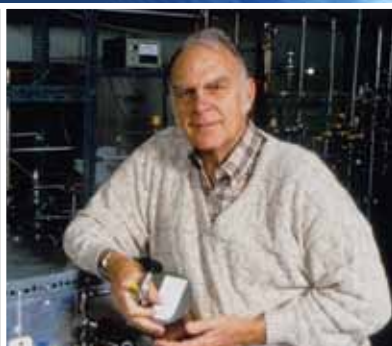
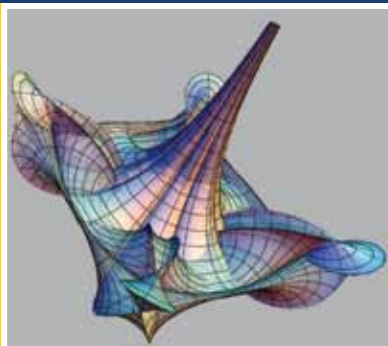


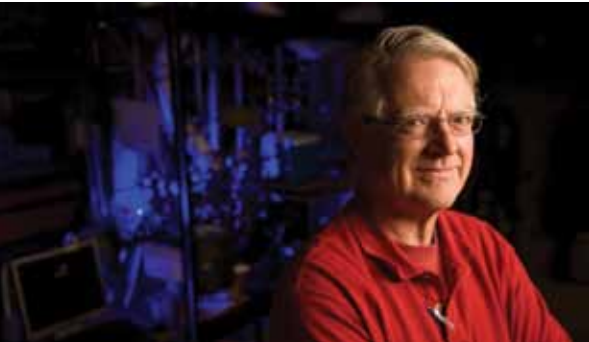
CURIOSITY

The Finest Spirit
of Science



UCI School of
Physical Sciences

Chemistry
Earth System Science
Mathematics
Physics & Astronomy



Open a window on the birth of the universe, or the quantum jitters of a single molecule. Track the acceleration of a glacier’s slide into warming seas, or take the first steps toward building an artificial leaf. Crack the code of the human immune system, then program it to defeat Ebola, cancer or HIV.

The researchers brought together under the University of California, Irvine, School of Physical Sciences might be said to share a single motivation: **curiosity**.

In the Department of **Physics & Astronomy**, **curiosity** drives them to reach out to the beginning of time, probing the enigma of dark matter, charting new galaxies and large-scale structures, or joining the hunt for the Higgs boson, ghostly neutrinos and other exotic particles.

In the Department of **Earth System Science**, **curiosity** inspires detailed measurements of climate change, providing ever clearer pictures of global alterations to come.

Chemistry is a domain big enough to capture the sun, or at least its energy, where researchers are developing more efficient ways to generate solar power, or provide hydrogen fuel by building an artificial leaf. UC Irvine chemists also are probing the interactions of tiny particles of pollution, revealing harmful chemical combinations that had previously gone unnoticed.

Mathematics researchers are uncovering the secrets of cancer cells by creating models of their spread, potentially improving cancer treatment and helping usher in an era of personalized medicine. Other mathematical researchers push new frontiers in the intricate world of cryptography and of high-speed finance.

I invite you to satisfy your own **curiosity** and explore with me just a few of the potentially world-changing research efforts in the School of Physical Sciences. They’ve already led to two Nobel prizes and recognition by President Barack Obama, who gave the commencement speech at UC Irvine in 2014 to celebrate the university’s 50th anniversary.

So let’s take a short tour. The future is waiting.

Dean Kenneth C. Janda
Dean and Professor
UCI School of Physical Sciences

3
Nobel
Prizes

8
Members of
the American
Academy of
Arts and
Sciences

11
Members of
the National
Academy of
Sciences

71
Patents issued
for Physical
Sciences
Research

8
Faculty members
participated in
the discovery
of the Higgs
boson

ESS 1st
department in
the world to
study climate
change

Founded in
1965

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OUR DEPARTMENTS:

Chemistry
Earth System Science
Mathematics
Physics & Astronomy

FOR THE CURIOUS

A CHANGE OF CLIMATE



Eric RIGNOT

was featured in the HBO series VICE where he discussed his findings of Antarctica's melting ice sheets and the global impact of sea level rise.

A CHANGE OF CLIMATE

Antarctic glaciers slide ever more quickly into a warming sea, California withers under severe drought, and projections of Earth's future climate suggest it's just a taste of things to come in the decades ahead.

Researchers in UC Irvine's Department of Earth System Science are deployed across the world and across a spectrum of climate-related fields, gathering data that bring the emerging picture into increasingly sharpened focus. They've imaged rapidly dwindling stores of groundwater around the world through the "eyes" of satellites – and found one of the most threatened groundwater supplies close to home, in California's Central Valley.

They've measured declining sea ice in the Arctic, and the destabilization caused by

warming waters at the toes of Antarctic glaciers, causing those glaciers to flow at a faster rate from land to ocean.

And with contributions to reports by the Intergovernmental Panel on Climate Change, they've revealed that the ravages of a sharply warming world are not comfortably remote, in some hypothetical future, but are happening now: rising sea levels, vanishing glaciers, escalation of extreme weather events.

UCI scientists also are working on some of the answers, including a more thorough accounting of worldwide greenhouse gas emissions, now and in the foreseeable future, pushing for development of new technologies to combat climate change, and spotlighting agricultural practices that reduce carbon footprints.

Professor Emeritus

Ralph CICERONE

established Earth System Science – the first interdisciplinary department in the United States dedicated exclusively to understanding the scientific basis of global environmental problems.



Can some of these projected changes be mitigated if we act now?

Photo: Maria Stenzel for UC Irvine

Wildfires and Climate

How massive wildfires affect the climate system is anything but straightforward. In the far north, UC Irvine researchers have found large-scale forest burning might actually cool the region's climate – while having no measurable effect on Earth's climate as a whole. Northern landscapes denuded by wildfire, then covered with snow, reflect more sunlight back to space instead of absorbing it, bringing temperatures down.

Meanwhile, in the southern hemisphere, the same research group found that even small shifts in ocean temperatures were linked to larger, more destructive fires months later in the Amazon rainforest.



Warmer ocean temperatures were followed by intensified drought conditions, which might have driven the larger fires.

The research is revealing the often baffling relationship between forest burning and global warming; the group also examines the climatic effects of shifting emissions of methane, the second worst greenhouse gas after carbon dioxide.

Oceanography

The atmosphere and oceans have a tempestuous relationship, with gases and molecules sloshing back and forth to create a global remix of environmental conditions. And it isn't only a rapidly changing climate that is having a profound effect on the world's oceans.

UC Irvine researchers have found that the hole in the protective ozone layer over the Antarctic – a discovery that itself grew from Nobel Prize-winning work at UCI – appears to be altering wind patterns over the southern hemisphere. This, in turn, is changing the way the southern oceans “breathe” – how they absorb atmospheric gases, distribute them to widely scattered points, and vent them again into the atmosphere.

The same researchers also have examined data on the global ocean's absorption of human-generated carbon dioxide from the atmosphere, comparing it closely with computer models. Their careful ground-truthing could lead to improvements in the models; while they matched the data on global scales, the models diverged from the data by as much as 50 percent on smaller, regional scales.

Air Pollution

Keeping smog in check requires computer modeling: simulations of how pollution particles move and interact. These, in turn, must be fed accurate data.

The research group known as **AirUCI** specializes in puzzling out the intricate interactions between pollutants, such as fine particles less than one-thirtieth the diameter of a human hair, and their environment.

Recent findings in their decades-long research have revealed that a large bulk of these fine particles, which can cause or aggravate a variety of respiratory illnesses, had previously gone unnoticed. Known as secondary organic aerosols, they were able to stay under the radar because they are not formed during combustion, like other types of pollution

tracked by regulators. Instead, they stick to airborne particles after combustion occurs in the engines of cars and trucks, lingering in the air far longer than previously known.

The findings mean pollution models might need correcting – along with the control measures that rely on such modeling. AirUCI has a habit of upsetting the computer-modeling apple cart; other work from the research group has revealed gaps in the understanding of how nitrogen oxides react on surfaces, such as leaves or concrete, which likely led to gaps in modeling as well.

The group also is known for its studies of sea salt particles and how they might affect formation of some types of air pollution.

Nobel Laureate

F. Sherwood ROWLAND

discovered that chloro-fluorocarbons (CFCs) released into the atmosphere from common household products like hairsprays and deodorants were depleting the earth's vital ozone layer.

How do pollution particles elude our attempts to find and destroy them?

“UC Irvine set up the first Earth system science department in America. A professor-student team won the Nobel Prize for discovering that CFCs destroy the ozone layer. A glaciologist's work led to reports showing one of the world's major ice sheets in irreversible retreat. Students and professors are in the field working to predict changing weather patterns, fire seasons and water tables – working to understand how shifting seasons affect global ecosystems... to help coastal communities adapt to rising seas.”

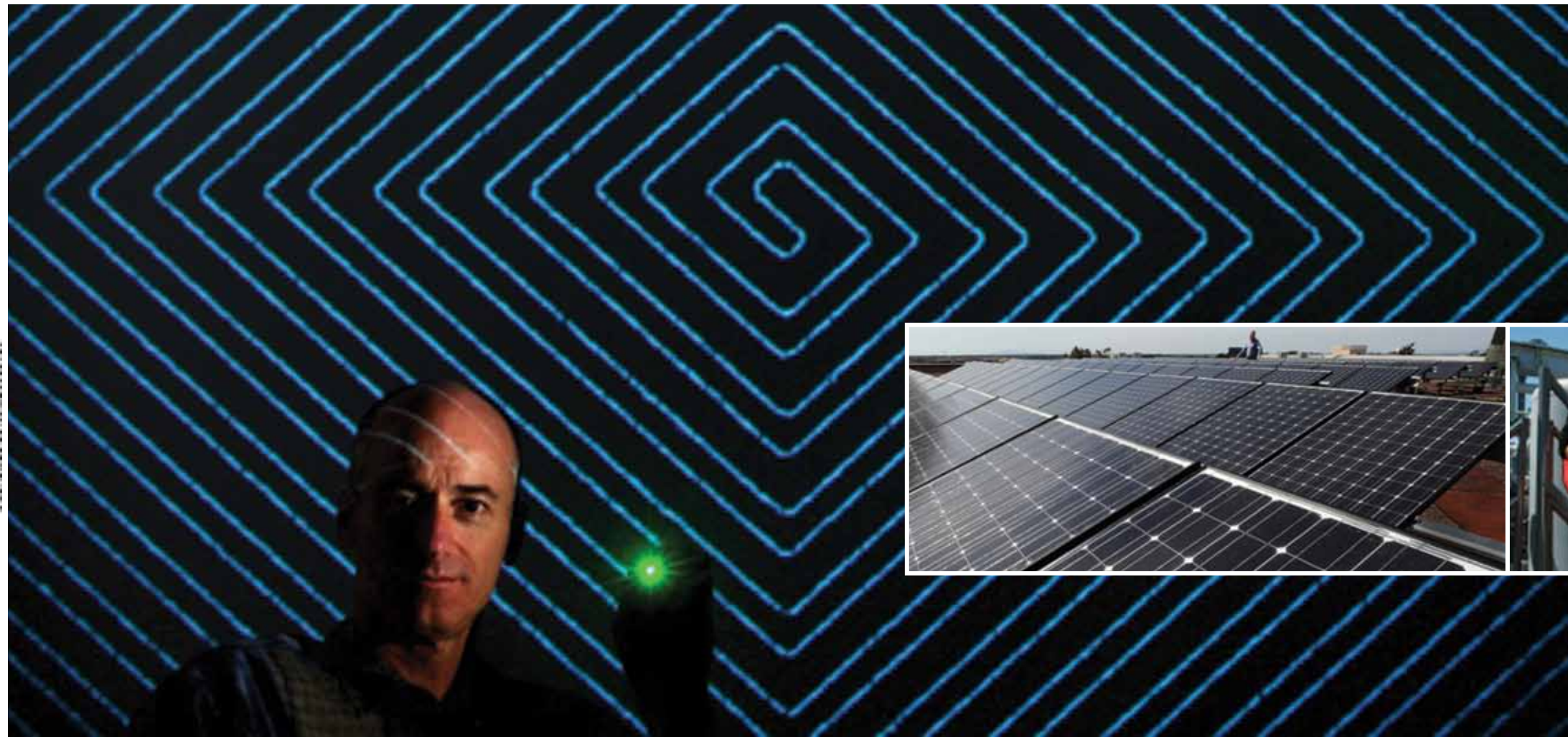
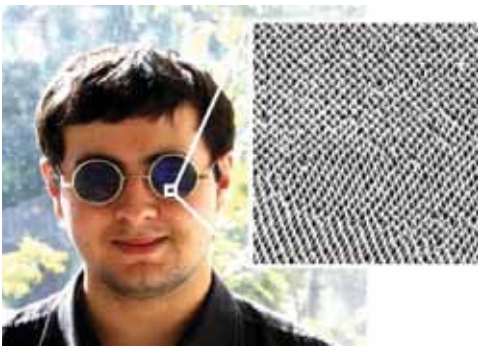
—PRESIDENT BARACK OBAMA
DURING THE 2014 COMMENCEMENT ADDRESS TO UCI



POWER PLAY

“Never stop asking
‘WHY’.”

—FREDERICK REINES



6

UC Irvine chemists are finding new ways to harvest sunlight, whether by the novel use of “fool’s gold” or, say, the creation of an artificial leaf. Among the research projects is an effort to turn iron pyrite – fool’s gold – into cheap, highly efficient solar panels.

Other researchers, meanwhile, are taking part in a nationwide, Department of Energy

funded program seeking to generate fuel by engineering an artificial leaf from materials like silicon, iron or nickel. Instead of building plant tissue like its natural counterpart, the leaf would split hydrogen from water, allowing the hydrogen to be used for fuel.

Both projects are part of UC Irvine’s **Center for Solar Energy**, established in 2007 to

study the basic principles of solar power and to educate scientists, and the public, about its potentially bright technological future.

7

Frederick REINES

was UCI’s Founding Dean of Physical Sciences and co-recipient of the 1995 Nobel Prize for his discovery of the Neutrino.



Past work of UCI's **NUCLEAR** Reactor includes measurements on the JFK assassination bullet lead, mercury levels in ancient specimens of swordfish and tuna, and sculptures in the Getty Museum in Los Angeles.

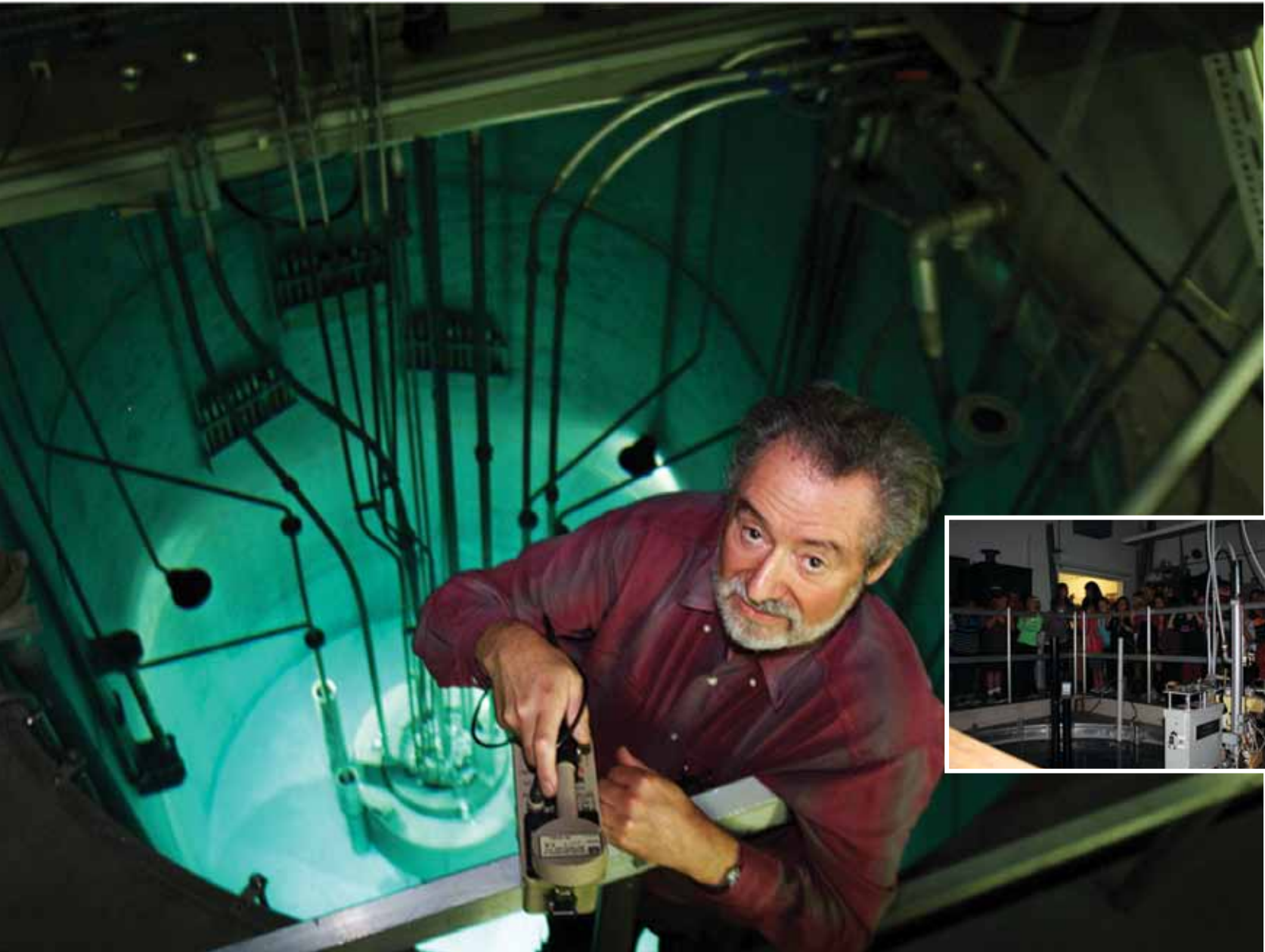
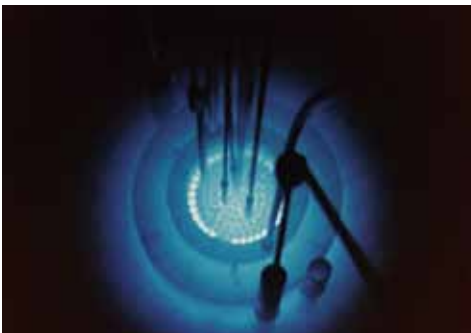
Nuclear Energy

UC Irvine's small research nuclear reactor, operated safely for decades thanks to careful engineering, remains central to a variety of projects. Several touch on aspects of nuclear energy that echo both its promise and potential difficulties in nuclear power plants across the nation, and the world, including safety and security issues.

The reactor is used to investigate details of spent nuclear fuel and medical use of radioisotopes, as well as playing a role in efforts to sharpen measurements of radioactive decay. Nailing down precisely the radiation emission rates of gamma rays or electrons – at the moment known with less precision than fundamental

constants like the speed of light – could prove immensely valuable to a new generation of investigators using nuclear materials. Some are exploring new ways to generate nuclear power, a matter of contention between those who see it as the best way to reduce greenhouse gas emissions and those who see it as an “unacceptable risk.”

New reactor designs, including one possible version using molten salt, could



vastly reduce generation of nuclear waste, cut substantially the risk of accident or exposure, and greatly increase power output.

Another research project seeks to better characterize how quickly the radioactive element plutonium, leaked from the decommissioned Hanford nuclear site, migrates through soil.

Solar Energy

One path to cheaper, more powerful solar-power generation involves hitching our fortunes to the photon – a particle of light. But a warning is in order: It's a strange path that will take us through the counter-intuitive quantum world.

UC Irvine scientists are part of a wave of recent research into the properties of

quantum dots. These extremely tiny, semi-conducting crystals could, if properly manipulated, lead to easily fabricated solar panels with a power output significantly greater than conventional panels. Instead of each photon producing a single electron as it moves through an array of quantum dots, it could produce two or more. This would boost the current flowing through the panels, increasing their efficiency – and

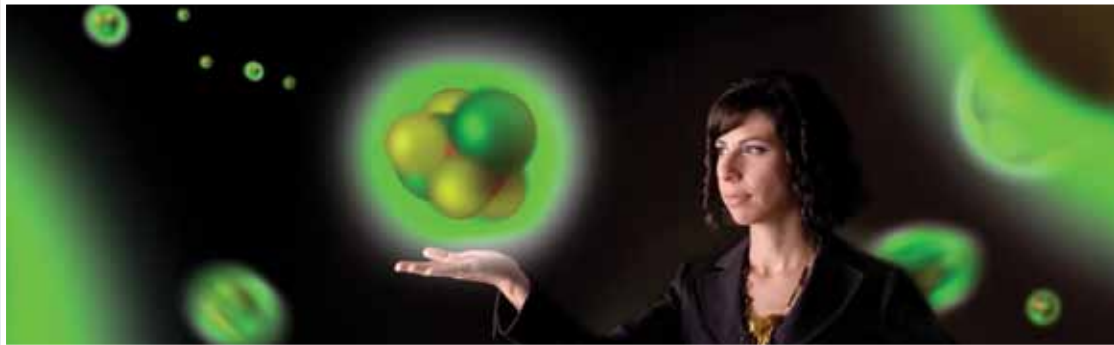
in turn, driving down the “dollars per watt” ratio to make the more powerful panels less costly to manufacture. To get there, however, researchers must overcome the capricious nature of quantum particles – specifically, their tendency to pop suddenly from one dot to the next in a phenomenon known as quantum tunneling.

UCI researchers are trying to counter this tendency with another somewhat strange quantum effect known as delocalization. The photon literally grows larger, spanning the entire network of quantum dots and causing electrons to travel farther, so they can be harvested, and put to work, before they vanish.

The primary use of the reactor is to support educational programs at UCI.

Group tours of the facility are available.

HEALTH FRONTIERS



“Proteins are the **workhorses** of your cells.

They are the things that make you do the things you do, that raise your arms, that provide the muscles, that run around the body and do all kinds of things. Those proteins are absolutely fascinating little machines that scientists like myself want to study.”

—PROFESSOR GREG WEISS
COMMENTING ON HIS DISCOVERY ‘UN-BOILING’ AN EGG

To design vaccines for deadly diseases like Ebola, it helps to know the language. In this case, it’s the chemical chatter between, say, a vaccine and the human immune system, a coded language that can switch on the destruction of viruses such as Ebola, malaria or HIV.

UC Irvine chemists are trying to decipher the immune system’s coding – to pick the

molecular locks and open the door to vaccines that target the viral bull’s eye, with far fewer side effects than the more blunt instruments of traditional approaches.

Another initiative seeks to unravel the broader workings of biological systems, one atom at a time. By teasing apart the atoms and bonds that form the scaffolding of cells, and their internal machinery, investigators

hope to engineer proteins and other vital components. They’ve already taken the first steps toward a long-sought goal: using biological markers to track the progression of diseases like cancer with an electronic readout. This could one day allow implanted sensors to flag cancer cells in a patient’s body and show them on a doctor’s display screen.

In another biotechnology breakthrough, a UC Irvine chemist helped discover how to unboil egg whites. The process, involving a chemical trick that liquifies boiled proteins in the egg whites and a “vortex fluid” device that forces the proteins to untangle, could lead to substantially lower costs for protein manufacturing – critical to the creation of cancer antibodies.

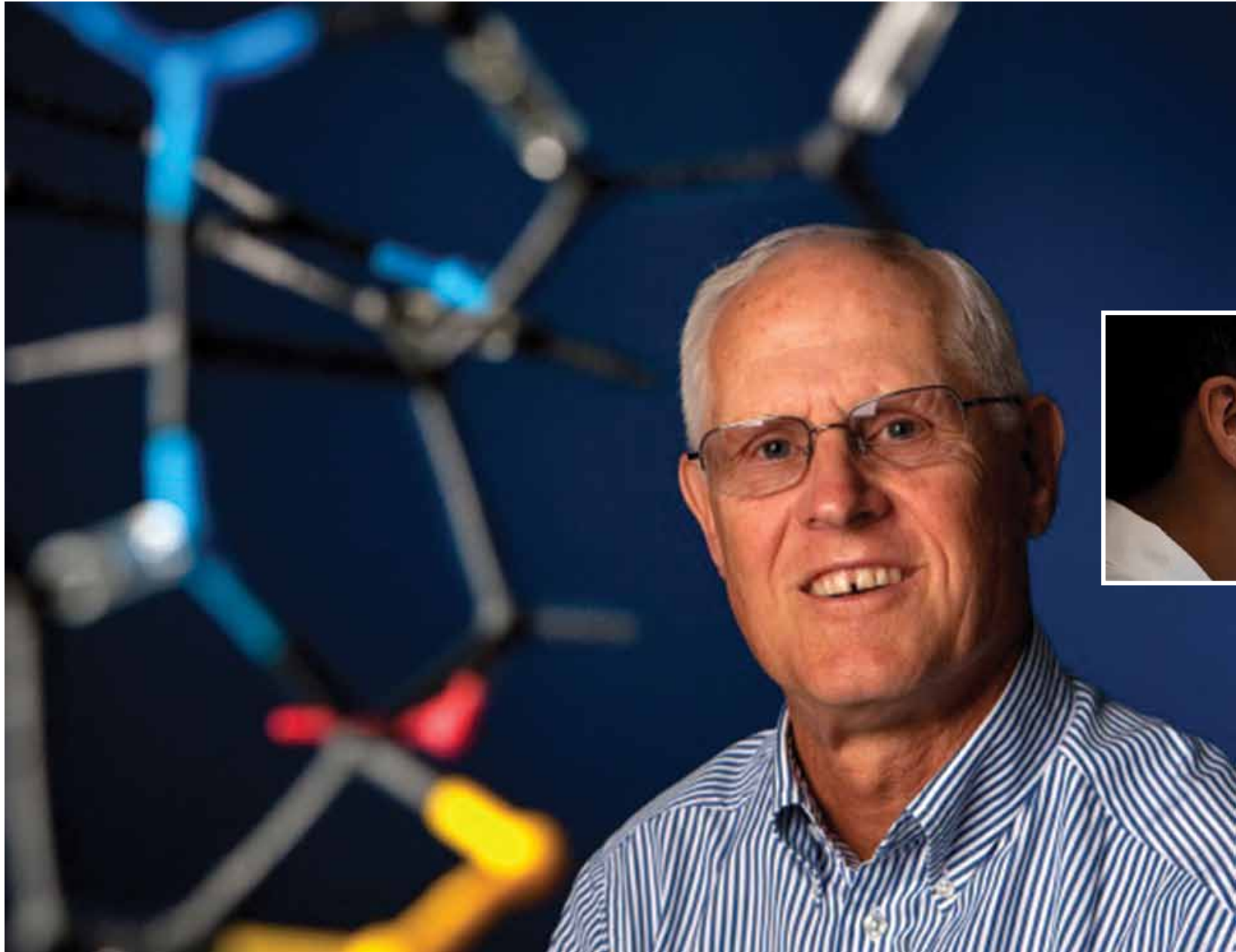
Could doctors one day view the spread of cancer cells in a patient’s body on a computer screen?

Drug Design

One of the most important weapons in the scientific arsenal against cancer and other diseases is, in a word, imitation.

Synthesizing natural compounds with the power to shrink tumors, while also simplifying them to subtract their toxic side effects, is one of several possibilities being investigated by UC Irvine chemistry researchers. They began with a natural alkaloid compound from mold that possessed tumor-fighting properties. Then, through careful chemical manipulations, they turned the compound into a molecular entity that was new to science. This new compound has shown promise in experiments with mice, reducing tumors while causing far fewer toxic effects; the scientists are now working with partners to move toward development of a similar drug for humans.

Another initiative targets so-called “epigenetic” factors, non-genetic elements that can, nevertheless, influence how our genes are expressed. This effort takes aim at histones, proteins involved in the transcription of DNA. Control the



Professor **Larry OVERMAN**, one of the world’s pre-eminent organic chemists, helped launch a company to produce new cancer therapies based on his research on epigenetic regulators.

12

histones and you can control transcription, altering the way DNA orchestrates the manufacture of proteins; that again could lead to more effective and less toxic drugs to treat cancer.

Other investigations seek to unlock the secrets of Alzheimer’s disease, and to find new ways to combat the rising resistance

of harmful microbes to antibiotics. All rely on some variation of chemical copycats that bring out the good in natural compounds while leaving out the bad.

Artificial Antibodies

Mimicking nature, with a few tweaks along the way, has been extended to another domain by UC Irvine chemists. They’re developing artificial antibodies, the proteins that neutralize disease-

causing microbes and other intruders in the bloodstream.

Natural antibodies can be a bit fragile and have proven extremely expensive to produce for medical treatment. So a few years ago, UCI researchers asked a key question: Could they employ polymers to create artificial versions – in other words, plastic antibodies?

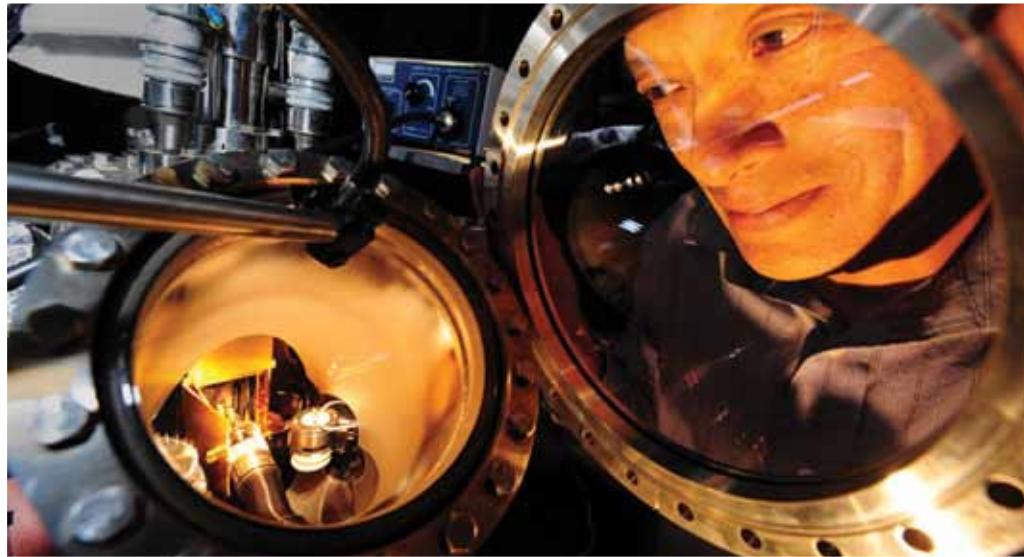
The first test of the idea zeroed in on honeybee venom. The scientists

developed a synthetic nano-size particle that binds to the toxin in bee venom, the same way antibodies bind to foreign intruders. And it worked. Mice given lethal doses of bee venom, then treated with injections of the plastic antibody, saw a huge increase in their survival rate. By engineering artificial antibodies that could bind to almost anything, these scientists offer tantalizing prospects: plastic antibodies binding to receptors on cell surfaces, for example, to switch off

blood-vessel formation in tumors, starving them of nutrients.

Researchers are pursuing not only medical applications for artificial antibodies, but also ways to use them as protein purification systems – binding to desired proteins and culling them from a stew of ingredients. Several companies are now leading the way to explore potentially life-saving, and lucrative, uses for these tiny bits of engineered biology.

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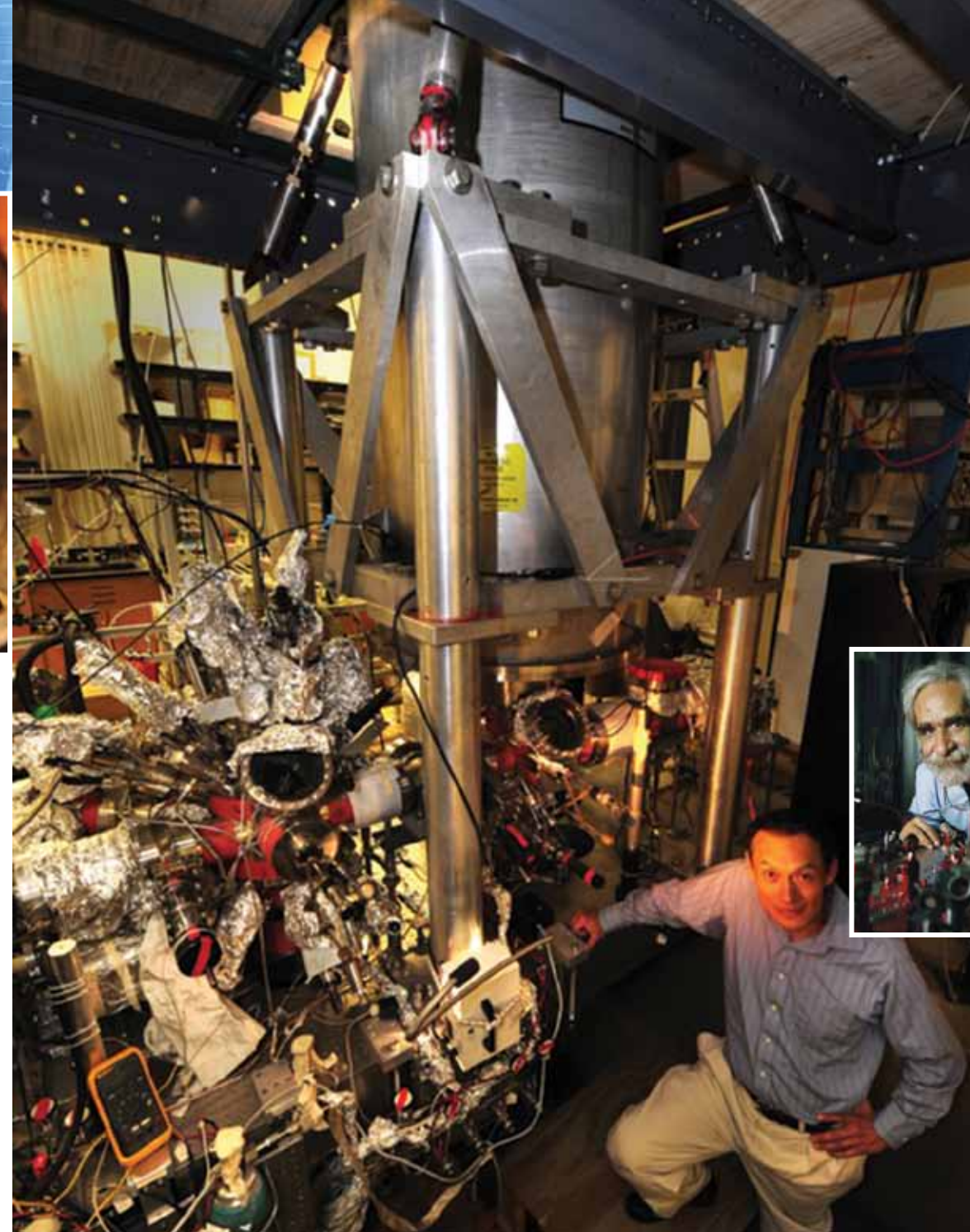


PICTURE THIS

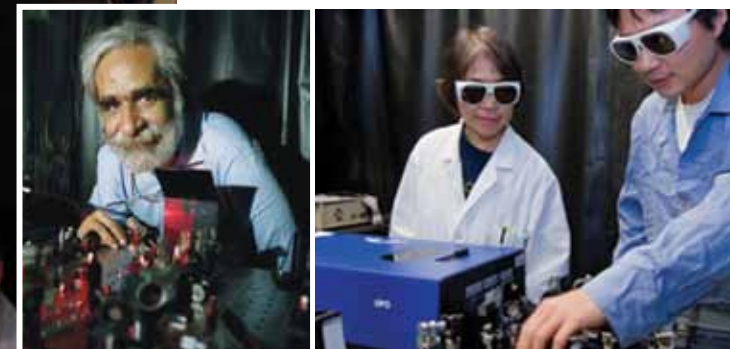
The first-of-its-kind breakthrough, a movie of a molecule in motion, might be more like a preview of coming attractions.

Experimenters at UC Irvine are working to develop a “chemiscope,” which is just what it sounds like: a kind of microscope, but one that can spy on interactions far smaller than those seen through any microscope today. The chemiscope would allow direct observation of the forming and breaking of chemical bonds within individual molecules.

These researchers are continuing the work that led to the first molecular movie – a tiny



Professor **Wilson HO** is renowned for developing a two-story-high scanning tunneling microscope to investigate single molecules.

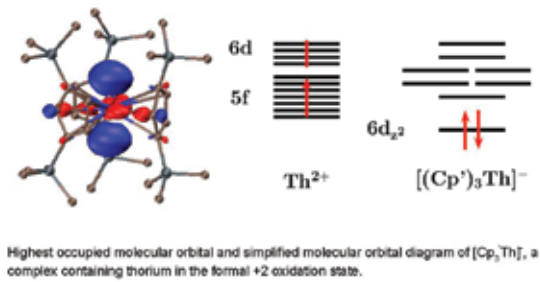
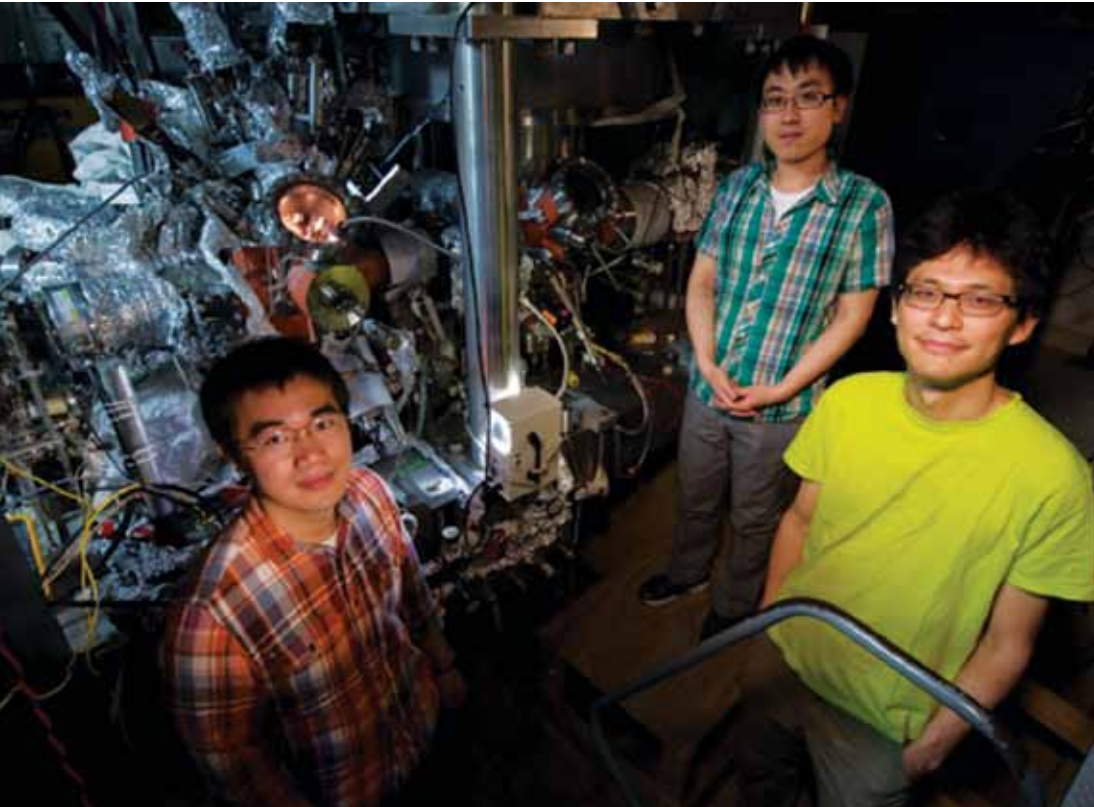


dot, pulsing with energy as it shifts from one quantum state to another. But their ambitions aim far higher. The movie required a tightly controlled environment, with a kind of antenna embedded in their molecule and finely tuned lasers to track its shifting state. The scientists hope one day

to image shifting states of molecules in a natural environment, without the constraints imposed by their successful laboratory method.



The School of Physical Sciences offers **state-of-the-art** research facilities in molecular modeling, mass spectrometry, transmission electron microscopy, X-ray crystallography and nuclear magnetic resonance spectroscopy.



Most proteins in our bodies break down, and must be regenerated within hours or weeks. The eyes are the exception: We keep eye proteins throughout our **LIVES**.

Scanning Tunneling Microscope

An instrument nearly two stories tall allows UC Irvine researchers to take snapshots of some of the smallest structures known: the inner architecture of individual molecules.

Called a scanning tunneling microscope, the mass of tubes and projections sprouting from a central cylinder takes advantage of the strange properties of the quantum world – the smallest of the small – to capture images of the arrangements of the atoms that form the molecule, as well as the bonds between them. The tunneling is the odd ability of electrons to “tunnel” across the tiny space that separates the tip of the microscope from the surface it is imaging; many such

scans produce a picture, line by line, of lights and darks, revealing the molecule and its interior.

Deeper understanding of chemical bonds within molecules could bring astonishing applications – converting the carbon dioxide that is heating the planet, for example, into clean fuel, such as methanol. Or turning pollutants into environmentally harmless substances. Or even unlocking the secrets of genetic mutations that result in disease.

Transmission Electron Microscope

UC Irvine is a powerhouse of technical mastery in another kind of submicroscopic exploration: the transmission electron microscope, or TEM.

Five muscular new instruments on campus extend the reach of UCI investigators into realms at and below the size of an atom, with a resolution high enough to see atoms and molecules in three dimensions – even to make them dance.

Among the instruments’ capabilities: shooting electrons through a thin foil, creating images of atoms much the way a doctor’s X-ray machine creates images of bone. One of the new instruments, in fact, relies on scanning technology (earning it the acronym, STEM) to image vibrations of molecules in real time, and to view directly how they react when forces, such as electric fields, are applied.

The new instruments could yield important insights into an eclectic variety of fields. Better understanding of catalysts, for instance, could lead to far more efficient exhaust treatment for cars and trucks, sharply reducing their pollution output. Improved understanding of catalysts also could bring advances in photovoltaic cells that convert sunlight into energy. And new, more powerful computer memory and even components for futuristic quantum computers could result from these instruments’ sharp new rendering of the subatomic world.

The TEM facility will also help chemical biologists to understand the structure of macromolecular complexes that are important for finding a cure for cancer.

Chemical Biology

The windows through which we view the world are made of amazing stuff. Human eyes are about 50 percent water and 50 percent protein, including remarkable proteins called crystallins.

Unlike most other proteins that make up our bodies, which break down and must be regenerated within hours or weeks, the crystallins in the lenses of our eyes last a lifetime. And when something goes wrong, the lenses can cloud over, forming cataracts that steal away our vision.

By employing sophisticated chemistry to manipulate biological material, UC Irvine researchers have pried out some of the secrets of cataract formation. One recent study revealed the precise structural effects of mutations in crystallin proteins, exposing them in stark molecular detail, that give rise to cataracts in children as young as six. It’s a discovery that could allow other scientists to develop treatments for the condition, targeting

the mutation to halt the clumping of crystallin proteins that leads to cataract formation.

The tools of modern-day chemical biology include nuclear magnetic resonance spectroscopy and a kind of laboratory sleight-of-hand that allows the recruitment of bacteria to manufacture virtually any proteins the researchers require; they are now using them to investigate similar mutations that mimic the damage caused by age-related cataracts.

Computational Chemistry

The jittery dance of molecules morphed and wiggled across the screen, eventually doing something that could change the way the world thinks about energy: The water molecules separated into their well-known components, oxygen and hydrogen.

Finding a cheaper, better way to part hydrogen from oxygen could vastly increase the appeal of hydrogen power; the short movie suggested that salting the water with nano-scale clusters of titanium dioxide might be the key.

But the simulation, created using a computer program devised by UC Irvine scientists, wasn’t simply a fictional mock-up. It was not derived from difficult, time-consuming observations made from a laboratory bench. Instead, using the principles of quantum mechanics, the computer program generated its own forecast of how the molecules would behave, evolving them forward in real time.

Computational chemistry, once thought by some scientists to be a blind alley, now offers the promise of allowing researchers to conduct virtual experiments without the messy, expensive and sometimes dangerous complications of a physical laboratory – though still yielding reliable results. Such simulations could bring powerful advances in everything from alternative energy to air-pollution control.

A UNIVERSE OF DISCOVERY



A UNIVERSE OF DISCOVERY

“Our universe began with a **BANG** 13.7 billion years ago. It is filled with dark matter, dark energy, and at least one planet with people who look up and ask **why**.”

—PROFESSOR JAMES BULLOCK

They’ve discovered a giant galaxy ten times the size of our Milky Way, as well as the “tiniest” galaxy – so small we normally can’t see it, even though it’s in orbit around our own. UC Irvine investigators are probing the cosmos using a dazzling array of instruments, including Hawaii’s Keck telescope and the European Space Agency’s Herschel space telescope.

The researchers at the **UCI Center for Cosmology** share time on these machines with scientists all over the world, combing through the data they gather and publishing new discoveries previously hidden in the sea of light and radiation.

Other insights come from precise computer simulations. Such simulations revealed, for instance, that the tiny galaxy in orbit around the Milky Way is likely one of many, all formed with the help of dark matter – and that such dwarf galaxies likely swarm around all galaxies the Milky Way’s size.

UCI researchers might even have glimpsed the dark side – a tell-tale pattern of gamma rays emanating from the heart of our galaxy that could be the signature of dark-matter particles, colliding and annihilating each other and emitting gamma rays in the process. That could

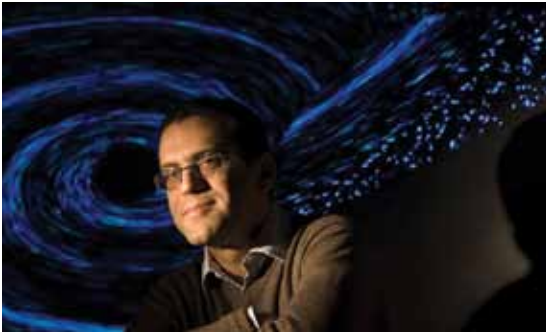
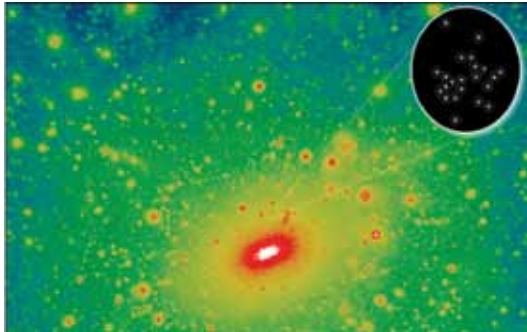
provide clues about enigmatic dark matter, which dominates matter in the universe but has so far evaded scientists’ attempts to detect it directly.

The Thirty Meter Telescope at Hawaii’s Mauna Kea volcano will allow humanity to see deeper into the universe than ever before, and UCI research has played a crucial role in its design. UCI researchers will be using the Thirty Meter Telescope, named for its 30-meter primary mirror, to continue breakthroughs in dark matter, galaxies, stars and much more.

What is dark matter?

“History tells us that most discoveries of fundamental laws of nature benefit humanity in ways that could not be envisioned at the time discoveries were made. I think the biggest benefit to the public will be indirect – by contributing to our long quest to **better understand** the world we live in.”

—PROFESSOR YURI SHIRMAN
COMMENTING ON THE DISCOVERY OF THE HIGGS BOSON



Plasma and Particle Physics

Many leading physicists might just as easily be described as hunters. UC Irvine scientists were part of an international cast of thousands hunting for the Higgs boson, the last exotic beast to be captured for the modern physicist’s particle menagerie. Evidence of the Higgs boson, itself evidence of the all-important Higgs field, which gives particles their mass, was picked up by detectors in the Large Hadron Collider on the Swiss-French border in 2012.

UCI physicists also hunt an equally strange particle called the neutrino in the forbidding cold and ice of Antarctica.

Forbidding, yet inviting: By peering through deep Antarctic ice, detector arrays such as IceCube can record tell-tale flashes of blue light that are signs of neutrinos, so ghostly they barely interact with matter at all – except those rare moments when, in their streaming trillions, one of them bumps into an atom in the ice. Untouched by dust or radiation, neutrinos flowing constantly through the Earth, and our bodies, might bear secrets from the beginning of time.

Other UCI physicists hunt high-energy cosmic rays; one professor will use smartphones around the world just for that purpose.

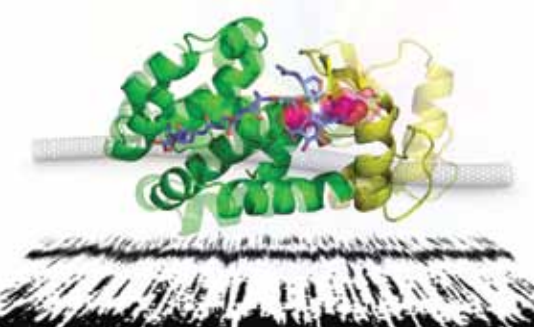
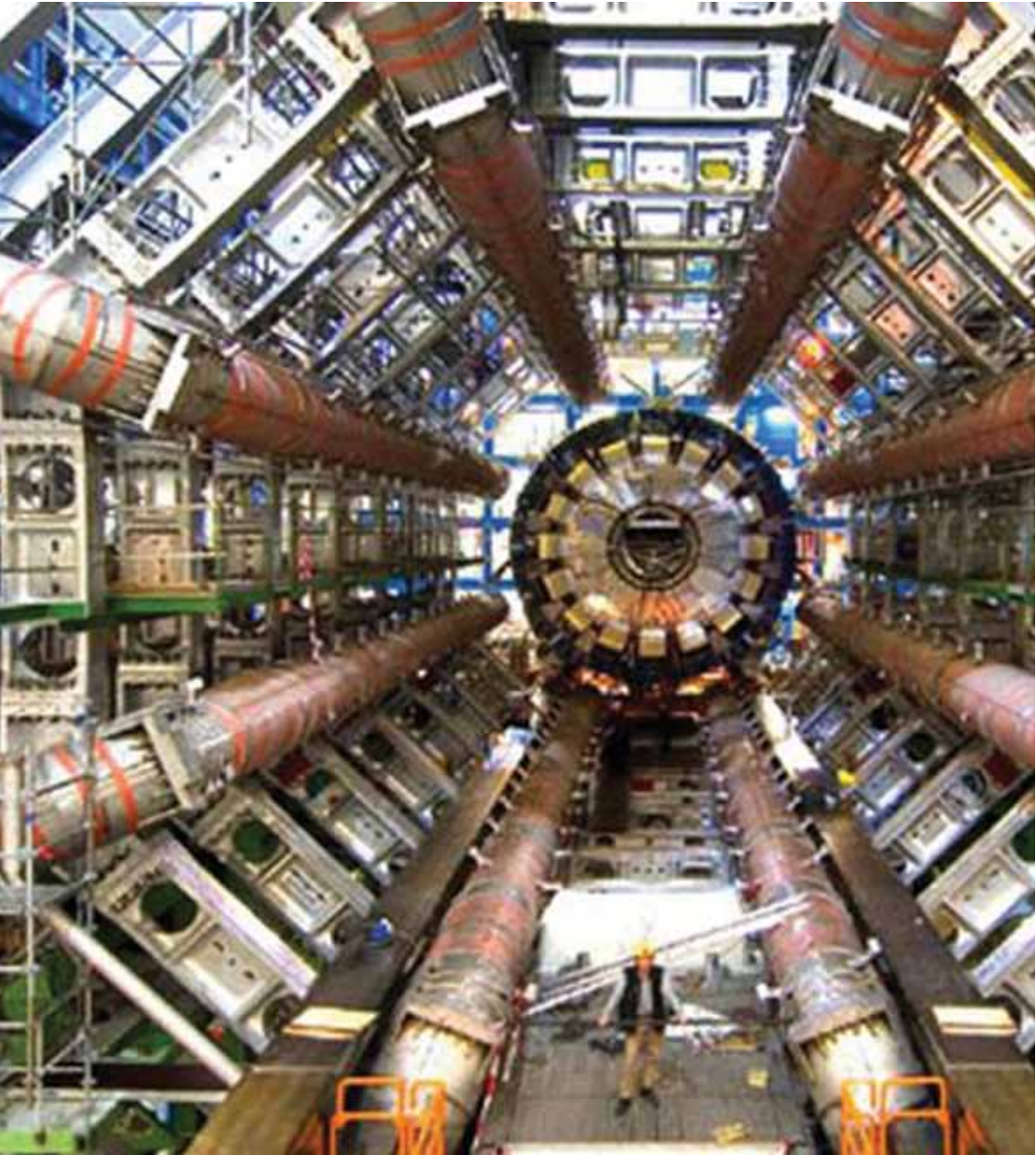
Nanotechnology

The astonishingly accurate prediction of Gordon E. Moore – that computer power would double roughly every two years – is now enshrined as Moore’s law, and has held true for decades. But UC Irvine nanotechnology researchers are actively plotting to break it.

As we reach for ever tinier, ever more densely packed computer circuits, we bump up against the weird world of quantum physics. This kingdom of the very small refuses to obey the rules of bulky classical physics; down here, everyone’s a lawbreaker. Yet mastering the strange rules of this alternative reality might not only open up a path to circumvent Moore’s law and break through the boundaries of classical

physics. It also could yield computer power far beyond anything most of us can imagine today. A smart watch, perhaps, that can diagnose a developing illness just by sampling chemicals oozing through your skin.

The researchers are laying the ground-work for computer circuits of the future, perhaps the size of the proteins found inside our cells – or, just maybe, using the proteins themselves as computer circuits, merging biology with computer science.



Using a microscopic-sized carbon nanotube as a kind of microphone, UCI scientists were able to eavesdrop on a protein as it attacked invading bacteria. The “sound” they recorded revealed that the protein molecule, called a lysozyme and found in teardrops, chomps away at the bacteria until it is cut to pieces.

Eight UCI faculty members and many postdoctoral researchers and staff members participated in the discovery of the Higgs boson. Among their contributions were the development of electronics, computer systems and software integral to collecting and recording data.

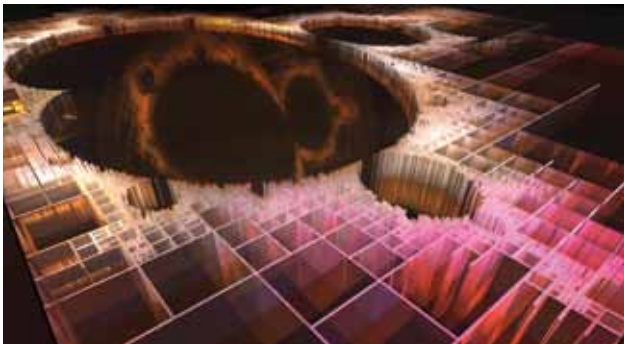


Photo: Richard Palais & Luc Benard



Name a topic that looms large in our daily lives, and **mathematics holds THE KEY.**

DO

THE

MATH

Health, finances, the flow of digital information. Name a topic that looms large in our daily lives, and mathematics probably holds the key. UC Irvine researchers seek to unlock the secrets of cancer cells with mathematical predictions of how they progress, perhaps rendering treatments more effective.

UCI mathematicians also are hard at work on high-security, coded communications known as cryptography, the nature and extent of “dark matter” in the universe, and the high-level mathematics that drive the complex calculations by the world’s most powerful computers.

Lightning-fast trading on Wall Street, far faster than individual human investors can track, also are coming under the scrutiny of UCI researchers. They are inventing ways to outsmart these cyber-traders, conducting transactions in a few thousandths of a second.

worlds as small as a single cell to the structure of the entire universe itself.

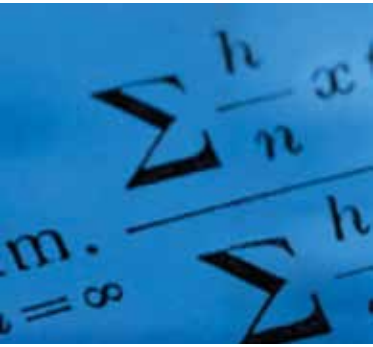
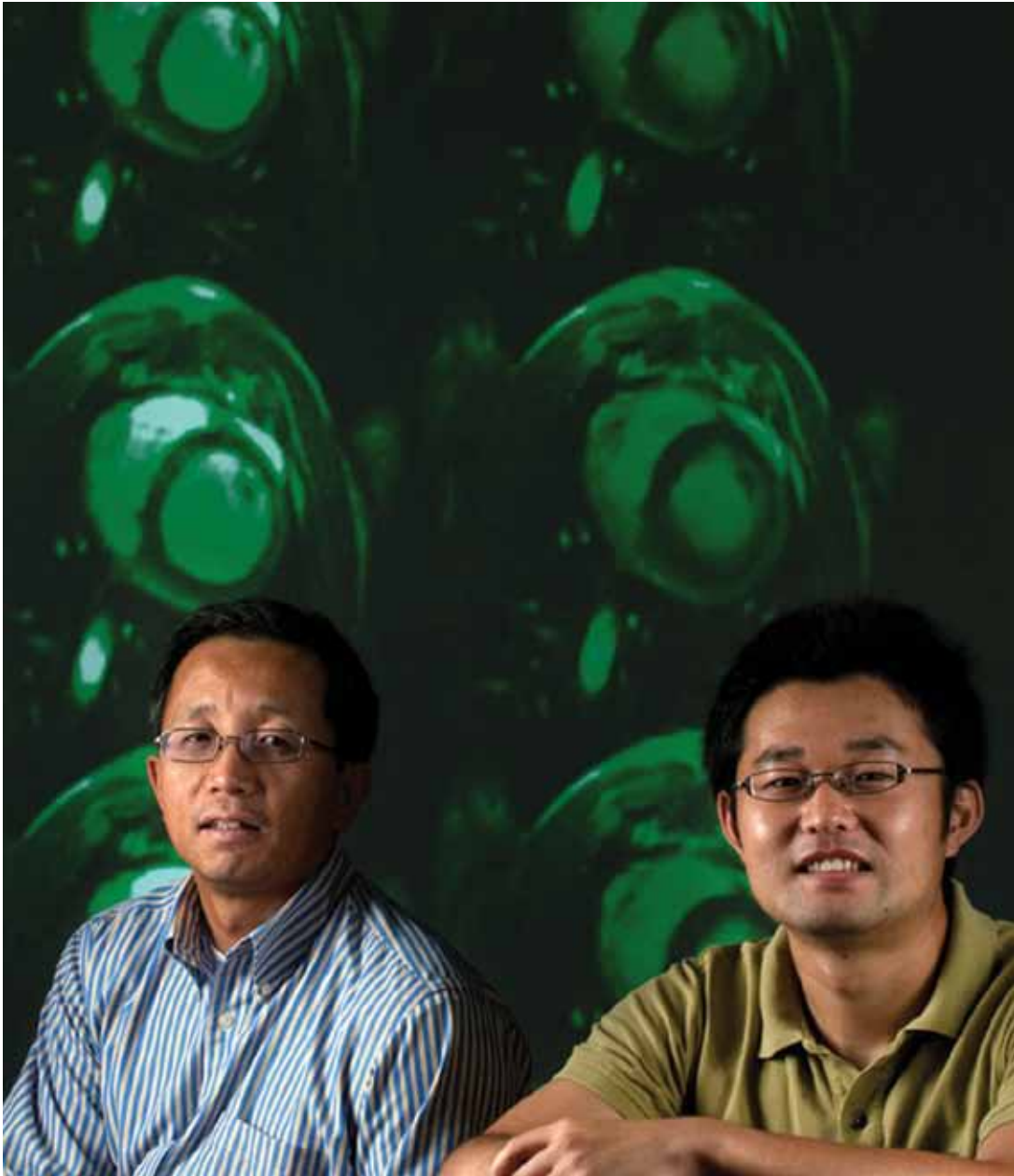
UC Irvine mathematicians stand at the forefront of research in geometry and topology, making fundamental contributions to deepen our understanding of this crucial subject and its applications throughout science and mathematics. Our research sheds light on the structure of soap films and other fluids, reveals the shape of black holes, and unlocks the mathematical mysteries behind string theory. This research stands to contribute to new developments in biology, physics, and beyond.

The Shape of Space

Geometry is a subject as old as human thought. When properly studied, its truths are universal and eternal, as evidenced by Euclid’s famous text surviving intact over millenia and still being taught in high schools today. However, we have progressed quite far from Euclid’s beautiful starting point. Indeed, today geometry influences all areas of science and mathematics, from

Can we use math to test the effectiveness of cancer drugs?

How can we use high-end mathematics to protect our investments?



The Math of Finance

In a few thousandths of a second, computer systems used by high-frequency traders can anticipate large purchases by pension and mutual funds, driving up prices and sharply reducing their returns. And the problem is widespread; such high-frequency transactions account for about 60 percent of modern stock-trading.

UC Irvine researchers are studying ways to outsmart these high-speed highwaymen. Mutual fund managers might, for instance, randomize their orders of stocks in a piecemeal fashion to conceal them from the lightning-speed analysis of high-frequency trading algorithms. Or they might time their orders to hit many markets simultaneously, leaving would-be scalpers no time to anticipate the investments and attack.

These are among several research efforts at UCI that explore the deeper mathematics behind the world of finance.

The Math of Disease

A drug designed to treat a common form of leukemia at first appeared to bring an alarming result: The number of cancer cells in the patient's blood spiked instead of decreasing. UC Irvine mathematicians brought powerful techniques to bear on the problem, helping usher in the emerging field of computational biology.

By building a mathematical model of the drug, Ibrutinib, and its effect on cancer cells associated with CLL-type leukemia, the scientists discovered that the drug really was doing its job – despite an initial increase in cancer cells migrating from tissues into the bloodstream. The drug was later approved for use in cancer treatment. A second leap of insight came when the researchers again used mathematical models to pin down the development of a patient's resistance to the same drug during treatment.

Simply by creating models that included the divisions, deaths and mutations of cancer cells, the scientists were able to predict how long it would be before the patient began to develop significant drug

resistance. That, in turn, will allow doctors to adjust drug combinations and create “personalized” treatments tailored to each individual patient.

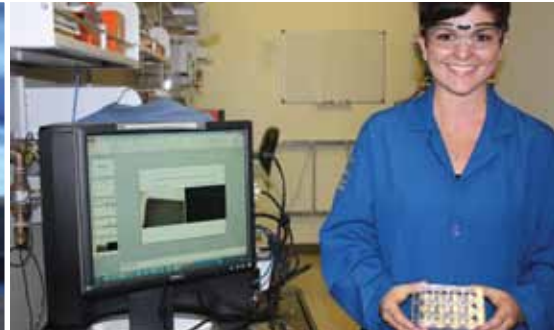
UCI mathematicians are at the forefront of the emerging fields of personalized medicine and computational biology. Their computer simulations range across the realms of biology and biomedicine, from stem cells and embryonic development to tissue regeneration and cancer. They're developing predictive models to unravel the mysteries of normal tissue development and how it can go awry, leading to birth defects, cancer and other diseases. The same tools could yield insight into both normal and abnormal functioning of the immune system, as well as improved treatment of cancer.

Cryptography and Cyber-privacy

So you want to store sensitive information in “the cloud,” and even borrow the cloud's computing power – but you don't want the cloud to learn anything about the data you're sending.

That's where UC Irvine mathematical researchers come in. The challenge is how to go about computing with encrypted data. A message that has been encrypted, or disguised, only can be read if its intended recipient possesses the key that decodes the encryption. With today's systems, if you ask the cloud to perform a calculation on your data, but withhold the key, the cloud would not be able to carry out your request. It's a mathematical frontier that has puzzled researchers for decades.

Recent developments, however, may place the answer within reach. Researchers at UCI are working on a system of nested encryptions that would allow an encrypted query to be sent to the cloud, and the cloud to carry out the requested calculation, returning the answer in encrypted form – all without ever being able to “peer inside” the encrypted data or learn any details about what it was calculating. The work could have major implications for data storage of the future, and even for national security.



“Accelerating the transfer of technology is critical to helping the country remain competitive in a global marketplace.”

—DON BEALL, CHAIRMAN EMERITUS,
RETIRED CHAIRMAN/CEO,
ROCKWELL

The Beall Innovation Awards

Think big. That’s a short and sweet piece of advice from a recent winner of the Beall Innovation Award, which seeks to encourage the entrepreneurial spirit among UC Irvine researchers. Taking discoveries and inventions from the laboratory to the marketplace means imagining the ways in which new technologies could sprout from existing science, as well as keeping close track of research trends that might point the way to the future.

The scientist who advised thinking big is now working to re-engineer bacterial viruses to become cancer detectors. By causing these viruses, which are harmless to humans, to capture cancer biomarkers in a urine sample, he would achieve a long-sought goal: connecting biology and electronics to create

medically useful devices. Such detectors could reveal growing cancers much earlier than conventional tests can, potentially saving the lives of patients as well as lowering costs; it also would represent a significant advance in biological chemistry.

The annual Beall Innovation Awards are sponsored by the Beall Family Foundation.

To view Beall Innovation Award recipients go to ps.uci.edu/innovation.

Teaching Frontiers

The way young adults absorb information is changing radically, and the hottest trends in teaching aim to keep pace. “Flipped”-style teaching turns traditional instruction on its head, as the name implies. Instead of listening to lectures, then going home to study classroom materials, “flipped” does the opposite: Students soak up information before class, arriving ready to engage in active learning with their instructors.

And even what they are soaking up is changing. Today’s students, accustomed to on-demand videos, respond better to videotaped lectures and online resources than to stodgier forms of communication. That can mean a sometimes steep learning curve for the instructors themselves; they must invert their class-time plans as well as become proficient at video presentation.

Another trend with a powerful effect allows students to grade and critique each other’s work. The act of providing feedback appears to enhance learning for the student who is doing the evaluating, as well as the one being evaluated. And it is perhaps inevitable that machines are getting into the act. Machine learning has become so sophisticated that – like the Netflix software that analyzes your movie-watching patterns, then recommends films you might like – adaptive-learning computer programs can analyze a student’s progress, customizing course work accordingly.

CalTeach Program

Another UCI program seeks to change the way the instructors themselves are discovered. Sponsored jointly by the schools of Biological and Physical

Sciences, along with the School of Education, the **CalTeach** program seeks talented undergraduates in science and math – identifying and recruiting them early for a teaching career. The students can choose a four-year option, earning both a teaching credential and a bachelor’s degree in science or math in four years, or a “four plus one” option: While they earn a bachelor’s in math or science, they can complete education courses that later can be applied to a post-baccalaureate teaching credential.

Instructors at UC Irvine are early adopters of these cutting-edge techniques, helping break new ground for advanced teaching styles that are gaining momentum across the country.

THINK BIG

The National Research Council ranks each of the four departments in the School of Physical Sciences in the top 15th percentile.



Dean’s Research Circle

The School of Physical Sciences is at the forefront of scientific questions and frontiers that engage faculty, students, and the citizens of our community. We invite you to join us on this journey of **curiosity** by supporting the Dean’s Research Circle Fund. This fund was established to equip our School to ignite projects, act swiftly on new opportunities, introduce new teaching technologies, and attract and support world-class faculty and young scholars.

FUND LEVEL	CONTRIBUTION
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More information: ps.uci.edu/researchcircle	

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