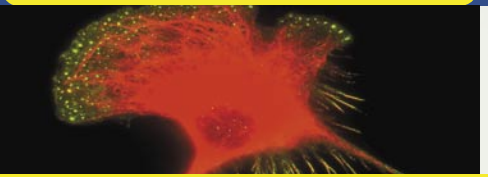
Microphage Moving Along Surface
This photograph shows a macrophage—one of the body's sanitation engineers—at work. Macrophages engulf and remove tissue debris after an injury, foreign particles from bodily fluids, bacteria, and dead cells.
Credit: Ivan Correia, Whitehead Institute for Biomedical Research

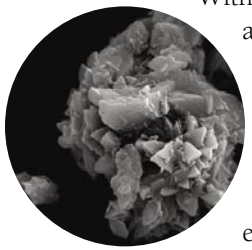


WHERE DISCOVERIES BEGIN

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 of long-term support of research and education projects that emerged and were reported in FY 2004.

Making the World a Safer Place

Advanced Nano-Engineered Products



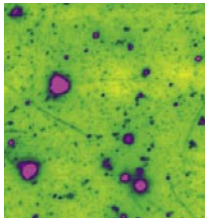
With support from NSF, researchers at NanoScale Materials, Inc., developed scaled-up production processes for FAST–ACT (First Applied Sorbent Treatment Against Chemical Threats), an advanced nano-engineered family of products designed to provide first responders, hazmat teams, and other emergency personnel with a single technology to counteract a variety of chemical warfare agents and toxic industrial chemicals.

Nontoxic, noncorrosive, and nonflammable, FAST–ACT is particularly useful when response personnel are confronted with a chemical spill of an unknown nature. While substances such as activated carbon can physically absorb toxic substances, FAST–ACT neutralizes, destroys, and renders them harmless. Independent testing by chemical warfare experts showed that FAST–ACT removed more than 99 percent of such agents as VX, soman, and mustard gas from surfaces in less than 90 seconds.

NSF-funded researcher Kenneth Klabunde at Kansas State University conducted the initial research that led to the development of FAST–ACT. NSF's Small Business Innovation Research (SBIR) program supported NanoScale's research to make production commercially viable.

Human Breathing Monitor

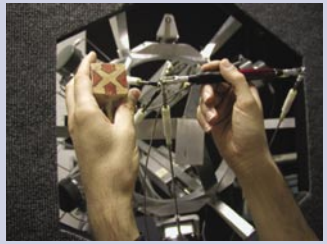
NSF's SBIR program also funded researchers at Nanomix, Inc., who created a tiny device that can monitor a victim's breathing in emergency situations by effectively shrinking an operating room machine into a small, disposable tool that can be carried to a disaster site. Nanomix scientists developed a transistor that fuses carbon nanotubes, polymers, and silicon into a capnography sensor—a human breathing monitor. Capnography sensors detect subtle changes in the concentration of carbon dioxide gas in a person's breath, revealing respiratory diseases in children and adults, and allowing anesthesiologists to monitor a patient's breathing during surgery.



For more information:

NSF Nifty Fifty: http://www.nsf.gov/about/history/nifty50/index.jsp

Other examples of NSF-supported discoveries: http://www.nsf.gov/discoveries/



A bimanual haptic interface developed at the University of Colorado at Boulder enables users to move and manipulate virtual objects easily with both hands. The "cube" has a 6-degree-of-freedom position sensor that allows the user to position virtual objects precisely so that he or she can then "operate" them with the actively force-controlled 6-degree-of-freedom "stylus." *Credit:* Jeff Fehring; courtesy of Dr. Lucy Pao, University of Colorado

The new South Pole Station replaces a 30-year-old facility that was no longer adequate in terms of capacity, efficiency, and safety. The new station is an elevated complex with two connected buildings that can support 150 people in the summer and 50 people in the winter. More than 40 engineering studies and reports were required for development and construction of the new station—including snowdrift minimization modeling, detailed analysis of power and heating requirements, preparation of an Environmental Impact Statement, energy conservation measures, fuel storage support system evaluation, and gray-water system evaluation. NSF has responsibility for overall funding and management of U.S. activities in Antarctica. *Credit:* NSF

In the field, emergency responders may be able to use the new sensor to verify the proper placement of a breathing tube, monitor the patient's respiratory patterns, and assess the effect of life support measures. While the device is already capable of monitoring human breathing in laboratory settings, the researchers are collaborating with anesthesiologists and other specialists at the University of California, San Francisco, to design and test a field-ready medical device.

Finding Cures from Corals

A chemical that protects a rare type of marine coral from predators may also prove to be a potent medicine for humans in the fight against cancer.

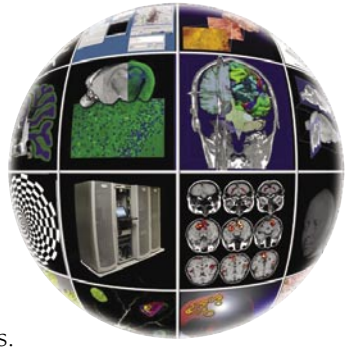
Surrounded by countless predators, many of the ocean's sedentary animals rely on powerful toxins for defense. NSF-funded researcher William Fenical and his colleagues have shown that in addition to defeating hungry sea creatures, these potent chemicals can actually help defeat disease.

While diving off the coast of Australia, Fenical, director of the Center for Marine Biotechnology and Biomedicine at the Institute of Oceanography, discovered a small yellow coral now called *Eleutherobia*. Eleutherobin—the chemical extracted from the coral—behaves like the anticancer drug taxol. Both chemicals bind to cellular microtubules, preventing cancer cell division. Eleutherobin may prove to have advantages over taxol, perhaps causing fewer side effects—including immune system suppression, nausea, and hair loss.

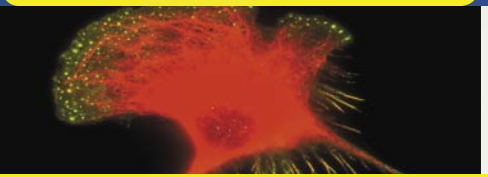
Fenical and his colleagues are now studying the myriad bacteria and fungi that live in the sea and the potentially revolutionary chemicals that these microorganisms produce. He and his colleagues recently identified two new compounds that are being developed for cancer treatments and one antiviral compound that may help patients with *Herpes simplex*. Fenical believes that microbes in the oceans may prove to be the most important new source for pharmaceuticals on the planet.

Facilitating Health Care Research

The study of Alzheimer's disease and the analysis of particle collisions may not appear to have much in common, but behind the scenes, middleware being developed with support from NSF is helping groups of researchers in neuroscience, physics, and other fields apply the power of grid-based computational resources.



Spanning 14 universities and 22 research groups, the growing Biomedical Informatics Research Network (BIRN) is establishing the cyberinfrastructure needed to facilitate health care research for large-scale data sharing and analysis. The ability to share and compare massive data sets such as magnetic resonance imaging brain scans or high-resolution electron microscopy images is essential to participants' research into Alzheimer's disease, depression, schizophrenia, multiple sclerosis, and other disorders.



With the participating laboratories connected by the Internet2 high-performance network, the BIRN cyberinfrastructure uses software from the NSF Middleware Initiative (NMI) to harness grid-based services and resources for the demanding computational tasks of data mining, analysis, and visualization. The BIRN is sponsored by the National Center for Research Resources at the National Institutes of Health.

By emphasizing open-source solutions that simplify resource sharing, NMI is making it easier for scientists, engineers, and educators to work with colleagues on a worldwide scale through high-speed networks. The integrated tools from NMI facilitate collaborations across organizations, information technology architectures, operating systems, and security policies.

Before NMI, many research communities were developing independent—and often incompatible—middleware solutions. The successful use of NMI releases by BIRN shows that NMI's open-source and open-standards approaches can help scientists avoid "reinventing the wheel" and provide a common foundation for building customized applications.

Discoveries on Two Continents

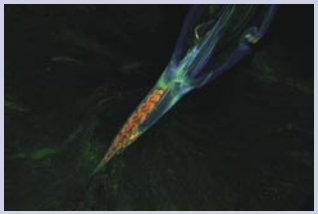
A Lost World

Against incredible odds, researchers working in separate sites thousands of miles apart in Antarctica have found what they believe are the fossilized remains of two species of previously unknown dinosaurs. One of the two finds, which took place less than a week apart, is an early carnivore that would have lived many millions of years after the other, a plant-eating beast, roamed the Earth. One was found at the bottom of the sea, the other on a mountaintop.

Working on James Ross Island off the coast of the Antarctic Peninsula, veteran NSF-funded dinosaur hunters Judd Case, James Martin, and their research team found the fossilized bones of an entirely new species of carnivorous dinosaur related to the enormous meat-eating tyrannosaurs and the equally voracious, but smaller and swifter velociraptors that terrified movie-goers in the film *Jurassic Park*.

The remains include fragments of an upper jaw with teeth, isolated individual teeth, and most of the bones from the animal's lower legs and feet. The creature likely inhabited the area millions of years ago, when the climate and terrain were similar to conditions in today's Pacific Northwest and radically different from the way they are today.

And the Winner Is . . .



On September 24, 2004, NSF and the American Association for the Advancement of Science announced the results of the second annual Science and Engineering Visualization Challenge. This annual international competition is designed to showcase and encourage an increasingly important aspect of science: the ability to convey the essence and excitement of research in digitized images, color diagrams, and multimedia presentations. The contest recognizes outstanding achievements by scientists, engineers, visualization specialists, and artists in the use of visual media to promote understanding of research results and scientific phenomena.
Credit: Marna E. Ericson, University of Minnesota, Minneapolis

2004 Visualization Results:
www.sciencemag.org/sciext/vis2004

Middle school students have fun building radios in a RASEM^2 mentoring project. RASEM^2 is an NSF-supported program whose mission is to level the playing field for students with disabilities.

RASEM^2 provides the means, support, and encouragement for students with disabilities to overcome the educational barriers they face in considering careers in science, technology, engineering, and math. These programs instill an appreciation of the excitement for discovery and the satisfaction of achievement in fields generally perceived to be beyond the reach of these students. For more information, visit http://rasem.nmsu.edu.
Credit: Photo courtesy of Dr. Ed Misquez, RASEM^2

At the same time, thousands of miles away, an NSF-funded research team led by William Hammer was working in the Antarctic interior on a mountaintop roughly 3,900 meters (13,000 feet) high near the Beardmore Glacier. They found embedded in solid rock what they believe to be the pelvis of a primitive sauropod, a four-legged, plant-eating dinosaur similar to better-known creatures such as brachiosaurus and diplodocus.

Field analysis of the bones has led Hammer and his fellow researchers to believe that the pelvis—roughly 1 meter (3 feet) across—represents one of the earliest forms of the emerging dinosaur lineage that eventually produced animals more than 30 meters (100 feet) long. The researchers estimate that the new, and as-yet-unnamed creature was between 1.8 and 2.1 meters (6 and 7 feet) tall and up to 9 meters (30 feet) long and lived roughly 200 million years ago.

Earlier Ancestors

NSF-funded scientists discovered that early humans lived in northern China about 1.66 million years ago. The finding suggests that humans—characterized by their fabrication and use of stone tools—inhabited the hostile environment of upper Asia almost 340,000 years before previous estimates placed them there.

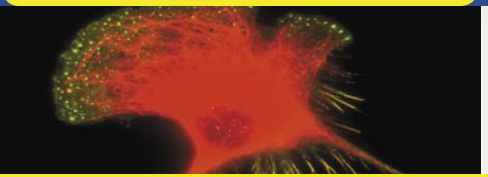
The research team excavated four layers of sediment at Majuangou in northern China. All the layers contained indisputable stone tools apparently made by early humans known to researchers as "hominins." The top layer, located about 145 to 148 feet deep, contains the oldest known record of hominin stone tools, dating back to 1.32 million years ago. But the fourth and deepest layer, in which the team also found stone tools, is about 340,000 years older than that.

All four sediment layers the researchers examined contained evidence that early humans used stone tools to strike other stones, most likely to fashion chopping and scraping tools. In the three deepest layers, the stone tools are made of rocks unlike those in the surrounding sediment, indicating that these Asian humans transported the rocks from another place. It also appears that these humans used their tools on the bones of deer- and horse-sized mammals, perhaps to butcher them for food.

These findings, which suggest that humans reached northeast Asia earlier than scientists had previously thought, demonstrate the adaptability of humans as they evolved and moved out of the tropics and into other environments. Furthermore, the evidence from the Majuangou site is only slightly older than evidence found at the same latitude in western Eurasia and about the same age as the earliest known human fossils found in southeast Asia. This implies that human populations came to Asia from Africa and spread rapidly to many areas.

New Planets Outside the Solar System

A team of astronomers has announced the discovery of some of the smallest planets yet detected



beyond our solar system: two worlds that represent a new category of extrasolar planets, as well as a significant and much-anticipated advance in the hunt for such objects.

Each of the newly discovered planets is roughly comparable to the planet Neptune in our own solar system, according to Geoffrey Marcy of the University of California, Berkeley, a veteran planet-hunter and a co-discoverer of this pair.

Although small in comparison to the largest planets in our solar system, these new planets are big on a terrestrial scale. They are, however, tiny compared the 120-plus extrasolar planets that have been discovered to date. Virtually all of those objects are considerably heftier than our own solar system heavyweights, Jupiter and Saturn, which have 318 times and 95 times the mass of the Earth, respectively.

In addition, these newly discovered Neptunes may well be the harbingers of many more (and smaller) things to come. Although lower-mass planets like these tend to be harder to detect than their higher-mass cousins, the statistics to date suggest that we may soon be seeing many more Neptunes—and that Earth-sized planets, if we can ever detect them, may be downright abundant. The discovery team was supported jointly by the NSF and the National Aeronautics and Space Administration (NASA).

Viruses on the Attack

Using a combination of imaging techniques, researchers have determined the mechanics that allow some viruses to invade cells by piercing their outer membranes and digesting their cell walls. The researchers combined their findings with earlier studies to create a near-complete scenario for this form of viral assault.

The results have a dual benefit: They show the inner workings of complex, viral nanomachines infecting cells (in a process nearly identical to some viral infections of human cells), and the images provide tips for engineers to design and build the gene delivery devices of the future.

Led by Michael Rossmann of Purdue University and Vadim Mesyanzhinov of the Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry in Moscow, the team added its findings to several decades of research into the structure of bacteriophage T4—a virus that attacks the familiar pathogen *Escherichia coli* (*E.coli*). Although some strains of *E. coli* can cause food poisoning, others supply essential products to the human gut. It is possible that studies of viruses could one day help biologists develop strategies to fight deadly bacterial infections. Similar efforts targeting antibiotic-resistant bacteria are already under way in other laboratories.

By combining thousands of images of the virus viewed from different directions, the researchers were able to create a model of how bacteriophage T4 infects cells. This work was supported by grants from NSF and the Howard Hughes Medical Institute.

EarthScope

EarthScope is a scientific exploration of the structure and evolution of the North American continent and the physical processes controlling its earthquakes and volcanic eruptions. The project will not only help reveal how the North American continent formed, but it will also make possible the mapping of the continent's changing structure. Using new broadband seismic sensors, developments in global positioning system technologies, and a data distribution infrastructure, scientists will collect and integrate scientific information derived from geology, seismology, remote sensing, and geodesy, the science of measuring the Earth's surface features.

EarthScope is a national multi-agency program that partners NSF, the U.S. Geological Survey, NASA, and other federal agencies. The program will also develop partnerships with state agencies, regional seismic networks, organizations in Mexico and Canada, and the International Continental Drilling Program. All EarthScope data will be available to the public in real-time to maximize participation from the scientific community and to provide on-going educational opportunities for students of all ages.