The New Electronics
The Next Big Things
Q & A: Nano in Society
Six Microns Under
Wireless Unjammed
Letter From the Deans

Everybody wants to know what’s just around the corner.

No matter what your field or métier, it’s a huge advantage to be able to see ahead, take advantage of emerging opportunities and avoid competition, problems or pitfalls.

At UC Santa Barbara, we’re in a great position to identify “the next big thing” in engineering and the sciences. Why? Because our faculty and students are discovering breakthrough technology, applying knowledge from other disciplines to their fields in fresh ways and collaborating with scholars from around the world. We’re elevating our understanding of everything from spin theory and its relevance to the evolution of semi-conductors to nanotechnology and its application to medical therapeutics. Our faculty’s research is among the most cited in their fields, evidence of the relevance and importance their colleagues everywhere place on their work.

Perhaps that’s one of the greatest contributions we make to the larger community. Because of our unique position as a leader in research and teaching in engineering and the sciences, we offer insight that allows others to more accurately anticipate the future.

In fact, every article in *Convergence* aims to do that. In this issue, in one particular piece, “The Next Big Things,” we interview faculty in seven different fields, asking the same question: What do you see that we probably don’t even know is coming?

But that’s just a start. Look to us – and this magazine – to provide information that will make it easier for you to know what to expect – and when.

Matthew Tirrell
Dean, College of Engineering

Martin Moskovits
Dean of Mathematical, Life and Physical Sciences, College of Letters & Science

Evelyn Hu
Co-Director, California NanoSystems Institute
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Future vision for an all-optical quantum information processor that exploits photonic communication between electronic spin-based qubits integrated within optical microcavities.

The Magazine of Engineering and the Sciences at UC Santa Barbara
The New Electronics

Semiconductor devices as we know them can’t get much smaller, so industry is looking for a revolution. Will it find one in “spintronics”?
The jury is out on that question and may not deliver a verdict for years. But Intel Corp. and other giants of the U.S. chip business are betting that researchers at UC Santa Barbara and other leading academic institutions will come up with a fundamentally new technology to process information. Spintronics – the manipulation of electrons by the quantum feature known as “spin” – is a leading candidate to play this revolutionary role.

UCSB has long been a key venue for spintronics research. Earlier this year, it joined UC Berkeley, Stanford and UCLA in forming the Western Institute of Nanoelectronics (WIN), one of the world’s largest joint research programs on spintronics and related technologies. WIN started out in March with a four-year grant of $18.2 million, of which $14.38 million comes from semiconductor industry sources and $3.84 million from state R&D funds. Intel is providing most of the industry funds through a newly-formed consortium, the Nanoelectronics Research Initiative (NRI), which it sponsors along with five other companies – IBM Corp., Advanced Micro Devices, Freescale Semiconductor and Texas Instruments.

Why are chip companies willing to commit this kind of money to research that isn’t close to delivering new products? The answer can be seen – through a microscope – in the tiny dimensions of a transistor. This basic component of computers and other semiconductor-based systems has been shrinking for decades due to advances in materials and production methods. The semiconductor business has lived by “Moore’s law” (named after Intel co-founder Gordon Moore) which predicts that the number of transistors that can be squeezed on a given chip will double every 18 months or so.

Feeling the Heat

Up to this point, the law has held. But sometime in the next decade, this march of miniaturization will run into an obstacle that may be insurmountable without a shift to some entirely new technology. Transistors and other devices based on the current technology, known as complementary metal oxide (CMOS) standards, will be too tightly packed to function efficiently. Too much energy will be dissipated as heat in the massive number of connections between the transistors. The seemingly inevitable progress toward smaller, faster devices will grind to a halt.

And why spintronics? The answer here is not quite as easy to picture. If you think of an electron as a body moving through space and rotating around its axes at the same time, like the earth around the sun, its spin is roughly like that rotation. It might even be said to generate a force something like a magnetic field, and different from the electron’s charge. In fact, spin is a basic element of magnetism – an important connection that is already being exploited in magnetic data storage devices such as high-density hard drives.

But with spin, as with other quantum properties, comparisons to objects like planets and the sun only go so far. For example, a rotating object can only spin in one of two directions. If its axis points sideways, it can spin up or down, and that’s it. Physicist David Awschalom, the WIN co-director representing UCSB, explains that quantum spin can be partially up and partially down at the same time. It can be in “an infinite number of states – a bit like a compass needle moving in three dimensions.” This leads to “almost infinite possible states for data storage,” he says. Spin is also a fixed property of each electron, and every electron has the same amount of it. (If electrons were actual spheres generating a spin force through rotation, the force would vary depending on how fast they were spinning). “And in the future, complete control of electron spin may lead to fundamentally new solid state technologies such as quantum computers and communication devices.”

A New Way to Carry Data

What makes spin so interesting to Awschalom and other physicists is the fact that it can be used to carry information. In effect, spin technology adds to an electron’s repertoire, giving it what scientists call an added “degree of freedom” by making it able to convey data by more than one means.

In today’s computers, the 0’s and 1’s of binary code are tapped out by electrons impelled by electrical charges. Manipulating electrons in this way and transporting them through small wires generates heat, which becomes a serious problem when many charges are being moved rapidly in a tiny space. Spin also can be manipulated, but with magnetism or polarized light in addition to traditional electric gates as used to control electric charge. A spin-based device would use these forces to convey data by creating and controlling spin-polarized currents, such as alternating herds of electrons with “up” and “down” spin. Awschalom says such
of key experiments, for instance, he showed that spins in semiconductors could be created coherently and exist for surprisingly long periods of time, and that a spin-aligned group of electrons could be moved up to 100 microns – a sizable distance in the computing microcosm – without losing its coherence.

By now, scientists have reached several key milestones. It is now possible to generate spin on a chip electrically or optically, to transport spin through semiconductors and to keep a coherent population of spins intact for "nanoseconds, even microseconds," says Evelyn Hu, a UC Santa Barbara professor of materials engineering and co-director of the California Nanosystems Institute. But that leaves plenty of work ahead before spintronics can replace CMOS technology in real-world applications.

One challenge is to come up with materials that make spin-based computing possible in not less-than-ideal conditions. It’s one thing for scientists to do a successful spin experiment at or below room temperature. A commercially viable spintronics device would have to perform the same feats reliably under hotter conditions.

"We’re all working on projects that focus on our research interests, but some significant fraction of these efforts are of great interest to industry," says Awschalom.

energy-efficient technology could keep the progress of miniaturization on track and lead to new kinds of multi-function devices, such as a single chip that combines logic, storage and communication.

The history of spin-based technology started with storage. It goes back to the 1988 discovery of the giant magnetoresistive (GMR) effect, in which small magnetic fields act on layers of magnetic and non-magnetic atoms to produce large changes in electrical resistance. GMR materials have been used to increase the capacity of computer hard drives. A new spin-based technology is being developed to create magnetic random-access memory (MRAM) devices that do not lose their data when a computer is turned off.

Spinning Forward

Awschalom, who came to UCSB in 1992 and holds professorships in physics and in electrical and computer engineering, has played a key role in research on spin-based semiconductors for information processing. In a pair of key experiments, for instance, he showed that spins in semiconductors could be created coherently and exist for surprisingly long periods of time, and that a spin-aligned group of electrons could be moved up to 100 microns – a sizable distance in the computing microcosm – without losing its coherence.

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Basic decisions also have to be made about the structure of spintronics devices and the means of connecting them. In fact, the problem of developing coupling and circuits has been designated as one of the central research themes for WIN. As circuitry specialist Mark Rodwell points out, it’s not enough to make semiconductors smaller, faster and more efficient. The whole system, of which they are just a part, has to improve. New spintronics chips may not be a net gain if they require elaborate, expensive and inefficient connections. So Rodwell, a UCSB professor of electrical engineering and head of the university’s nanofabrication facility, is participating in the WIN effort as something of a reality checker, “looking over the shoulders of the guys who are making these devices … to see how they are better for computing.” (Rodwell is also working with Physics Professor James Allen, head of the WIN spin logic devices team at UCSB, to create spin-based radio-frequency filters that could be placed on mobile-phone chips).

Back to Bell Labs?

This focus on the practical extends to another main WIN research theme – metrics and benchmarking, which Hu calls “unusual for a university.” WIN is clearly designed to point the way toward workable technology and marketable products. But at least for the near term, it will be mostly about basic research. Scientists will be exploring new frontiers of technology while trying to keep an eye on the ultimate goal of producing something useful.

Hu compares this effort to corporate-sponsored research of an earlier era – such as AT&T’s Bell Laboratories, where she worked as a researcher before coming to UCSB in 1984. In those days, giant companies such as IBM, Hewlett Packard and the old AT&T had the means (and relative freedom from competition) to hire scientists and give them free rein to do work with no apparent near-term payoff. Those days are gone, Hu says, and even an industry leader like Intel can’t afford to fund such research on its own. But “high technology companies will have to look ahead,” she says, “and take advantage of things that come out of left field.” And to get the benefits of basic research, they are banding together with major universities to probe the potential of spintronics.

As with any basic research, where it ultimately leads is not obvious. But industry seems happy to pay for a major program that focuses academic brainpower on the goal of a new electronics. And plenty of scientists have their eyes on the same prize. “We’re all working on projects that focus on our research interests, but some significant fraction of these efforts are of great interest to industry,” says Awschalom. “That’s the motivating basis for coordinating a spintronics science and technology program within WIN.” He adds that the outcome may surprise everyone: “With any new discovery, the greatest impact is rarely the one you foresee.”

Conceptual view of a multifunctional spintronic chip that combines high-speed logic, memory and communication functions within a single platform.
As UC Santa Barbara professor Joel Rothman describes it, the ability of our cells to self-destruct is as crucial to our health — and as routine — as is their constant reproduction. Of the approximately 100 trillion cells in each of us, about 100 billion cells are born, and another 100 billion die on any given day. For instance, cells are programmed to die when infected by a virus, so that the virus cannot spread. This programmed cell death process is also used to eliminate the large number of potential cancer cells that we generate each day. The death program is tightly orchestrated so that, rather than bursting and releasing dangerous substances, cells are cleanly eliminated and their remnants neatly absorbed by healthy cells. “If our cells weren’t able to commit suicide, we would not survive for long,” Rothman says.

Scientists have long known about this process, and they know what happens when it goes awry. Too little cell death leads to out-of-control cell growth, as in cancer. Too much leads to degenerative diseases, such as Parkinson’s, ALS and Alzheimer’s. Cell death on a massive scale occurs when oxygen re-enters tissue after a heart attack or stroke; in these cases, the harm done in the aftermath of the event is often much more serious than damage arising during the initial event.

All our cells are poised on the knife edge, and it is critical that the death switch is triggered only at the right time and place," Rothman explains. "Because of that, the architecture of the death switch — its regulatory system, is very complex. There are lots of inputs, and the switch needs to be keenly tuned."

Researchers in Rothman’s group are investigating the nature of the cell-death program and how it might be manipulated. “We’re trying to understand this on-off switch and how to control it,” says Rothman, who holds positions in the BioMolecular Science and Engineering Program and the Neuroscience Research Institute, as well as the Department of Molecular, Cellular and Developmental Biology. What Rothman and his colleagues have learned so far is that the cell death process is anything but simple.

“If the trigger were a simple switch, we’d probably have it mostly figured out,” Rothman says. On the contrary, the mechanism works as a high-performance computer, constantly analyzing a flood of data to choose continued life or death in the cause of ensuring the larger organism’s survival. “All our cells are poised on the knife edge, and it is critical that the death switch is triggered only at the right time and place,” Rothman explains. “Because of that, the architecture of the death switch — its regulatory system, is very complex. There are lots of inputs, and the switch needs to be keenly tuned.”

Reading the Body’s Signals
Those inputs include both internal and external signals, and come from a wide variety of sources. The cell-death process can be triggered by infection, damage to the cell’s DNA from radiation or toxins or normal tissue development (for example, embryonic human fingers initially grow with webs that are programmed to die away). Another factor is homeostasis, the maintenance of a stable environment within an organism.

The dying process itself is complex. “Apoptosis,” the most common type of programmed cell death, is activated by specialized proteins called caspases. These cellular knives selectively break down the cell’s structure and shut down its functions, until the remnants of the cell are ready to be consumed by scavenging phagocytes — cells that destroy and ingest foreign matter to keep it from harming an organism.
The study of the genetic programs for cell death goes back at least to the mid-1980s, when MIT biologist H. Robert Horvitz identified the first genes required for apoptosis and later showed that a caspase is the essential trigger for this process (Horvitz shared the 2002 Nobel Prize in Medicine for this work). The pace of discovery has accelerated in recent years with the advent of a powerful tool, called RNAi (RNA interference), which can be used to turn off the functions of genes individually, allowing researchers to determine the role of that gene in the entire organism. Scientists thus can learn which genes influence which processes, and how those processes might be changed by manipulating genes.

Tim Bloss, a post-doctoral researcher working with Rothman, says a typical experiment involves using RNAi to stop the activity of a particular gene and comparing the numbers of live and dead cells that are found when the gene is active. “I can literally count the number of cell deaths that occur in the presence of this activity and in the absence of this activity,” Bloss says.

From Genes to "Modules"

By using RNAi in experiments on the tiny roundworm Caenorhabditis elegans (C. elegans), scientists have greatly expanded the list of genes that have some role in cell death. Rothman says about 100 new genes have been found in his laboratory that help to keep cell death turned off, though this is not necessarily their only function. These genes do not work independently. They act as part of a system — more precisely, in what Rothman calls “modules” within a system. Among the 100 or more genes involved in cell death, for instance, several may work together to carry out a particular function. Rothman uses the analogy of a carburetor in an automobile engine. A particular gene may be analogous to a valve in the carburetor, while the carburetor as a whole is a “module” that mixes fuel and air for the engine.

Rothman is currently working with Ambuj Singh, a UCSB professor of computer science, to figure out how the genes and modules work together. Success in this quest may lead to the development of precisely targeted drugs. Several mechanisms — genetic modules — apparently work together to make a cell commit suicide or to prevent it from doing so. If there were three such modules in a particular type of cell, for instance, separate drugs might be developed to interfere with each of them, either to hasten cell death in a malignant tumor or, in the case of degenerative disease such as Alzheimer’s, to slow it down.

Using both computational and functional genomics methods, Pradeep Joshi, a postdoctoral scientist in Rothman’s lab, has discovered that many of the new genes they have identified appear to link the cell death process with other cellular functions. “We were startled to find that the genes that we implicated in cell death regulation
UC Santa Barbara, already a key venue for nanotechnology research, recently broadened its research focus to take in the big picture. Its Center for Nanotechnology in Society, which opened in January 2006 with a five-year grant from the National Science Foundation, brings scholars from the humanities and sciences together to study how the new ultra-small-scale science and technology are affecting – and being affected by – public perceptions, attitudes and actions. Convergence recently interviewed the Center’s co-directors, Barbara Herr Harthorn and W. Patrick McCray. Harthorn, an associate research anthropologist, is associate director of the Institute for Social, Behavioral, and Economic Research (ISBER). McCray is an associate professor of history with a research and teaching focus on contemporary science and technology. Here are highlights of the interview.
W. Patrick McCray: I would broaden that even further and say that nanotechnology is only one of a whole host of emerging technologies. Surrounding emerging technologies, whether it’s stem cell research or genetic research, involve a certain realm of speculation. Accompanying that is a fair amount of hyperbole both in terms of possible benefits as well as possible detrimental outcomes. I think the research that’s being conducted at the CNS gives us a chance of peeling back some of those layers of hyperbole and studying some of the underlying issues involved with promoting science and technology.

Barbara Harthorn: Well, I would say the “why now?” is not so much what we proposed, but the fact that the National Science Foundation put out a call for such a national center proposal. Our fundamental mission is to contribute to the understanding of societal issues around emerging nanotechnologies.

McCray: I have a Ph.D. in materials science.

Harthorn: Right. But with the benefit of focused assistance from our nanoscience and engineering colleagues.

McCray: Also, from the very beginning of putting the proposal together we have very good and close collaborations with people from the sciences and engineering. Evelyn Hu [professor of electrical and computer engineering and materials, and co-director of the California Nano-Systems Institute] is on our executive committee. Also, we not only have five fellowships for students from the social sciences and humanities, but we also have four fellowships for people from the sciences and engineering.

Harthorn: I’m the daughter of an acoustics physicist and a civil engineer, so I don’t have a disinclination toward science. But like most of the social scientists involved in this, I have had to work hard to increase my own literacy, and our social science graduate fellows have to do the same. There is a benefit to that. I’m a participant in the process of becoming knowledgeable enough to understand what nanotechnology is about and what the societal benefits and risks might be.

In other words, you’re walking in the public’s shoes.

McCray: I was in Montana at a science policy conference and got an email from Evelyn [Hu] saying that the NSF had made an announcement that they were going to fund
think the work on nano-electronics allows us to shine a light on the synergistic relationship between the university, industry and military. I am also interested in how instrumentation like molecular beam epitaxy has facilitated scientific research.

You mention on your website the transistor as something that at the time – 1947 – no one had any idea of the vast effect it would have on the life everybody leads. Would it have made any difference if there had been something like this center around then?

McCray: I’m inclined to think that the things – whether it’s in science or society – that are truly revolutionary are happening underneath our noses and we’re not aware of them, and it’s only with the benefit of hindsight, of looking back a number of years and saying, “Oh, the invention of the transistor. This was a pivotal moment.” At the time of the transistor’s invention, the news from Bell Labs was buried on page 46 in The New York Times. No one other than a few people in the Army Signal Corps had any interest in applications for this new device, and for them it was primarily seen as a way to make electronics lighter so that soldiers could carry more stuff and so forth.

Harthorn: As an applied anthropologist, I guess I would take a more optimistic stance about the possibility of change. I do think that if you look at the way past risk controversies have emerged, there are lots of examples available now and they’re well acknowledged in a whole series of National Research Council publications, for example. I think we’re at a point in this society where there’s no alternative but to go down this path, to move toward more public engagement in development.

Dr. Harthorn, in your area it seems that your focus is almost automatically going to be toward trying to shape policy, or certainly to shape attitudes.

McCray: My group’s looking at historical context of nanotechnologies. I’m doing this in conjunction with a colleague at Chemical Heritage Foundation in Philadelphia and another colleague at Duke University. For the first year or so we are going to be looking at the history of the work in nano-electronics, which works out well because there is so much activity here on campus with that. I’m interested in studying the effects of different funding agencies on the nurturing of nano-electronics.
how to assess them – how it’s not one thing, but rather it’s chemicals, it’s particles, it’s hybrid materials and complex systems, and many different things that are being regulated.

That raises another question about nanotechnology. First, exactly what is it? There is a functional definition of things happening at the scale of one to 100 nanometers, but is there a more precise way to identify what you’re talking about?

McCray: The definition that we’re using at the center is one that is drawn from the National Nanotech Initiative web site, and I think it is a fairly good one. It talks about not only the size scale, which is important, but it also talks about the second component, which is a certain amount of precision control over what you’re doing. So I think it would be a real reach to refer to a diesel bus as producing nanoparticles simply if it forms exhaust, since the exhaust isn’t something that’s being precisely controlled, whereas with MBE techniques or whatever, you’re attempting to precisely build up a certain type of structure at the nano-scale with actual control over the process.

How much does the public need to learn about nanotechnology?

Harthorn: There’s no question that public awareness in the U.S. is low, which again is an incredible opportunity for a research operation like this. It’s part of our mandate as a center to be an information source for the public. I also think enhanced understanding will reduce the kind of bifurcated polarization I talked about earlier, because the more you know, the more complicated things get, and the less you tend to reduce things to really simple yes-no kinds of solutions.

One more question for both of you. What do you expect, if we were to have this conversation five years from now? What would you like to say you have accomplished by then? And where do you see nanotechnology by that time?

McCray: I like to think that at the end of five years we will have done a lot of really interesting research in the social sciences and humanities. We will have trained and have helped train a cohort of undergraduate and graduate students. I think we will have a better sense of how science and technology initiatives work and how science communities emerge and change over time. As a historian, I certainly wouldn’t want to make any predictions as to where nanotechnology will be in five years, but my guess is that if I read this interview five years from now I will be surprised by what has taken place. My guess is that it will not be anything that I have thought of.

Harthorn: I agree with that, and I also hope we will have both participated in, and to some extent have helped shape, the debate in constructive directions – and that’s an ambitious and worthwhile and indeed necessary goal.
SOLVE THIS.

See solution on inside back cover.
Researchers here have developed a new biotechnology that enables scientists to identify and engineer protease substrates, giving them the means to craft pharmaceuticals to outsmart disease. Their work, authored by Patrick Daugherty, an assistant professor of Chemical Engineering, and Kevin Boulware, a PhD candidate, were published in the *Proceedings of the National Academy of Sciences*.

Proteases (or peptidases) are encoded by about two percent of genes in the human genome and play key roles in nearly all diseases. They act as “molecular scissors” by attaching to specific sequences contained within other proteins, called substrates, and cutting them in specific locations.

For example, proteases are responsible for digesting food, for determining the proper time for cells to die, and for removing damaged proteins from the body.

But the substrates for most proteases are unknown, and this has limited researchers’ ability to facilitate or thwart protease action. By identifying substrates, scientists gain the ability to regulate protein function, creating the capacity to speed up, slow down or eliminate particular protease actions. Daugherty’s approach also makes it easier to measure protease action and thus develop pharmaceuticals that control protease activity.

Daugherty and Boulware developed a general combinatorial approach to identify optimal substrates of proteases, using quantitative kinetic screening of cellular libraries of peptide substrates (CLiPS). The results suggest that CLiPS will be broadly useful for characterizing proteases and developing optimal substrates for therapeutic applications.

Of the roughly 1,000 proteases in the human genome, only about 10 percent of the targets have been identified, but Daugherty believes that scientists will identify nearly all of them in the next five to 10 years. “This technology will give us a scalable tool that will allow us to effectively tackle this challenge,” he says.

### Shape matters to macrophages; phagocytosis depends more on particle shape than size.

The UCSB research, which has far-reaching implications for immunology, vaccine development and drug delivery, was published in the *Proceedings of the National Academy of Sciences* by Samir Mitragotri, a UCSB professor of chemical engineering, and graduate student Julie A. Champion.

Phagocytosis, a key part of the body’s innate immune system, depends on macrophages – the cell’s clean-up crew. The macrophages find and frequently remove particles from the body. Prior to this discovery, it was believed that the ability of a macrophage to process a particle through phagocytosis was dependent solely on its size. Previous studies have been performed only with spherical samples because it was presumed that size was the main issue in phagocytosis, and because fabrication of non-spherical particles of controlled dimensions has been difficult.

The researchers used macrophages from alveolar (lung sac) rat tissue and developed polystyrene particles of various sizes and shapes as model targets. Mitragotri and Champion used scanning electron microscopy and time-lapse video microscopy to study the action of the macrophages when presented with targets of varying shapes.

Mitragotri says the next challenge is clear: learning how to engineer the shape of particles to enhance, delay or prevent phagocytosis. Such a discovery, for example, could allow researchers to design drug carriers that can be purposefully retained by the body for a longer period of time, or could help researchers create vaccines that would be quickly removed to stimulate a rapid immune response.

### Overfishing presents a much greater risk to the kelp forest ecosystems than do the effects of run-off from fertilizers or sewage.

Overfishing presents a much greater risk to the kelp forest ecosystems that span the entire West Coast than do the effects of run-off from fertilizers or sewage, say scientists here. In an article published in Science, researchers describe the first study to compare the top-down versus bottom-up human influences on the food chain of the kelp forest ecosystems. The study was conducted by scientists at UCSB’s National Center for Ecological Analysis and Synthesis, known as NCEAS.

“Overfishing presents a much greater risk to the kelp forest ecosystems than do the effects of run-off from fertilizers or sewage,” says first author Ben Halpern, project director...
at NCEAS. The research team took data from four years of marine life surveys by the National Park Service. The park service regularly checks 16 different kelp forest sites around the Channel Islands off the coast of Central California, an area about half the size of Rhode Island. Next, the scientists matched data from the park service with data provided by SeaWiFs, a satellite monitoring project that photographs and analyzes ocean color for information about ocean life.

Organic coastal run-off – from fertilizers and sewage overflow – increases the amount of organic material in the near-shore ocean. According to the study, differences in the amount of organic material do not have much effect on the delicate food chain of the kelp forest ecosystem, except at extreme levels. However, removal of the fish at the top of the food chain has a profound effect.

An international team of scientists are delving into secrets of the ocean’s crust. The researchers have, for the first time, recovered black rocks known as gabbros from intact ocean crust, according to an article in Science Express, the Internet edition of the journal Science.

Douglas S. Wilson, an associate research geophysicist with the Marine Science Institute at UCSB, is co-chief scientist among five and was involved with three expeditions. Wilson originated the idea for these missions through study of the ocean crust’s magnetic properties. The site of the drilling was approximately 800 kilometers west of Costa Rica.

Geophysical theories have projected that oceanic magma chambers freeze to form the coarse-grained, black rocks known as gabbros, commonly used for facing stones on buildings and kitchen countertops. Although gabbros have been sampled elsewhere in the oceans, where faulting and tectonic movement have brought them closer to the seafloor, this is the first time that gabbros have been recovered from intact ocean crust.

“Finding the right place to drill was probably key to our success,” said Wilson. His research identified a 15-million-year-old region of the Pacific Ocean that formed when the East Pacific Rise was spreading at a rate of more than 200 millimeters per year, much faster than any mid-ocean ridge on Earth today.

This achievement will ultimately help science answer the important question of how new ocean crust is formed. The formation of ocean crust is a key process in the cycle of plate tectonics and constantly “repaves” the surface of the Earth, builds mountains, and leads to earthquakes and volcanoes.

Scientists discover a genetic switch that links animal growth and cancer.

Experiments were carried out by first author Masamitsu Fukuyama, a postdoctoral scientist working in the laboratories of Joel H. Rothman, a professor in the Department of Molecular, Cellular and Developmental Biology at UCSB, and Ann Rougvie, a professor in the Department of Genetics, Cell Biology, and Development at the University of Minnesota. The findings are reported in Current Biology.

“The parallels between the control of development during the normal process of maturation and the control of cancer growth are striking,” said Rothman.

“We recognize that cancer cells in many ways simply mimic what normal cells do in a developing animal, only at an unfortunate time and place.”

Many cells remain quiescent until they are triggered to grow or multiply by an environmental cue, such as a hormone or injury. Cells possess natural braking mechanisms that keep them in this quiescent state. When the brakes fail, cells that should be static start growing and dividing, leading to cancer. These brakes are proteins called tumor suppressors.

Working with a tiny roundworm known as Caenorhabditis elegans, an important animal model in biomedical science, the researchers discovered that a tumor suppressor known as PTEN also functions to keep the animal in a waiting state by blocking cell growth when food is absent.

If these animals hatch from their eggs without any source of nutrition, they are able to remain in a perpetually young state for a long time without growing. When they eventually find food, they start maturing. The researchers discovered that this juvenile-to-adult switch is controlled by PTEN. When the gene for PTEN is defective, the animals attempt to grow and become mature even when they have no food.
A new lipid molecule discovered here may help fight disease through gene therapy. For more than two decades, gene delivery has been accomplished by using engineered viruses as a vehicle to get into diseased cells. But, the viruses used for gene delivery occasionally evoke severe immune responses, so scientists continue to search for non-viral delivery vehicles.

Reporting in an article in the Journal of the American Chemical Society the authors describe the synthesis of a new lipid molecule created at UCSB. Lipid DNA complexes are attracting increasing attention as non-viral DNA delivery vehicles.

The novel lipid molecule has a tree-shaped, nanoscale head group and displays unexpectedly superior DNA-delivery properties. “It generates a honeycomb phase of lipid DNA complexes,” said Cyrus R. Safinya, a professor of materials; of molecular, cellular and developmental biology; and of physics here.

The new molecule was synthesized in Safinya’s laboratory by first author Kai K. Ewert, a synthetic chemist who is a project scientist in the research group.

“We’ve been trying to get a lipid-based honeycomb lattice for a long time,” said Ewert. The structure of lipid DNA complexes strongly affects their ability to deliver DNA.

Five UCSB faculty members win National Science Foundation CAREER awards from the National Science Foundation. The Faculty Early Career Development (CAREER) Program supports the early career development activities of those teacher-scholars who the NSF identifies as being the most likely to become academic leaders.

CAREER awardees are selected on the basis of creative proposals that effectively integrate research and education within the context of the mission of their organization. The financial awards will be paid out over a five-year period.

The winning faculty members and their projects are: Jeffrey Moehlis, assistant professor of mechanical and environmental engineering, who will receive $400,000 to pursue a project entitled “Dynamics of Individual and Coupled Oscillators”; Chandra Krintz, assistant professor of computer science, who will receive $400,000 to pursue a project entitled “VIVA-Vertically Integrated Virtualization: Automatic, Full System, Specialization for High-Performance Computing”; Ben Zhao, assistant professor of computer science, who will receive $400,000 to pursue a project entitled “GAIA: A Self-organizing, Self-healing Network Infrastructure”; Thuc-Quyen Nguyen, assistant professor of chemistry and biochemistry, who will receive $511,278 to work on a project entitled “Structure-Function-Property Relationships in Charged Conjugated Polymers”; and Jennifer Earl, assistant professor of sociology, who will receive $404,999 to pursue a project entitled “The Internet, Activism and Social Movements.”

Two UCSB professors — David Awschalom and Michael Goodchild — have been elected fellows of the American Academy of Arts and Sciences. Also elected was Fred Kavli of Santa Barbara, for whom UCSB’s Kavli Institute for Theoretical Physics is named.

The academy’s 2006 class of 175 fellows and 20 foreign honorary members also includes former Presidents George H.W. Bush and William Jefferson Clinton; Supreme Court Chief Justice John Roberts; Nobel Prize-winning biochemist and Rockefeller University President Sir Paul Nurse and many leading scientists and scholars from across the nation. The academy’s broad-based membership, composed of scholars and practitioners from diverse fields, enables the organization to conduct a wide range of interdisciplinary studies and public policy research. The current membership includes more than 170 Nobel laureates and 50 Pulitzer Prize winners.

The election of Awschalom and Goodchild brings to 23 the number of UCSB faculty members who have been elected fellows of the academy. Awschalom, a professor of physics and of electrical and computer engineering, is director of the Center for Spintronics and Quantum Computation at UCSB and associate director of UCSB’s California NanoSystems Institute. Goodchild is a professor of geography and an internationally recognized pioneer in computer-based geographical information systems.
Frédéric G. Gibou, an assistant professor of mechanical engineering and computer science at UCSB, has won a Sloan Research Fellowship from the Alfred P. Sloan Foundation. Sloan Fellows are engaged in research at the frontiers of physics, chemistry, computational and evolutionary molecular biology, computer science, economics, mathematics, and neuroscience.

The new Sloan Research Fellows were selected from among hundreds of highly qualified scientists in the early stages of their careers on the basis of their exceptional promise to contribute to the advancement of knowledge. In the 50 years that the Alfred P. Sloan Foundation has been awarding research fellowships, 34 former Sloan Fellows have received Nobel Prizes.

Gibou’s research is focused on the design of new computational algorithms for a variety of applications including materials science, computer vision with an emphasis on the segmentation of medical images, and computational fluid dynamics.

The Sloan Fellowships are intended to enhance the careers of the very best young faculty members in specified fields of science. The award is for $45,000 over a two-year period. Funds are awarded directly to the Fellow’s institution and may be used by the Fellow for such purposes as equipment, technical assistance, professional travel, trainee support, or any other activity directly related to the Fellow’s research.

The once generic “Engineering I” building has been renamed Harold Frank Hall in recognition of the generosity of Diana and Harold Frank, of Santa Barbara. Harold Frank, an engineer, has been a great friend of UC Santa Barbara and a distinguished local business leader who built and headed Applied Magnetics for many years.

“We believe in the school and love having it here in Santa Barbara,” said Diana Frank. “Harold met with much success in this town and we want to give back.”

Matthew Tirrell, Richard A. Auhll Professor and Dean of the College of Engineering, said the faculty, students and staff are grateful for the Franks’ generosity and commitment. “The Franks are wonderful people who have a deep interest in supporting higher education and engineering and believe in the work we do,” he said.

The 60,000 square foot, five-floor building was built in 1966 and houses the Dean’s office, the departments of Computer Science and Electrical and Computer Engineering, research and teaching labs, classrooms, a lecture hall and conference rooms. The Franks’ gift will help renovate and update the building.

A small, private celebration with the donors was held in May.
The Neuroscience Research Institute was awarded a $1.25 million grant by the W.M. Keck Foundation. The funding will be applied to a multidisciplinary research initiative focusing on microRNAs and their impact on the regulation of gene function.

“The scientific knowledge that is likely to emerge from the proposed work will be fundamental for a comprehensive… understanding of the biological pathway to therapeutics,” said Kenneth Kosik, M.D., who will lead the project. Kosik is the Harriman Professor of Neuroscience Research and co-director of the Neuroscience Research Institute. Although many laboratories have validated the biological and potential therapeutic importance of microRNAs, UCSB is the only campus moving this technology to actual intervention, said Kosik, who is also a professor of molecular, cellular, and developmental biology.

Funding from the W. M. Keck Foundation will also support Keck Graduate Fellows and Keck Postgraduate Fellows who will work under the direction of six leading UCSB scientists. That research team includes Frank Doyle, Mellichamp Professor of Chemical Engineering; Samir Mitragotri, assistant professor of chemical engineering; Linda Petzold, professor of mechanical and environmental engineering; Joel Rothman, professor of molecular, cellular, and developmental biology; and Boris Shraiman, professor of physics and a permanent faculty member at the Kavli Institute for Theoretical Physics.

UCSB-led collaboration of six universities received a Department of Defense grant to develop a multifunctional chip. The Department of Defense has awarded up to $5 million over five years for a multi-university research initiative (MURI) led by David D. Awschalom, a professor of physics and of electrical and computer engineering, to develop a chip that can independently process electronic, magnetic, and optical information and convert from any one type to any other type of information.

Described as a “multifunctional” chip, it would be highly compact and use considerably less power than would a system constructed from several components to perform the same function. Current electronic devices rely on the electron charge to transport and store information, but the new technological approach to be pursued by this collaboration relies on using another property of the electron, called “spin,” to store and transport information, and to interface with optics and magnetics. The MURI consortium includes UC Santa Barbara, Cornell University, Pennsylvania State University, The University of Iowa, The University of Minnesota, and the University of Virginia.

This work opens the door to new opportunities for research and technology in the emerging fields of semiconductor spintronics and quantum computation, including the development of fundamentally new systems for high density storage, ultra-fast information processing, and secure communication.

Awschalom is director of the Center for Spintronics and Quantum Computation at UCSB. He also serves as associate scientific director of the California NanoSystems Institute (CNSI).

Written and reported by staff writers and editors, and by staff from the Office of Public Affairs.
What discoveries and technologies are set to transform the sciences – and our lives? Convergence asked seven UCSB experts to take a five-year forward look at their research fields, ranging from computer science and cancer to earthquakes and astrophysics. Here are some of the major developments they expect to see.

The Next Big Thin
The Everywhere Internet

You may think the Internet is already well-nigh ubiquitous, what with Wi-Fi at the local Starbucks and email to go via BlackBerrys and Treos. But Kevin Almeroth, a UCSB professor of computer science, says you will see a lot more of it in the next few years—and that, in its way, it will be seeing a lot more of you.

Almeroth contemplates a future in which “bandwidth and latency in transmission speeds are never a concern” and people can access whatever data they want. “In the next five to 10 years, everything is going to be essentially at your fingertips and instantaneous,” he says. The Net also will work unnoticed, deeply embedded in devices such as phones and automobiles. Almeroth offers a “far out” example that is really not so far away: Imagine driving a car wearing goggles that display information while allowing you to keep your eyes on the road. Now imagine getting messages from the Internet about traffic conditions, shopping en route and much else—like the McDonald’s up the road where there’s no line at the drive-through window. “We won’t even think that the network is there,” he says.

Computer scientists will be kept busy working on the protocols and other infrastructure to extend the Internet’s reach. But Almeroth thinks the more interesting developments will be societal, not technological—such as expanded social networks and new methods of political organizing.

The flip side of all this networking is that the Internet will be hard to escape or avoid. Online threats to privacy are already a hot topic, and Almeroth suggests they’ll just keep getting hotter. In the future, he says, “we’ll look back and say, ‘Wow, it’s amazing how anonymous everyone was.’ You will have a hard time going anywhere and not having information collected on you. All information, even stuff you don’t want people to know, is going to be available, and we’ll need mechanisms to deal with that.”

Almeroth is optimistic that such problems can be worked out, though not without “growing pains.” And for all our complaints about new technology, he says, it’s hard to imagine going back to the old days: “You only have to think how traumatic it was before cell phones when a meeting had to be re-scheduled at the last minute.”

Cracking the Stem-Cell Code

Among the many scientific, ethical and political questions concerning embryonic stem cells is a very basic one: How do they work? Their capacity to develop into most types of human tissue makes them potentially valuable on many medical fronts—healing injuries, growing organs and treating degenerative diseases such as Alzheimer’s and Parkinson’s. But the genetic program that underlies this quality called “pluripotency” is not yet known.

Dennis Clegg, professor and chair in UCSB’s department of Molecular, Cellular and Developmental Biology, says cracking that code is the most significant development on the horizon in stem-cell science. Once it’s known, scientists will have the key to creating stem cells out of the vastly more numerous “differentiated” cells that can replicate only one kind of tissue. “If we can understand the molecular basis of ‘stemness,’ it will be possible to reprogram a differentiated cell and make it a stem cell,” says Clegg. “So if one suffers from heart disease, one’s skin cell could be extracted and converted to a heart cell to treat the condition.”

It will be no small task to find all the genes (out of about 33,000 in the human genome) that have a role in the production of stem cells. But scientists have shown that it is possible for a nucleus from a somatic cell (not an egg or sperm) to become an egg-cell nucleus when inserted into an oocyte, a precursor to an egg cell. This is the process by which “Dolly” the sheep was cloned. Clegg says “there must be factors in the nucleus” that make this reprogramming possible.

Finding the secret of “stemness” would not just open a possible path to cures for dreaded diseases and paralyzing injuries. It also would bypass the central stem-cell controversy by showing how to produce stem cells without using human embryos. And Clegg hopes to see another controversy—over the legality of a $3 billion bond issue that California voters approved for stem cell research in 2004—brought to a favorable close. Getting that money “would really step up the pace” of scientists’ work, he says. “California could become the real center for stem-cell research.”
Robo-Viruses for Gene Therapy

Delivering the goods is also a key theme for the near future of gene therapy. UCSB’s Cyrus Safinya says scientists are working to create chemical carriers that work just like viruses without the risks.

Gene therapy seeks to treat disease by inserting DNA or other genetic material into cells. The object is to replace defective genes with healthy ones (particularly in hereditary diseases) or, using molecules that “turn off” certain genes, to suppress harmful genes in diseases such as cancer. Safinya, a physicist by training who holds faculty positions in materials science and biology, says viruses are logical carriers because of their evolved ability to penetrate cells and proliferate. Most gene-therapy clinical trials use actual viruses. But viruses have a way of getting out of hand and harming the patient that gene therapists want to save.

Enter the synthetic virus. Safinya and other researchers are designing new substances – such as cationic lipids and polymers – that ape the behavior of viruses as chemical carriers without reproducing uncontrollably. They are also working on molecular-scale nanotubes, of viral size or smaller, to replicate viruses’ size and shape. “The object in the end is to copy as much of the virus as possible,” says Safinya, because the virus through evolution “has figured out how to get to the optimal size.”

It will take some time to put this research into practice. Over the next five years, Safinya says, “there will be a lot of progress in the development of carriers, but in terms of applying this technology to therapies, that’s another 10 years. There’s a lot of R left in the R&D.” But if it’s hard to predict the next five years, he says it’s “easier to guess the next 10 to 20” – when he hopes to see robo-viruses entering the medical mainstream.

Cancer: Delivering the Cure

One of today’s big stories in the fight against cancer is the development of targeted therapies – drugs, such as Herceptin for breast cancer and Avastin for colon cancer, designed to destroy specific types of tumor cells while leaving healthy cells unharmed. The shotgun approach of chemotherapy, which attacks harmful and healthy tissue alike, may soon be a thing of the past.

The task now, says biologist Erkki Ruoslahti, is not only to come up with new tumor-specific drugs but also to develop technologies to get them to their targets. Understanding of cancer at the molecular level has advanced sharply in recent years. Now, Ruoslahti says, “the biggest challenge and the biggest development in the next few years will be the application of what we have learned about cancer in new therapies.”

Ruoslahti holds the post of distinguished professor at UCSB and a similar position at the Burnham Institute in San Diego. He says he has spent most of his career studying cell adhesion – “how cells find their right place in the body, and why cancer cells don’t follow these rules.” That line of inquiry has led him recently to focus on the chemical structure of blood vessels and how certain molecules home in on certain “ZIP codes,” or points along the blood-vessel lining that are associated with specific tissue types (including tumors). He is isolating peptides (a type of molecule formed by amino acids) that recognize these signatures and may then carry drugs or other therapeutics to their appropriate targets.

Meanwhile, the genetic science that led to these targeted therapies continues to advance. “The next thing will be to reduce the cost of determining anyone’s genetic makeup,” Ruoslahti says.

“They’re talking about the $1,000 genome. Of course, we’re nowhere near that. But it’s coming.”

Viral-sized molecular-scale nanotubes developed in Safinya’s laboratory are able to replicate a virus’ shape and size. This enables them to cross cell membranes and be effective non-destructive drug delivery agents.
From Light Waves to Gravity Waves

Since at least as far back as Galileo, astronomy has lived by technology. New tools, especially new telescopes, have advanced the science by opening new vistas on the universe. Lars Bildsten, a UCSB professor of physics and a permanent member of the Kavli Institute for Theoretical Physics, says this process is far from over. “The field is still very much driven by which telescopes and technologies we have, and the discovery space is still quite large.”

In fact, he says, the next few years will see not just more powerful telescopes, but at least one telescope of an entirely new kind, measuring waves of gravity rather than waves of light.

Gravity waves are different. These changes in the gravitational field caused by massive objects such as neutron stars and black holes roll through space unimpeded and undiminished. Two gravitational-wave detectors, together known as the Laser Interferometer Gravitational Wave Observatory (LIGO), are now going through a lengthy test run. Unlike like traditional telescopes, they consist of corridors more than two miles long in which laser beams detect gravity waves by recording the minute movements (less than the width of an atomic nucleus) between suspended balls of fused silica.

Federal budgets permitting, Bildsten says, LIGO should be ready for full-scale observational work in four years or so.

In the meantime, optical astronomy is continuing to move forward with the aid of computing. Like massive digital cameras, telescopes can now record vastly more data than was possible with film or glass plates. One telescope soon to come on line in Hawaii will take a minutely detailed picture of the whole sky each night, giving scientists new ability to detect changes and find new objects such as near-earth asteroids. Thanks to the marriage of telescopes to digital technology, Bildsten says, “You will see a huge explosion of data in the next one to five years.”

"In fact," Bildsten says, "the next few years will see not just more powerful telescopes, but at least one telescope of an entirely new kind, measuring waves of gravity rather than waves of light."
The Future Looks Colorful

Shuji Nakamura, professor of materials at UCSB and winner of the 2006 Millennium Award, has made his mark on the world by inventing the white, green and blue light-emitting diodes (LEDs), as well as the blue laser. The results of his work show up all over – in forms such as energy-efficient flashlights, high-definition DVD and multi-story TV screens. He says more bright ideas are on the way.

One is the green laser. Added to the current palette of red and blue lasers, a laser beaming green light would enable engineers to create any color in the rainbow. Television using laser diodes in these three colors would be exceptionally vivid and lifelike. The challenge, says Nakamura, is to find a material that can emit pure green light. So far, engineers haven’t found one, but he thinks the problem will be solved. Five years from now, he says, “We probably could make a laser-diode TV.”

The LED technology in which Nakamura has played such a key role is also headed in new directions. One is up the frequency scale, from blue to higher-energy ultraviolet LEDs (Japanese researchers recently announced the creation of a deep-UV – 210 nanometer – LED made from aluminum nitride doped with silicon). One use for this new technology is environmental. “UV emissions could be used to clean the air and water,” Nakamura says. The U.S. military has shown an interest in using UV LEDs not just to decontaminate water (by killing bacteria and viruses) but also to detect biological agents such as anthrax.

In Nakamura’s view, the LED revolution is just getting started. Already, LEDs are significantly more efficient than older methods of converting electrical light. The same amount of power that produces 15 lumens from an incandescent bulb and 70 lumens from a fluorescent light can generate 100 lumens from a white LED. Thanks to advances in materials, Nakamura says the LED could be in the 150-to-200 lumen range in five years. And that level of efficiency, he points out, “can save a lot of energy.”

From Quakes to Climate, a Drive for Data

What’s the forecast for the earth sciences? Maybe less predicting – or at least a shift in emphasis, away from exact prediction and toward deeper understanding of the past and present in order to determine probabilities of future events. Bruce Luyendyk, professor and former chair of Earth Sciences at UCSB, says “the need for data is definitely the big thing” in geosciences such as seismology and climate change studies.

In other words, the public shouldn’t hold its breath waiting for a reliable method of pegging the time and place of the next Big One. Scientists “have sort of drawn back from the idea of predicting earthquakes,” Luyendyk says. Quake forecasting today is something like “predicting weather back in the 1930s,” long before the days of radar and satellites: “Forecasting earthquakes is a data-rich game, and we don’t have the amount of data for the earth anything like what we have for the atmosphere today.”

Luyendyk says scientists at UCSB and elsewhere are especially interested in data on “strong ground motion” – the amount of shaking one can expect during a major quake. What they learn here can help them better estimate what impact an earthquake on the San Andreas Fault, say, will have on Los Angeles and Santa Barbara, even if they don’t know when such a quake will occur. Gathering such data is expensive, since instruments for measuring ground motion have to be deployed and ready at the time and place of a big quake. And though California “is probably the best instrumented place in the U.S.” in this regard, Luyendyk says “we’re way behind the curve if you compare what we’re doing to what they’re doing in Japan and Taiwan.”

As for climate, the scientists are looking for answers to crucial (and politically sensitive) questions about the causes of climate change and the role that humans play in the process. They have plenty of information about the present climate, but they know too little about the distant past. By drilling for core samples in ice caps and ocean floors, they have reconstructed detailed climate records going back up to one million years. But that may just be the start of their data quest. As Luyendyk puts it, “We need to learn not just how climate worked recently, but also how it worked over the past thousands and millions of years.”
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The venue for this new strain of research, which uses software to store, sort, share and analyze images of the cellular and sub-cellular processes, is UCSB’s Center for Bio-Image Informatics. In operation for about two-and-a-half years under the direction of Bangalore Manjunath, professor of electrical and computer engineering, the center has a mission that might be summed up in two words: organize and interpret. “The goal of the center is to build the infrastructure to facilitate” those processes, Manjunath says.

Biology is a science driven by images. Just think how little would be known about the life of a cell if it were not for the imaging power of the microscope. But when it comes to analyzing these pictures, Manjunath says biology “is probably lagging behind other scientific disciplines” such as earth sciences, where remote sensing and geological image analysis are well advanced. Part of the problem is that the images in biology are extremely complex. They show a great many things going on at once and each image is in some way unique. Their information is difficult to measure, and they are not easily broken down into data that computers can analyze.

Also, the sheer number of images – all the digital files produced from electron and optical microscopes in the course of research – is daunting.

Dealing with Image Overload

The need for new image-organizing tools is easy to understand when one realizes how much data can be created by electron and optical microscopes. Steven Fisher, a UCSB professor of molecular, cellular and developmental biology who is affiliated with the bio-imaging center, studies the mechanics of retinal detachment. He says one set of experiments typically produces a gigabyte of files. This is on top of his analog negatives of 22,000 electron microscope images, most of which have never been published for other scientists to see. A lab at the University of Utah has 100 gigabytes of images directly related to retinal degeneration, Fisher says, “but we have no convenient way to access or browse these images.”

In the old days, Fisher says, he kept analog images organized in notebooks, numbered consecutively for easy reference. “In my file cabinet, I can find one,” he says – though sharing them with other scientists is not so easy. The newer digital files require a more sophisticated system. Filing and retrieving them is a task akin to the managing of digital pictures at home with a program such as iPhoto, but it’s far more complex and cumbersome.

Manjunath and other computer scientists at the center have addressed this problem by developing software to identify and sort image files by animal species, date and other tags (called “meta-data” to distinguish because it is not data within the image itself). To simplify the uploading of images and related information, they have developed a “Digital Notebook” that can load data directly from microscopes.

Building a Visual “Thesaurus”

On the interpretation side, the center has been developing software to mine the image files for scientifically useful knowledge. This can be quantitative, such as the number of cells that survive in a given type of tissue under certain conditions of injury or disease. The software also looks for identifiable patterns or objects, such as a particular cell or molecule. “Visual vocabulary” (ViVo) software treats a recognizable shape as a unit of information – in effect, a word – not only to describe an image but to classify it for retrieval. In a ViVo-based system, a researcher could search a databank to find images containing a particular feature, what Fisher calls a “searchable icon,” much as they would search for text files containing a common keyword.
A mosaic program: analyzed images of control (9 images), 3-days detached (8 images), and 7-days detached (9 images) retinas. Thickness changes are all significant (p = 0.05). Density changes between normal and 3-days detached is significant (p = 0.05), but there is no clear change between 3 days and 7 days detachment.

Fisher says a searchable icon might be an antibody that recognizes the retina's photoreceptor cells. “Lots of other people have used this antibody to study retinal diseases,” he says. “We want to see how it shows up in our images versus those of others.” ViVo software makes this possible. Ambuj Singh, a UCSB professor of computer science who is affiliated with the center, says ViVo is a means of building an “image thesaurus,” which can ultimately be used not only to track the occurrence of individual objects, the “words” of image analysis, but to identify larger structures. Singh calls these “visual phrases,” and they would be searchable much like recurring phrases in a poem.

Image-analysis software also gives scientists a way to track changes within a cell at the molecular level. From a sequence of images they can precisely measure the speed at which microtubules – protein structures with a key role in cell division and other processes – lengthen or shorten. Two center-affiliated UCSB biologists, Leslie Wilson and Stuart Feinstein, are using the new technology to study the growth and shrinkage of microtubules in cancer and degenerative neural diseases (such as Alzheimer’s). Normal microtubule dynamics “are finely tuned and contained in narrow range,” says Wilson, who like Feinstein is a professor of molecular, cellular and developmental biology.

In both cancer and degenerative diseases, the microtubules are outside the range, either growing too fast or too slowly. With imaging informatics, Wilson and Feinstein can measure their growth and shortening in real time. A process that once was done laboriously by hand, one image at a time, is now automated and conveys much greater detail than was possible before. Ken Rose, a professor of Electrical and Computer Engineering, and Statistics Professor Sreenivas Jammalamadaka have been supervising the development of pattern recognition and modeling techniques for microtubules. Also working with Wilson and Feinstein is Sanjoy Banerjee, professor of mechanical and environmental engineering, who has concentrated on high resolution imaging of microtubules.

This image informatics technology is widely applicable, Wilson says. “The kinds of things they’re doing [in the center] are not only relevant to tracking microtubules, but for tracking any particle that you have in cells, even bacteria infecting cells.”

An Expanding Software Toolkit

Most of this analytic software is in development and not yet ready for distribution beyond the community of researchers associated with the center – and with a partner program at Carnegie Mellon University. The “Digital Notebook” software is available via download from the center’s Web site (www.bioimage.ucsb.edu). Also on the site are programs to read and convert image formats, and to count cell nuclei within an image. Led by postdoctoral researcher Kristian Kvilekval, the center has created a data management system called BISQUE (for “Bio-Image Semantic Query User Environment”) as a platform for searching, storing, comparing and exchanging images. Ready for distribution soon will be a tool for image registration, the process of precisely matching multiple images taken of the same object. Another project in the works is a mosaic program, which fits images together automatically to cover large areas at every high resolution.

These and other tools in the pipeline are expected to spur new discoveries once they come into wider use. At this point, though, the excitement among the center’s scientists is mainly about the tools themselves and what they can do. “With our computer capacity we are doing what a human can do, only 100 times faster,” says Wilson. And though human observers will never be out of the picture, he says, they are starting to practice a new, powerful form of observation – a “marriage between the individual person looking at structures and the use of computers to do so in a more quantitative way.”
Southern California commuters know exactly what happens when too many people try to get somewhere on the same freeway at the same time. Everyone sits there and no one gets anywhere. Out of sight and (for most of us) out of mind, the electromagnetic freeway of wireless communication is facing the same fate not far in the future if it is not used more efficiently. The spectrum may be invisible, but it’s not infinite.

What does look infinite, or close to it, is the potential marketplace of devices and services that use the spectrum and demand increasingly larger expanses of it to fit their expanding data. More people are going wireless and demanding richer content when they do. They’re surfing the Internet at the local Starbucks, for instance, rather than just chatting on the cell phone. Meanwhile, new devices keep piling into the wireless networks. Radio sensors beam signals to track merchandise. Robots and other gadgets keep doctors posted on patients. And much of the spectrum is already allocated to designated uses – such as AM and FM radio, television, mobile phones, the military, pagers – leaving precious little for all the new technologies.

The spectrum isn’t filled up yet. But it will take some ingenious management of the available space to keep all those signals moving smoothly. This is where researchers such as Haitao (Heather) Zheng are making their mark. Zheng, an assistant professor of computer science at UCSB, is working on new ways to allocate available frequencies through decision-making rules programmed into the devices – such as laptops – that use a wireless network. This technology is called “cognitive radio,” and it draws on game theory as well as electronics.

Finding and Filling Spectrum Gaps

The traditional method of divvying up the spectrum is top-down: Assigning frequencies to users through licenses or designated bands (as in citizen’s band radio). But this is not a practical way to organize wireless networks that serve a constantly changing population of users, as in airport terminals or coffee shops. It’s also inefficient, because assigned frequencies...
often sit idle. At certain locations and times of day, Zheng says, up to 70% of the spoken-for spectrum may go unused while users without allocated frequencies jostle for room in the available free space.

Cognitive radio, in contrast, is a bottom-up solution. It consists of electronics that scan the spectrum for unused frequencies, enabling wireless devices to find any open slots available for a local network. When they exit the network – when the laptop user leaves the Starbucks, for instance – the slot is freed up for another device (as long as the licensed user of the frequency doesn’t want it).

In cognitive radio parlance, licensed users are “primary” and everyone else is “secondary.” The challenge is to make as much room as possible for secondary users and to distribute it fairly.

That’s not a simple task when the demand for available spectrum nearly outstrips the supply. With no central authority assigning frequencies to the free-floating secondary users, it’s up to the users themselves to work out spectrum-sharing arrangements on the fly. They could do so by communicating with one another – like drivers using turn signals, horns and gestures (friendly or otherwise) to change lanes on a clogged freeway. But this communication uses some of the precious bandwidth. Far from being a solution, it adds to the problem.

Rules for the Wireless Road

The alternative approach – and the focus of Zheng’s work – is to program each of the wireless devices with decision-making rules that enable them to share bandwidth without conflict and without having to send messages. “If you let them collaborate and have certain rules to regulate their behavior,” she says, “then they can sort out all the optimizations on their own without centralized controls.” Zheng has developed an algorithm which each device first detects and chooses idle channels, and then (if necessary) takes channels from other users who have more than they need. The rules boost the overall efficiency of the system by leading users to use channels with the fewest competing users.

Zheng has run simulations to test the validity of this “device-centric spectrum management” model, as she calls it. On that level, it works. But will it keep order in an actual coffee house or university campus? To find out, Zheng is setting up a “test bed” of 20 to 30 users to try out her theory under something like real-world conditions. She says she will have this experiment up and running “probably in a few months,” and she hopes to expand it to include students all over the UCSB campus.

The 30-year-old Zheng is completing her first year at UCSB but has already gained an international reputation for her research. In October 2005, MIT’s Technology Review honored Zheng as one of the top 35 innovators under the age of 35. In April 2006, the magazine listed cognitive radio as one of its “10 Emerging Technologies” and noted Zheng’s work in this area. Entering China’s Xian Jiaotong University at just 15, she started graduate work at the University of Maryland when she was 20 and earned her PhD at 24. After four years at Lucent Technology’s Bell Labs, she returned to China at Microsoft Research Asia in Beijing. Interacting with students there piqued her interest in teaching, and last year she joined the UCSB computer science faculty. There she continues her research on cognitive radio and spectrum allocation as well as directing the LINK Laboratory for Intelligent Networking. “We have a great department moving upward,” she says of UCSB Computer Science, and she is now doing her part to raise its profile further.
By using RNAi in experiments on the tiny roundworm Caenorhabditis elegans (C. elegans), scientists have greatly expanded the list of genes that have some role in cell death.

As well as a failure of cells to commit suicide, this research suggests that TFG may play a role in preventing cancer and in maintaining normal health and homeostasis.

Such discoveries point to the importance of studying genes in the context of “modules.” Genes don’t act in isolation, and their impact on a cell depends on their interaction with other genes. Researchers in Rothman’s lab are studying the behavior of various gene combinations. These pairings are part of more complex groupings that are revealed in part by their computer-based approaches.

As scientists move up the scale of complexity from single genes to vast networks, their hope is to find the switches – the genes or gene groups that can be suppressed or activated as needed to reverse the course of disease. While it’s early to be speaking of potential cures, Rothman says that his group is beginning to test C. elegans genes on human cells. The knowledge of cell death is advancing quickly with the help of tools such as RNAi and the new computer-driven science of systems biology. “Programmed cell death underlies a wide range of diseases in one way or another,” Rothman says, and the potential payoff of understanding the cell death process is likewise enormous.

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are predicted by the computer to constitute a coherent functional network,” he says. “Some of the components in this network operate in very different cellular processes, including cell proliferation and cellular differentiation.” By dissecting these connections with other cellular processes, the researchers hope to learn how the machinery for cell suicide is assembled from normal cellular components.

Scientists are only beginning to reach the point where they can precisely manipulate the cell-death process in humans. But they are homing in on particular genes or gene groups that may be key players in human diseases and that could provide invaluable new diagnostics and drug targets.

One of these is ICD-1 (inhibitor of cell death gene 1). Identified several years ago by Bloss, Rothman, and doctoral student Eric Witze, ICD-1 prevents normal cells from committing suicide. What makes this gene especially interesting is that, when it is turned off by RNAi, the cell death process is different from the typical sequence of events in cells normally programmed for suicide. As doctoral candidate Tom McCloskey explains, the discovery of this “non-canonical cell death” associated with ICD-1 “showed that the pathway to cell death isn’t as simple as believed previously.” And as scientists find alternative routes to cell death, they can identify more avenues by which they can intervene in the process or even control it. ICD-1 acts with another protein, ICD-2, that Bloss has shown also functions in this alternative pathway. The latter protein is expressed at abnormally high levels in certain types of cancer, suggesting that it might contribute to cancer formation by preventing the normal cellular suicide program.

Growth and Death: The Cancer Link

Another postdoctoral researcher in Rothman’s lab, Ling Chen, is studying the gene TFG (for “Trk-fused gene”) that is altered in human thyroid cancers, lymphomas, and chondrosarcomas (cancers of cartilage). In these tumor cells, TFG is fused with other genes, resulting in an abnormal “fused” gene that causes tumor formation. Chen has not only found that TFG inhibits cell death, but that it also causes cells to grow to their correct size. Thus, TFG connects the programs for cell suicide and cell growth and size control. Since cancer results from excessive growth

959 nuclei survive
131 nuclei die

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Solved...

Solution from page 12

A shape-shifting, adaptive organic molecule. UCSB Graduate student Alex Lippert and Professor Jeffrey Bode have synthesized this "smart" molecule, which can be activated under basic conditions to form a functionalized hydroxy-bullvalene, whose unique bonding arrangement allows it to dynamically interconvert between over a million isomeric structures. Their clever design allows diverse recognition elements to be easily appended to a single dynamic core. When its shape-shifting properties are switched on, these molecules could morph themselves to fit into a drug target, making possible the rapid discovery of novel highly potent and unpredictable drug candidates. Their design also opens up the possibility to fabricate smart materials capable of dynamic activity on the nanometer scale and molecules capable of adapting to and navigating in a variety of environments.

May we brag a little?

Convergence won a Bronze Anvil Award of Commendation from the Public Relations Society of America, in New York in June. The young magazine, which has published just five issues to date, also won a Prism Award of Excellence from the Public Relations Society of America’s Los Angeles chapter last year. The judges noted that Convergence “deserved recognition as an example of outstanding achievement.”

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