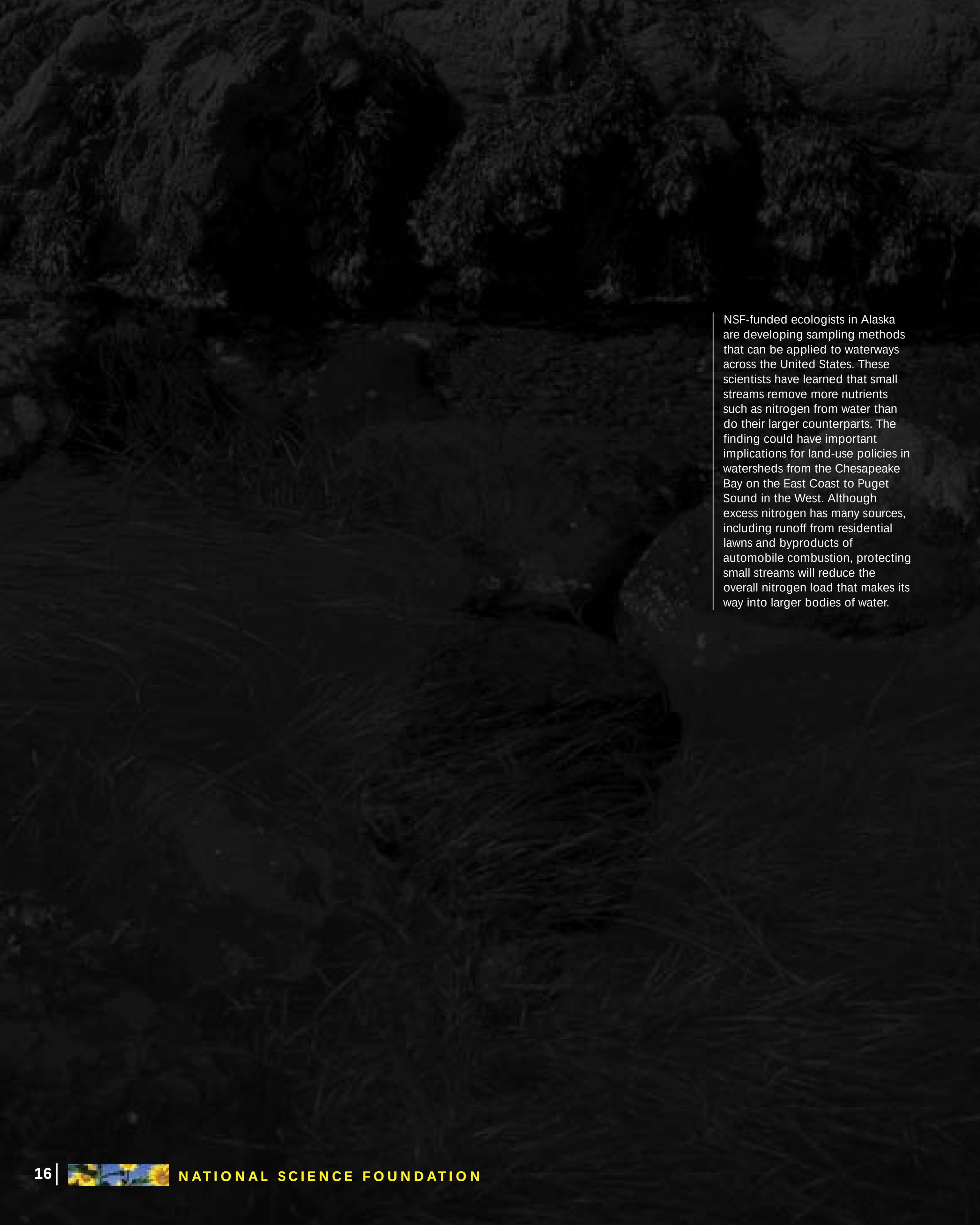

NSF-funded ecologists in Alaska are developing sampling methods that can be applied to waterways across the United States. These scientists have learned that small streams remove more nutrients such as nitrogen from water than do their larger counterparts. The finding could have important implications for land-use policies in watersheds from the Chesapeake Bay on the East Coast to Puget Sound in the West. Although excess nitrogen has many sources, including runoff from residential lawns and byproducts of automobile combustion, protecting small streams will reduce the overall nitrogen load that makes its way into larger bodies of water.

WHERE DISCOVERIES BEGIN

NSF supports cutting edge research that yields new discoveries over time. These discoveries are essential for maintaining the nation's capacity to excel in science and engineering and lead to new and innovative technologies that benefit society. The following examples illustrate the impact and success of NSF's programs in achieving important discoveries and supporting education efforts. Because many research results appear long after an investment is made, these discoveries are the outcome and results of long-term support of research and education projects that emerged and were reported in FY 2001. Other examples of NSF-supported discoveries are available from NSF's Public Affairs Website (www.nsf.gov/od/lpa/).

Oceans Reveal Their Secrets

Scientists exploring a remote area of the central Indian Ocean seafloor 2½ miles deep have found animals that look like fuzzy snowballs and chimney-like structures two stories tall spewing super-heated water full of toxic metals. Another team in the northern Pacific has found astounding numbers of *archaea*, a microscopic life form distinct from plants and animals once thought to exist only in extremely hot or acidic environments. Yet another team in the Atlantic has found hydrothermal vents towering 180 feet above the ocean floor.

An NSF-supported team of thirty-four scientists and engineers from a dozen institutions explored the Indian Ocean aboard the Woods Hole Oceanographic Institution's 279-foot research vessel *Knorr*. They deployed instruments, like the remotely operated vehicle *Jason*, to explore temperature variations, which led them to the discovery of the hydrothermal vents resembling smokestacks and the sea anemones resembling snowballs.

David Karl, Markus Karner, and Edward DeLong of the NSF-sponsored Hawaii Ocean Time-series project sampled the northern Pacific Ocean from the surface to a depth of 4,750 meters deep and found that *archaea* may make up as much as 50 percent of the biomass in the open sea.

Another expedition of scientists from the Scripps Institution of Oceanography, Duke University, the University of Washington, and other institutions explored a mid-Atlantic mountain ridge. The towering hydrothermal vents they discovered are the largest ever observed. They are also unique in their composition of carbonate material and silica and the fact that dense macrofaunal communities such as clams, shrimps, mussels, and tube worms, which typify most other mid-ocean ridge hydrothermal environments, are absent in the area.

Researchers at the University of Washington and Woods Hole Oceanographic Institution discovered a new hydrothermal vent system—dubbed "The Lost City"—on an undersea mountain in the Atlantic Ocean. Using the submersible *Alvin* and deep-towed vehicle *Argo*, researchers observed a field of active and inactive hydrothermal vents. The steep-sided deposits, shown here, are composed of multiple spires that reach 30 feet in width at their tops.

These findings may provide critical answers to long-standing questions about the diversity of life in the deep sea, how the oceans function ecologically, how animals move from place to place, and how the ocean crust is changing.

Synthetic Clay May Clean Waste

Researchers at Pennsylvania State University completed an important step in the drive to remove harmful materials from waste streams and drinking water. A team led by Sridhar Komarneni, professor of clay mineralogy, demonstrated that a synthetic clay known as swelling mica can separate ions of radium, a radioactive metal, from water. The finding could have implications for radioactive and hazardous waste disposal, particularly in the cleanup of mill tailings left after uranium processing for the nation's nuclear industry. The tailings contain radium and heavy metals that can leach into groundwater and contaminate drinking water supplies.

The swelling mica, known as Na-4, is one of a group of clays not found in the natural environment. Created specifically for water treatment purposes, swelling micas expand as they absorb metal ions and then, reaching their capacity, collapse and seal the contaminants inside. The swelling micas are being explored for potential use in separating ions of heavy metals such as lead, zinc, and copper as well as other radioactive materials, including strontium, from waste streams. Because they trap the ions, the micas can permanently immobilize these pollutants. They could also prove useful for the recovery and recycling of valuable metals.

"Silent" DNA Speaks Up

By moderately raising the temperature of cells, biologists have broken through what was considered an impermeable barrier that kept half the genes in some cells "silent." The surprising results, that these heated genes reached 500 times their normal rate of expression, could lead to a better understanding of the cellular processes involved in aging, fever, and toxicity.

Biochemistry and molecular biology professor David Gross and graduate student Edward Sekinger conducted the research at Louisiana State University Health Science Center with NSF support. Their findings appeared in the May 2001 issue of the journal *Cell*.

These findings could turn the gene-expression field upside down. The process that makes some genes silent could help scientists understand aging. Apart from these possible implications, the research could eventually help explain why certain cells are more vulnerable to fever and toxic chemicals and how to control these negative effects.

Math and Science Gains

In 1993, NSF undertook a bold initiative to encourage and invest in system-wide reform of K-12 mathematics and science education in some of the most disadvantaged urban school systems. Students in these systems were performing poorly in mathematics and science, with wide gaps evident between minority and majority students. NSF introduced Urban Systemic Initiatives (USI) to enable cities to implement wide-ranging reforms through standards-based curricula, professional development for teachers, and accountability for achievement through data collection and assessment. Now, an external evaluation team reports some dramatic payoffs from these investments.

Academic Excellence for All Urban Students, a summary report on urban programs making up NSF's USI, shows that students in most of the twenty-two cities where school systems undertook reform efforts are making progress in several areas.

The report is part of a larger, ongoing NSF-funded evaluation study. The study has found that in most of the USI cities, students are taking more math and science courses and increasing their achievement levels, as demonstrated through various assessment tools. Minority students, meanwhile, are making even greater gains in enrollment and performance, reducing the "achievement gap" between themselves and majority students.

These preliminary indicators provide insight into what can happen when school systems use investments wisely to support system-wide learning policies to develop teacher capabilities and to create community partnerships. Great returns on investment are possible when all the pieces fit together.

Although evaluating system-wide change is a long-term process, many urban systemic programs are producing noticeable gains in math and science achievement.

Superconductivity: Making It Work

A new high-temperature superconductor found in January 2001 by a Japanese team in a simple, commonly available compound has profound potential for future uses. U.S. scientists at an NSF materials research center at the University of Wisconsin, in collaboration with an NSF-funded solid-state chemistry group at Princeton University, have shown that the compound, magnesium diboride or MgB_2, will be useful for real-world applications in electronics, communications, and industrial tasks that would benefit from the passage of large amounts of current with no resistance.

Superconductors are materials that lose all their resistance to electrical current flow below a certain critical temperature. The higher the critical temperature, the more useful the material for practical applications. MgB_2's critical temperature at 39 Kelvin is lower than other candidate materials—generally copper oxides—but the compound has other properties that this team says make it a "go."

In the copper oxide superconductors discovered so far, the interfaces between the crystals of the material—the so-called "grain boundaries"—interfere with the efficient flow of current, severely limiting their usefulness. In the case of MgB_2, the research team has shown that the current passes smoothly between the crystal grains. Potential applications include magnetic resonance imaging (MRI) devices, more efficient power transmission lines, and a variety of electronic devices.

Genome Sequencing Yields Insights

Genetics reached a major milestone in December 2000 when an international research team announced it had completed the first plant genome sequence. The species *Arabidopsis thaliana* has emerged as the plant counterpart of the laboratory mouse, offering clues to how all sorts of living organisms behave genetically, with potentially widespread applications for agriculture, medicine, and energy.

The Arabidopsis Genome Initiative (AGI) is a collaboration of research groups in the United States, Europe, and Japan funded by government agencies, including NSF. Because it is a model for over 250,000 other plant species, Arabidopsis is yielding insights that scientists are already applying to make other plants easier to grow under adverse conditions and healthier to eat.

The complete sequence of Arabidopsis is directly relevant to human biological functions because many fundamental life processes at the molecular and cellular levels are common to all higher organisms. Arabidopsis contains numerous genes equivalent to those that prompt disease in humans—ranging from cancer to premature aging. To help researchers capitalize on the genome sequence, NSF has begun a “2010 Project” to determine the function of 25,000 Arabidopsis genes.

The applications of this project are not confined to biology and medicine. Plants hold great potential as sources of renewable energy, although they currently represent just 3 percent of U.S. energy resources. Study of the *Arabidopsis* genome sequence is revealing how photosynthesis converts solar energy and carbon dioxide into biomass, helping scientists develop better plants for fuel and chemical uses.

Another NSF-funded team of scientists has completed the genome sequence of *Halobacterium* species NRC-1, a microorganism that is among the most ancient forms of life. This achievement is especially significant given this bacterium’s widespread use as a model for genetic manipulation.

The research was led by microbial geneticist Shiladitya DasSarma at the University of Massachusetts at Amherst in collaboration with molecular biotechnologist Leroy Hood at the Institute of Systems Biology in Seattle. DasSarma and Hood led a consortium of researchers from twelve universities and research centers in the United States, Canada, and the United Kingdom on the three-year project. *Halobacteria* convert sunlight to energy, giving off a red byproduct whose light sensitivity may make it commercially useful in applications such as information storage for computers.

These tiny creatures will provide many insights into how more complex creatures manage life functions, including cell division, and how cells transport proteins across biological membranes. Several biomedical applications using *Halobacterium* are now being investigated, including the development of orally administered vaccines and the design of new antibiotics.

Full of Holes

Scientists developing photonic devices for optical and electronic applications may get a boost from a new process for “cutting” three-dimensional arrays of holes in a polymer material. Mohan Srinivasarao found a way to create an orderly pattern of air bubbles throughout a polymer film using a simple solvent. By controlling the polymer, solvent, humidity, and flow of air across the polymer, scientists can trigger condensation of tiny uniform water droplets that sink into the polymer film. The process repeats itself on its own until the film is filled with a three-dimensional array of water bubbles. When the solvent and water evaporate, they leave behind a polymer scaffold with a lattice of equal-sized air bubbles.

The process could contribute to the development of optical switches and the ability to direct or "steer" light beams, just as electrical switches and conducting materials control and direct electrical current. Potential applications include lasers, antennas, millimeter wave devices, and solar cells. This discovery represents an easy way of making materials with the regular structure needed for optical and photonic applications in a completely self-assembled process.

Researcher Srinivasarao, a physical polymer chemist in the Georgia Institute of Technology's textiles and fiber engineering department, is an NSF CAREER awardee. The Foundation-wide CAREER program recognizes and supports the early career development activities of those teacher-scholars who are most likely to become the academic leaders of the 21st century. CAREER awardees are selected on the basis of creative career development plans that effectively integrate research and education within the mission of their institution.

The Birth of the Universe

Two teams of cosmologists have released new findings about the nature of the universe in its infancy. Their spectacular images of the cosmic microwave background (CMB), taken with instruments operating from Antarctica, reveal the strongest evidence to date for the theory of inflation, the leading model for the formation of the universe.

Equipment from the BOOMERANG (Balloon Observations of Millimetric Extragalactic Radiation and Geophysics) project in Antarctica has given scientists valuable new information about the birth of the universe.

The announcement represents the first release of data from the Degree Angular Scale Interferometer, a thirteen-element ground-based instrument operating since last year at the NSF Amundsen Scott South Pole Station. Scientists also released similar results from further analysis of data from the Balloon Observations of Millimetric Extragalactic Radiation and Geophysics project, obtained in 1998 and first reported in 2000.

These spectacular results represent a payback from the significant national investment in research conducted in the polar regions. The Antarctic environment provides exceptional clarity for astrophysical observations, and the U.S. Antarctic Program provides unmatched support for such world-class research. Both analyses, unveiled at the American Physical Society meetings, support the model that the universe experienced a tremendous spurt of growth shortly after the Big Bang. Cosmologists believe the structures that formed in the first moments of the cosmos left their imprint as a very faint pattern of variations in the temperature of the CMB, the radiation left over from the intense heat that filled the embryonic universe during the initial growth spurt. Some 12 to 15 billion years later, these temperatures have become detectable from Earth with highly sensitive instruments. Multiple teams supported by NSF have probed the CMB for these minute temperature variations, including the two teams operating from the polar region. Two other teams using instruments in the continental United States also released data.

This is an outstanding example of how NSF supports multiple scientific projects, leading to rapid, new results. It took more than a decade to get the initial observations of the cosmic microwave background with the COBE satellite, but over a few short years, the progress in sharpening those observations has been truly astounding.

The teams used independent methods and two different technologies to obtain detailed observations of the CMB. The observations provided so much data that new methods had to be invented to analyze them. As the data analyses continue, they are providing precise measurements of parameters that cosmologists have long used to describe the early evolution of the universe, but in the past could illustrate only with models.