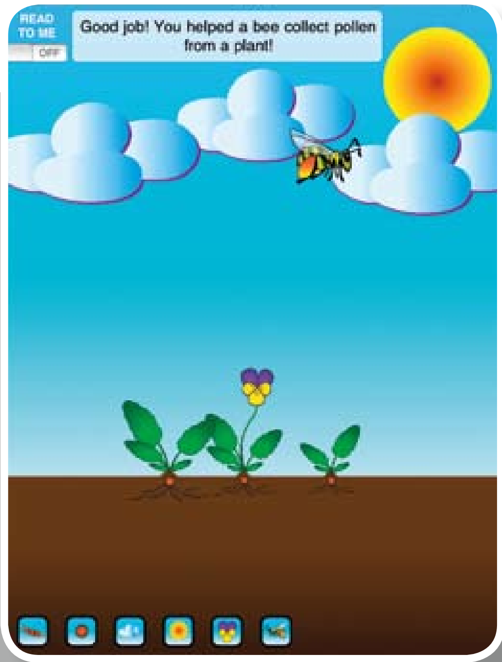
Call it a reunion of sorts. Six former undergraduate research Fellows returned to Calit2 in July, offering advice and inspiration to the newest batch of SURF-IT participants (see pg. 14). While the alumni have moved on to careers in industry, entrepreneurial endeavors or graduate school, all credit their summer research experience as instrumental in shaping their future. Andrew Zaldivar ('08), now a third-year doctoral student in cognitive neuroscience, had just transferred to UCI when he was chosen to participate in the program. "I wasn't sure if I wanted to do research but SURF-IT provided me the opportunity to test myself and it worked out big time. I'm now doing research full-time, not just in my lab but I'm also collaborating with other labs and it all started here." In a casual roundtable setting, the group offered personal insights and sage instruction for getting the most out of the summer program. Among the advantages discussed: improved presentation skills, an ability to better understand research across disciplines and the abundance of networking opportunities, which was particularly important to Jeremy Roth ('06). Roth received seven job offers upon graduation, three of which he credited to relationships he made as a SURF-IT Fellow.

Phase 2 of New Student Program Set to Launch

Calit2's newest research program for undergraduate students concluded with group presentations at the end of spring quarter. The Multidisciplinary Design Program (MDP) teams students from a variety of disciplines working on a range of projects under the guidance of at least two faculty mentors from different departments. In collaboration with UCI's Undergraduate Research Opportunities Program, MDP launched last March with 83 UCI undergrads selected for 17 projects. The second year of the program will commence in January, giving teams two consecutive quarters to incorporate their multidisciplinary knowledge and skills in developing a solid project design.

Ten Years Under Review

As Calit2 leadership and staff prepared for the two-campus institute's 10-year review, the administration sought input from its advisory board during the annual summer meeting hosted this year by the Irvine division. The advisory board consists of national policy leaders, technology industry senior executives and influential researchers from major universities. The June meeting focused on the 10-year report, which is based on a specific set of metrics set forth by the UC Office of the President. Because it was to be followed in October by a site visit of third-party reviewers, the advisory board previewed some of the research demonstrations planned for the site visit team. Board members, including Google's Vint Cerf (pictured), tried out the prototypes and quizzed the graduate researchers to prepare them for the reviewers' potential questions. The feedback enabled the research teams to fine-tune their presentations.



A Nurturing Application

Inspired by their toddler's curiosity, two Calit2-affiliated professors combined their disciplinary strengths to create an engaging, interactive experience for children. Bill Tomlinson and Rebecca Black developed Seed Cycle, a colorful and easy-to-understand iPad app for very young wannabe gardeners. "Rebecca's expertise in education and my background in designing and programming interactive graphics made it seem like we might be a good team," Tomlinson quipped. By following the prompts, children can create their own gardens while learning about plant growth and pollination. The young users are incentivized by earning badges for various tasks; in the process, they discover new concepts and improve vocabulary skills. "We went through several iterations, trying to integrate feedback from our young beta-testers and their parents with accurate and fun science content," added Black. While the couple do not plan to expand the project to other platforms, they have branded their endeavor as Seed Pod Productions and plan to further a theme-based line of life-cycle apps for beginning learners.

Fostering External Collaborations

Visits to Calit2 from two Orange County business leaders are paving the way for future collaborations among researchers, industry and community partners. Retired Rockwell International CEO Donald Beall was followed a week later in May by Michael Mussallem, CEO of Edwards Lifesciences. Both men have ties to Calit2, and both are instrumental in providing guidance and support to the institute's efforts. Beall served an eight-year term on the institute's advisory board; in 2009, Edwards Lifesciences joined the board. Calit2 Director G.P. Li invited Beall and Mussallem to see firsthand the eHealth Collaboratory, the institute's newest endeavor, hoping the visits lead to more productive teaming opportunities that will foster research development and deployment, and lead to product commercialization.

"As we develop new programs in Calit2, I am appreciative for the advice and expertise these prominent individuals can offer to help us foster stronger partnerships with industry and community organizations," said Li. "They are great mentors to me."

A Fitting Occasion

A group of academically talented high school students spent a day in the Calit2 eHealth Collaboratory testing prototypes and collecting data. The students were part of UCI's annual COSMOS program for mathematics and science. The summer experience includes on-site teaching labs, making Calit2 a natural host for the program's various clusters. In this case, Professor Dave Reinkensmeyer, a collaboratory participant, was asked to host the clinical translation science group. Several UCI graduate and undergraduate students helped the COSMOS students conduct simulated clinical studies by experimenting with rehabilitative prototypes such as the Music Glove (pictured). Finger sensors built into the glove generate musical notes, encouraging the "patient" to exercise the limb by creating music. Data is captured from the computer-generated simulation, enabling healthcare providers to track the user's dexterity over time.

Paging High-Touch Healthcare

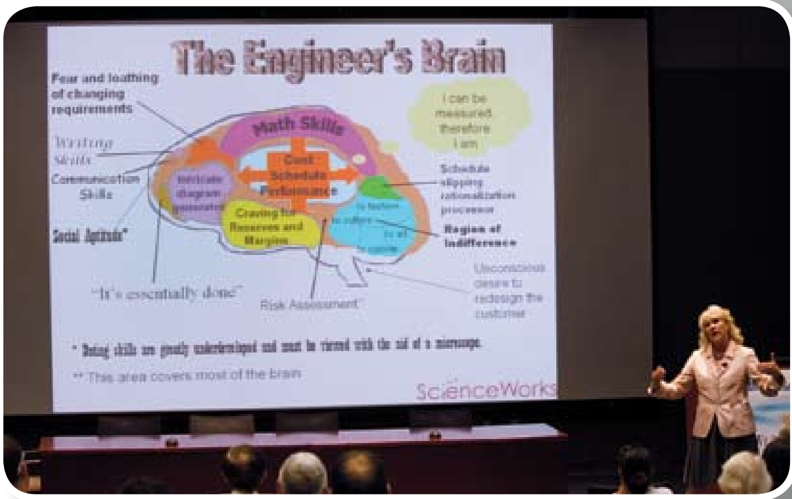
The digital transformation of healthcare took center stage at Calit2's semiannual Igniting Technology event sponsored and moderated by IP law firm Knobbe Martens. The June program showcased the newly opened eHealth Collaboratory on the institute's third floor. True to its name, the evening's presenters included eHealth collaborators from four different schools – engineering, arts, medicine and business – as well as the head of a non-profit organization devoted to advancing wireless healthcare and access. Rob McCray (pictured), CEO of Wireless Life Sciences Alliance, explained to the audience that healthcare purchasers "don't want devices or parts of solutions, they want a problem solved." The collaboratory is a prototyping and demonstration space, where technologists team with healthcare providers, patients and their families to develop working solutions based on existing needs. All facets of eHealth including telemedicine, mobile operating systems and wireless devices are in the scope of work, with user empowerment the ultimate goal.

Open Dialogue Opens Doors

As baby boomers age and the need for healthcare grows, the nation's nursing shortage is expected to intensify. One possible remedy for treating the shortfall and extending the reach of nursing may be found via eHealth technologies and telemedicine. Calit2 hosted a group of UCI nursing science faculty last spring to introduce them to the institute's latest efforts in healthcare applications. eHealth Collaboratory researchers presented their work and demonstrated prototypes. Given the trend toward early hospital discharge, the group discussed how home health monitoring and communication tools can extend the reach of care. Finding user-friendly solutions is a priority, especially those that are affordable and adaptable. The meeting has led to further conversations and project-specific collaborations.

High-Stakes Research Advice

The message resonated with an attentive audience in the Calit2 auditorium this summer: Kathie Olsen, former chief operating officer for the National Science Foundation, said, "When it comes to research, today's big unanswered questions are complex and multi-scale, requiring an interdisciplinary, collaborative approach." Invited by UCI's Office of Research, Olsen was joined by Robin Staffin, director of basic science in the Department of Defense. In her talk, Olsen shared the lessons learned during her 20-plus years of scientific leadership in federal research funding agencies. She stressed the importance of understanding the different cultures and review processes of various agencies. Olsen, who earned her doctorate in neuroscience from UCI, recently launched ScienceWorks, a consulting business that helps people and organizations succeed in science and engineering research. For his part, Staffin shared his philosophy about basic research funding, which is to choose projects that will have long-range, integrated implications. Staffin encourages his proposal reviewers in the defense department to take a chance and go for a bold idea. "A crazy but plausible idea needs to have a home," he offered.



Strengthening Global Connections

International visits tend to be a summer mainstay at Calit2. While this year was no exception, the overriding theme was familiarity. A few highlights include:

A group from Germany's Generation Research Institute (GRP) spent a week in September learning more about the collective medical and technology research efforts at UCI. GRP conducts interdisciplinary research in aging and technology use, brain research and product usability, and assistive systems and environments. In the fall of 2010, GRP invited a contingent of Calit2 eHealth researchers led by Director G.P. Li to visit their Munich-based headquarters (pictured). The groups exchanged information about their respective activities and discovered a large number of mutual interests. A year later, they reconnected, this time at Calit2. Their visit included participation in a day-long "Workshop on Technology for Living and Caring," which explored health and wellbeing themes from traditional and non-traditional perspectives.

At the request of the Taipei Economic and Cultural Office in Los Angeles, Calit2 hosted vice chancellors for research from Taiwan's top 10 universities. The group came to Irvine in June to learn more about the campus's Centers of Excellence – how they were established, their funding sources, research activities and collaborations. Several Calit2-affiliated researchers presented their work, which caught the attention of National Taiwan University's (NTU) Ji-Wang Chen, who returned to Calit2 in August with NTU President Si-Chen Lee and five college deans to further discuss the opportunity for institute-to-institute collaborations. The delegation expressed interest in solar technology, stem cell research and eHealth Collaboratory activities (pictured). Forging international alliances with universities that have similar research-center strengths is a growing part of NTU's strategic plan.

In a similar fashion, Kanto Gakuin University professor Hideo Honma brought a group of Japanese colleagues to Calit2 in late September to exchange expertise. Considered a pioneer in advanced electroplating technology, Honma became aware of the micro-electronic device work at UCI after hearing a presentation by professors G.P. Li and Mark Bachman at an international conference earlier this year. The research groups recognized they had complementary knowledge and skills. Their three-day stop at Irvine included a full day of touring Calit2, exchanging ideas and sharing prototypes (pictured); the rest of their time was filled with stops to four area companies that partner with the Calit2 researchers.

In July, Calit2 hosted a contingent of senior academic leaders from Al-Kharj University, a Saudi Arabian campus that was originally a college of engineering under the neighboring and well-established King Saud University. Now that it is an independent university, Al-Kharj is looking to develop stronger ties with UCI, including student programs, curriculum development and faculty collaborations. Towards that end, a memorandum of understanding was inked with the hope of providing a UCI summer training experience next year for a select group of Al-Kharj students. During their visit, the delegation toured state-of-the-art facilities, such as Calit2's Microscopy Center (pictured), available to further the skills of young researchers.

Calit2@UCI is a multidisciplinary research institute that develops information technology-based innovations. By integrating academic research with industry experience, the institute seeks to benefit society, incubate new technology companies and ignite economic development. Calit2 focuses on the digital transformation of healthcare, energy, the environment and culture.

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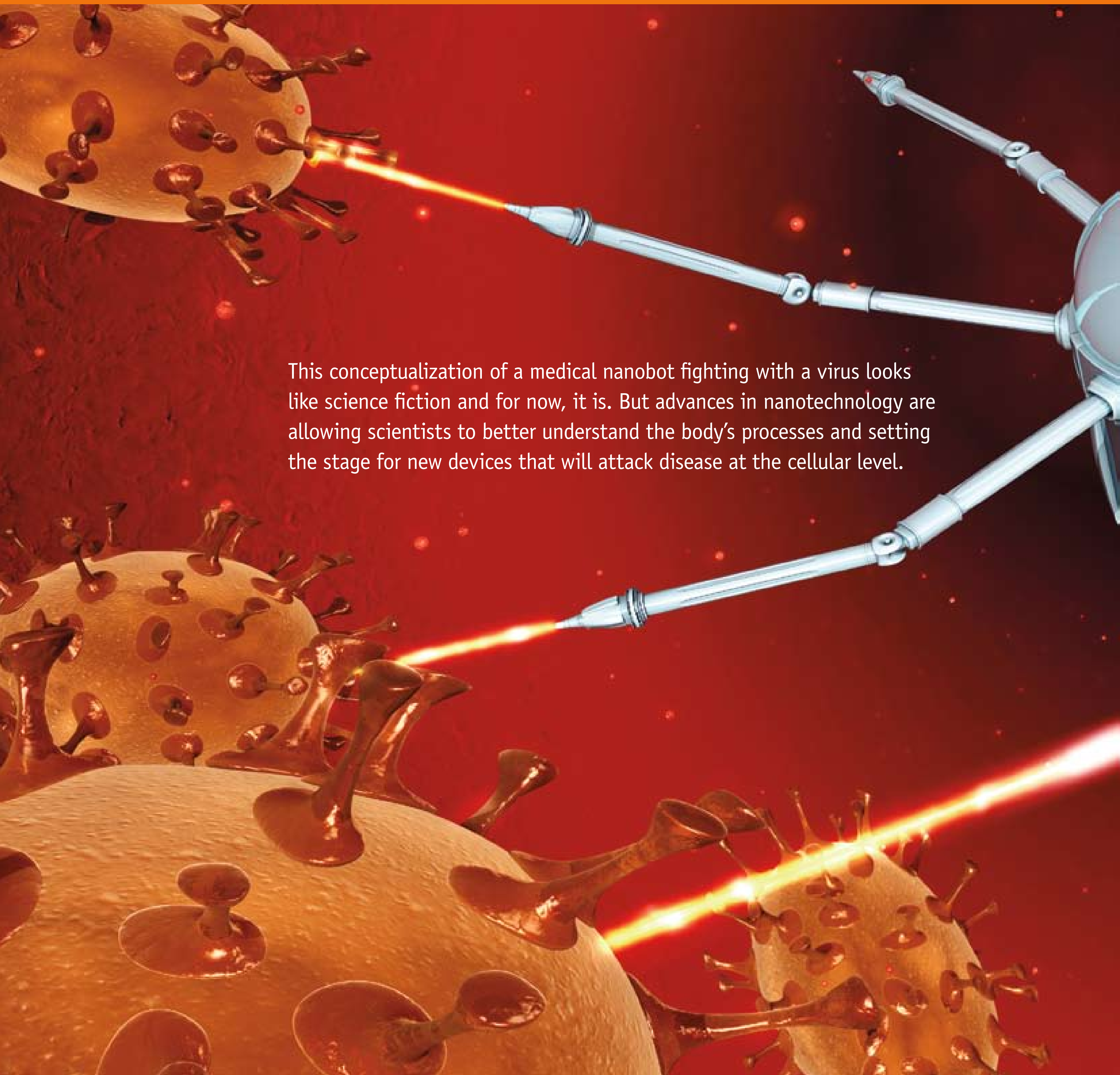

This conceptualization of a medical nanobot fighting with a virus looks like science fiction and for now, it is. But advances in nanotechnology are allowing scientists to better understand the body's processes and setting the stage for new devices that will attack disease at the cellular level.