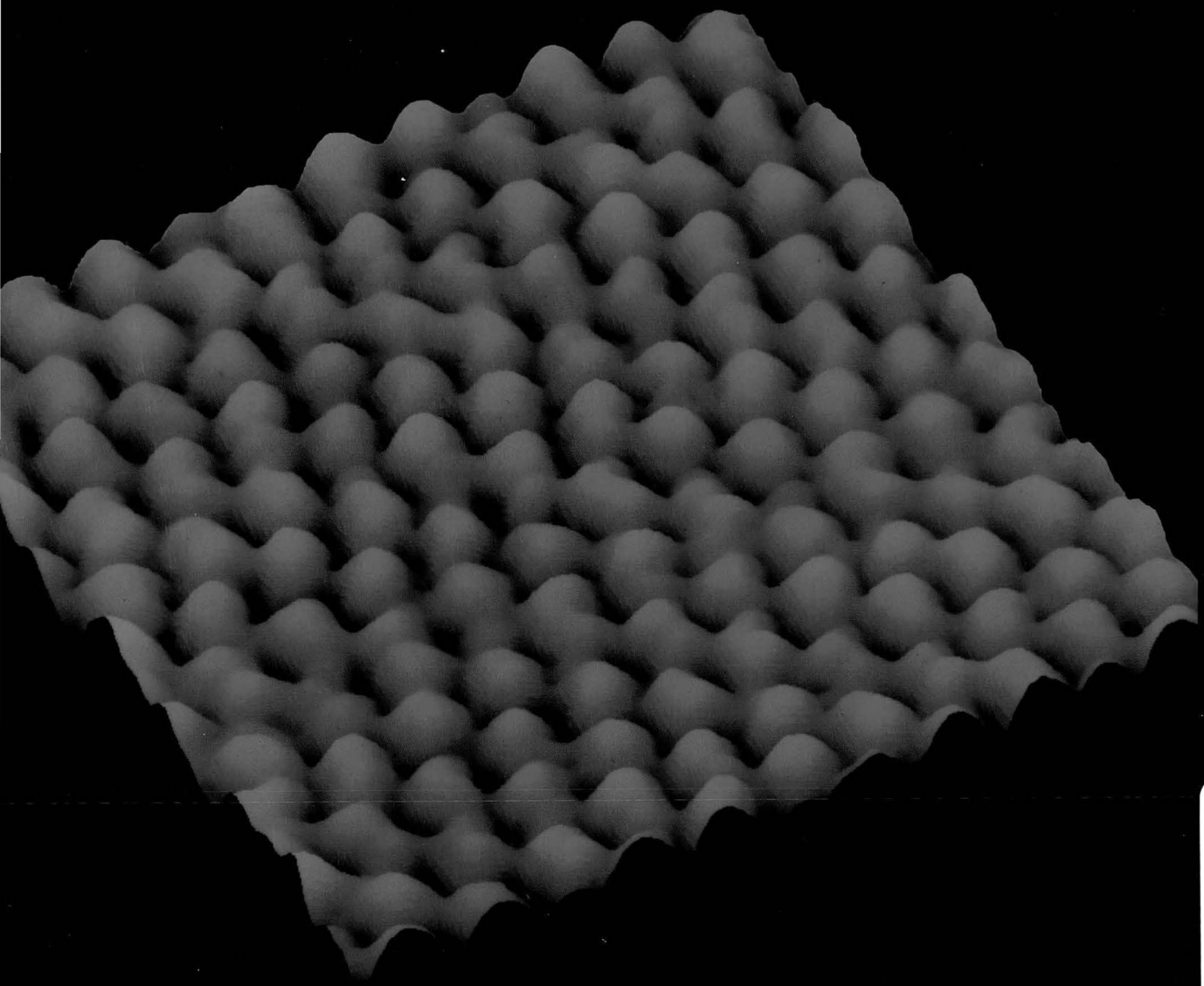
HIGHLIGHTS 1993



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On the Cover:

A topographic map of a gold surface at one angstrom shows the drag force of friction as a unique bidirectional Atomic Force Microscope (AFM) tip rocks over the gold atoms. Lightened areas reveal high friction; darker areas show low frictional drag. Using the AFM, researchers from LBL's Center for Advanced Materials are able to study the atomic origin of frictional forces. Story on page 14.

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FOREWORD:

Charting Our Future

For more than half a century the Lawrence Berkeley Laboratory has been at the forefront of scientific research. Throughout these years it has benefited enormously from its partnerships with the University of California, other laboratories and private industry, garnering nine Nobel prizes and hundreds of major scientific awards. The 1993 research highlights featured here represent a sampling of the many outstanding projects being conducted throughout the laboratory. As we approach the new century, LBL remains committed to scientific excellence in fundamental research. At the same time, we strive to seek new partnerships to fully exploit the potential of our scientific endeavors—for public health and environmental safety, science and math education, and industrial applications that will help the nation develop its technology to better compete in the global marketplace. The following achievements represent another step toward fulfilling these goals.

PROBING THE GENETIC BASIS FOR BREAST CANCER

Molecular cytogenetics leads to improved methods for studying gene function

The genetic basis for breast cancer is beginning to be understood.

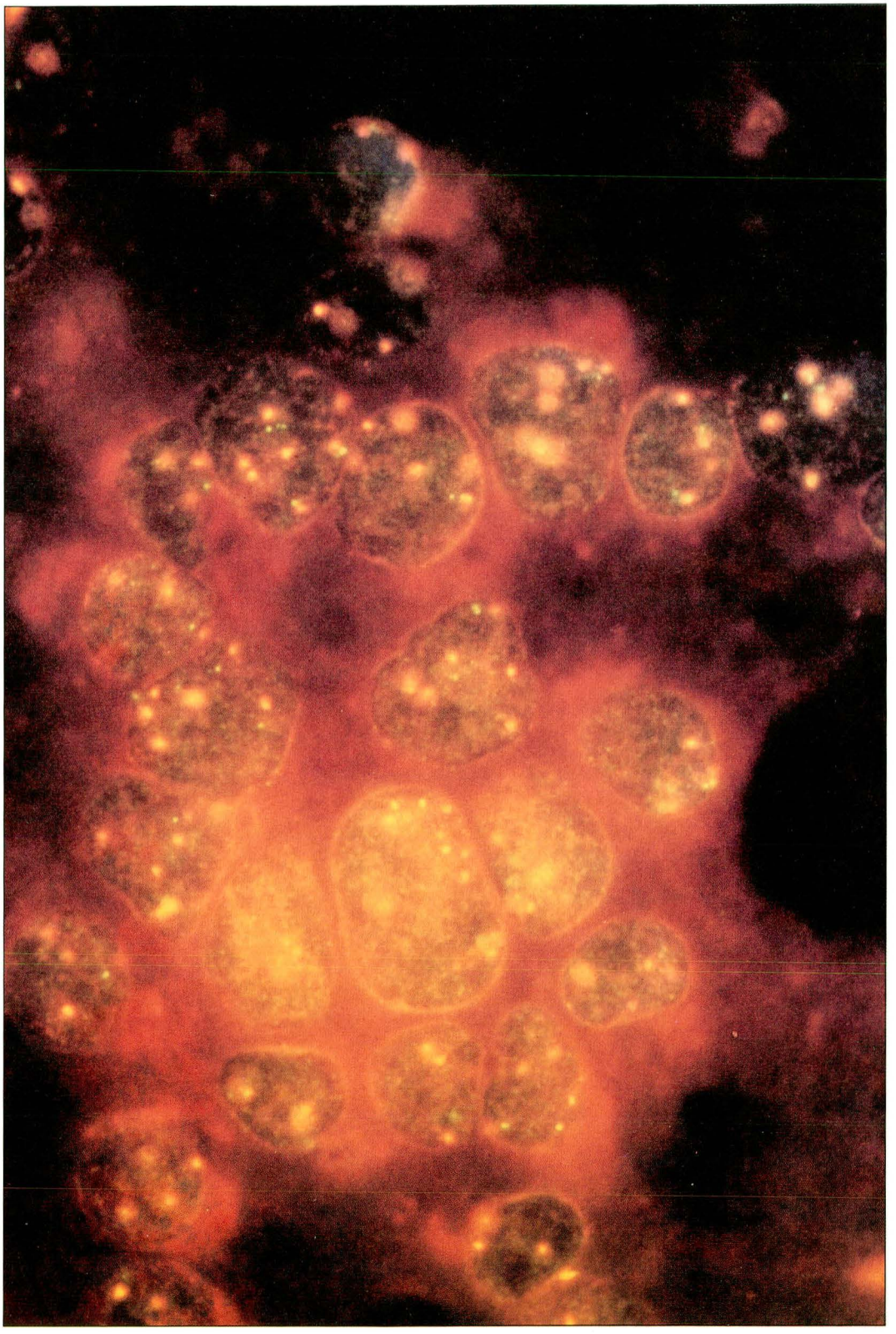
Applying the massive amount of information being generated by the Human Genome Project is an important mission of the Resource for Molecular Cytogenetics. The Resource, a joint effort between LBL and UCSF funded by DOE and private industry, is pioneering improved methods of detecting and studying genetic abnormalities in cancer and other genetic diseases, including those found prenatally and in newborn infants.

An LBL/UCSF team, led by Resource principal investigators Joe Gray and Dan Pinkel and UCSF scientist Fred Waldman, is applying these methods to study genetic changes implicated in breast cancer progression. With support from the Bay Area Breast Cancer Program, the genetic basis for breast cancer is beginning to be understood.

In recent work, a technique called comparative genomic hybridization (CGH) was applied to detect and determine the chromosomal location of genetic aberrations in a large number of breast cancers. Many of the tumors showed loss of material on chromosome 16. Probes to this chromosome obtained from the Los Alamos National Laboratory were used to define the precise region involved on chromosome 16. The gene coding for the cell adhesion molecule E-cadherin was located in the region indicated as being abnormal by these studies. This information, plus evidence from others suggesting that E-cadherin function is frequently lost in advanced cancers, prompted a more detailed investigation of the E-cadherin gene.

First, the investigators, in collaboration with the LBL genome project, isolated a YAC (yeast artificial chromosome) probe for E-cadherin and used this probe to measure the number of copies of the E-cadherin gene in breast cancer cell lines. These studies suggested a strong association between loss of one allele (normal cells have two) of E-cadherin and loss of E-cadherin function. Next, the investigators obtained information about the E-cadherin DNA sequence from the human genome project DNA sequence database and used this information to study the remaining allele. This work showed that the allele was mutated. Thus, loss of E-cadherin function in breast cancer seems to be caused by a physical deletion of one allele and mutation of the other. Loss of function in this gene, which normally produces a protein that binds cells together, may lead to increased ability to invade and metastasize.

The next step is to study E-cadherin in tissue isolated from actual tumors of the breast and other tissues, such as the bladder, ovary and prostate, to determine whether similar mutations and deletions occur there. Identification of E-cadherin mutations and deletions in human cancers may improve prognosis in these cancers, and may further our understanding of how cells escape from their normal location and spread through the body.



Loss of E-cadherin expression, associated with an increased ability for a breast tumor to metastasize, is illustrated by fewer copies of the E-cadherin gene (green spots) than the reference section of the chromosome (orange spots).

BRIGHT LIGHT

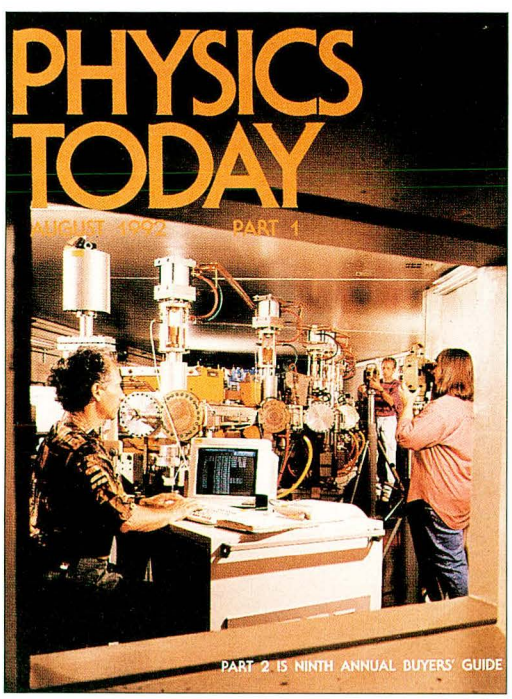
LBL's newest facility, the Advanced Light Source, prepares to begin operation

March 1993 marked the commissioning of LBL's Advanced Light Source, the brightest soft x-ray and ultraviolet light source in the world. Less than five years after its groundbreaking, the ALS fulfilled the requirements of its funding agency, the U.S. Department of Energy, for project completion.

Commissioning of the ALS was accomplished a week ahead of schedule, within the project's $100 million budget, and with a rating of "excellent" from a panel of final reviewers.

The ALS consists of a high-energy electron storage ring equipped with special magnetic devices that produce x-ray and ultraviolet light and coupled to advanced beamlines and experimental stations. The facility's project plan called for 50 milliamps of electron-beam current in the storage ring by March 31, 1993. The ALS passed that mark on March 24 when it reached 65 milliamps, and has now exceeded its design goal of 400 milliamps.

Secretary of Energy Hazel O'Leary sent a letter of congratulations to LBL Director Charles V. Shank and the staff at the Laboratory for achieving the beam-current milestone. In the letter, she especially praised physicists Jay Marx and Brian Kincaid who oversaw the construction of the Light Source.



The ALS was featured on the cover of *Physics Today* in August 1992.

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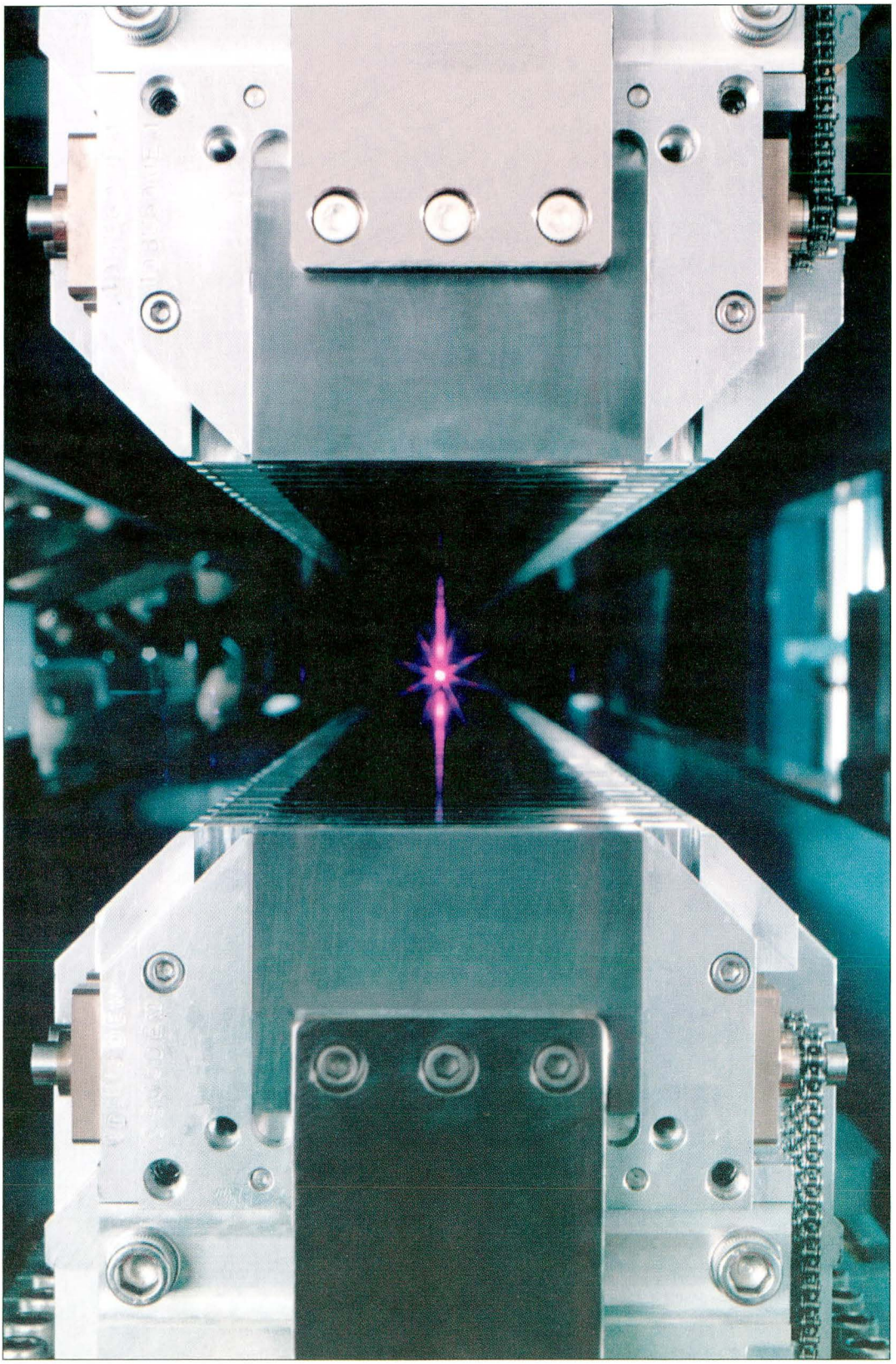
Underneath the dome of the ALS—the same structure that crowned the 184-inch cyclotron built by LBL founder Ernest O. Lawrence during World War II—is a complex of electron accelerators and a state-of-the-art electron storage ring that is 200 meters in circumference.

An electron beam that has been accelerated to 1.5 billion electron volts circulates in the storage ring for several hours, guided and focused by hundreds of precision electromagnets. Undulator and wiggler magnetic "insertion" devices that are also in the ring produce synchrotron radiation at the soft x-ray and extreme ultraviolet wavelengths.

Installation of the storage ring was completed in December of 1992. Electrons were injected into it less than a month later and allowed to coast around it. Two months later, on March 16, 1993, when the radio-frequency power system began operating, an electron beam was stored in the ring for the first time. The beam made millions of turns, reaching a current of 6 milliamps. Little more than a week later, the current surpassed the requirement for project completion and by the first week in April had climbed to 407 milliamps. The ALS is scheduled to begin operating in fall, 1993. It will be open to qualified scientists and engineers from throughout the United States.



A strobe light simulates the bright light that will be generated by the magnetic devices called undulators. (This light will not be in the visible region of the spectrum).

SHEDDING LIGHT ON SELENIUM

X-rays are being used to characterize soil contamination at the Kesterson Reservoir and Wildlife Refuge in the San Joaquin Valley

X-rays, produced in synchrotron radiation facilities that pre-date LBL's Advanced Light Source, have been used to identify and characterize the contamination of soils by selenium and other environmental pollutants.

Tetsu Tokunaga, of the Earth Sciences Division, is using two techniques, x-ray absorption spectroscopy (XAS) and synchrotron x-ray fluorescence microprobe mapping (SXRFM), to study selenium-contaminated soils from the Kesterson Reservoir and Wildlife Refuge in the San Joaquin Valley. His early work has demonstrated that both techniques show great promise for helping future environmental cleanup operations.

The XAS technique provided the first direct evidence for the presence of elemental selenium at Kesterson.

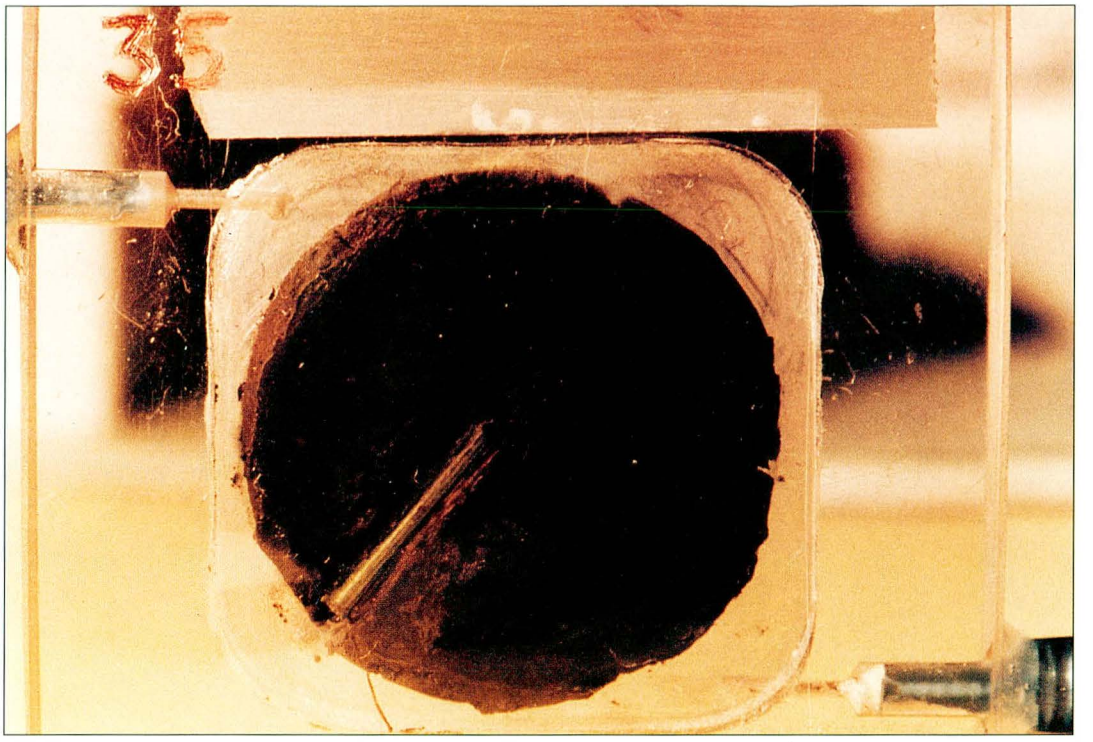
The XAS technique provided the first direct evidence for the presence of elemental selenium at Kesterson—which is good news for wildlife, because this insoluble form of selenium is not likely to be transported from the soil into the water. The SXRFM technique demonstrated that the distribution of selenium in contaminated soil is not uniform. In water-saturated soil immediately adjacent to decomposing plant roots, the concentration of selenium was found to be 20 times greater than in the surrounding soil. This selenium enrichment helps explains some puzzling observations made at Kesterson monitoring sites.

Selenium is a naturally occurring, potentially toxic trace element that became an issue of great public concern in California in the early 1980s with the poisonings and deaths of wild birds at the Kesterson Reservoir. Subsequent analysis indicated that selenium in agriculture drainage water was responsible. Ever since, Tokunaga and some two dozen other LBL researchers have been learning how to control selenium contamination.

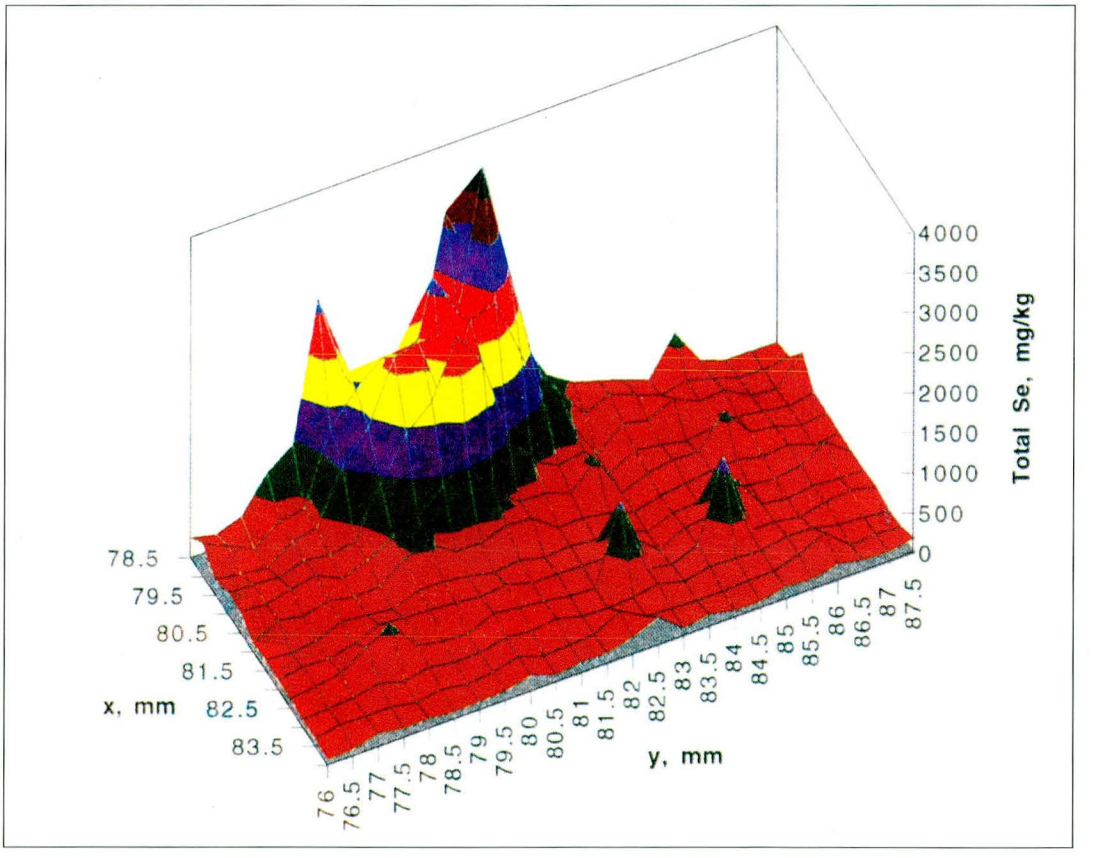
Tokunaga applied XAS to the Kesterson soils after others proved the technique is effective for obtaining information on trace elements in pure mineral specimens. Collaborating with Gordon Brown, Ingrid Pickering, and others at Stanford Synchrotron Radiation Laboratory, he demonstrated that not only does XAS provide quick, accurate and detailed measurements of selenium speciation, it does so without the elaborate extraction procedures required of conventional analytic methods that may alter the chemical form of the selenium being measured.

For his SXRFM studies, Tokunaga and collaborator Stephen Sutton used beams from the National Synchrotron Light Source at the Brookhaven National Laboratory. With this technique he was able to map the distribution of selenium throughout a soil sample and show that the fate of this contaminant is linked to heterogeneously distributed microbial activity, such as the decomposition of plant material.

The brighter, more sharply focused x-ray beams of the ALS will enable Tokunaga to expand his research from selenium to other major soil contaminants, such as boron.



This soil sample with an imbedded decomposing plant root was initially uniformly contaminated with soluble selenium. The sample was later imaged with the x-ray fluorescence microprobe to monitor selenium redistribution.



This image shows the synchrotron x-ray fluorescence microprobe mapping of selenium distributions in contaminated soils. The measurements demonstrate that extremely elevated concentrations of selenium can occur in the vicinity of buried, decomposing plant tissue.

AUTOMATED COLONY SORTING

Advanced engineering speeds up efforts to map and sequence the human genome

LBL's Human Genome Center maintains a leadership position in many activities related to genetic mapping, sequencing, and related instrumentation development. Recently it has become one of the major distributors of DNA clone libraries to research organizations across the nation, thanks to a high-speed automated colony picker and associated automated replication techniques. Designed by the Genome Center's instrumentation group, under the leadership of Joe Jaklevic, a physicist in the Engineering Division, the colony picker can pick and array colonies of yeast or bacteria at the rate of nearly one colony per second, or more than 3,000 an hour, which is about what an experienced human can total after an eight-hour workday, but with greater accuracy and information management.

The automated colony picker eliminates human errors and frees up scientists for more creative endeavors.

Human chromosomes are far too large to be handled intact by any known biological procedure and therefore must be broken into smaller pieces. These fragments of human DNA are then cloned in colonies of yeast or bacteria cells, which are carefully arranged in ordered libraries so that geneticists can later determine their original chromosomal position. A DNA clone library may consist of 50,000 or more individual fragments, each growing in its own colony.

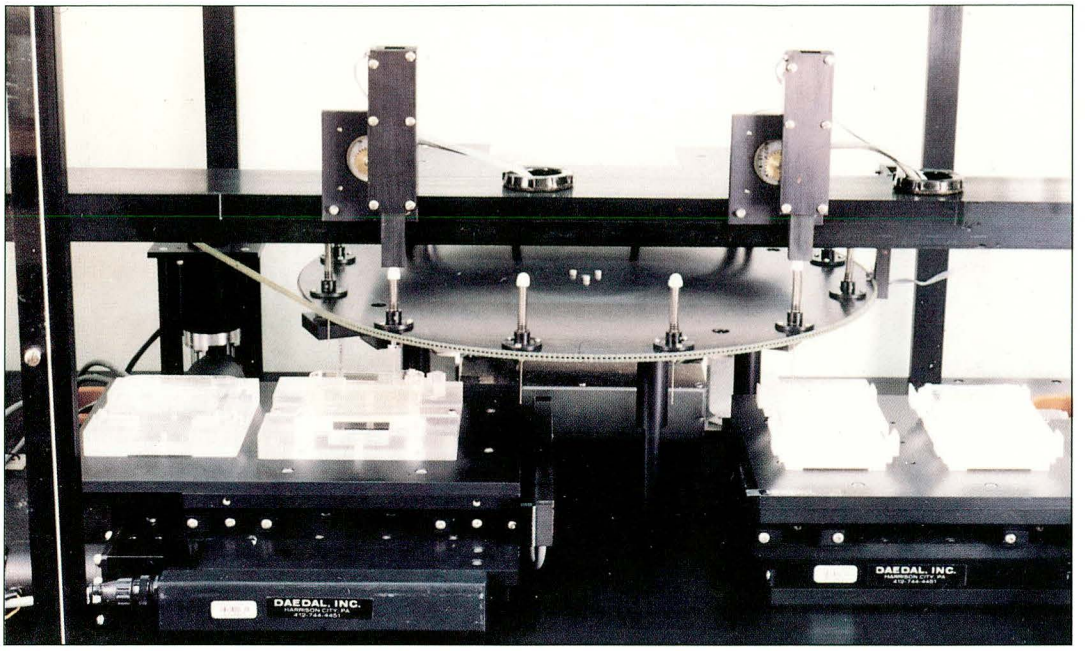
Assembling DNA clone libraries for subsequent replication and manipulation requires that cells of yeast or bacteria growing at random in Petri dishes be picked up and transferred to a growth medium in microtiter plate wells. The task is traditionally done by hand with a toothpick. It is tedious work and the potential for human error is high.

The automated colony picker eliminates human errors and frees up scientists for more creative endeavors. It consists of two computer-controlled tables, positioned underneath a rotating carousel wheel of twelve plungers, each with a sterilized needle.

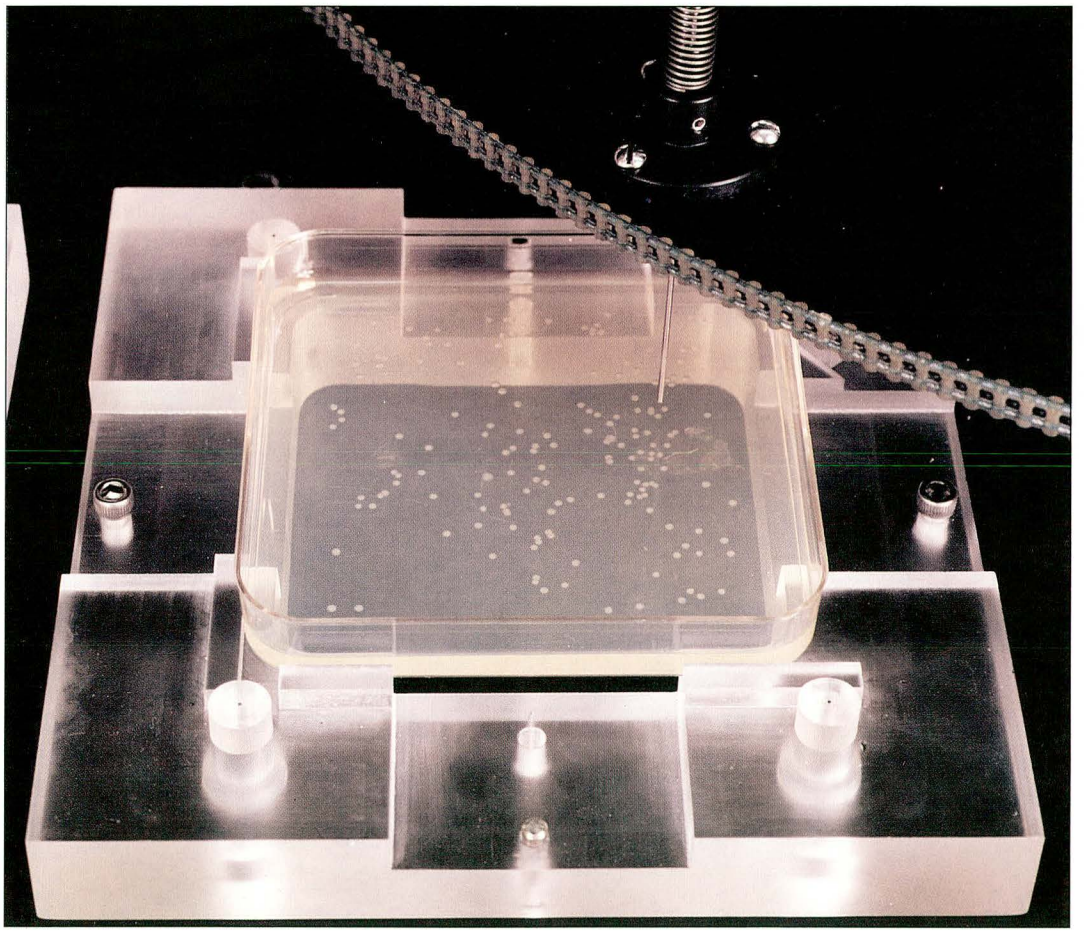
To operate the system, a Petri dish containing colonies of yeast or bacteria is placed on one table, and a 96-well microtiter plate is placed on the other. Guided by a digital image that shows the location of colonies in the dish, the first table moves a colony so that a plunger can pick cells onto a needle. The needle is then rotated by the carousel over to the second plunger and the table bearing the microtiter plate moves a well underneath.

The computer activates the second plunger, dipping the needle into the growth medium where some of the cells will be deposited. After retraction from the growth medium, the needle is rotated through a tank filled with sterilizing liquid and made ready for reuse.

In the future, the colony picker will be integrated with other custom automation modules currently under development by the instrumentation group, including an automated image digitization system, a rapid thermal cycler for DNA amplification, and a robotic system for extraction of DNA from cells. When fully operational, the automation designed for LBL's Human Genome Center will establish a production capability to map and sequence millions of base pairs per year.



The high-speed colony picker is able to "pick" colonies of yeast or bacteria cells containing cloned human DNA fragments at the rate of one per second, 10 times faster than experienced humans.



Close-up view of rotating carousel with needle dipping into petri dish containing yeast or bacteria cells with cloned human DNA.

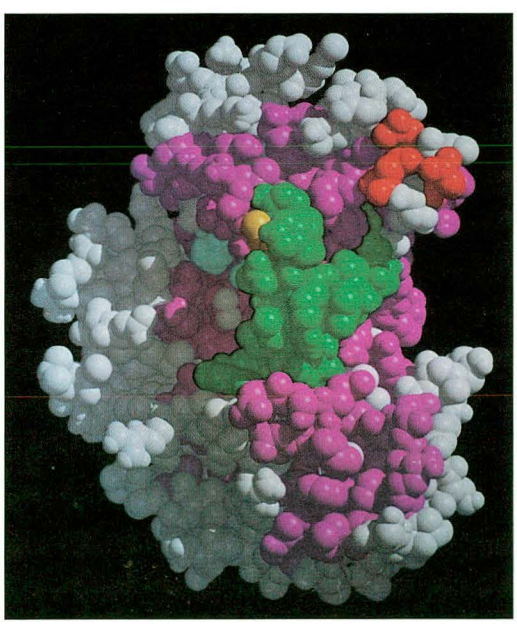
CANCER DRUGS: THE NEXT GENERATION

Scientists use x-ray crystallography to decipher the structure of a key protein involved in cell division

In simple terms, cancer can be described as cell division run rampant. The process of cell division is driven by a cascading path of signals, with each event catalyzed by a unique enzyme. One strategy to impede the destructive course of the disease is the design and use of drugs that inactivate one of these enzymes, halting the division process.

Scientists from LBL's Structural Biology Division, in collaboration with colleagues at UC Berkeley and UC San Francisco, have achieved an important step toward realizing this strategy—by solving the three-dimensional structure of a key protein that triggers the last step of the events which culminate in cell division. This is the first time the structure of a protein involved directly in controlling cell division has been determined.

Cyclin-dependent kinase 2 (CDK2) is a member of a large family of protein kinases that initiates the principal transitions of the eukaryotic cell cycle, attaching phosphate groups onto their target enzymes. Various types of kinases are involved in the chain of reactions that follow cell stimulation by a growth factor. The critical step in the sequence of events is known as *Start*, the moment when the cell becomes committed to a new division cycle. It is at this stage when cell division can go awry, leading to cancer.



The shape of the CDK2 protein provides the key information in the design of an inhibitor drug. A successful drug must have a complementary shape.

The three-dimensional structure of CDK2 was determined by Sung-Hou Kim's x-ray crystallography group at LBL—an effort led by Hendrik L. De Bondt and Jarmila Jancarik. David Morgan led the San Francisco group in isolating and purifying the protein. The researchers collaborative effort was recently featured in an issue of the journal *Nature* .

X-ray crystallography merges art with science by growing a crystal from the protein of interest and then shooting it with an x-ray beam. The process generates distinct patterns which can be analyzed by computational methods to reveal a molecular structure. Computer graphics serve as a powerful tool to visualize the molecular surface and highlight possible targets for inhibitor design.

With the three-dimensional structure of CDK2 now determined, several research groups, including some biotechnology companies, are beginning to design potential drugs that bind and inactivate this protein.

This powerful tool, soon to be enhanced by beams of incomparable brightness generated by the Advanced Light Source, will provide promising opportunities for industrial linkages, furthering the investigation of structure-based drug design.

In this computer-generated model, ribbon diagrams are used to show the architecture of the CDK2 protein.

UNVEILING THE SNO BALL

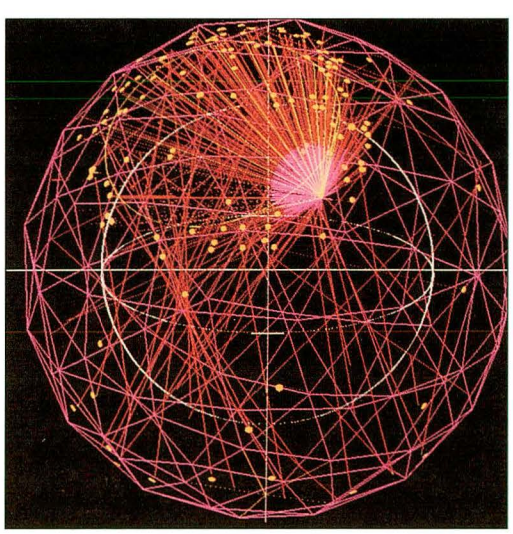
Major component of the international neutrino experiment is assembled

On July 8, 1993, a ribbon-cutting ceremony at a machine manufacturing company in Petaluma, California, celebrated the completion of a 60-foot-diameter stainless-steel geodesic sphere. The sphere will be a major component of an international scientific experiment known as the Sudbury Neutrino Observatory (SNO).

Designed by LBL's Nuclear Science and Engineering Divisions and assembled at Donal Machine, Incorporated, the 58,000 pound sphere will serve as the supporting frame for 10,000 photomultiplier tubes. These tubes are the heart of the SNO experiment.

SNO is a collaboration involving more than 60 scientists from LBL and 10 other laboratories and universities in the United States, Canada, and the United Kingdom. Its purpose is to answer some of the most perplexing questions about neutrinos, the ghost-like particles emitted from the sun and exploding stars, which could hold the key to the future of our universe.

Scientists think the universe began some 10 billion years ago with the Big Bang. Created in that explosion were neutrinos and every other type of particle that has ever existed. According to calculations, if neutrinos have sufficient mass, the universe will stop its current expansion and eventually collapse. SNO should tell scientists whether neutrinos have such a mass.



Computer model of a solar neutrino event at the Sudbury Neutrino Observatory. A deuterium nucleus captures a neutrino, producing an energetic electron, which in turn generates Ĉerenkov light. This light is detected by an array of 10,000 photomultiplier tubes placed in the geodesic support structure.

Another question to be answered by SNO is the mystery of solar neutrinos — why do experiments record fewer solar neutrinos reaching the earth than theory predicts? This discrepancy casts doubts on our understanding of the nuclear reactions occurring in the sun, and on the Standard Model, the basic theory of particles and forces now invoked to explain virtually all the phenomena of modern physics.

The geodesic sphere has been shipped to the town of Sudbury, Canada, for reassembly some 6,800 feet underground in a cavern as large as a ten-story building. The sphere and the photomultiplier tubes connected to it will be suspended in the cavern, which will then be filled with 7,800 metric tons of ultraclean ordinary water. Suspended inside the sphere itself will be a plastic tank filled with the target material, 1,000 metric tons of heavy water (deuterium oxide).

When SNO begins operating, flashes of light known as Ĉerenkov radiation will be produced when neutrinos interact with deuterium nuclei or electrons. Through the detection of these flashes with the photomultiplier tubes, scientists will be able to count the three different types of neutrinos and compare the various interactions between neutrinos and the electrons and deuterium nuclei contained in the target. The SNO experiment will last at least 10 years and is expected to record between 10 to 20 neutrinos each day.

The SNO ball suspended from a 170-foot crane at the ribbon-cutting ceremony in Petaluma, California.

USING MICROSCOPES TO MEASURE FRICTION

Researchers are using Atomic Force Microscopes to look into the atomic origin of frictional forces

Exploring the mystery of friction, LBL scientists have devised an instrument that records frictional forces while mapping a surface at an atomic scale.

A scientific team led by Miquel Salmeron of LBL's Center for Advanced Materials has developed a unique bidirectional Atomic Force Microscope (AFM) that can simultaneously map surface topography and measure the "dragging" or frictional force of the tip as it scans across a surface.

The instrument opens a window that will allow researchers to investigate friction, adhesion, wear, and the effect of different lubricants.

When two surfaces come in contact with each other, the atoms do not roll across one another like balls. Instead, they have chemical bonds and clouds of electrons (atomic orbitals) which determine the maximum drag. The properties of these orbitals and their relative orientations determine the strength of the frictional forces.

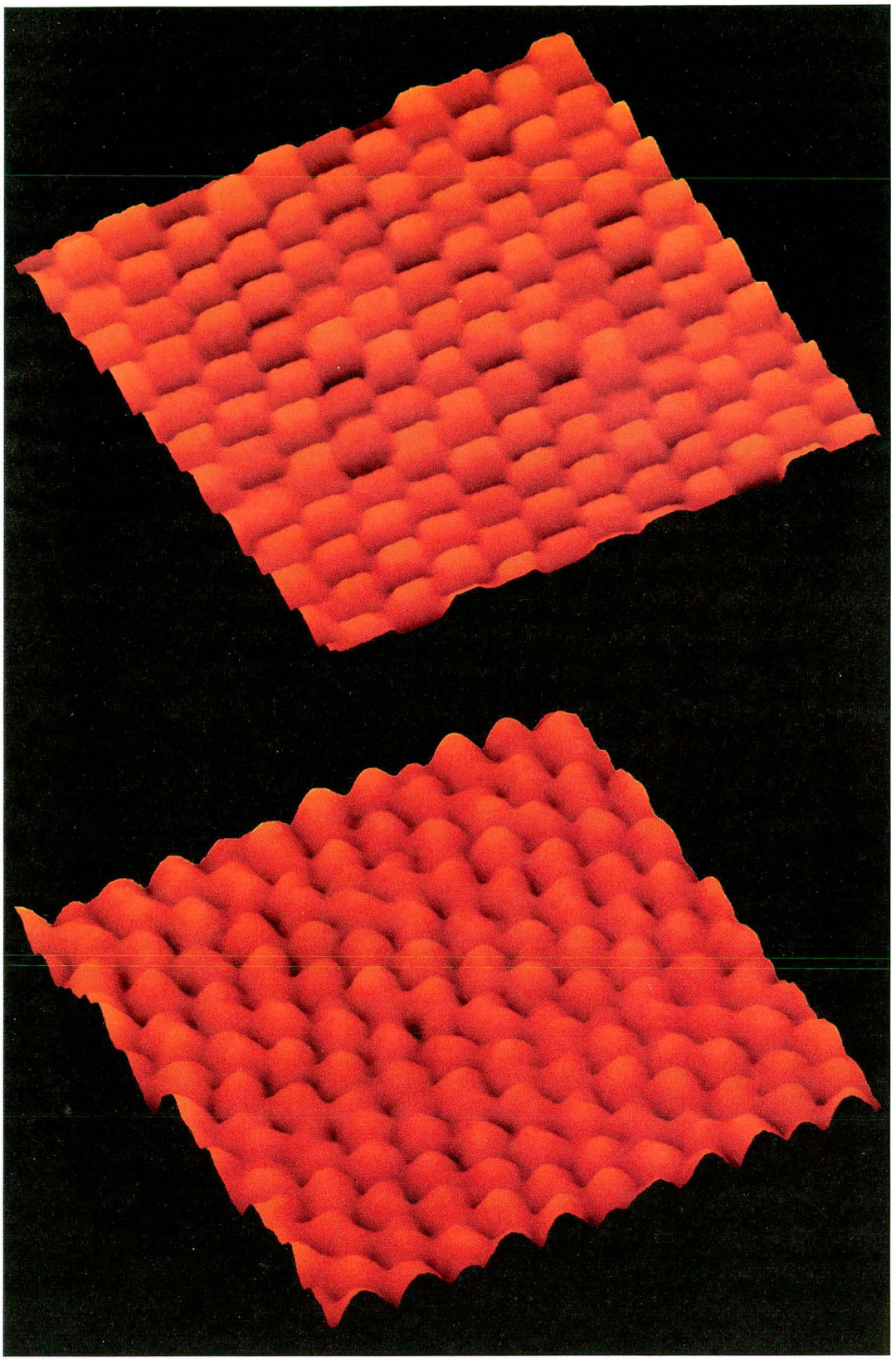
What factors increase or decrease these frictional forces? If we put oil or water molecules on the surface, how are the frictional forces altered? The bidirectional AFM will help us begin to understand such basic questions.

Much like a phonograph player, the bidirectional AFM maps a surface by scanning a very sharp tip across a sample, but with a force so slight that single atomic bonds are not broken during the scan. A conventional AFM measures surface topography as the tip moves up and down over individual atoms. To measure drag, the bidirectional AFM incorporates features which also allow a computer to record the sideways or rocking motion of the flexible, cantilevered tip.

The instrument allows scientists to study wear at an atomic scale, increasing the compressive force on the tip and measuring how much force is required to dislodge single atoms. Researchers also can measure whether frictional forces are uniform or if they vary based upon a pattern that is correlated to the atomic topography of the surface.

In biology, chemistry, and physics, practical questions are addressed and resolved based on research at the atomic scale. But in the study of the mechanical properties of surfaces, researchers have not yet made that leap. This instrument gives scientists the capability to explore the mechanisms underlying lubrication, adhesion, and the interaction between surfaces. Ultimately, what we learn should lead to better lubricants which extend the lives of moving parts and improve the energy efficiencies of mechanical devices.

This instrument gives scientists the capability to explore the mechanisms underlying lubrication, adhesion, and the interaction between surfaces.



Topographic map of a gold surface at one-angstrom resolution showing atoms as small protrusions.

Map of the same surface showing the drag force of friction as the bidirectional AFM tip rocks over the gold atoms. Lightened areas reveal high friction; darker areas show low frictional drag.

MAPPING THE RADON RISK

An LBL researcher develops a strategy for locating homes with unusually high concentrations of radon

Researchers in the Energy and Environment Division's Indoor Environment Program have been at the forefront of radon research for more than a decade. Now, a group headed by Tony Nero is developing a statistical model for estimating actual indoor radon concentration in houses by geographical area.

When concentration distributions can be reliably predicted from area to area, efforts can be focused on monitoring those homes expected to have especially high amounts of radon and therefore the greatest potential for inducing lung cancer in occupants. Without such a focused effort, a nationwide program would be extremely—perhaps prohibitively—costly.

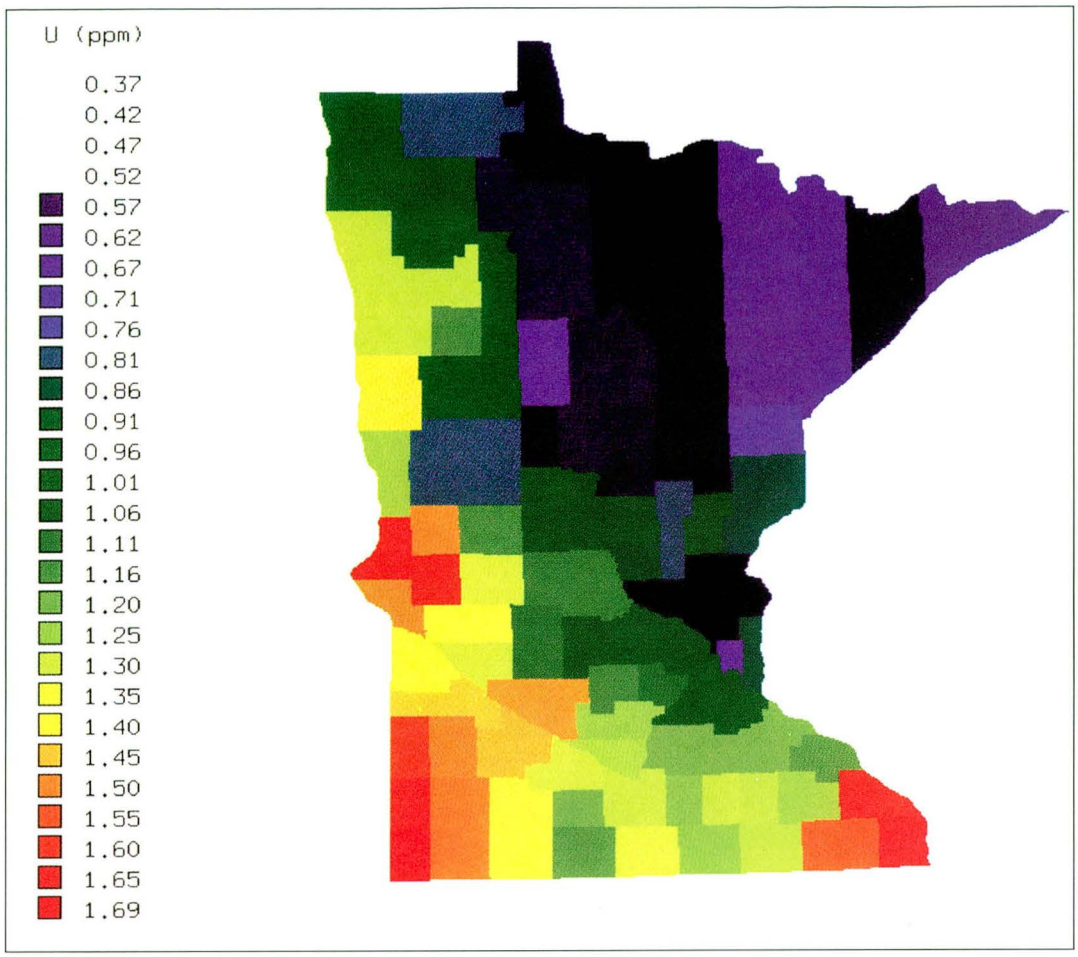
Radon-222, the most significant isotope, is produced by the radioactive decay of radium-226, which in turn is produced by the decay of trace amounts of uranium-238 found in the earth's crust. Since radon enters buildings in soil gas, indoor concentration depends on such factors as soil radium content and permeability to gas flow. House characteristics, such as the configuration of the substructure, and weather conditions also play a role.

Studies by Nero and his coworkers have shown that a small but significant number of houses have concentrations much larger than the national average of one picocurie per liter (pCi/l). One to three percent of houses (about one million U.S. homes) have concentrations above 8 pCi/l, a level at which occupants are receiving a radiation dose greater than the average for uranium miners. In 50,000 to 100,000 homes, concentrations exceed 20 pCi/l, causing occupant exposures near or above the occupational radiation dose limit. About 90 percent of these are believed to be located in 10 percent of the country.

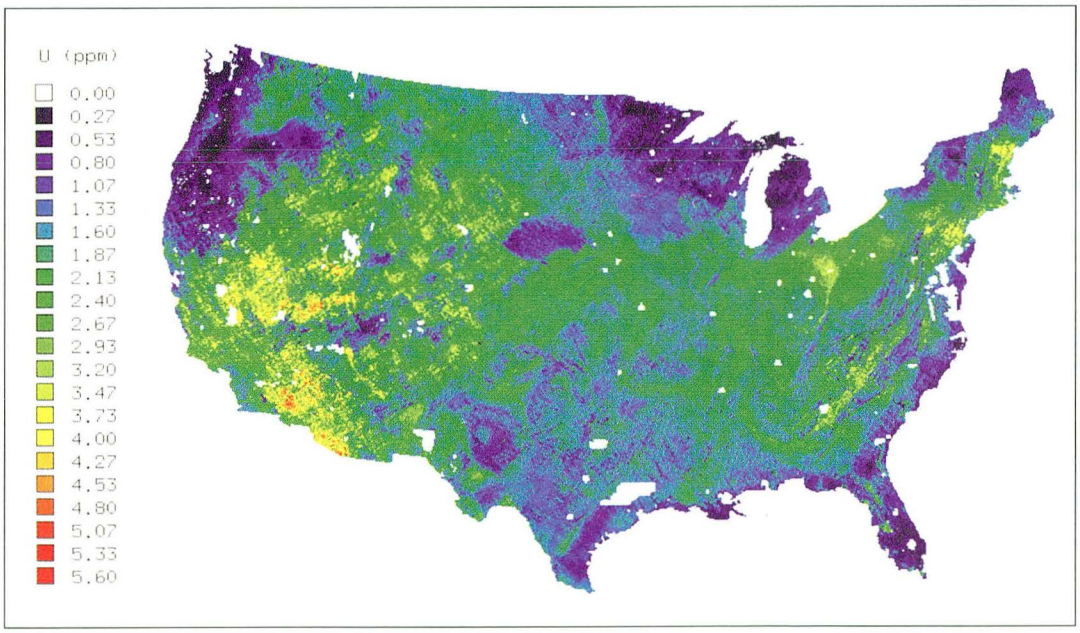
In a demonstration case in Minnesota, LBL researchers found that radiometric data obtained from previously conducted aerial surveys, combined with geologic data from soil permeability studies, correlated highly with direct in-home radon measurements. By using data on each county's average radium concentration to predict the county's average indoor radon concentration, the researchers can identify areas where homes should be monitored and where remediation efforts, such as modifying substructure ventilation, should be carried out.

The long-term aim of Nero and his coworkers is to estimate average local concentrations across the nation, down to a census-tract scale (4000 people).

The ultimate outcome will be a decrease in the incidence of lung cancer. Currently in the United States, as many as 10,000 cases of lung cancer per year may be caused by radon exposure, a very large number compared to the estimated risk from other environmental pollutants.



This Minnesota county map shows average "equivalent uranium" concentrations in parts per million, which are proportional to the radium concentrations in the soil. LBL researchers have found that these concentrations correlate closely with indoor radon concentrations. This map and the U.S. map shown below were derived from aerial monitoring conducted by the U.S. Geological Survey in the 1970s for the National Uranium Resource Evaluation program.



PUTTING THEORY TO THE TEST

An experiment with ketene is helping chemists understand and predict chemical reactions

Observation of the rate at which a molecule undergoes the transition from reactant to product has provided the first experimental evidence for a critical prediction of one of chemistry's most fundamental theories.

Results of an experiment led by Bradley Moore, a chemist with LBL's Chemical Sciences Division and a professor of chemistry at UC Berkeley, will help chemists in their ongoing effort to understand, predict, and, ultimately, control chemical reaction rates and products.

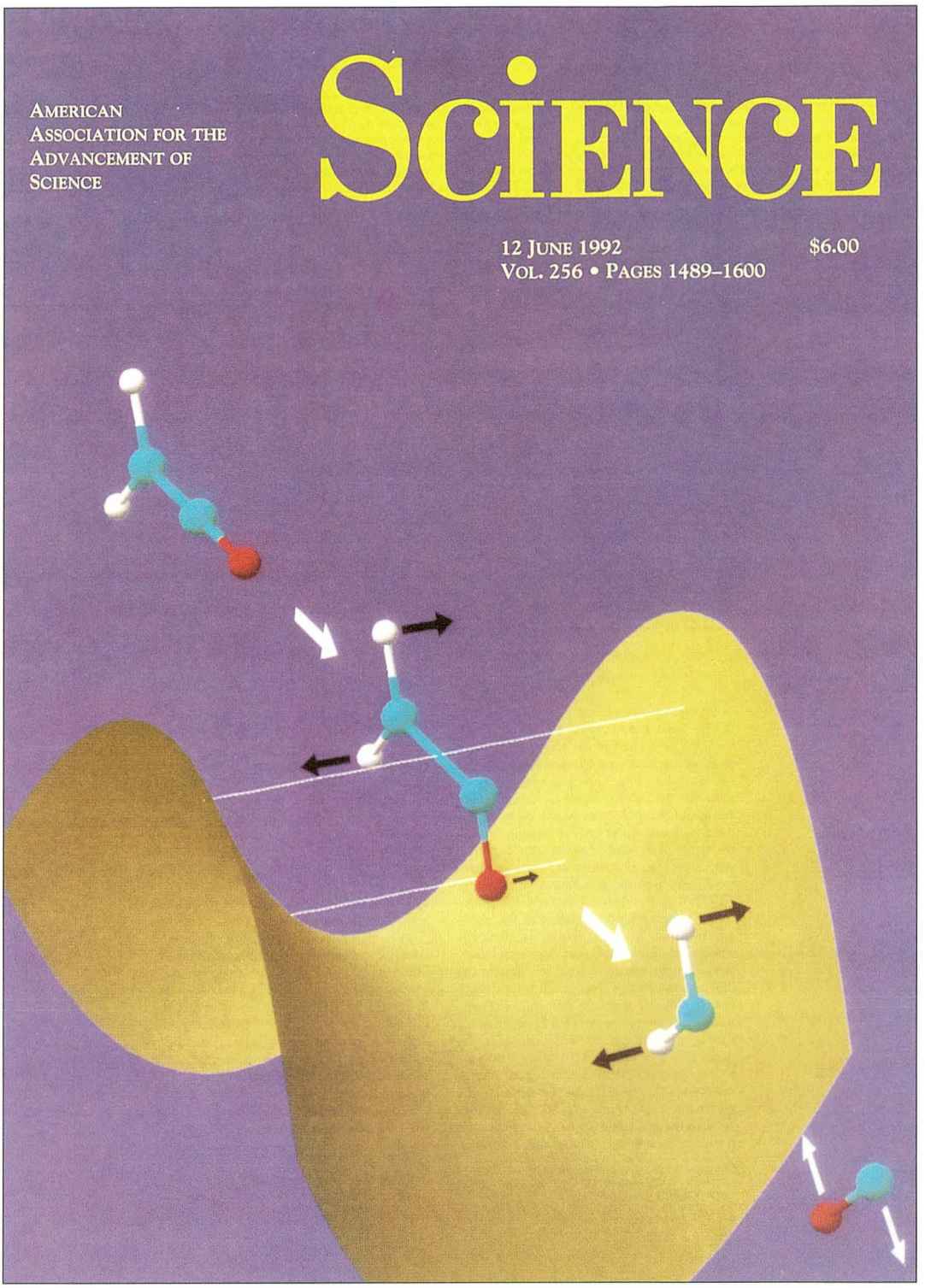
We now have a much sounder basis for modeling chemical reactions in combustion and in the earth's atmosphere.

It is no exaggeration to say that a society's standard of living is largely dependent upon its knowledge of chemical reactions. For more than 50 years, much of our knowledge of chemical reactions has been derived from transition state theory, which explains how the movement of atoms in a molecule during a reaction determines the reaction's outcome. However, few of the theory's predictions have been experimentally tested because, until recently, chemists lacked the tools to do so.

Using a technique called photofragment spectroscopy, Moore and his research team were able to make the first direct observations of transition state quantum energy levels in a unimolecular reaction — one involving only one molecule as the reactant — and deduce the associated molecular motions. In accomplishing this, they were able to confirm that the rate of a reaction is proportional to the number of different ways a molecule can vibrate at the transition state.

The tests were conducted on ketene (CH_2CO), a reactive gas that absorbs energy from ultraviolet photons and separates into CH_2 and CO. A sample of ketene molecules was chilled to nearly absolute zero in order to ensure that all of the molecules started out at the same energy. Ultraviolet laser light was then flashed on the molecules to cause the reaction breaking the C-C bond and separating the CH_2 and the CO fragments of ketene.

The excitation energies pumped into the molecules corresponded to the energy levels predicted in transition state theory. Reaction rates were measured by monitoring the appearance of CO fragments at each energy level with vacuum-ultraviolet laser-induced fluorescence. A photofragmentation spectrum of the CO was also taken. It was found that the rate of the reaction increased in a stepwise manner with increasing energy, as predicted by transition state theory. Each step corresponds to a vibrational energy level for the transition state: steps were found close to the energies predicted by quantum chemical calculations. With these results, we now have a much sounder basis for modeling chemical reactions in combustion and in the earth's atmosphere.



Experimental results by LBL's Brad Moore, which confirmed one of chemistry's most important theories, made the cover of June 1992 *Science* Magazine. The schematic depicts the dissociation of ketene (CH_2CO), showing how the rate of reaction increases in a stepwise manner as the total energy increases through transition state vibrational thresholds (white lines), and how motions (black arrows) at the transition state carry through to products.

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TRACKING B MESONS AND SEARCHING FOR THE TOP QUARK

An LBL team develops innovative electronics that permit high-resolution measurements of charged particle tracks

A new measurement of the lifetimes of charged and neutral B mesons is a major achievement of scientists from LBL's Physics Division, working at the Collider Detector Facility (CDF) at Fermilab. B mesons are particles containing a "b" or "bottom" quark, the fifth of the six quarks that are believed to be the fundamental constituents of matter.

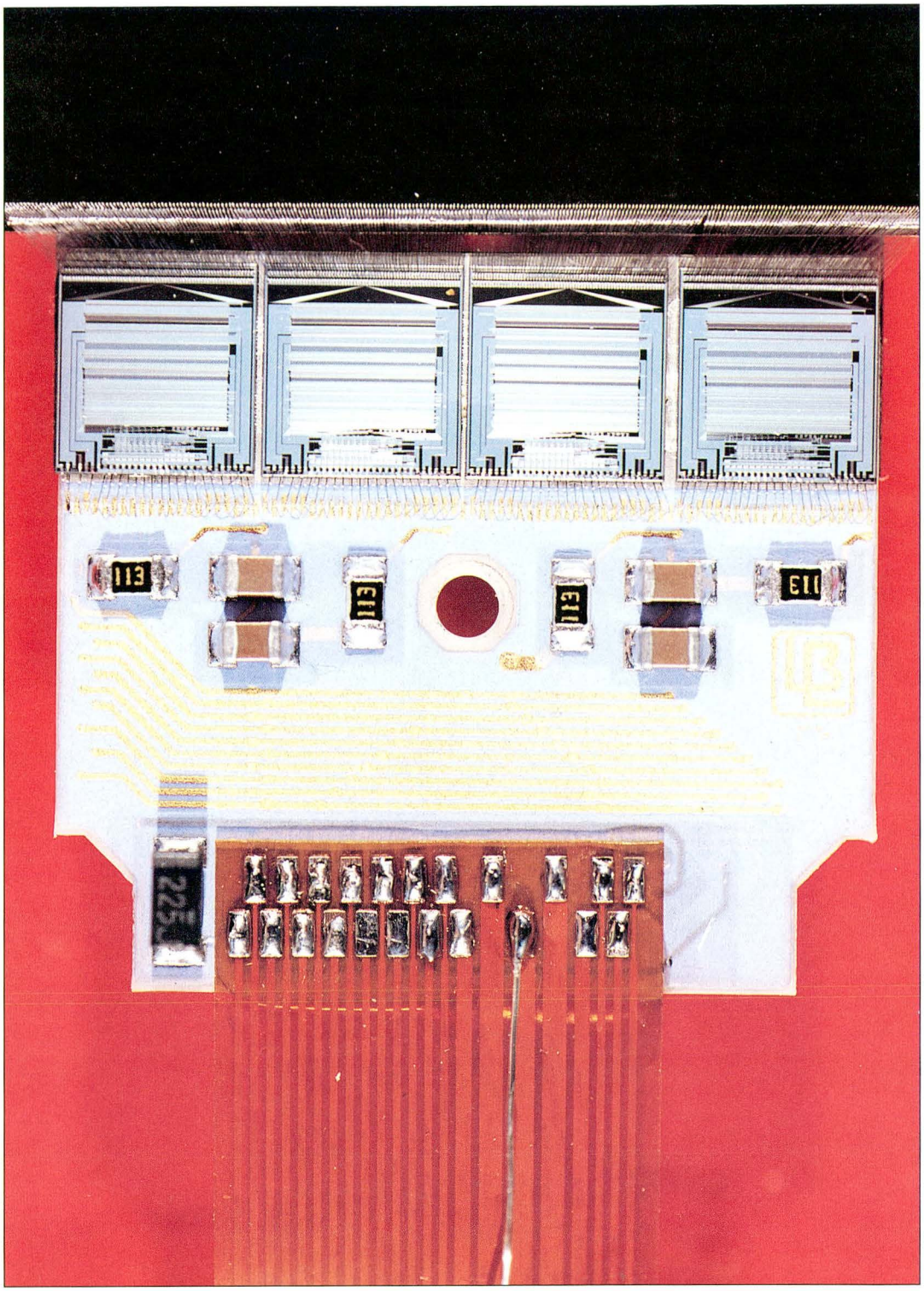
LBL members of the CDF collaboration include 17 physicists, headed by Lina Galtieri.

The new measurement was made possible through the successful exploitation of the Silicon Vertex Detector (SVX). LBL physicists and engineers led the development of innovative integrated circuit design and readout electronics which enable the SVX to measure tracks of charged particles with very high spatial resolution. There are 500,000 particle collisions per second occurring at the center of the CDF. The SVX is able to accommodate this enormous rate, and as a result CDF is now able to compete with electron-positron machines in measuring the properties of B mesons.

Physicist Lina Galtieri holds the electronics package designed by LBL.

B mesons can be identified because they usually travel several hundred microns before decaying. The SVX allows the tracks to be traced back to their origin with a precision of about 12 microns in the plane transverse to the incoming proton and antiproton. Without the SVX, the resolution was about 300 microns and thus obscured the separation between the collision vertex, where the B meson was produced, and the vertex where it decayed.

In addition to their role in developing the SVX, LBL scientists in the CDF group played a leading role in the data analysis, which produced new measurements of the lifetimes of neutral and charged B mesons and, more recently, has found evidence for the B_s meson, a particle containing a b quark and an s quark. The same group of LBL scientists is also searching for the t or "top" quark (the sixth quark, yet to be found), an effort which also exploits the high-precision B vertex measurement provided by the SVX.



A close-up of the LBL-designed integrated circuit electronics package, which enables the Silicon Vertex Detector to measure tracks of charged particles with high spatial resolution in the face of an enormous flux of produced particles.

SCIENTIFIC VISUALIZATION

Employing high-speed networks and distributed computing, researchers are able to use highly sophisticated imaging techniques

LBL and Berkeley researchers recently completed a project linking the two institutions with an optical-fiber gigabit (billion bit per second) computer network. Sending information at a rate almost a million times faster than a standard modem on a home computer, the link opens up a new era in scientific visual experimentation.

The new network link is part of a joint research program between LBL and Electrical Engineering/Computer Science at UC Berkeley. LBL's Bill Johnston was instrumental in the development of the network. The collaboration also includes Professor Domenico Ferrari and Professor Randy Katz of UC Berkeley.

Johnston notes that images and video are becoming integral to more and more research. Typically, researchers must be able to isolate features and extract their geometry as they perform a frame-by-frame mathematical analysis of motion or shape change.

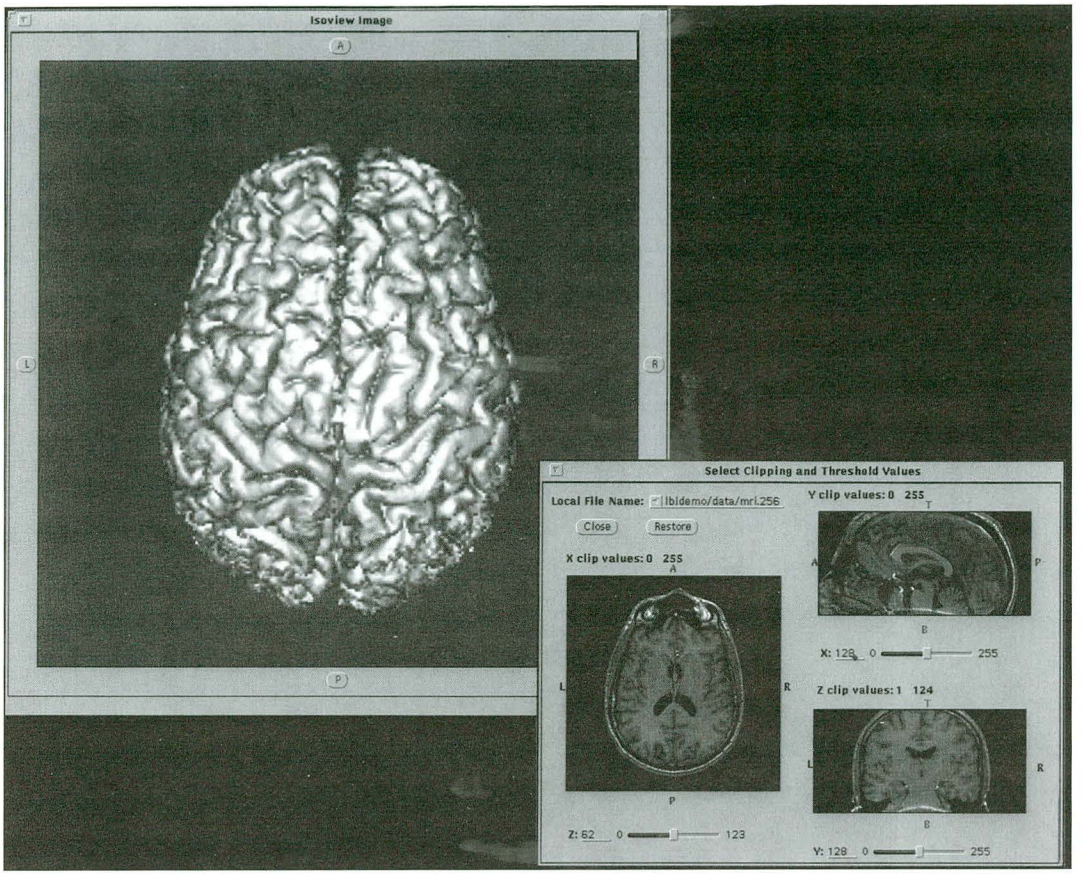
Until now, the vast amounts of digital information inherent in images, along with the processing and storage demands, have retarded the growth of image-based research. A conventional monochrome instrumentation camera generates 30 frames per second, or a data rate of 120 megabits per second, information which must be transmitted, stored, and processed if it is to be scientifically useful.

In the distributed system under development at LBL and UCB, researchers connected to the gigabit network can look at a workstation monitor and see the data culled from a live video even as the experiment is running. The video camera is connected to a network where storage devices such as RAID II save the images. The network can also transmit them to LBL's new MasPar massively parallel processing system. The MasPar processes and analyzes the video input, providing an instant display of data at any engineering workstation on the LBL/UCB gigabit network.

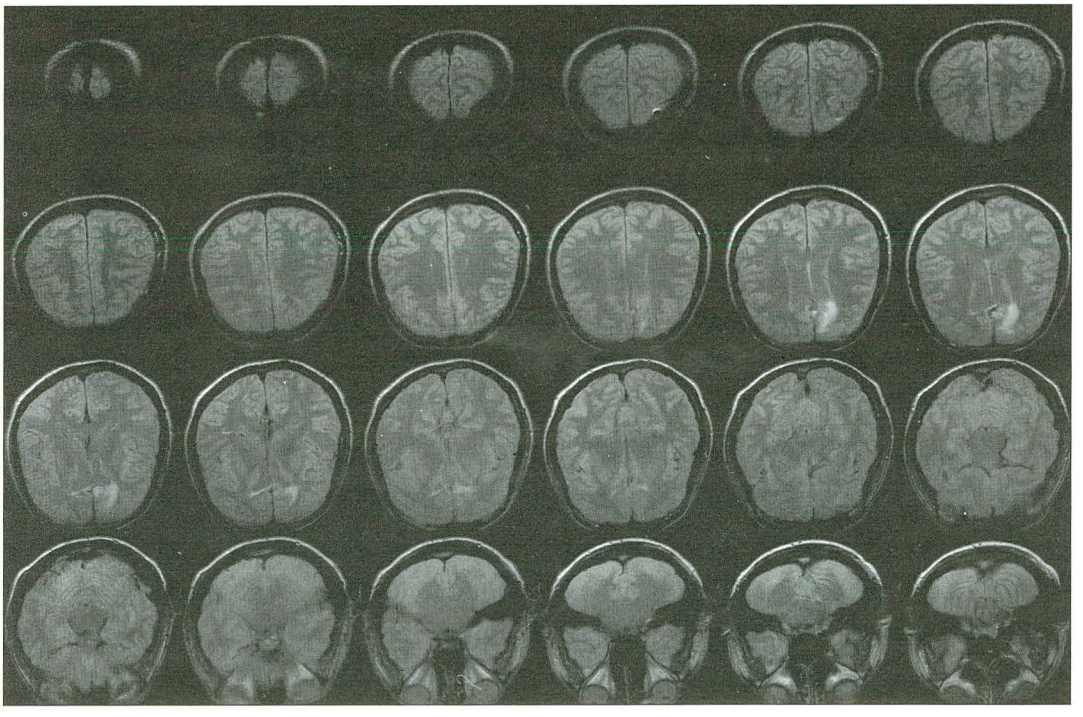
The new computing environment is versatile. It supports video and audio conferencing between multiple individuals. It allows individuals, workstations, and scientific instrumentation at multiple locations to be temporarily configured into a virtual computing system. And it makes possible a new generation of collaborative experiments.

A cortical anatomy project, for example, would allow researchers to put together a database composed of different types of brain scans of normal and abnormal patients. Through a comparison of these two- and three-dimensional images, medical researchers would be able to organize, catalog, and characterize features of the brain. Scientists involved in combustion dynamics and geophysics are discussing use of the network to compare video recordings of experiments with synthetic images produced from simulations. By allowing researchers to compare theory with practice, the gigabit network should narrow the distance between the two.

The gigabit network, the MasPar, and connections to worldwide networks open up a world of possibilities. With the fall 1993 start-up of the Advanced Light Source, the new computing environment will help LBL realize its vision of opening the facility to scientists working at remote locations around the world.



A three-dimensional model of the brain is created by remote super-computers and is displayed locally on a graphics work-station. Control panels permit scientists to vary parameters of the modeling and display.



The raw data for the model, which were provided by Tom Budinger and the staff at The Center for Functional Imaging, consist of many two-dimensional images which are obtained by Magnetic Resonance Imaging (MRI).

TECHNOLOGY TRANSFER

LBL scientists join with industry to bring advanced scientific techniques to the marketplace

In a rapidly expanding international marketplace, emerging technology drives the world's economy. The challenge to commercialize new technology will play out in fields such as advanced materials, biotechnology, and electronics, with the winner reaping worldwide economic rewards. Therefore, the value of technology transfer between national laboratories and the industrial community is more important in maintaining America's competitive edge than ever before.

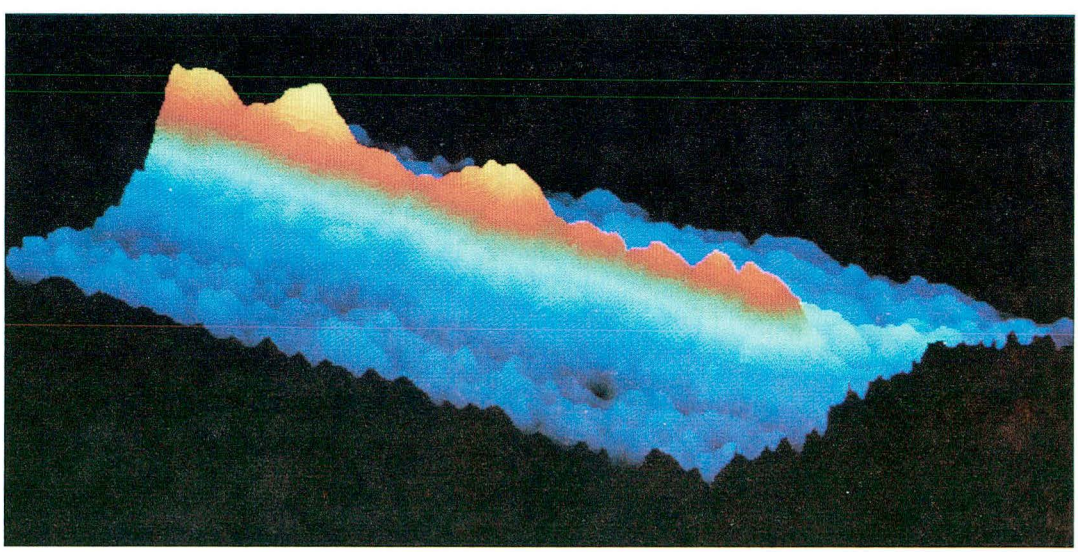
At Lawrence Berkeley Laboratory, we are working with U.S. industry to meet this challenge. LBL will continue to emphasize research excellence while actively seeking and establishing working partnerships with industry across the U.S. Our commitment to research innovation is the foundation for new high-potential technology applications.

Reflecting its multidisciplinary research efforts, LBL has established working partnerships with a wide range of companies in industries as diverse as bioscience, computers, advanced materials, automotive, and energy.

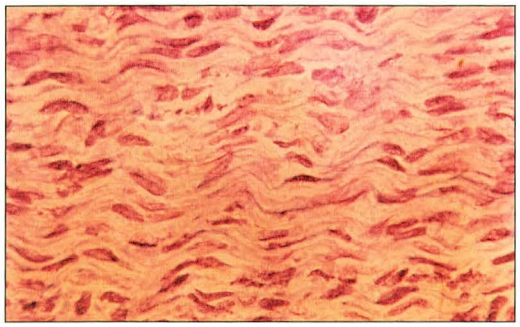
LBL And Seagate To Develop Computer Disk Coatings

Lawrence Berkeley Laboratory and Seagate Magnetics, a firm in Fremont, California, that manufactures computer disk drives, signed a half-million dollar Cooperative Research Development Agreement (CRADA) to jointly develop a new process for making carbon coatings that protect hard disks.

Under the terms of this agreement, $285,000 will be provided over the next three years through LBL by the U.S. Department of Energy, and $235,000 in research costs will be shared by DOE and Seagate. The goal is to develop new types of amorphous carbon coatings that can be applied during the production of a hard disk's thin magnetic layer. Considered a key requirement for increasing the stor-



Lawrence Berkeley Laboratory and Seagate Magnetics of Fremont, California, a major manufacturer of computer disk drives, signed a CRADA to develop superior disk drives. Shown here is a depiction of a crack in a new ceramic material. The image was created by LBL-designed software called ChemMap. LBL researchers are assessing ChemMap's use as a nondestructive characterization tool for the evaluation of thin-film disk media.



Tendon tissue from 16-day-old fertilized eggs (left) contains many more cells than tissue from a 4-month-old chick, where cells are scattered between tough collagen fibers (right).

age capacity and reliability of hard drives, these coatings protect a magnetic layer from wear and tear that occurs during the start-up and operation of a computer.

Critical to achieving the goal of the LBL-Seagate CRADA will be the ability to characterize the carbon coatings produced at the atomic level. Such characterizations reveal much about the relationship between atomic structure and properties in a material and can lead to ways of optimizing manufacturing processes to improve the material's performance.

Scientists at LBL, led by Gerd Rosenblatt and Joel Ager of the Center for Advanced Materials, have developed a unique Raman spectroscopy technique whereby properties associated with changes in the position of atoms with respect to one another across the surface of a material can be determined thousands of times faster than ever before. This technique along with other research findings will be passed on to experts at Seagate, who will apply it to their work. LBL and Seagate scientists and engineers will also collaborate on the design of new experiments that will further increase the value of Raman spectroscopy in the field of computer disk drive manufacturing.

LBL and Amgen CRADA to Focus on Growth of Tendon Cells

Lawrence Berkeley Laboratory signed a (CRADA) with Amgen Inc. of Thousand Oaks, California. The focus of the CRADA is a cell density signal (CDS-1), which was discovered at LBL's Cell and Molecular Biology Division. According to LBL scientist Richard Schwarz, a CDS-1 could be part of a chemical switch that promotes growth of tendon cells and expression of collagen in tendon cells. Collagen is the basic building block of connective tissues.

Under terms of the CRADA, the U.S. Department of Energy will support LBL with 25% of the total projected development cost and Amgen will fund the remaining 75%. Total projected development costs are estimated at $1.8 million over the next three years. Forty percent of the total projected costs will be in direct support of the research program at LBL. Dr. Schwarz is collaborating with Amgen scientists in characterizing the nature of CDS-1.

Amgen Inc. is a California based global pharmaceutical company that develops, manufactures, and markets human pharmaceuticals based on advanced cellular and molecular biology.

LBL Promotes Partnerships

LBL's Technology Transfer Department aggressively promotes the laboratory's licensing and collaborative research opportunities. These may lead to an active alliance that delivers innovative solutions to create new technologies, products, and systems of value to society.

In addition to the Amgen and Seagate CRADAs, cooperative research agreements valued at approximately $32 million, have been signed with Conductus, IBM, Glycomed, Motorola, Rouge Steel, the American Textile Manufacturers (AMTEX), Dow, EPRI, the U.S. American Battery Consortium (USABC), the California Institute for Energy Efficiency (CIEE), and Orion A.C.T. Several other promising CRADAs are being negotiated.

A UNIVERSAL VIEW

The Hands-On Universe program brings startling astronomical images from professional telescopes to high-school classroom computers

Just like modern astronomers, students in a new, nationwide program called Hands-On Universe are retrieving colorful astronomical images from remote telescopes, using nothing more than their classroom computers. LBL is leading the development of the NSF and DOE supported program, which brings real-life, real-time experimental science into classrooms across the country.

With user-friendly image processing software developed by the Hands-On Universe team, teachers and students can request observations of astronomical objects over phone lines and Internet and transfer them back to their classrooms. Students can zoom in on the blazing halo of the eclipsed sun, search for exploding stars in distant galaxies, and manipulate rich-hued portraits of planets, doing real scientific problem solving while learning astronomy, physics, and mathematics. As they do, they will become part of the global electronic community as well as collaborators in ongoing scientific research with their fellow students and professional astronomers.

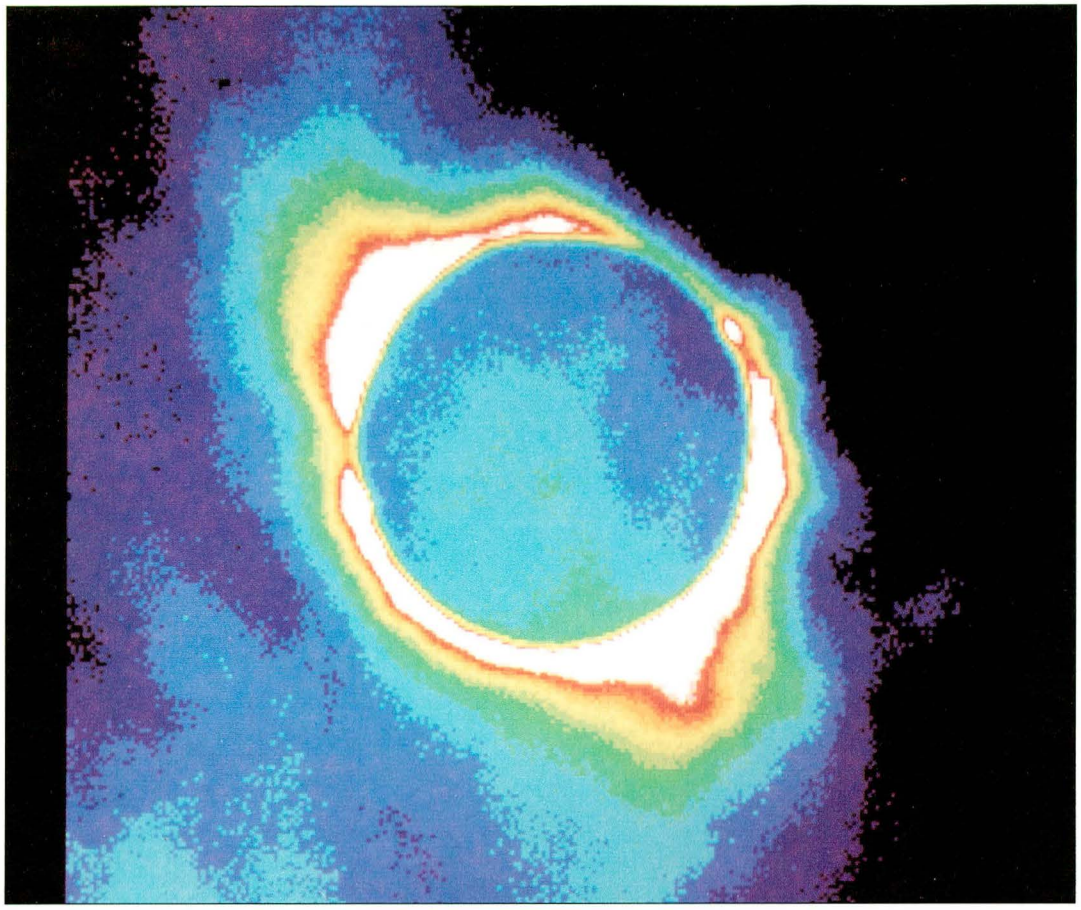
LBL astrophysicist Carl Pennypacker is lead scientist for the Hands-On Universe program. Pennypacker, along with UC Berkeley Space Sciences Lab Hands-On Universe Program Manager Elizabeth Arsem, and a core of about 40 teachers and their students have developed the program during the past two years, in conjunction with LBL's Center for Science and Engineering Education.

"A lot of high-school kids will be able to do real and relevant professional-grade astronomy research for the first time in history."

The Hands-On Universe program serves a rich cultural cross section of American students. In order to reach students in the largest possible number of schools, the cost of the tools needed for the program has been kept low. Program leaders have made special efforts to actively recruit and support schools in under-served communities and provide them with the assistance they need to get "on-line." Hands-On Universe students in America can also collaborate with other participants in the program—students from the Navajo Community College in Arizona, the Southwest Indian Polytechnic Institute in New Mexico, and those affiliated with England's Royal Greenwich Observatory and the Instituto de Astrofisica de Carnarias in Spain.

In its first year, Hands-On Universe classes worked mostly with images stored in a database, plus the few images per week that they could request directly from the telescopes. The program is now fully operational, and Hands-On Universe schools can request observations from the UC Berkeley Astronomy Department's telescopes at Leuschner Observatory. Within a few years, students will be be able to request images from an LBL telescope in the Canary Islands. There are also plans to open a national observatory with an automated telescope dedicated solely to high-school observers.

Says Pennypacker, "A lot of high-school kids will be able to do real and relevant professional-grade astronomy research for the first time in history."



This digital CCD image was taken on July 11, 1991, at Hapuna Beach, Hawaii, by Hands-On Universe high school teachers Curtis S. Craig of American Fork High School, American Fork, Utah, and Bruce Downing of Albany High School, Albany, California, during a DOE supported Hands-On Universe eclipse expedition and teacher-training workshop.

Dr. Carl Pennypacker is shown here demonstrating the Hands-On Universe image processing package to a group of girls attending the DOE sponsored "Spectacles" program, a science and math education program for young women.

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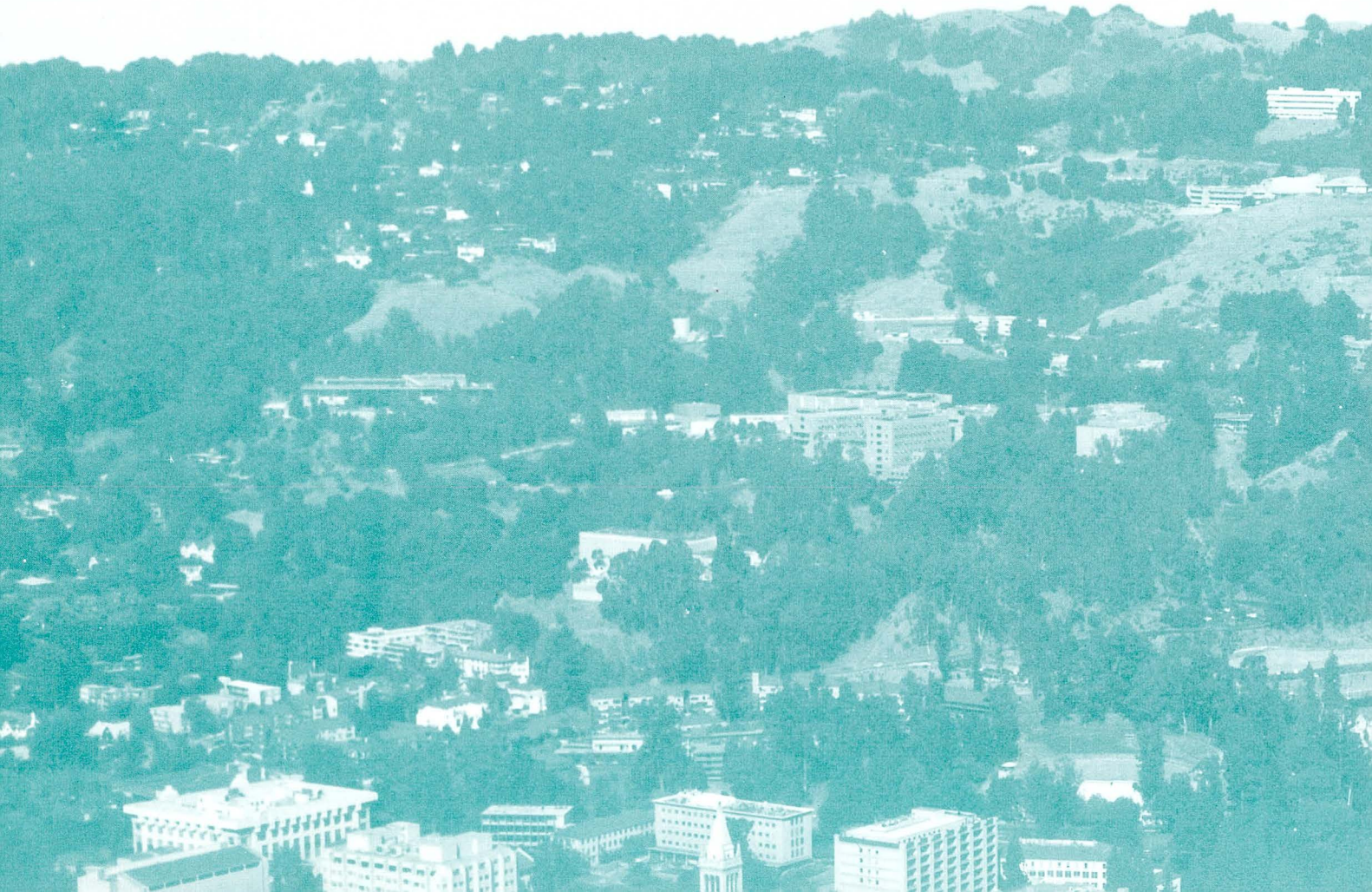

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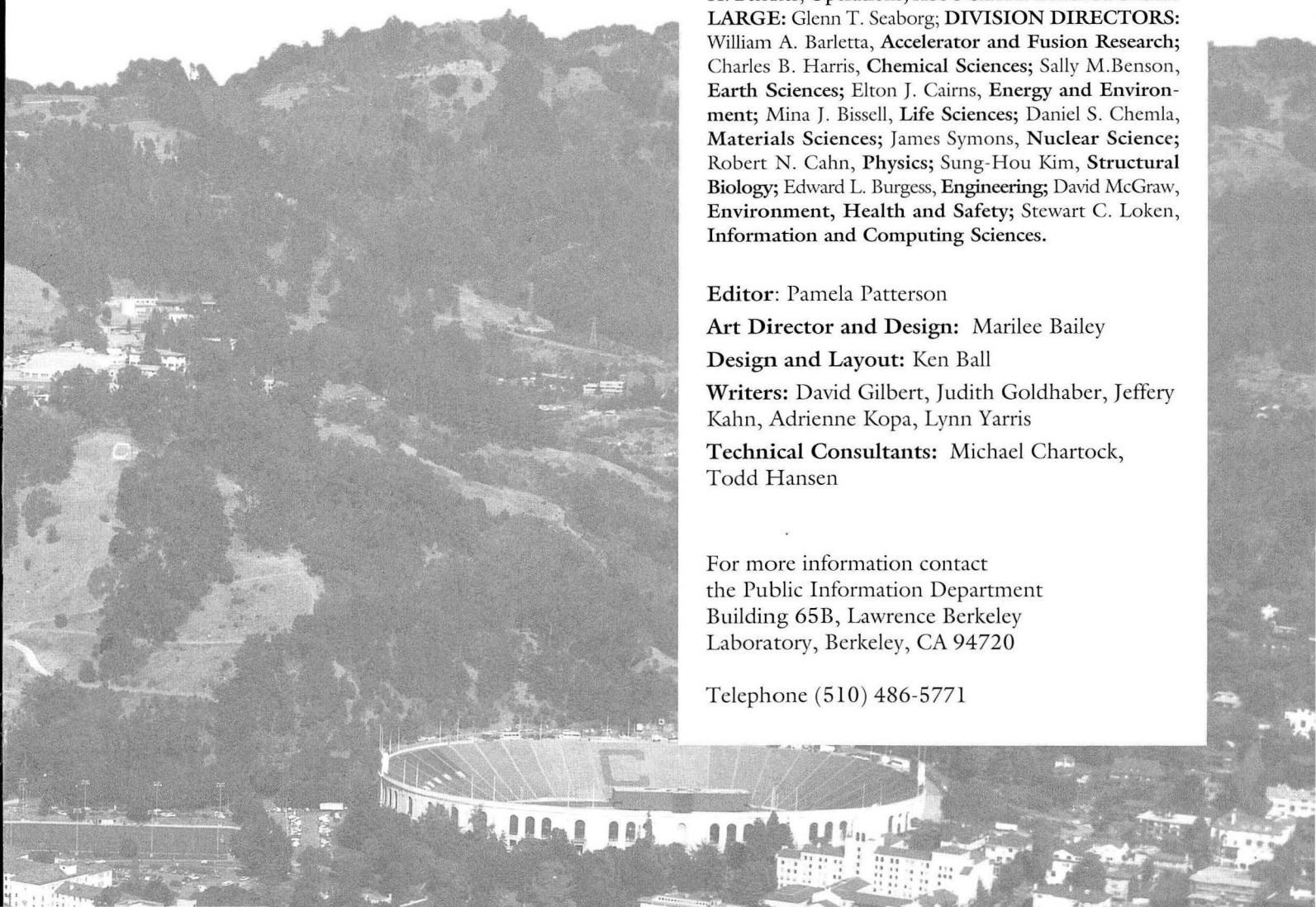

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