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 2002. Other examples of NSF-supported discoveries are available from NSF's Public Affairs Website (*www.nsf.gov/od/lpa/*).

Understanding A Crop Killer

In July 2002, the first draft sequence of a worldwide crop-killing fungus genome was completed by researchers in the joint NSF–U.S. Department of Agriculture Microbial Genome Sequencing Project.

The fungus *Magnaporthe grisea* causes rice blast disease, which is estimated to destroy annually enough rice to feed more than 60 million people. The fungus was recently recognized by the U.S. Centers for Disease Control and Prevention as a potentially significant biological weapon that could be used for agricultural terrorism.

Certain strains of the fungus can attack domesticated grasses such as barley, wheat, pearl millet, and even turf grasses. Rice blast disease, once thought to be confined to developing nations, has emerged in the United States over the past decade with the widespread introduction of rice as a crop in the South. In the Midwest, golf courses also have been devastated by the disease's attack on cool-season grasses.

Previously, rice blast outbreaks were controlled through the application of costly and potentially hazardous chemicals. Genome sequencing will allow scientists to understand the interactions between the fungus and grasses, and identify the mechanisms that regulate infection of a host plant. This knowledge could help scientists discover new ways to prevent fungal crop infection and the spread of rice blast disease.

Completing the first draft sequence is an important first step toward understanding how this fungus attacks the rice plant. The scientific community needs this information to fill long-standing gaps in understanding the disease and to develop new strategies for controlling this destructive pathogen.

Researchers in a joint NSF–U.S. Department of Agriculture project have made significant progress towards controlling a worldwide crop-killing fungus—a fungus that many consider to be a potential biological weapon for agricultural terrorism. Shown here are rice terraces in Indonesia.

Searching for Clues to Climate Change

In March and April 2002, a group of NSF-funded scientists scoured the Alaskan tundra for clues to the role snow cover plays in climate change. The six-member Snow Science Traverse—Alaska Region (SnowSTAR 2002) expedition used snowmobiles to cover 1,000 miles—from Nome through the Brooks mountain range to Barrow.

The team was following up on previous research, which indicated that climate change is likely to be amplified in the arctic and, therefore, easier to detect. Air temperatures in the Alaskan arctic have increased 2 to 4º Celsius in the past 30 years, and evidence suggests changes are already occurring in terrestrial ecosystems. Snow covers the arctic for 7 to 10 months of the year and is thought to play a key role in this process of change.

During the 36-day traverse, the team braved temperatures of 0º Fahrenheit (–17º Celsius) to take 33,000 measurements and to conduct several hundred experiments on snow strength.

Chemical sampling of the snow will help determine whether there is a difference between the source of winter precipitation in the arctic slope and the area south of the Brooks Range and if the precipitation source changes as the Chukchi, Beaufort, and Bering Seas freeze. By tracing the snow's chemicals, such as calcium, magnesium, and various isotopes such as boron and deuterium, the team hopes to pinpoint where the snow originated and its atmospheric history. The data gathered will help show how key meteorological events determine the characteristics of the snow.

The researchers also studied the relationship of snow and vegetation to test previous findings, which indicated that the presence of vegetation may promote further shrub growth by increasing the amount of snow on the ground. Climate warming also promotes increased plant production, so the two processes may interact in complex ways.

The snowmobile traverse is part of ATLAS (Arctic Transitions in Land Atmosphere System), a larger project to understand climate change in the Arctic.

The 6,000-square-mile Innoko National Wildlife Refuge near McGrath, Alaska, is home to a tremendous array of wildlife and diverse habitats. The goal of the NSF Arctic Research Program is to gain a better understanding of such wildlife and habitats by funding studies of Earth's biological, geophysical, chemical, and sociocultural processes, and the interactions of ocean, land, atmosphere, biological, and human systems.

Sustainable Mobility

According to the Alliance to Save Energy, we Americans spend more than $500 million a day to fuel our cars, SUVs, and light trucks. These vehicles account for 40 percent of U.S. oil consumption—8 million barrels a day. More than half of the oil we use is imported. In addition to the potential problems associated with dependence on foreign sources of crude oil, gasoline is a major contributor to greenhouse gas emissions and smog.

NSF is one of several federal government agencies funding research on the development of fuel-cell technologies. Fuel cells are energy conversion devices that use hydrogen to power clean-running vehicles, whose only emission is water. Over the next decade, scientists will continue to perfect the technology and develop a nationwide hydrogen distribution system that will make fuel-cell vehicles a sustainable alternative to the gasoline-powered engine.

Engineering Marvels

Building Bones

NSF-funded materials scientists at Northwestern University have used nanoscale self-assembly to create a composite material very similar to bone tissue. Their research could be the first step in creating better material for bone repair.

The discovery of a composite material similar to bone tissue may lead to a better material for repairing bone. NSF-funded materials scientists at Northwestern University used nanoscale self-assembly to create the material. Such techniques may lead to the development of artificial bone.

Samuel Stupp and his colleagues synthesized new polymeric molecules that self-assemble to form cylindrical nano-sized fibers. When a reinforcing mineral is added, the fibers direct the growth of the mineral's crystals into an alignment very similar to that around the collagen fibers in natural bone.

Developing bone repair materials, especially for load-bearing bones, is a continuing challenge for bioengineers and biomaterials researchers. Current technology usually relies on solid metallic implants that are coated to minimize rejection by the body.

The self-assembly techniques not only hold promise for development of artificial bone but are also expected to be useful for a wide variety of other applications, such as repairing nerve fibers, creating nanoelectronic wires, or preparing high-strength polymeric composites.

Researchers Find Trigger for Devastating Digestive Disease

NSF-funded scientists found a peptide molecule that triggers celiac sprue—a severe inflammation of the intestine that affects as many as 1 in every 200 Americans—and proposed a treatment that relies on bacterial enzymes to break down the offending molecule in the digestive tract.

Researchers were able to disassemble the large, complex mixture of gluten proteins and identify a single component that triggers the autoimmune response to wheat and related grains characteristic of the disease. The technology used to isolate and identify the peptide trigger and the enzymology used to neutralize the disease are marvelous examples of how research into the fundamental understanding of life processes can directly influence human health.

Chaitan Khosla and his colleagues at Stanford University and the University of Norway in Oslo determined that the autoimmune response in people with celiac sprue can be traced to an unusually long molecule—a chain of 33 amino acids—that cannot be broken down by the human digestive system. Khosla, who received NSF's Alan T. Waterman Award in 1999, used the award to pursue research on the disease after learning that a member of his family had the disease.

Celiac sprue is often diagnosed only after years of painful symptoms. Presently, there is no cure. The only treatment is to completely avoid grains that contain gluten, such as wheat, rye, and barley. The disease usually surfaces in early childhood. Symptoms include chronic diarrhea and an inability to gain weight or grow normally. When the disease arises in adulthood, symptoms can also include fatigue, weight loss, anemia, and neurological symptoms. Over time, celiac sprue can lead to overall sickness and even intestinal cancer.

In people with celiac sprue, the stable 33-amino acid peptide molecule is seen as a threat to the immune system. The researchers believe that the bacterial enzymes may result in a simple, oral supplement that can eliminate the harmful effects of gluten. The treatment approach would be similar to enzyme supplements taken by people who cannot digest lactose, a sugar found in milk. An approved therapy could be as many as 5 to 8 years away, although research is already under way and the treatment should be available for clinical trials within 2 to 3 years.

In the roughly 1 in 200 Americans with celiac sprue, gluten, which is found in wheat, rye, and barley, can trigger a severe intestinal inflammation. NSF-funded scientists have discovered the peptide molecule responsible for this inflammation. They believe that the bacterial enzymes may lead to the development of an oral supplement that can eliminate the harmful effects of gluten.

Potential Diabetes Breakthrough

Pushing the frontiers of drug delivery technology, an NSF-funded biomedical engineer at the University of Illinois at Chicago has developed an implantable capsule that releases a steady supply of insulin into the bloodstream of people with diabetes.

The biocapsule, developed by Tejal Desai, features two innovations designed to overcome previous obstacles. A biological process allows the capsule to continuously produce insulin, rather than using up a limited supply. The capsule is made of a material designed to overcome the problem of implant rejection.

The capsule acts as a bioreactor; it contains insulin-secreting cells that borrow nutrients from the body to keep producing insulin indefinitely. As long as the body produces glucose, the cells will respond with insulin.

Desai has also broken new ground by developing a successfully implantable microscale device. Tiny devices made with microchip technology have been researched extensively for implantable medical applications, but biocompatibility has been a continuing problem.

To prevent the capsule from being attacked and destroyed by the immune system, Desai developed a silicon membrane covered with tiny uniform pores, each seven nanometers across. The membrane acts as a microfilter, allowing the secretion of insulin from the capsule but blocking the entrance of antibodies. The membrane is fabricated with photolithographic techniques commonly used for manufacturing silicon microchips. The next step in Desai's research is to test long-term usage and evaluate dosage levels.

Improving Hurricane Prediction

In a key step toward improving hurricane prediction, NSF-funded scientists at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, have reproduced in a computer model the fine-scale structure that drives the birth and strengthening of tropical cyclones. NCAR scientists Jordan Powers and Christopher Davis used the NCAR/Pennsylvania State University Mesoscale Model, Version 5 (MM5), to create their simulation. This marks the first time a cloud-resolving simulation has been able to reproduce the formation of a tropical cyclone, given only information about atmospheric conditions on a scale much larger than that of the cyclone. The breakthrough points toward future forecasting power that will soon be available.

For their MM5 experiment, Davis and Powers studied Hurricane Diana, which struck North Carolina in 1984. Diana was chosen because of ample surface data and because a well-defined nontropical low preceded its formation. The MM5 successfully reproduced several stages in Diana's development, from its original state as a nontropical low to its intensification to hurricane status more than a day later.
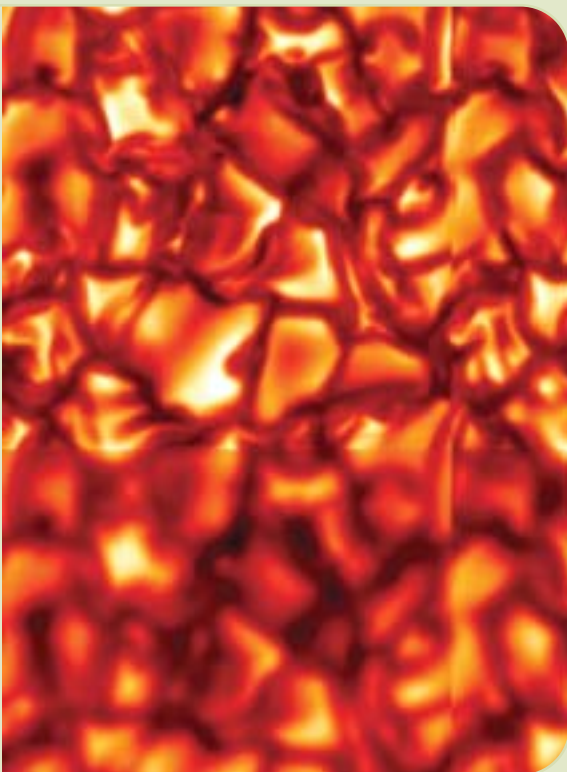
One of the remaining mysteries about hurricanes is how they form, especially when they are influenced by midlatitude weather systems that move into the subtropics and tropics. The researchers hope that by analyzing the mechanisms behind storm formation in these simulations, they can make hypotheses of tropical cyclone formation that can be tested using aircraft, radar, and satellite data. They also hope to understand what is needed to predict storm formation in operational weather forecast models.

Computer models used for day-to-day weather prediction have become increasingly adept at projecting a hurricane's motion. Yet even the best models have little skill in predicting intensity, especially the rapid strengthening often noted in the most powerful hurricanes. Part of the problem is that the compact core of a hurricane, including the spiral bands of showers and thunderstorms that gather and focus energy, cannot be modeled in sufficient detail on the computers and models used for everyday forecasting.

The flying scientists from the National Oceanic and Atmospheric Administration (NOAA) found beauty in the eye of this hurricane. Data gathered by NOAA are helping NSF-funded researchers at the National Center for Atmospheric Research in Boulder, Colorado, create computer models to improve the prediction of severe storms.

Newfound Planetary System Has "Hometown" Look

After 15 years of observation and a lot of patience, the world's premier planet-hunting team found a planetary system that reminds them of our home solar system.

With funding from NSF and the National Aeronautics and Space Administration, Geoffrey Marcy, astronomy professor at the University of California, Berkeley, and astronomer Paul Butler of the Carnegie Institution of Washington, announced in June 2002 the discovery of a Jupiter-like planet orbiting a sun-like star at nearly the same distance as the Jovian system that orbits our sun.

All other extrasolar planets discovered up to now orbit closer to the parent star, and most of them have had elongated, eccentric orbits. This new planet orbits as far from its star as our own Jupiter orbits the sun.

The star, 55 Cancri in the constellation Cancer, was already known to have one planet. That planet is a gas giant slightly smaller than the mass of Jupiter and whips around 55 Cancri in 14.6 days at a distance only one-tenth that from Earth to the sun. The newfound star is 41 light years from Earth and is about 5 billion years old. Further data are needed to determine whether yet other planets are orbiting it.

This simulation depicts solar granulation as seen in radiation emerging from the surface of the sun. NSF-funded scientist Robert Stein, a physics and astronomy professor at Michigan State University, and Aake Nordlund of Copenhagen University Observatory in Denmark, used the National Computational Science Alliance's SGI Origin2000 supercomputer, located at the National Center for Supercomputing Applications, to create massive models of portions of the sun to simulate the processes behind its smaller-scale features. Using these models, the team focused on understanding convection and magnetic flux near the solar surface. Stein and Nordlund have used supercomputers to study the nature of the sun for more than 15 years.

In addition to the discovery of 55 Cancri, Marcy, Butler, and their team also announced a total of 15 new planets, including the smallest ever detected: a planet circling the star HD49674 in the constellation Auriga at a distance of .05 AU, one-twentieth the distance from Earth to the sun. Its mass is about 15 percent that of Jupiter and 40 times that of Earth. This brings the total number of known planets outside our solar system to 91.

This illustration shows a newly discovered Jupiter-like planet and its hypothetical moon (blue orb) circling the star 55 Cancri. Copyright 2002 Lynette Cook.

TEACHING EXCELLENCE

Early Career Support for Teachers a Success

To address the need for more science and mathematics teachers, the Montana Systemic Teacher Excellence Preparation (STEP) project has connected state universities and colleges with Tribal Colleges and has combined distance education courses with onsite courses. In Years 3–5 of the project, investigators developed an "early career support program" that served 127 beginning teachers and continues to serve about 60 new teachers per year. To date, there is a 95 percent retention rate in the profession for teachers who participated in the program.

In addition to providing professional development for new teachers, the Montana STEP project has established an M.S. in Science Education program, which is an interdisciplinary program involving both on-campus and distance learning. It is the only intercollege program for science education in the United States with a 65 percent distance education component. To date, over 100 teachers have been admitted to the program, 42 have received graduate degrees, and 77 are currently enrolled.

Early Exposure to Physics Boosts Student Performance

What would happen if you introduced physics into the curriculum in ninth grade before chemistry and biology? Active Physics, an innovative curriculum supported by the Instructional Materials Development program, is expanding the number of students taking physics and strengthening conceptual learning and inquiry skills using themes surrounding communication, home, medicine, predictions, sports, and transportation. Since 1998, more than 500,000 students have completed units, and market potential is expected to reach millions.

A growing number of the 322 implementing districts already show gains in student performance using the Stanford Achievement Test (SAT–9). In addition, University of California faculty recently approved the curriculum as meeting the "d-laboratory science" requirement, finding that it provides a solid foundation for college-level work and a deeper conceptual understanding than is achieved through traditional approaches emphasizing number problems. The U.S. Department of Energy has adopted the Active Physics model in content, design, and pedagogical format.

Second graders at Hartford Avenue University School in Milwaukee, Wisconsin, invent their own math games. The school is a participant in the Milwaukee Urban Systemic Initiative (MUSI), an NSF-funded program. MUSI seeks to create fundamental changes in the way math and science are taught in the Milwaukee public schools by setting curriculum standards and providing teachers with continuing education on inquiry-based teaching methods. One of the most successful components of MUSI involves identifying lead teachers—those whose teaching methods are especially interactive and exciting—and providing them with in-depth training on how to use an inquiry-based curriculum. The teachers will take this knowledge back to their schools and classrooms and share it with their colleagues.

International Research Gains From Optical Networking

The next generation of global scientific research will require networking services that are significantly more sophisticated, with much higher-capacity potential and substantially higher performance, than the services available today. NSF-funded researchers Thomas DeFanti, Maxine Brown, and colleagues from the Electronic Visualization Laboratory at the University of Illinois at Chicago are developing StarLight, an advanced optical infrastructure and proving ground for network services optimized for high-performance applications. Pictured above is some of the fiber at StarLight's Chicago-based co-location facility. StarLight provides space and collaboration opportunities for advanced data mining, video streaming, caches, and network monitoring and analysis, as well as optical switching and, eventually, optical routing.

The StarLight network-research facility opened for business in December 2001, providing high-speed connections for U.S. researchers to communicate with colleagues abroad. Short for "Science Technology and Research Light-Illuminated Gigabit High-performance Transit," StarLight uses the latest optical technology to achieve speeds of 2.5 billion bits per second (gigabits). StarLight uses both electronic and optical switches to manage the individual wavelengths (called "lambdas") of existing local, national, and international fiber-optic bandwidth. The resulting optical connection is a stable resource for far-flung scientists and engineers, while also presenting a unique "laboratory" for researchers who study advanced networking itself.

StarLight is an NSF-funded project of the University of Illinois at Chicago, Northwestern University, and the Argonne National Laboratory. The facility is an important part of the growing "cyber-infrastructure" that supports applications such as real-time, multisite virtual reality presentations, advanced interactive data mining, and remote control of large-scale instrumentation (including telescopes and microscopes). StarLight will also host connections to the world's most-advanced multisite supercomputing system, the TeraGrid.

NSF supports StarLight for numerous reasons—as an experimental testbed for new networking technologies and a tool that provides scientists and engineers with ultra-fast access to online resources across the world. By stretching the boundaries of what is feasible, StarLight helps envision the future of global networking while helping to solve today's pressing scientific problems.

Center for Spatially Integrated Social Science

Over recent decades, major advances in three sets of technologies (geographic information systems, the Global Positioning System, and remote sensing) have provided dramatic new insights into patterns, processes, and changes on the Earth's surface. Although many disciplines have adopted these technologies and use them successfully for a variety of inquiries, few social and behavioral scientists have begun to use them on a significant scale. To accelerate the adoption and use of these technologies, a national center based at the University of California–Santa Barbara is focusing on the methods, tools, techniques, software, data access, and other services needed to promote and facilitate a novel and integrating spatially enabled approach to the social and behavioral sciences. The center builds on the efforts of the National Center for Geographic Information and Analysis, engaging in six core programs that are targeted across the full spectrum from inductive, exploratory science to theory-based, confirmatory science. Among major research areas that are benefiting as a result of these efforts are human environmental interactions, urban studies, social and economic inequality, social and business networks, health and disease, criminal justice, and community-based grassroots organizations.