NSF

National Science Foundation

Annual Report 1985

National Science Foundation (U.S.)

Annual Report, 1985

Thirty-Fifth Annual Report for Fiscal Year 1985

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About the National Science Foundation

The National Science Foundation is an independent federal agency created by the National Science Foundation Act of 1950 (P.L. 81-507). Its aim is to promote and advance scientific progress in the United States. The idea of such a foundation was an outgrowth of the important contributions made by science and technology during World War II. From those first days, NSF has had a unique place in the federal government: It is responsible for the overall health of science across all disciplines. In contrast, other agencies support research focused on specific missions.

NSF funds research in all fields of science and engineering. It does this through grants and contracts to more than 2,000 colleges, universities, and other research institutions in all parts of the United States. The Foundation accounts for about 28 percent of federal support to academic institutions for basic research.

NSF receives more than 27,000 proposals each year for research and graduate fellowships and makes more than 12,000 awards. These go to universities, colleges, academic consortia, nonprofit institutions, and small businesses. The agency operates no laboratories itself but does support National Research Centers, certain oceanographic vessels, and Antarctic research stations. The Foundation also aids cooperative research between universities and industry and U.S. participation in international scientific efforts.

NSF is structured much like a university, with grant-making divisions for the various disciplines and fields of science and engineering. The Foundation's staff is helped by advisors, primarily from the scientific community, who serve on formal committees or as ad hoc reviewers of research proposals. This advisory system, which focuses on both program direction and specific proposals, involves more than 50,000 scientists and engineers a year. NSF staff members who are experts in a certain field or area make final award decisions; applicants get verbatim unsigned copies of peer reviews and can appeal those decisions.

Awardees are wholly responsible for doing their research and preparing the results for publication. Thus the Foundation does not assume responsibility for such findings or their interpretation.

NSF welcomes proposals on behalf of all qualified scientists and engineers and strongly encourages women, minorities, and the handicapped to compete fully in its programs.

Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1985 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

Erich Bloch
Director, National Science Foundation

The Honorable
The President of the United States

Cover

Fractal patterns generated by simple mathematical expressions (photo by Robert L. Devaney, Boston University).

An Ongoing Commitment to Excellence

Contents

Director's Statement

Fiscal Year 1985 marked the National Science Foundation's 35th year of operations—years that saw the Foundation grow from an agency with a few research programs to one supporting an increasingly broad range of activities in science and engineering research and education.

Our mission has always been challenging: we are the only federal agency charged with promoting general scientific progress, rather than a specific area such as space, health, or agriculture. But the way we carry out that broad charge is very different today from what it was in the 1950s.

In fact, the contrast between then and now is dramatic. Today, for example, we must be more vigilant than ever before about supporting the basic research required to keep our economy healthy and competitive—and our defense and social needs satisfied as well.

Thirty-five years ago we were secure in the knowledge that, in most cases, each discipline defined a well-bounded subject area. The linkages between the fields were not matters of great concern. Today we find that these neat boundaries are breaking down everywhere, and frequently the most exciting science is going on at the interface of established disciplines.

Thirty-five years ago the Foundation dealt almost entirely with the university research community. Industrial research was separate, and few were concerned with possible connections between the two. Today we seek linkages between academic and industrial research in several NSF programs, because we understand how much each has to offer the other.

Over these 35 years we have seen science policy swing from the *laissez faire* attitudes of the post-World War II years, to a frenzy of activity in the decade after the Sputnik launch in 1957, and then to a period when we assumed that science should be oriented to some extent toward social problems. Today we have a more settled view of the place of science and engineering research and a clearer understanding of what the federal government should do, what industry should do, and what the states, local governments, and universities should do for themselves.

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The most salient aspects of economic life today are its global nature and its ubiquitous challenge. Thirty-five years ago the United States was economically supreme, secure in its technological lead and the competitiveness of its industries. Today our industries are threatened with erosion of their home markets, and they have difficulty competing in foreign markets. Our traditional trading partners are more competitive in an economic and research sense, and challenges are arising from the newly industrialized countries. Suddenly our industries must be concerned with global competitiveness if they want to survive.

Key Themes and Initiatives

In this new world the National Science Foundation has a greatly enhanced role to play. Three themes now dominate our programs:

- ***Continuing support for the best research in every field.*** While emphasis and attention may shift from one area to another, we need always to remember that basic research is unpredictable, and that core support must be maintained in all areas.
- ***Concern for freeing research from arbitrary limits imposed by disciplinary bounds.*** The connections between the disciplines have often been the least explored, and thus are often the most productive. And as we look for the most challenging problems on which to focus our research, we find that many of the most important ones are inherently multidisciplinary.
- ***Cooperation in everything we do.*** Universities and industry must cooperate because industry has the problems—and often the resources to solve them—while universities have the research talent and ideas. Industries must cooperate among themselves because many research problems are beyond the reach of any single company but will yield to joint approaches. The federal government must cooperate with industry, academia, and state and local gov-

ernments because we must use all our resources in the most efficient way possible. And researchers themselves must cooperate, because the multidisciplinary problems that we are increasingly concerned with will rarely yield to the efforts of a single investigator working within the bounds of a traditional discipline.

During 1985 the Foundation made the first awards in an important new program: **Engineering Research Centers.** From 140 proposals, we selected 6 for awards. All are in areas that offer new research opportunities, all focus on problems that are important to industry, and all deal with the concepts and technologies that American industry will need to remain competitive in the years ahead. But

"As we look for the most challenging problems on which to focus our research, we find that many of the most important ones are inherently multidisciplinary."

they are also areas in which the challenges involve the most basic research—and thus require the imagination and innovative thinking that are characteristic of the best in the universities. Finally, all of the areas the Engineering Research Centers will work in are thoroughly multidisciplinary.

These centers can be depended upon to produce important research, but they will have another effect as well: the move toward multi-disciplinary collaboration will begin to change the way American universities operate. The established disciplines serve many useful purposes in structuring research, defining important questions, and maintaining quality. But as the nature of research changes the social structure for performing it must change also, and the Engineering Research Centers are an indicator of the way we will move.

Advanced Supercomputing Centers (and access to them by university researchers) is another new program that demonstrates the themes of cooperation across the disciplines and between different sectors of society. Supercomputing centers will make available the resources needed to solve advanced problems; through them the computer can also be used to simulate and model complex systems and interactions. Resources of this sort are beyond the ability of most universities to provide for themselves. Among the kinds of cooperation needed here are university cooperation with industry to develop the machines that will do the job tomorrow.

In **Science and Engineering Education,** as in other programs, we are pursuing the themes of cooperation and a multidisciplinary approach. During Fiscal Year 1985 the education programs of the Foundation were redefined. The revised programs stress cooperation between researchers in universities and education professionals at the precollege level, between education specialists and disciplinary specialists, and between local industry and local education officials. The goal of these programs is to improve education in science and engineering at all levels, so that the nation will have the people we need for success in a technological world.

The Foundation took a big step in 1985 toward improving public awareness of science, mathematics, and technology—especially awareness among young people. With financial support from private industry, NSF launched the first **National Science Week** during May 1985. As part of the Week's activities, organizations all over the country—elementary and secondary schools, universities, libraries, museums, community groups, and professional associations—participated in science and math competitions, lectures, exhibits, science fairs, open houses, teacher workshops, and much more.

National Science Week is an important way to reach young people and stimulate them to consider science or engineering as a career. It is also a good example of cooperation between government, industry, and private groups. For 1986, National Science Week will be held May 11-17.

Cooperation and multidisciplinary approaches will continue to be the dominant themes of the Foundation's new activities in the coming year. We

"Cooperation and multidisciplinary approaches will continue to be the dominant themes of the Foundation's new activities in the coming year."

expect to expand the concept of Engineering Research Centers to other areas, and we will encourage the development of cooperative efforts in our other programs. The goal, however, will remain the same: to ensure that the nation's basic research capacity in science and engineering—and the people employed in those enterprises—are the best that we can make them.

There was never a time when this mission was more important, and there was never a time when the opportunities for developing and exploiting new knowledge were more promising. The Foundation can be proud of its accomplishments so far, but the future has a potential far beyond anything we have yet seen. We face that future with hope, with confidence, and with excitement.

ERICH BLOCH
DIRECTOR

Recent Achievements Supported by NSF

PURDUE UNIVERSITY NEWS SERVICE

A supercomputer success. Purdue's Michael Rossmann (above) and the cold virus model, at right, that he and his coworkers developed.

SPECIAL SECTION

Mapping a Common Cold Virus:

Researchers have finally seen their first three-dimensional picture of an animal virus. *Michael Rossmann* at Purdue University, *Roland Reuckert* at the University of Wisconsin at Madison, and their colleagues used the Cornell High Energy Synchrotron Source and a supercomputer to look in detail at the structure of a common cold virus.

A cold virus (there are nearly 100 different ones) is a twisted strand of RNA, surrounded and protected by a coat made of a number of different proteins. The structure of that coat—what the proteins are and how they are put together—determines what cells the virus can attack. In other words, knowing the structure of the coat might tell us how the virus causes infections and how medicine could intervene. So far this particular cold virus, named HRV14, has a coat that thwarts any straightforward medical intervention, so there is still no cure for the common cold. Nevertheless, Rossmann's and Reuckert's techniques will make mapping other viruses easier. And that in turn should help with a general understanding of how viruses infect, and how we can make vaccines to stop them.

The Fastest Semiconductor Device:

Electronic devices for sending and receiving signals, like those used in communications systems and computers, are analogous to devices for sending and receiving Morse code: to send a lot of information, send it fast; to send it fast, have a fast-operating on-off signal switch. A team from both AT&T Bell Laboratories and the Submicron Structures Facility at Cornell University has made a semiconductor device as part of a circuit that can switch on or off in 5.8 trillionths of a second.

The semiconductor circuit, called a ring oscillator, is engineered so that an electric signal will cross it quickly and be easy to control. The circuit is really a series of devices, tiny switches each under a thousandth of a millimeter, or submicron-sized. Each switch is built up of alternating layers of compound semiconducting materials, each only atoms thick. To get layers that thin, researchers had to make each surface exquisitely smooth, and (using a very high vacuum apparatus) lay down the next layer with exquisite uniformity. These semiconducting layers behave electronically with properties intermediate to conductors and insulators. Electric signals going across a semiconductor film are easy to control by turning the device switch on or off. And each switch's submicron size and thin layers ensure that an electric signal will cross it quickly.

In effect, the ring oscillator acts like a bucket brigade, each bucket carrying an electric signal. The signal passes from one bucket to the next in 5.8 trillionths of a second. The Bell Labs-Cornell ring oscillator is the fastest one yet.

Antarctic field camp.

Antarctic Bacteria Make Genetic Engineering Easier.

Biologists from the University of Southern California (USC) found a group of bacteria that live in freezing seas under two meters of ice, conditions that would kill most of their kind. Furthermore, the biologists learned that these bacteria manufacture an enzyme that will make genetic engineering much easier.

In the sea ice of McMurdo Sound in Antarctica, *Cornelius Sullivan, Hiroaki Shizuya,* and *Hiromi Kobori* found colonies of bacteria that serve as food for krill and other tiny crustaceans. While studying the way these bacteria operate in such extreme cold, the researchers discovered that they produce a kind of enzyme called alkaline phosphatase, or APase. This enzyme is widely used by genetic engineers to cut out certain sections of strands of DNA or RNA, in order to substitute one section for another. Most APase used for this purpose is manufactured by the ubiquitous bacteria *Escherichia coli.* But the APase from *E. coli* works slowly and requires an elaborate procedure to get it out of the experimental solution once it is no longer wanted.

The USC team found that APase from the antarctic bacteria works 50 times faster than its counterpart. Moreover, because the bacteria's native environment is so cold, its APase can be cleared out of a solution just by heating it up to 104 degrees Fahrenheit.

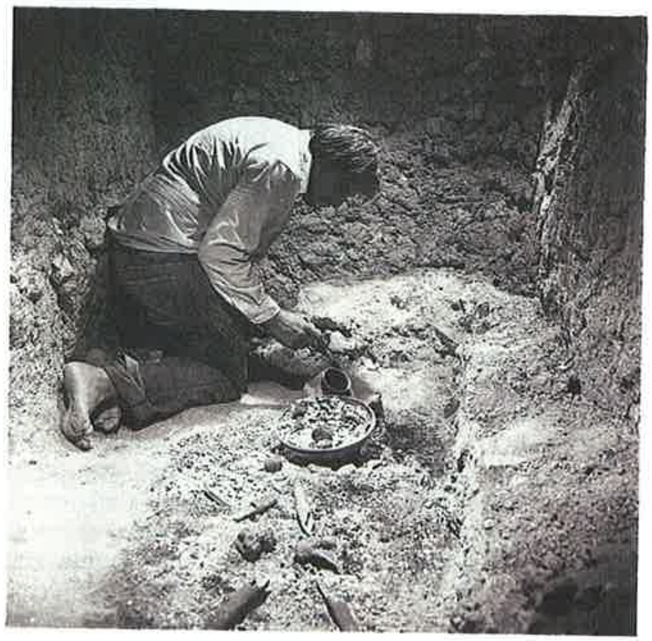
Recent Achievements Supported by NSF

Graves Offer a New View of Mayan Culture:

From around 250 AD until 900 AD, the Mayas of Central America built spectacular and intricate pyramids. After that period, they seemed to build only on lesser scales; archeologists assumed that Mayan civilization was accordingly in decline.

Recently, *Diane* and *Arlen Chase,* archeologists at the University of Central Florida in Orlando, found a tomb that challenged that assumption. The tomb, from the mid-1500s, held a skeleton decorated with a type of jade and turquoise ear jewelry that the Mayas did not make. The Chases surmise that these decorations had been traded for, probably from the Aztecs.

This finding, combined with other artifacts, implies that perhaps the Mayas shifted their attention away from building pyramids and toward making political and commercial alliances with their wealthy and powerful neighbors. The Chases postulate that the Mayan civilization flourished right up until the arrival of the Spanish conquistadores, only to perish at their hands. The conquistadores brought with them the infectious diseases that, within 150 years, killed three-quarters of the Mayas.



Mayan artifacts. Dr. Arlen Chase explores tomb of a Mayan ruler. Among the artifacts found by the Chase team were two figurines depicting blood-letting rituals, and a limestone bowl.

Astronomers Make Safer X-Ray Exams Possible:

Astronomers trying to capture on photographic plates the faint light from galaxies near the edge of the universe and biomedical researchers looking for ways to reduce exposure in X-ray exams can now use the same techniques. In 1977, University of Florida astronomer *Alex Smith* and his colleagues developed a technique that made photographic plates more sensitive to the faint light from distant galaxies. Their method, gently baking the plates in a mixture of nitrogen and hydrogen, is now standard practice in observatories around the world. More recently, however, Smith proposed that the approach which worked so well for astronomical photography might also work for medical X-rays.

Together with *Catherine Phillips,* a biomedical researcher at DuPont, and *Edward Hahn* of Eastman Kodak, Smith experimented with baking X-ray films in the same gas mixture. They discovered that treated films were twice as sensitive as untreated ones, reducing the possible exposure to patients having X-ray examinations. And, in an interesting reversal, Smith took the treated X-ray film back to his telescope and found it to be even more sensitive to light than was an emulsion widely used by astronomers.

Why Seals Don't Get the Bends:

B. M. ANDERSON, U.S. NAVY

Weddell seal in McMurdo Sound, Antarctica.

The bends are an occupational hazard of human divers who breathe air at high pressure for more than short periods of time. Seals, by contrast, do not seem to get the bends. Some in antarctic waters dive to nearly 2,000 feet and pop back up with no ill effects at all. Members of an international team working in the antarctic now believe they know more about this phenomenon.

Normally a human diver inhales nitrogen along with other gases in the air. If divers go down long enough and deeply, i.e., at high pressures, a large volume of nitrogen in the lungs becomes dissolved in the blood. Then when they swim back up to lower pressures, the nitrogen—like carbon dioxide in a just-opened bottle of soda—bubbles back out of the blood. The bubbles collect and expand in the spinal column, damaging or destroying the major nerves. The result is the bends, which can kill.

To find out how seals avoid the bends, the team of scientists from West Germany, Denmark, Australia, New Zealand, Canada, and the United States studied Weddell seals from the McMurdo Sound in Antarctica. Unlike human divers, seals can function for long periods using the oxygen stored in tissue. The team fitted the seals with devices to monitor the nitrogen levels in their bloodstreams. They found that such levels did increase slowly down to around 200 feet, then declined slowly.

The researchers speculate that at around 100 feet, the lungs of seals collapse because of water pressure, preventing further exchange of gases between the lungs and blood. Nitrogen in the blood is in part redistributed into blubber and muscles where it will not cause bends.

Just as interesting as these results, which confirmed an earlier theory, was the way they were found. The international team glued a cigar-box-sized computer to the back of each seal. Attached to the computer were devices to monitor the animal's heart rate, blood pressure, breathing rate, and body temperature, plus a syringe for taking blood samples. Researchers on the surface directed the computer on the diving seal to activate each of these devices; when the seal returned to the surface, the researchers read out the data the computer had collected. The technique, like that of an underwater Viking lander, essentially allowed biologists to dive with the seals into pressures too tremendous for humans to stand.

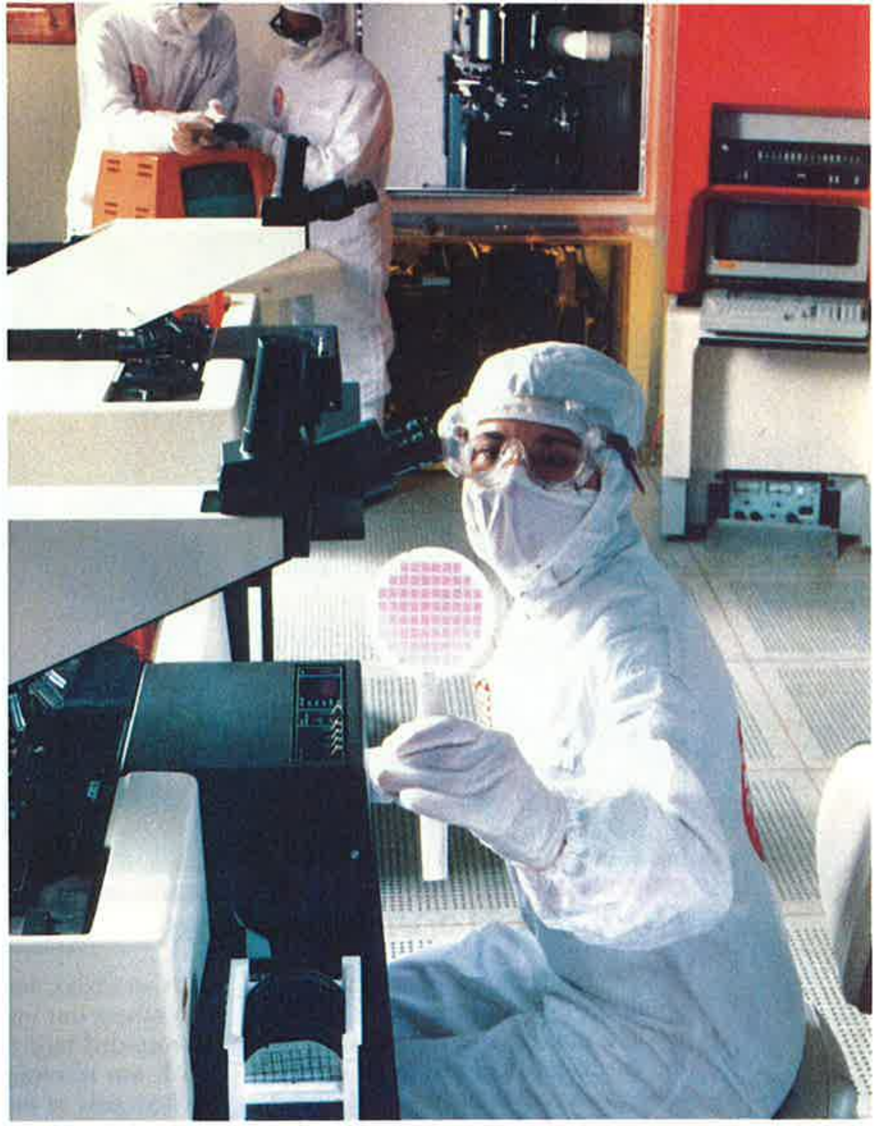
SPECIAL SECTION

How the Moon Was Born:

Scientists have always speculated about the origin of the moon. Perhaps it was a passing asteroid captured by the Earth's gravitational field. Perhaps long ago another planet-sized object hit the young Earth, and the debris from both coalesced into the moon. Or perhaps the moon and Earth both grew out of the same primordial cloud of gas and dust. All these speculations present problems. The moon is spinning more slowly, has less spin angular momentum, than the Earth; how then could the moon have once been part of a rapidly spinning young Earth? The moon has much less iron than the Earth; how could the moon and Earth have been formed from the same cloud?

Richard Durisen, an astronomer at Indiana University, has added a new speculation about the moon's origin which solves some of the problems of the older ones. Durisen used a supercomputer to simulate how a spinning fluid object might become unstable and fall apart. He found that such an object would not split into two others but into a single object surrounded by a thick ring. If the early Earth was spinning and not solid but molten, part of the ring that spun off it could have condensed into the moon. The rest of the ring then would have been fragmented and lost; in the process, it would have carried away much of the spin angular momentum of the original system. Furthermore, in any molten, spinning object, the heavier elements sink to the center and the lighter float to the outside. As a consequence, more iron would have collected in the center that became the Earth than in the outer ring that became the moon.

At this writing, Durisen is applying the same model to the solar system to see if he can explain why its outer planets—Jupiter, Saturn, Uranus, Neptune, and Pluto—are so much less dense than inner ones.



Pollution in Clean Rooms:

The manufacture of computer chips and other tiny precision devices requires a room absolutely free of dust and dirt. Researchers had known that most pollution comes from humans, in the form of what they shed, such as bits of skin or hairs. Now engineer *Stuart Hoenig* at the University of Arizona has found that smokers, even when not smoking, are also a source of contamination.

Hoenig discovered that 10 minutes after finishing a cigarette, a smoker still breathed out 35 times more particles than did a nonsmoker. The particles, though invisibly small, are large enough to foul precision machinery. Hoenig is also looking into whether eating or drinking mitigates the number of particles in a smoker's breath. By identifying yet another form of human pollution, Hoenig's discovery should help researchers keep a clean room cleaner.

Clean room. A technician examines a solid-state device in an environmentally "clean" area at the Eastman Kodak Company.

Recent Achievements Supported by NSF

New Finds in Dinosaur Research:

Paleontologist *Jack Horner* and his team from the Museum of the Rockies in Bozeman, Montana, continued their much-publicized work with dinosaur fossils, exploring new dig sites during 1985. Among their discoveries were the skeleton of a small dinosaur that may be the earliest of the triceratops, a rare three-horned creature from the Cretaceous Period, and an iguanadont (ancestor of the duck-bills). Overall, the 1985 field season was the most productive yet for the research group.

Horner began the year in France, where he and associate Jill Peterson joined with renowned paleohistologist Armand de Ricqles at the University of Paris for a two-month study on dinosaur growth rates. The team hopes to produce a physiological model that will lend credence to the argument that the ancient reptiles were warm-blooded, contrary to previous assumptions.

Horner has been featured on the NSF-funded public television show "3-2-1 Contact," discussed in chapter 1 of this report. He also appeared in a CBS television special in the fall of 1985 and was a popular guest lecturer in Washington, DC during the first National Science Week, another NSF activity described elsewhere in this report.


PATRICK OLMERT

Dinosaur model at Academy of Natural Sciences in Philadelphia.

The Most Distant Galaxy Ever Seen:

Hyron Spinrad at the University of California at Berkeley and *Stanley Djorgovski* at the Harvard-Smithsonian Center for Astrophysics have found the most distant galaxy yet observed at this writing. In our universe, which is about 20 billion years old, they found a galaxy around 14.5 billion light years away. That means it was giving off light 14.5 billion years ago, not that long after the universe began.

Cosmologists know that galaxies are ancient but do not know how they were born. One way to find out is to examine the light of the most distant, and therefore, earliest, of these celestial systems. Spinrad's and Djorgovski's galaxy, though it may not settle the question of how galaxies were born, is two to three times more distant than any others. Finding more of these distant systems and analyzing their light with better techniques could fill in this missing piece of the universe's history.

Six-Legged Robot Takes Its First Steps:

In the fall of 1985, in a laboratory at Ohio State University, a three-ton, six-legged robot took its first steps. The dinosaur-sized robot has infrared laser eyes, sonar ears, a gyroscope to help it balance, and a brain—16 computers—in its interior. Its builders, *Robert McGhee* and *Kenneth Waldron*, say that six legs help it balance, walk, and run better than four would; in order to see what gaits are most effective for six-legged creatures, they watched insects.

Originally built to test theories of robotics (and funded in its first year by NSF), the robot is also the result of discoveries in the fields of computer control, biology, and anatomy. The machine already has suggested new applications in making artificial limbs for humans. For the future, its strong but delicate legs should be able to carry humans over fragile arctic environments; its greater agility should be helpful in places such as the interiors of nuclear reactors.

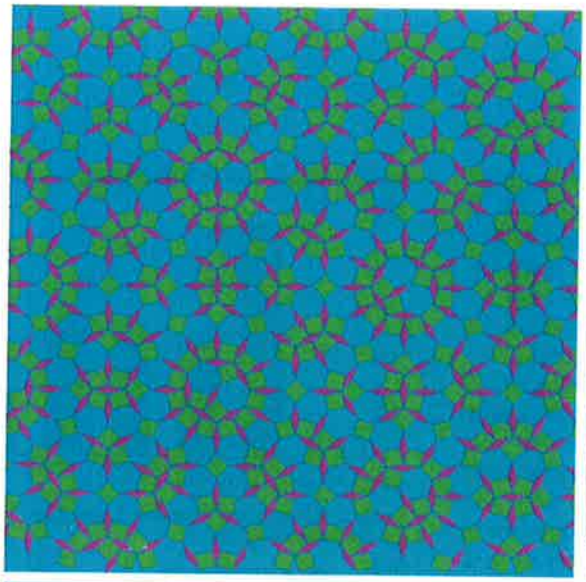
A Trap for an Electron:

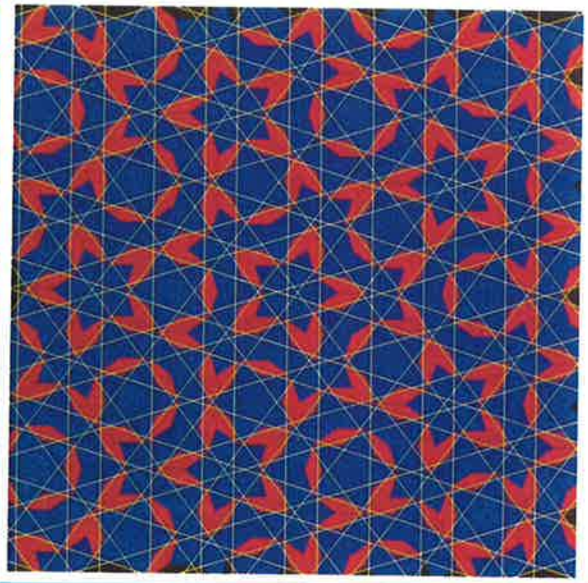
Evidence for the theory of the electromagnetic force at its most fundamental lies in measuring the characteristics of an electron: how much charge it carries, what mass it has, how it spins. But not only do electrons move constantly, they exist in the environments of atoms, and any measurements must subtract out the effects of that environment. For really accurate measurements, physicists need to get an electron free of its outside trappings and hold it still. *Hans Dehmelt,* at the University of Washington in Seattle, has found a way to trap a single electron in an electromagnetic field and bring it essentially to rest.

Dehmelt injects a single electron into a magnetic field which in turn is in a high vacuum. He places an electric field perpendicular to the magnetic field so that the electron, slowly following the magnetic field lines, has its motion limited by the electric field. The confining fields are so gentle that they have little effect on the electron, but they nonetheless trap and hold it to a tiny area. He then slows the electron down by cooling the whole system to a fraction of an absolute degree. With his trap, Dehmelt is able to measure the characteristics of an electron and thereby verify predictions of the basic theory of quantum electrodynamics, to an unprecedented accuracy of 12 significant figures.

Recent Achievements Supported by NSF

Quasicrystal patterns.





Quasicrystals, a New Form of Solid:

Scientists have always believed that solids come in two forms. Disordered solids, such as glass, look like a snapshot of a liquid. Their atoms are arranged haphazardly, no set distances apart, and their nearest neighbors are likely to be found in any direction whatsoever. In perfectly ordered solids, or crystals, atoms sit in strict rows regular distances apart. The atoms in a crystal are arranged in a regularly repeating geometrical structure, of the sort one obtains by stacking a child's building blocks, leaving no empty spaces. The nearest neighbors of any atom in a crystal are always in fixed directions, along the edges of the repeating blocks. Obviously, only certain building blocks, including cubes, will repeat regularly and fill all available space; others, such as a 20-sided icosahedron, will leave holes between repeats.

Paul Steinhardt and *Dov Levine,* at the University of Pennsylvania, were studying configurations of atoms in which the directions to the nearest neighbors are obtained from an icosahedron. They found that by assembling blocks called Penrose tiles (after mathematician Roger Penrose), they could construct solids whose neighbors are always in these forbidden (for a crystal) directions, but whose building blocks—although they fill space—are not regularly repeated. These solids, which they called quasicrystals, are a third form, somewhere between crystals and glasses.

Meanwhile, *Dan Schechtman, Ilan Blech, Denis Gratias, and John Cahn* at the National Bureau of Standards had been experimenting with cooling different metal alloys rapidly to see how their properties would change. One alloy of aluminum and manganese, when examined at the atomic level, turned out to have the same forbidden patterns as Steinhardt's and Levine's quasicrystal. Since then, researchers have made other alloys and found more quasicrystals. Nature apparently connives in breaking her own rules.

Meeting the Challenges

The responsibility of the National Science Foundation, unlike that of any other government agency, is to promote the overall progress of science and to advance education in science and technology. The strength of science and engineering is fundamental to this country's quality of life, its national defense, and its economic vitality. In the past, the United States has been unarguably preeminent in both basic research and technological development. Of the 286 Nobel Prizes awarded scientists between 1961 and 1983, for instance, the United States alone won exactly half. In 1985, five U.S. citizens won or shared in these prizes. Two of them—Herbert Hauptman, who shared the Nobel Prize in Chemistry, and Franco Modigliani, who won the Prize for Economics—have been supported by the National Science Foundation.

But these honors reflect past research; recently this nation's preeminence in science and engineering has been challenged on several fronts.

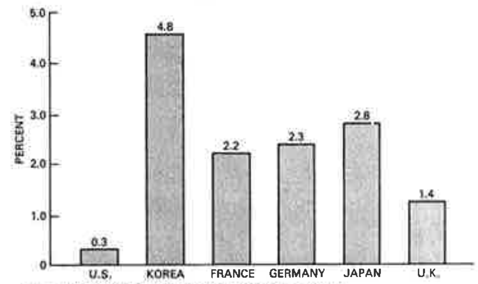
One challenge is external and economic. Competition from industry in other countries is increasing, especially in the fields of materials research, computer science, and biotechnology. True, productivity in the United States remains higher in absolute terms than anywhere else. But in relative terms it has been declining rapidly, according to a 1985 report of the President's Commission on Economic Competitiveness. From 1973 to 1983, U.S. productivity rose at an annual rate of only 0.3 percent (see figure 1). The annual gain for Britain was almost five times that. French and German productivity rose seven times as fast as ours, Japan's rate was nine times ours, and Korea's fifteen. Although the U.S. rate has improved considerably in the last two years or so, this country continues to lose ground relative to its competitors.

Another challenge is internal and technological. In the fields of engineering, computer sciences, and the physical sciences, where discoveries often depend on more and more powerful instruments, only an eighth of the university equipment is state-of-the-art. Fully a quarter of it is obsolete. More than 90 percent of department heads in those fields have reported that researchers were unable to do critical experiments because of lack of equipment.

A third challenge is internal and human. Over the last 20 years, in Japan, West Germany, Britain, France, and Russia, the proportion of scientists and engineers engaged in research and development has been growing. In the United States, that proportion is about the same as it was 20 years ago (see figure 2). Nor is the situation improving. Between 1974 and 1983, the number of entering freshmen intending to major in science and engineering did not grow—in fact it dropped from 33 to 32 percent. In the last decade, the general population of 22-year-olds rose, while the number of those receiving bachelor's degrees in science fell (see figure 3). Even in engineering, where enrollments have been rising in recent years, only about 7 of every 1,000 students receive a degree in engineering; in Japan the figure is 40. By not training enough young people, this nation is perpetuating its deficiencies.

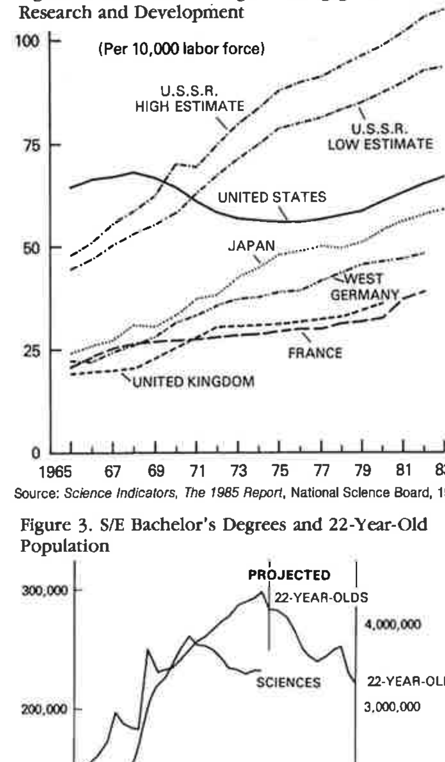
The response to these challenges must come from all sectors—the federal, state, and local governments;

Figure 1. Average Annual Productivity Gains, 1973-83



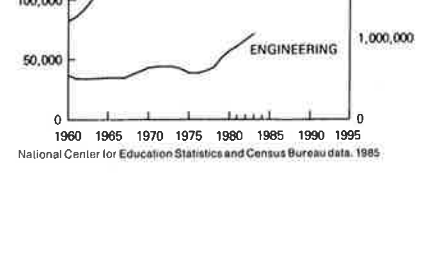
SOURCE: U.S. DEPARTMENT OF LABOR, BUREAU OF LABOR STATISTICS, MAY 1984

Figure 2. Scientists and Engineers Engaged in Research and Development



Source: *Science Indicators, The 1985 Report*, National Science Board, 1986.

Figure 3. S/E Bachelor's Degrees and 22-Year-Old Population



National Center for Education Statistics and Census Bureau data. 1985

Major 1985 Initiatives

1

CHILDREN'S TV WORKSHOP

Shedding some light. Judy Leak is co-host of "3-2-1 Contact," the children's public television series on science. (See page 14.) Here she visits San Francisco's Exploratorium to learn about the properties of light.

Scene from "The Voyage of the Mimi," a science series for TV and classroom use, funded in part by NSF.

universities; and the private sector, including industry. The National Science Foundation, for its part, continues to sponsor excellent basic research in science and engineering. And in addition to its historic responsibility, NSF is now funding initiatives specifically to meet the new challenges of international competition, technological development, and decreasing numbers of scientists. Furthermore, these initiatives either encourage or require cooperation between government, the universities, and industry.

The major initiatives:

- In 1985, the first awards were made for six university **Engineering Research Centers**. Each Center is dedicated to an area of research that is critical to the country's economic competitiveness but at the same time requires a multidisciplinary approach. The areas of research are robotics, telecommunications, composite materials manufacturing, systems research, intelligent manufacturing systems, and biotechnology process engineering. Industry will participate actively in the Centers, partly by providing funding, equipment, and facilities; partly by lending them researchers; partly by offering advice. And the Centers, because they are located at universities, will give undergraduate and graduate students a chance to learn on up-to-date equipment and in a uniquely cross-disciplinary atmosphere. For more about the research done at Engineering Research Centers, see the "Special Focus" section following.

- Four **Supercomputer Centers**—located at the University of California at San Diego, the University of Illinois at Champaign/Urbana, Cornell University, and near Princeton University—are the nucleus of a growing national network of advanced computers. Supercomputers are to computers what computers are to calculators. Because they allow consideration of complex problems previously thought impossible, supercomputers are increasingly crucial to reseachers in all disciplines. The Centers will bring together scientists and computer specialists, will train students, and will stimulate the computer industry to develop even better supercomputers in the future. Support for this program comes partly from funds leveraged both from industry and from state and local government. For a sampling of recent projects done with supercomputers, see the "Special Focus" section following.

- This was the first year of the **College Science Instrumentation Program**, which helps to provide critically needed scientific equipment to four-year colleges. Obsolescence, changes in laboratory techniques, and the advent of new tools such as computers make their instrumentation shortage at least as critical as that of the research universities. NSF made 234 awards under this program, for a total of $5.5 million. An additional $5 million came from local sources.

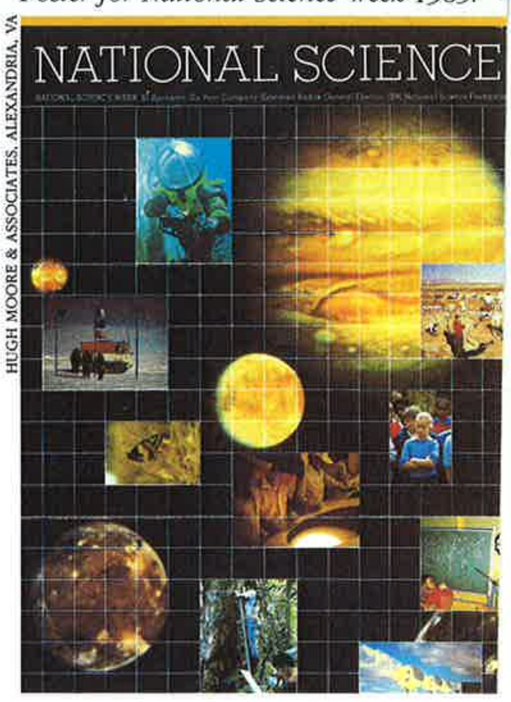
- The revamped **Precollege Science Education Programs** are designed to emphasize the quality of education for elementary and high school students—reaching young people at a time when critical skills and concepts are established, together with life-long attitudes and career decisions. One program focuses on the competence of working science teachers, updating their knowledge of scientific developments and instructional techniques through workshops with local universities, scientific societies, laboratories, and museums.

  Another program supports cooperative efforts by publishers, universities, and educators to develop instructional materials that fill gaps in existing curricula, offer better presentation of traditional subjects, or improve the breadth and quality of science and mathematics education in elementary and high schools.

  Still another program supports learning outside the school, from such informal sources as television and museums. Widely acclaimed television series like "3-2-1 Contact," "The Brain," "Reading Rainbow," and a new daily mathematics program are complemented by museum activities and traveling exhibits visited by millions of adults and children.

- NSF sponsored the first **National Science Week** during May 12-18, 1985. Communities of every size in all 50 states held programs to boost public awareness of science and technology and to encourage young people to study science. Research facilities held open houses, schools had science fairs and competitions, and museums and libraries sponsored lectures and special exhibits. National Science Week is a partnership between NSF, professional societies, community groups, educators, and industry. In

Poster for National Science Week 1985.



HUGH MOORE & ASSOCIATES, ALEXANDRIA, VA

1985, it was underwritten by grants from the DuPont Company, Eastman Kodak Company, General Electric, and IBM.

- The **Presidential Young Investigator Awards** program, in its second year in 1985, addresses the growing faculty shortages in highly competitive fields of engineering and science. The awards represent a partnership between outstanding researchers starting their careers, their institutions, private industry, and the federal government. NSF gives each awardee an annual base grant of $25,000 for up to five years. The Foundation will also provide up to $37,500 in additional funds each year, matching dollar-for-dollar any funds made available to the awardee from the industrial sector. Altogether, this five-year package provides a significant start to an academic teaching and research career; in 1985 awards went to 200 investigators, about half of them engineers.
- In 1985, NSF headed a committee of 11 federal agencies seeking to comply with the Arctic Research and Policy Act. The **Interagency Arctic Research Policy Committee** was created to set research priorities and eliminate duplication of effort in arctic research. It will also explore ways to match the more advanced technologies of other countries with arctic borders, most notably the Soviet Union. The Committee recommends research priorities, develops policy, and coordinates industry, government, and local cooperation in arctic research matters.
- NSF **increased support for mathematics** by 15 percent. In 1981, the National Research Council in the National Academy of Sciences appointed an ad hoc committee on Resources for the Mathematical Sciences. Chaired by electrical engineer Edward David, the committee was asked to review the health of mathematical research in the United States. The David Report, published in 1984, found that between 1960 and 1980, federal support of mathematics declined by a third.

Mathematics is the fundamental language of most of the other sciences. It plays an increasingly vital role in technology and the computer sciences and has had, in that 20-year period, what the Report called "a dazzling record of achievement." In one two-year span, four U.S. scientists won Nobel Prizes in astrophysics, medicine, economics, and physics, for work that was essentially mathematical. The National Science Board urged all federal agencies, especially NSF, to bring the funding of mathematics to a more appropriate level.


DAVID BENNETT, ACADEMY OF NATURAL SCIENCES

Museum talk. Children learn about dinosaurs via computer at Philadelphia's Academy of Natural Sciences.

- Last spring, NSF created an **Office of Biotechnology Coordination.** Biotechnology includes any technique that uses living organisms to make products or to improve plants or animals. NSF supports the basic research needed to develop that technology (about $80 million of the Foundation's budget in 1985). Biotechnology-related research cuts across numerous NSF divisions: Chemistry; Chemical, Biochemical, and Thermal Engineering; Biotic Systems and Resources; Behavioral and Neural Sciences; Cellular Biosciences; Molecular Biosciences; Emerging and Critical Engineering Systems; and Engineering Cross-Disciplinary Research. The Office of Biotechnology Coordination provides a central clearinghouse for planning, budgeting, and reporting on biotechnology-related research. It also advises on environmental concerns about the potential effects of such research.

In addition to its own biotechnology office, NSF is one of five federal agencies[1] on the Biotechnology Sciences Coordinating Committee. That group's job is to develop regulatory mechanisms that ensure adequate protection of the public from substances engineered by scientific research. At this writing the group is chaired by NSF's Assistant Director for Biological, Behavioral, and Social Sciences.

- In 1985, NSF established several procedures for **reporting on science in other countries**. One procedure allows for identification of the research areas that are progressing most rapidly in other countries. A technique called bibliometric analysis shows which research in which country is cited by other researchers most often. Once NSF identifies areas of exceptional international scientific activity, it can make plans for cooperation between the countries.

Another procedure allows for increased reporting on trends in Japanese scientific policy and on the state of Japanese science. These reports are disseminated widely throughout U.S. government agencies. A third procedure makes possible the publication of international science indicators—what resources go into science from public and private sectors internationally, how many international patents are granted, what undergraduate and graduate enrollments in other countries are.

[1]Other members of the group: The National Institutes of Health, the Environmental Protection Agency, the Food and Drug Administration, and the U.S. Department of Agriculture

Meeting the Challenges

Special Focus on Supercomputer Centers

Making Impossible Research Possible

Until recently, researchers with the kind of complex problem that could only be solved with a supercomputer faced difficulties. They had to buy and schedule time on a machine in industry, or clear security measures in a government laboratory dedicated to military research, or travel to a foreign university. In 1985 NSF made supercomputers much more accessible to university researchers by funding four Supercomputer Centers, the beginning of a national network.

A problem that would take hundreds or thousands of hours on a computer will take hours or even minutes on a supercomputer. Most importantly, supercomputers can handle problems that a computer could not do at all, making possible research that was previously impossible. Supercomputer graphics allow researchers to see the unseeable—events that happened too far away, or too long ago, or that are too large, too hot, too brief, too small. Biologists can model the way atoms combine into molecules, molecules into proteins, proteins into viruses—and they can find vaccines effective against the viruses. Physicists can calculate how best to hold and heat an already hot, charged, turbulent gas until it reaches the temperature necessary for fusion. Atmospheric scientists can simulate the flow of air over whole hemispheres, using the simulation as a base for accurate, long-range weather forecasts. Astronomers can model how stars are born, how material falls into a black hole, and how galaxies formed.

Ronald Levy at Rutgers University has used supercomputer simulations to understand how protein molecules work. A protein molecule is a chain of amino acids; their exact configuration on the chain is called the protein's structure. The structure determines what the whole protein molecule does—whether it binds to food and helps digest it, whether it binds to a bacterium and kills it, or whether it binds to oxygen and carries it through the bloodstream. Change the amino acid, or move it (even by the slightest fraction), and the structure of the whole protein changes. As a result, the binding will happen differently or not at all.

Normally scientists find the structure of a protein with X-rays. The X-ray picture shows the protein at a fixed instant with a certain structure. Unfortunately, in real life the protein spins, vibrates, collides with other molecules; as it does so, its structure changes subtly.

Levy tries to model the structure of the protein as it changes. He puts all possible positions of the molecule on a supercomputer, watching how the binding tightens or loosens, or fails to connect. Once he finds a structure that increases the binding for, say, a protein that binds to and kills bacteria, then perhaps protein engineers can recreate that particular structure (in other words, create an antibiotic). Levy's particular work has application to proteins that control blood pressure or store energy in muscles.

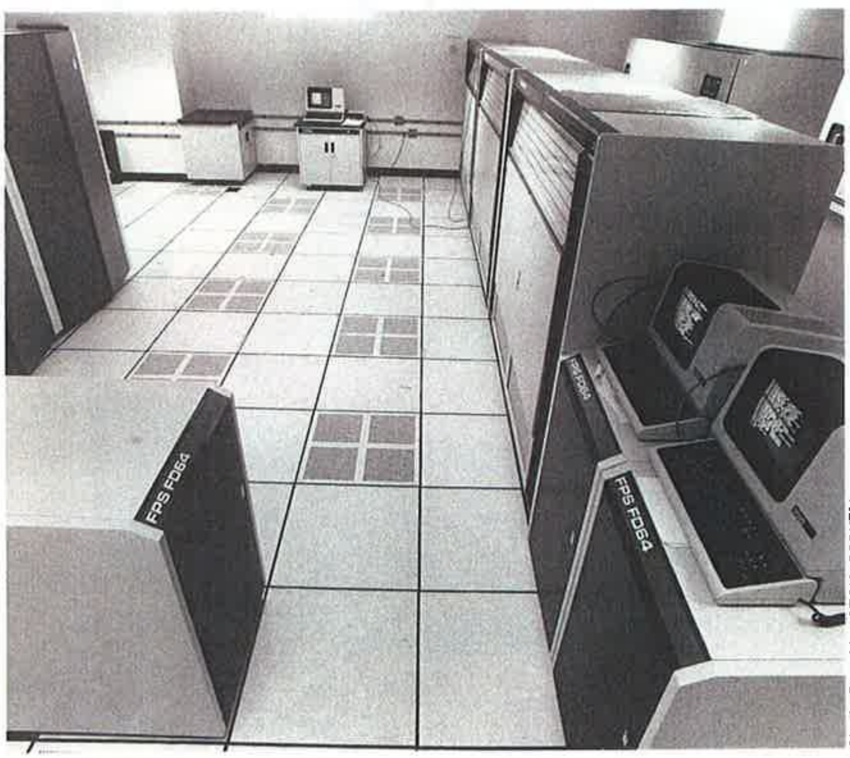
Supercomputers are useful for modeling not only the very small but also the very large. Drexel University physicist *Joan Centrella*, working with colleagues *James Wilson* at California's Lawrence Livermore Laboratory,

Cray supercomputer at University of Illinois (see page 14).

Richard Matzner at the University of Texas (Austin), and *Tony Rothman* in Capetown, South Africa, has used a supercomputer to study the way the early universe may have developed.

The very early universe apparently was a glowing ocean of elementary particles, which later combined into simple hydrogen nuclei. The universe was still so hot and so dense that the hydrogen nuclei collided with enough energy to fuse together and form the heavier nuclei of helium and deuterium. Exactly how much helium and deuterium were made depends on how dense the universe was. Earlier estimates of the amounts of helium and deuterium were based on the more or less unverifiable assumption that the universe's density was absolutely uniform, the same everywhere.

Centrella (also a Presidential Young Investigator) and her colleagues made the opposite assumption, that gravity would make some parts of the universe denser than others. They wanted to find out if these areas of greater density, these lumps, would change the amount of helium and deuterium. They combined the equations of general relativity with those describing the process of helium and deuterium creation, and those describing the motion of matter in a supercomputer. In doing so, they tested not only the earlier estimates of helium and deuterium but also the original assumption of a uniform universe. (The density of the universe is of overriding interest to cosmologists: with enough density, the universe will expand forever; with too much, it will stop expanding, contract, and eventually close up into one big black hole.)



CHARLIE HARRINGTON, CORNELL

Cornell's IBM supercomputing equipment (see page 14).

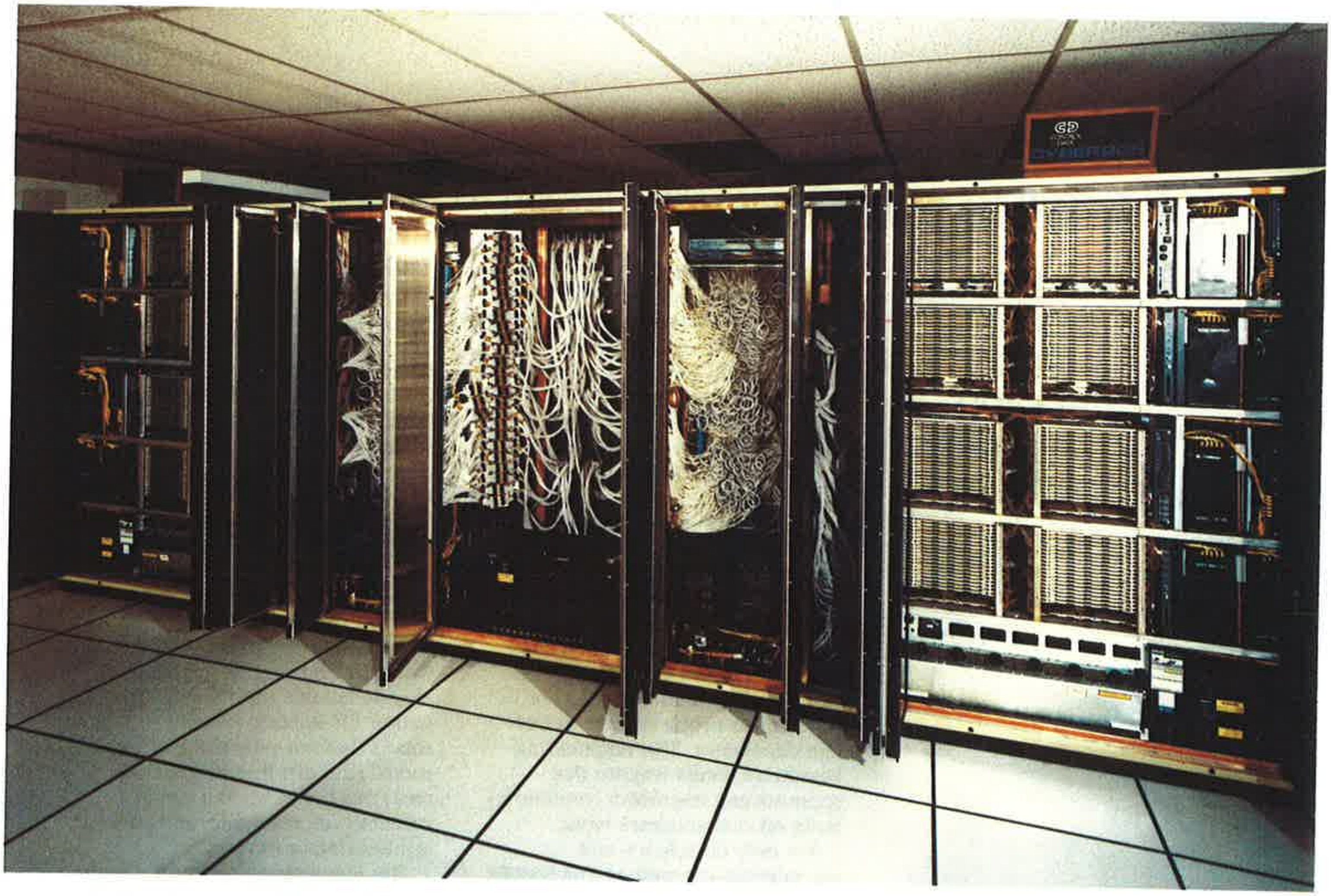
DREXEL UNIVERSITY

Presidential Young Investigator and supercomputer researcher Joan Centrella.

One field especially suited to supercomputers is materials research. *Arthur Freeman*, a physicist at Northwestern University, has used a supercomputer to model the precise structure of a metal's surface. Much future technology may depend on what goes on at the surface of metals: as transistors and computer chips become thinner and thinner, understanding those surfaces is increasingly important. How a metal reacts, whether it conducts, and whether it is magnetic depend in part on the exact structure of its surface.

Freeman has modeled the surface of a metal atom by atom. He builds a grid of atomic nuclei, then adds a sea of electrons. The electrons will dispose themselves around the nuclei in the configuration that requires the least energy. To determine what the configuration is, Freeman follows the path of each electron, which means solving the equations of motion and energy for each of them. Using the supercomputer to do this, Freeman can calculate which configuration of electrons is least energetic and therefore most likely to resemble the surface of a metal. Modeling the surface opens the way for creating new materials with custom-designed properties.

Another problem that requires supercomputers is heat flow. A baseboard heater is really a heat transfer device in which water is



heated, warming its container, which in turn heats the air outside. Chemical and power plants have tons of heat transfer equipment; on a much smaller scale, tiny electronic chips with millions of electrons inside them also need to lose heat.

Bora Mikic at the Massachusetts Institute of Technology has used a supercomputer to find how heat is most efficiently transferred. One transfer method is standard: increase the area of the surface that radiates the heat by carving grooves in it. In a normal process, then, fluid flows over a grooved surface and carries away the heat. Depending on the groove's design, the fluid flows into it, then back out, carrying heat with it. To find out how efficient the process is, standard procedure is to run a series of expensive experiments. Instead, Mikic runs a supercomputer simulation, feeding the complicated equations that describe heat transfer into the supercomputer. If the fluid stays in the groove longer, it can collect more heat, then it is expelled forcefully. Mikic has found this forced transfer to be a more efficient design. Improved designs like this could be used to improve systems ranging from baseboard heaters to power plants.

Cyber 205 supercomputer.

Meeting the Challenges

Special Focus on Engineering Research Centers

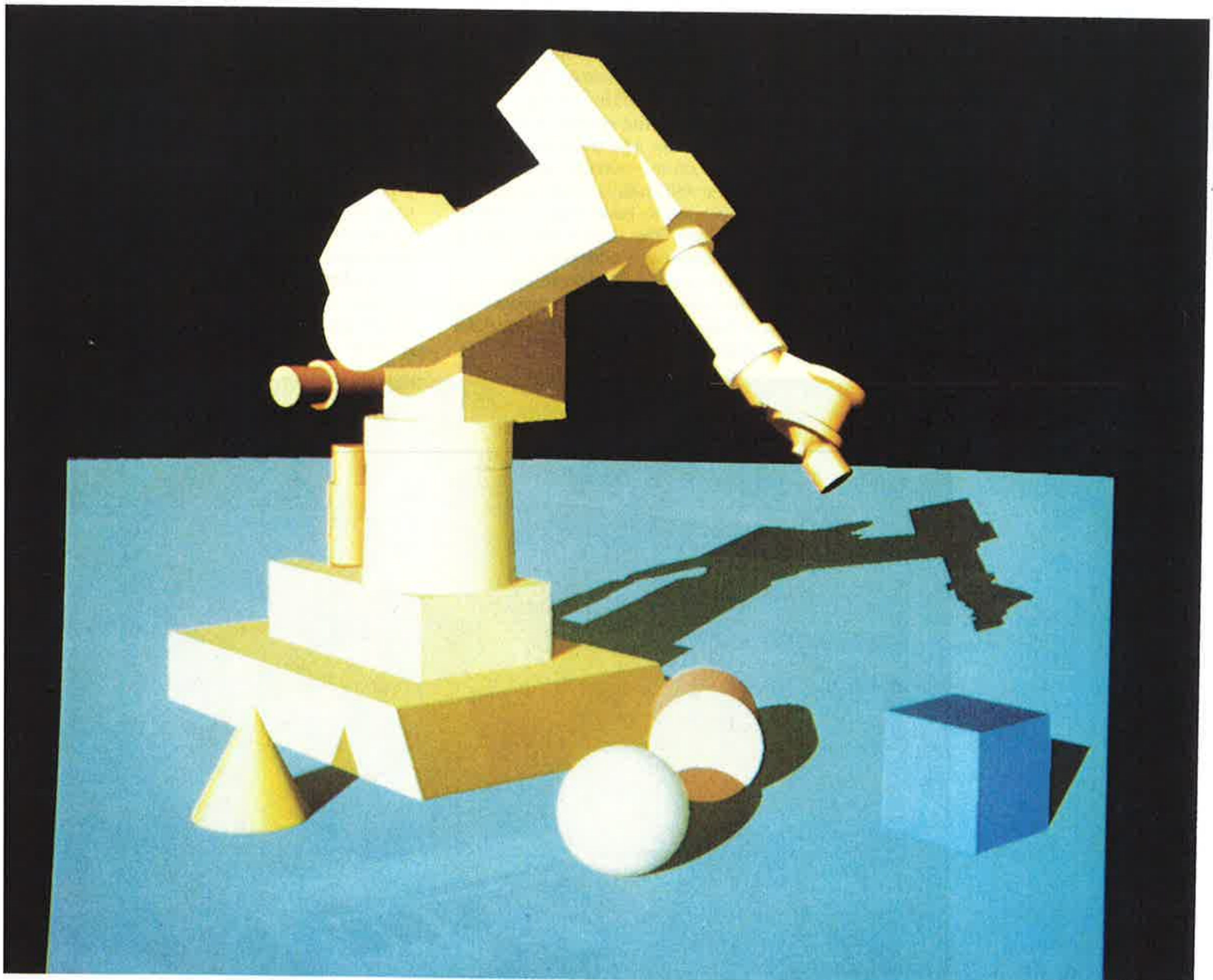
Industry/ University Collaboration and Cross-Disciplinary Activities

The Engineering Research Centers focus on areas requiring cooperation between engineering and science. Sometimes scientific understanding of a phenomenon precedes an application for it; Charles Townes and Arthur Shawlow, for example, proposed that light waves could be synchronized before anyone knew of uses for a laser. Other times, engineers invent something that scientists don't yet understand; Alexander Volta invented the battery 40 years before Michael Faraday explained how it worked. But science, the more theoretical investigation of phenomena, and engineering, the more pragmatic investigation of solutions to problems, are in fact interdependent. The Engineering Research Centers require that scientists and engineers continue to build on one another's work.

Not only do science and engineering—as well as universities and industry—need to cooperate; the particular focus of each Engineering Research Center is also an area that requires various subdisciplines within science and engineering to cooperate. Depending on the area, researchers need to come from fields as various as electrical and computer engineering, mathematics, computer science, mechanical engineering, solid-state physics, chemical engineering, polymer chemistry, biochemistry, biology, and the social sciences. The particular focus of each Engineering Research Center is also an area crucial to our country's industrial competitiveness.

The **Center for Robotic Systems in Microelectronics** at the University of California at Santa Barbara designs and builds robots that can manufacture semiconductor devices, such as computer chips. Humans making these devices unfortunately bring with them a major disadvantage: they sluff off skin, hair, dandruff, makeup, and the like; particles of skin alone come off at the rate of 100,000 an hour. A hair 10 microns wide can interfere with an etching on a computer chip 1 micron wide, causing defects that lead to electric failures on the chip. The Center for Robotic Systems builds robots that not only make a "clean room" (the dirt-free production area) much cleaner but can also manufacture, assemble, and package semiconductor devices.

The **Engineering Research Center for Telecommunications** at Columbia University explores what it calls a "fully integrated telecommunication system"—a sort of combination telephone-personal computer with a screen on which both parties can write, use graphics, see each other, and talk. Such a device would require that all data be compressed into a single stream and sent quickly, so the Center is developing a single computer chip that can handle both optical and electronic information. To cut down on the amount of information on each chip, researchers will have to edit out parts of the audio or video signal not normally per-



Engineering Research Center work. Computer graphics done at Purdue University's Center for Intelligent Manufacturing Systems (see also page 22).

ceived. This device could revolutionize communications.

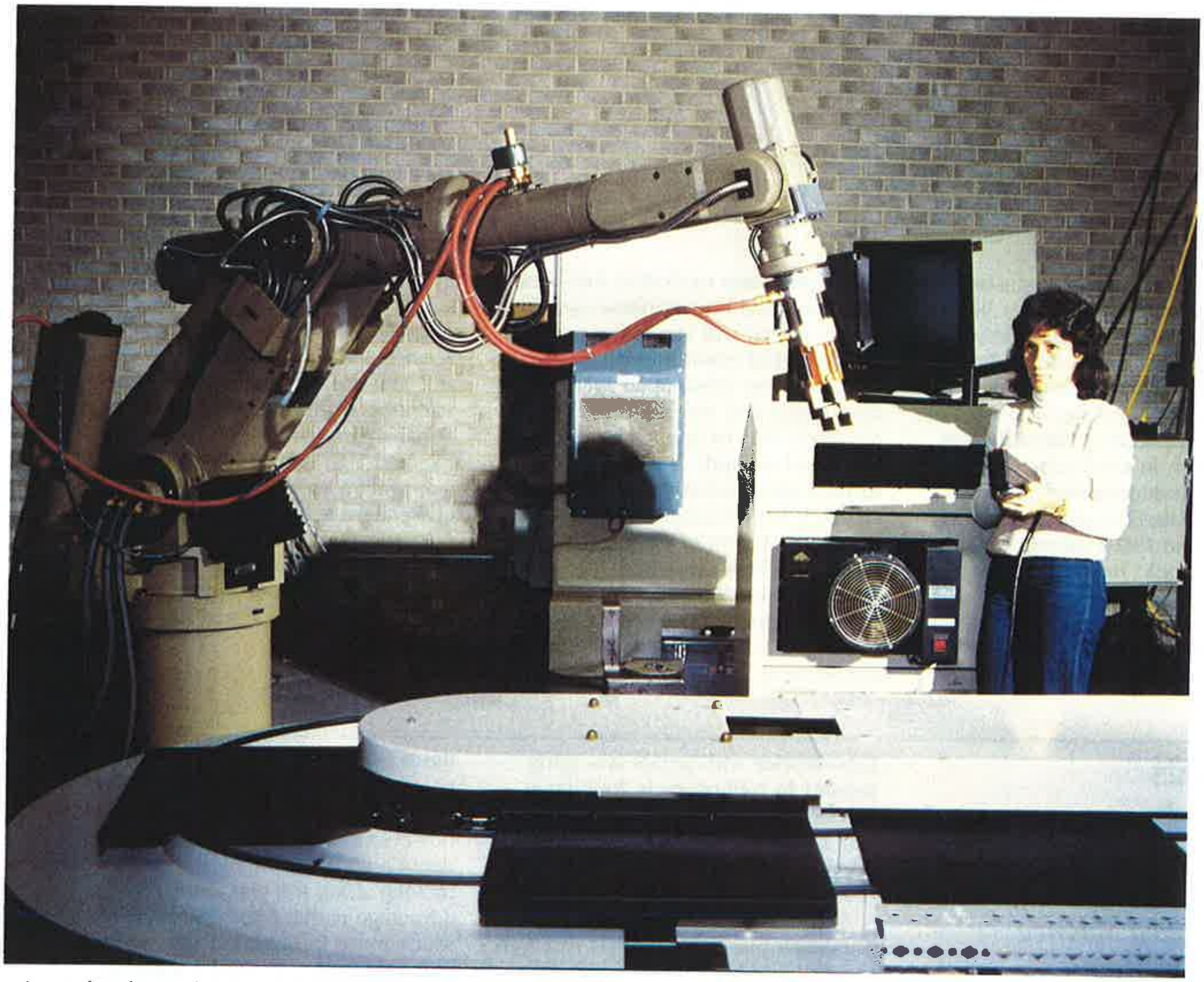
The **Center for Composites Manufacturing Science and Engineering** at the University of Delaware is affiliated with a program on ceramics at Rutgers University. Composites are generally combinations of polymers with fibers of fabric, glass, or metal. Automobile tires that combine fabric with rubber are one example; the tail of an F-16 airplane that blends carbon fibers with a polymer is another. Composites have both great strength and light weight; depending on their materials, they will not disintegrate. The car of the 1990s may have a replaceable engine in a composite body that never wears out.

The Rutgers program extends possible composite materials to combinations of ceramic fibers with polymers and metals. The Center tests different materials in terms of the way they behave—for example, how they respond to various stresses—and whether they can be manufactured cheaply.

The **Center for Systems Research** is a collaboration between the University of Maryland and Harvard University. The systems investigated here can be anything from a videotape recorder to a robot arm to the process that makes an airplane flap move or breaks down crude oil. Researchers want to be able to design these systems with the aid of a computer—for example, feed a computer information on the components of the system and what they should do, add what the system looks like on the outside, and the computer will indicate how it can be best designed to have high reliability and low cost. The Center for Systems Research develops computers with very-large-scale integration architectures and writes programs for them based on research into artificial intelligence.

The **Center on Biotechnology Process Engineering** at the Massachusetts Institute of Technology concentrates on actually accomplishing, in a marketable way, those techniques that the revolution in biotechnology is making possible. Working together, geneticists, molecular biologists, chemists, and biochemists can now alter the genetic code on a DNA strand, change a sequence of amino acids on a protein, and create wholly new proteins. These changes in turn modify the activities and properties of living organisms.

Biotechnology's opportunities are enormous and diverse: pharmaceuticals to prevent, detect, or treat diseases or genetic defects; herbicides or fungicides that are target-specific and thus environmentally safer; improvements in plant varieties; and chemicals to detect and degrade environmental hazards. Until now, much of this



science has been the painstaking work of individuals. The Biotechnology Center looks for ways to manufacture these substances in bulk. To do that, engineers first need to understand the basic biology of the substances. Then they need to design systems (called bioreactors) that take an isolated substance, culture it on large scales, keep viable those cells that do the actual manufacturing, keep the cultures pure, and extract the product.

The **Center for Intelligent Manufacturing Systems** at Purdue University focuses on ways to automate the manufacture of items in small batches. Batch manufacturing is the opposite of, say, the automobile industry, which can mass produce millions of the same V-8 engine over and over. Other products require smaller numbers and custom building—for example, a gadget that controls overloading on an electric motor needs to vary with differing motors. The Center for Intelligent Manufacturing Systems develops sensors or computers, capable of semiautonomous reasoning, to reduce the cost, time, and mistakes involved in such batch manufacturing.

Robot at Purdue Engineering Research Center.

Basic Research and Education

The National Science Foundation's historic responsibility has been to support basic research and science education. Investigators doing basic research are working directly on neither technological development nor immediate application. Nevertheless, basic research in this country is amazingly productive. For example, scientists studied the genetics of bacteria in the 1950s without knowing the results would be the fields of genetic engineering and biotechnology. Engineers invented transistors with no idea of modern computers in mind. And recently oceanographers exploring the ocean floors learned how mineral ores form, a finding that will surely have technological implications.

Discoveries come at an increasingly faster pace, and the gap between a discovery and its application has narrowed abruptly. A modern technological society without basic research is unthinkable; NSF funds about 27 percent of such research performed at universities.

The Foundation supports nonmilitary and nonclinical research and related activities in the astronomical, atmospheric, earth, and ocean sciences; in the biological and behavioral sciences; in the mathematical and physical sciences; in engineering; in science and engineering education; and in a broad, general area called scientific, technological, and international affairs. The Foundation is also the lead U.S. agency in Antarctica, managing a multidisciplinary research effort there according to terms of the Antarctic Treaty. At this writing 32 nations have signed that treaty.

Some examples of cutting-edge research and educational activities follow.

Materials Research Groups

Middle-Sized Science for Big Problems

In studying metal, glass, ceramics, polymers, and the like, materials researchers want to know which materials conduct electricity, hold up best under pressure and temperature extremes, resist aging, corrode least, are most flexible. These and a host of other questions need to be answered before using a material to, say, build a bridge. Until this year, NSF funded materials research in one of two ways: either the science was small—an individual investigator working on a single question, on a grant averaging $100,000—or the science was big—for example, 14 Materials Research Laboratories with grants averaging around $4 million each, looking at broader questions. As it turned out, NSF rarely funded middle-sized science, collaborations of 5 or 10 researchers.

Collaborations are especially important because materials research is peculiarly interdisciplinary: answering questions about any given material could involve physics, chemistry, metallurgy, mathematics, ceramics, and any of several fields in engineering. In 1985, NSF began a program to fund middle-sized collaborations, called Materials Research Groups, each with grants of around $1 to $2 million. At this writing, groups at five universities have formed such groups; each devotes its attention to a certain problem.

A group at **Rensselaer Polytechnic Institute** studies the stability of glass. Technologists are particularly interested in the use of glass to make fiber optics—long, flexible glass tubes the size of a hair which, like copper wires, can be used to transmit information. Information is carried, however, not by electrons moving down a wire, but by light waves moving along the glass tube. The advantage is that fiber optics carry much more information than electric wires do, and even under extreme conditions they last much longer—20 to 100 years. The disadvantage, of course, is that glass breaks easily. In hopes of developing a more stable glass, the Rensselaer group studies the way glass reacts under high pressures and high temperatures, and how cracks propagate under stress.

Another group, at the **Polytechnic Institute of New York**, studies the way blends of different polymers age. Polymers are long strings of molecules; examples are polyethylene, polyurethane, or polyvinyl chloride. Some polymers, such as the plastics, have been created to have certain

The Historic Responsibility

2

Aurora australis, *the South Pole equivalent to the northern hemisphere's* Aurora borealis.

LAURA KAY

qualities: transparency, flexibility, strength. Unfortunately, they can lose these qualities when they age; cellophane tape, for example, becomes yellow and brittle. Recently researchers have begun blending several polymers together; the blends have characteristics different from those of any of their constituents.

The Polytechnic researchers synthesize different blends, then expose them to light, high temperatures, or any other condition under which aging occurs. By studying what types of conditions cause what types of aging, the group hopes to find blends that resist degradation.

A third Materials Research Group at **Pennsylvania State University** is studying new methods for making ceramics. Ceramics are technologically important, most notably because of their resistance to heat. The high temperatures at which they must be fired require a lot of energy, and ceramics are notoriously fragile. The technique for making them is one of the oldest in the world. The group at Penn State modernizes that technique by bonding the ceramic powders together, not with high temperatures but with chemical binders. This method not only makes ceramics cheaper to produce but may also overcome their inherent brittleness. Perhaps ceramics can even be engineered to have electronic properties.

At the **University of Texas at Austin**, materials researchers work on understanding the fundamentals of photoelectrochemistry, the study of how light energy is converted efficiently into chemical energy. They focus especially on discovering and designing new materials to raise the efficiency of photoelectrochemical devices. The Austin group studies, among other things, which semiconductor can absorb different wavelengths of light most efficiently, how to stabilize a semiconductor against corrosion, and what catalyst will enhance the rates of specific photoelectrochemical processes.

The fifth Materials Research Group, at the **California Institute of Technology**, studies at the atomic level the interfaces between different solids and between solids and liquids. They want to know, for instance, what happens when they cool liquids quickly. Rapid cooling, called quenching, takes a material from its liquid to its solid state in hundredths of a second. Cooling a material this rapidly produces new kinds of materials—glasses whose normally disorderly atoms now line up in crystals, metals whose normally aligned atoms become random—with interesting magnetic properties. Exactly how that happens is the subject of the Caltech Group's investigations.


KENT STATE NEWS SERVICE

Liquid crystals, a subject for study in materials research.


JEFF WASSMANN

Materials research in polymers. Wet-spinning fibers of an electrically conducting polymer.

Chemistry of Life Processes

Chemical Methods for Biological Problems

Biologists have traditionally studied living systems such as plants and animals; chemists analyze the substances of which plants and animals are made. When the living systems under examination are cells or molecules, biology and chemistry begin to converge. The convergence is making possible a revolution in biotechnology: researchers can, by combining biologists' and chemists' methods, design new molecules by taking natural molecules apart and putting them back together differently. This year, four NSF divisions—Chemistry, Molecular Biosciences, Cellular Biosciences, and Behavioral and Neural Biosciences—are part of a joint effort called Chemistry of Life Processes. This activity has supported small groups whose work in biotechnology requires the methods and models of more than one field.

One example is a collaboration at the California Institute of Technology by *Harry Gray*, an inorganic chemist, *Judith Campbell*, a biochemist, and *John Richards*, an X-ray crystallographer. They have been studying the fine details of respiration, exactly how our bodies make energy from the oxygen we breathe. Hemoglobin in the blood carries oxygen to all cells. There electrons normally attached to iron and copper atoms in the hemoglobin are removed. The electrons join the oxygen, turning it into water. This transfer releases energy, which is stored in the form of a high-energy molecule called adenosine triphosphate, or ATP. Because the body uses ATP to run all its systems, the transfer of electrons from iron and copper to oxygen is a link essential to life.

The Caltech group studies electron transfer in detail. Why do the electrons leave the iron and copper atoms in the first place? How do they jump to the oxygen over what, for them, are long distances? And how are they attached so accurately at the exact place on the oxygen molecule that will accept them? By creating a protein with an iron atom in one place and an atom of a second metal a fixed distance away, the group at Caltech can determine exactly how far the electron jumps.

A second collaborative effort examines photosynthesis, the process by which green plants feed off sunlight. Photosynthesis takes place when certain molecules in membranes at the surface of the plant absorb light. *Therese Cotton*, a chemist at the University of Nebraska at Lincoln, and *Michael Seibert*, a biophysicist at the University of Denver, work with simple green plants, such as algae, to find which molecules are at or near the surface of the cell membranes. Then they determine where on the surface those molecules are.

Cotton and Seibert put the plant membranes in a solution into which they have placed metal electrodes. Those molecules on the surface of the membrane adhere to the surface of metal electrodes. Then, using a special technique called Surface-Sensitive RAMAN Spectroscopy, Cotton and Seibert can examine the electrode's surface and identify even tiny concentrations of molecules on it. Not only should their work help in understanding photosynthesis, but their techniques are flexible enough to use in identifying such things as traces of poisons in the environment.

Ocean Drilling and the Continental Lithosphere Program

In an age of discoveries about other planets and distant galaxies, we know surprisingly little about the earth beneath us. We have navigated the seas and explored the surface of the land for centuries, but only recently have we had the tools to look beneath the surface. There we see the basement structures and discover the deep-seated dynamic processes that assembled the earth and continue to affect our lives through earthquakes and volcanic eruptions today.

Two NSF activities, the Ocean Drilling Program and the Continental Lithosphere Program, are pioneer efforts to explore the "inner space" below the earth's surface and to understand the processes that shape our physical world, create its mineral resources, and occasionally unleash dramatic violence upon us.

From 1966 to 1984 the drillship *Glomar Challenger* was used to obtain geologic samples from the deep seafloor to document the history of the ocean basins. The scientific program sampled all the major seas

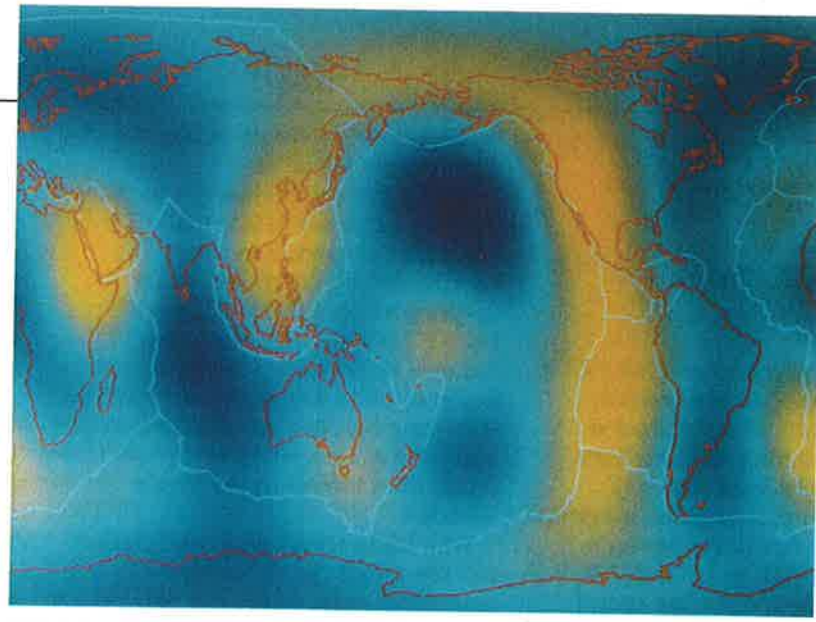
The drillship JOIDES Resolution *(registered name: SEDCO/BP 471).*

except the Arctic Ocean. Support was provided by the NSF and up to five additional countries, reflecting the global thrust of this research.

Early expeditions provided convincing confirmation of the then new and revolutionary concepts of seafloor spreading and plate tectonics. They found evidence for a history of drastically changing climates with more ice ages than were previously known. Major new insights developed concerning the circulation of the oceans, the age and composition of the ocean crust, and the volcanic processes that form the deep ocean crust and other structures.

In 1985 NSF—together with Canada, Germany, France, Japan, and the United Kingdom—agreed to a new 10-year scientific drilling program. A modern drillship called the *JOIDES Resolution* was leased and equipped with state-of-the-art scientific laboratories. The new ship completed six drilling "legs" by the end of 1985. Specific goals ranged from determining the history and origins of the tropical carbonate banks forming the Bahamas Island region to solving the tectonic and glacial history of Baffin Bay off northern Canada. As one example, Leg 104 took the ship to the coast of Norway. There the cores showed that the currents along Norway had once been warm; they also detailed the history of an ice age and documented a number of climatic coolings. Unfortunately, Leg 104 could neither confirm nor deny a theory that the coast of Norway had once been a part of North America, ripped away by ocean-floor spreading. The deeper cores, however, did show some fragments of continental crust which may resemble the rocks of the Appalachian Mountains.

The Ocean Drilling Program is only one of a series of global ocean studies that attempt to understand the oceans as integrated physical, chemical, biological, and geological systems.



Seismic tomograph. A picture of the Earth at a depth of about 90 miles, made by computer from earthquake shear waves. Light areas represent relatively hotter material where the waves travel more slowly. Darker areas are relatively cooler material.

These programs deal with the flows and balances of water, energy, plants, animals, minerals, and the influences all these things have on one another and on the world's climate.

The ocean floor has proved to be geologically very young (less than 200 million years old) and relatively simple to understand in terms of the concepts of plate tectonics. The continents, by contrast, are extremely old (at least 3.8 billion years) and structurally very complex; they record a history of repeated rifting, collisions, subsidence, and uplift. One of the Foundation's newest efforts is the Continental Lithosphere Program begun in 1985. The lithosphere is the outer, rocky portion of the earth that forms the tectonic plates and rests upon the hotter and more yielding interior. It includes the layer known as the "crust" (rocky layer ranging in thickness from about 3 miles under the oceans to about 25 miles beneath the continents), as well as the layers immediately below the crust that support and move with it.

The new NSF program supports some of the first concerted efforts by earth scientists to apply modern tools to study the deeper parts of the continental lithosphere. These tools include direct drilling to depths as great as six miles as well as seismographic arrays that can create tomographic images of the earth's interior (these images resemble medical CAT scans of the human body).

Using these tools, scientists hope to answer such questions as: How are continents put together? How do earthquake faults and other structures seen at the surface change with depth? Are there mineral resources at depths greater than those we know about now? What controls their distribution? Why do earthquakes occur in the interior of plates as well as at plate boundaries? Already, participants in the program believe they have found the ancient (and now deeply buried) suture zone in Florida and Georgia that marks the former boundary where Africa and North America collided some 300 million years ago.

The Very Long Baseline Array

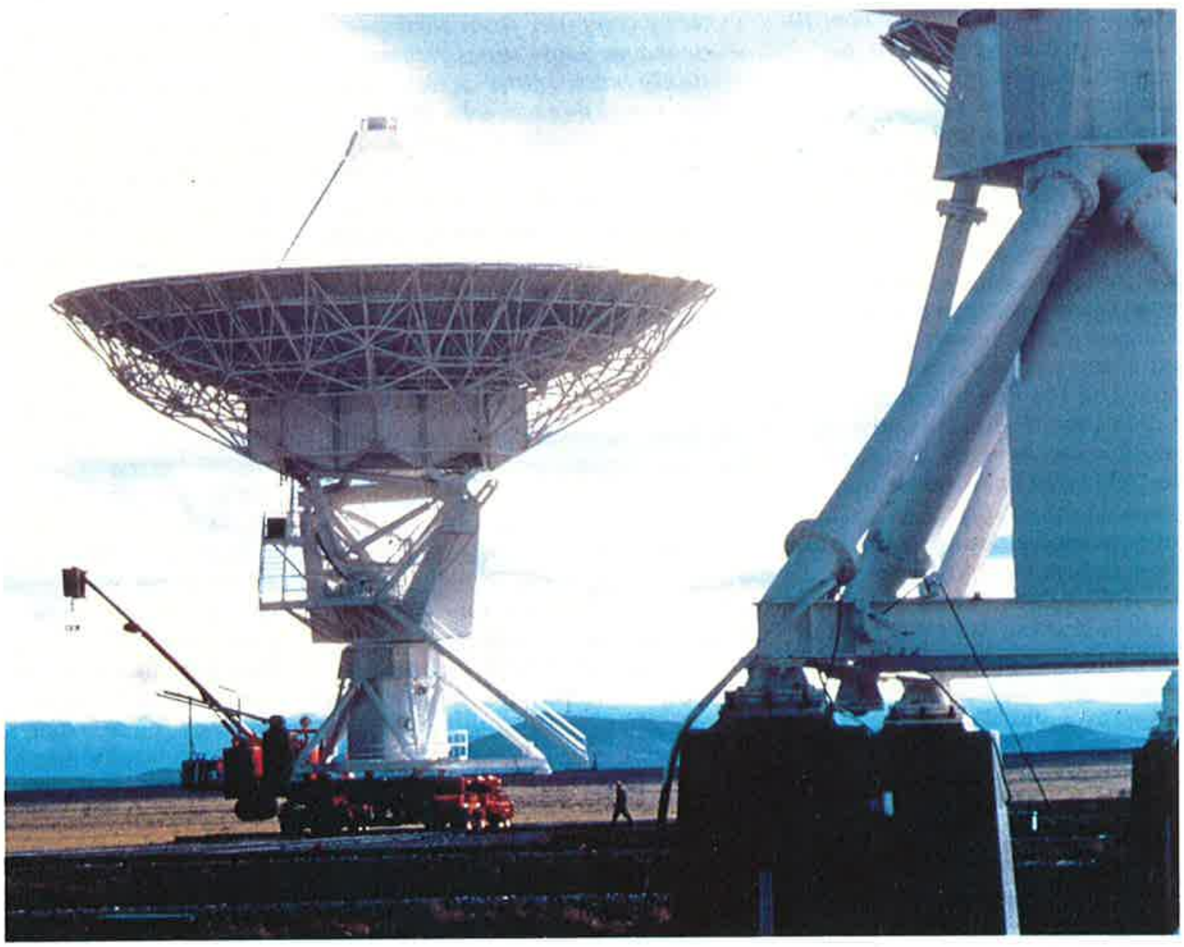
A 5,000-Mile Radio Telescope

Normal optical telescopes miss a lot. They are equipped to receive only those wavelengths of light, around .0000001 meters long, that our eyes also see. But light from stars and galaxies and clusters of galaxies comes in wavelengths that range between .0000000000000001 and 1,000,000 meters long. The longest are radio waves, and the radio telescopes equipped to receive them are correspondingly large.

The largest such telescope to date, the Very Large Array, is actually 27 telescopes operating as one, coordinated by computer, and covering an area 20 by 20 miles. During 1985, the NSF-supported National Radio Astronomy Observatory began to build a new instrument. The Very Long Baseline Array, 10 telescopes operating as one, will stretch 5,000 miles, from Hawaii to the Virgin Islands.

With radio telescopes, astronomers can see things not otherwise detectable: radio waves can slip through clouds of gas or dust that surround stars and galaxies and deter other wavelengths. The Very Large Array, for example, was used to observe newly born stars inside their cocoons of gas and dust, to watch debris drift away from the explosion of a supernova, and to penetrate to the energy source (probably a black hole) at the center of our galaxy. Moreover,

The Very Large Array. An assemblage of 17 steerable antennas that can move on railroad tracks. The Array is the predecessor to the Very Long Baseline Array (VLBA), whose 10 antennas are fully steerable but otherwise fixed. Projected VLBA sites are shown on page 31.



with the Very Large Array astronomers can see these things as precisely, in as much detail, as with a large optical telescope.

The resolution of a telescope, however, depends on its size. The much larger Very Long Baseline Array will have unprecedented resolution, more than any optical telescope present or planned. With a telescope of this resolution, one could stand in New York, pick out a dime in Los Angeles, and read its motto, "In God We Trust."

Astronomers will use this array to study, among other things, the ancient, violent quasars, starlike sources of radio waves so far away they must have formed soon after the universe began. Quasars may be young galaxies, or a type of galaxy that only formed early on. Understanding them will help piece together the life history of the universe.

Quasars seem to be found at the centers of galaxies. They are so bright, however, that they outshine their galaxies: a quasar at the center of ours would make the night sky brilliant. Astronomers do not understand why quasars are so bright. They speculate that these objects are not stars at all but black holes into which stars fall, colliding and swirling into a disk around the black hole before they disappear. What the energy source at the center of quasars actually is and how, if galaxies began as quasars, they settled down into stable middle age, are questions astronomers hope to answer with the Very Long Baseline Array.

Less dramatic but equally important is the fact that the Very Long Baseline Array will allow astronomers to fix exact distances to stars and galaxies. Measurements of distance are crucial to theories of how stars evolve, how galaxies are born, how the universe has developed, and how it will end. The most exact measurement of distance, a method called parallax, uses geometry known since the Greeks. The problem is, the distances involved are so great that astronomers can find the parallaxes of only a few stars. They estimate the distance to the nearest galaxy, Andromeda, only by inference, and they reckon their inferences to the farthest galaxies may be wrong by 50 percent.

With the new array, which will take several years to build, astronomers will be able to improve measurements of distance by close to a thousand times. That should put their theories on the evolution of the universe and everything in it on firmer ground.

Molecular and Cellular Biosciences

How Cells Know What to Do

Every cell in a human's body, or a frog's body, or a corn plant carries deoxyribonucleic acid, or DNA. The DNA makes the proteins that carry oxygen in blood, digest food, fight off infections, make pigment, or photosynthesize. Each cell in a given individual has the same DNA: a cell in your bloodstream has the same DNA as a cell in your finger. That means that every cell has the capability to make all the proteins the animal or plant needs to stay alive. The problem is immediately obvious. If DNA makes proteins, and all cells in an individual have the same DNA, then why don't the cells in a finger make hemoglobin?

No one knows the answer to that, although it is now one of the most important issues in genetics. *Vicky Chandler,* at the University of Oregon in Eugene and a Presidential Young Investigator, is trying to answer the question by focusing on the DNA of a corn plant. This plant's DNA makes certain proteins found in corn kernels; those proteins make a pigment called anthocyanin, which turns the kernels of Indian corn purple. The production of anthocyanin is actually the last in a series of steps, each making a different protein that makes the next step possible. The whole pathway is masterminded by a gene called the B locus. If the B locus happens to mutate, the pathway is interrupted and the corn will be colorless.

The B locus not only controls the pathway that ends with the kernel being purple; it also controls whether the purple is pale or intense, which tissue is to be colored, and when in the life of the plant the coloring takes place. And oddly enough, variant forms of the B locus will turn not the kernels but the leaves purple.

MARTIN GELLERT

Model of a highly supercoiled DNA molecule, above; double helix at right.

Chandler suspects that perhaps the B locus is somehow responsible for a cell's specificity. To find out more about this locus, Chandler first clones it, then takes it apart. Ultimately, she would like to insert a clone of the B locus into corn that lacks anthocyanin and see what happens. Her work with the B locus should illuminate how a cell knows to do its job and no others. That in turn should teach scientists more about the most fundamental processes of living systems, and should point out the most effective response when those processes—as in cancer—go wrong.

Behavioral and Neural Sciences

How a Rabies Virus Works

A virus, a protein coat covering a molecule of RNA or DNA, is one of the simplest possible parasites. It cannot reproduce on its own. Instead, through parts of the protein coat it attaches itself to a cell, breaches the cell membrane, and establishes itself inside. The virus takes over the cell's reproductive apparatus: the virus' RNA or DNA directs the cell's own metabolic systems to reproduce copies of the virus. Unable to manufacture what it needs to stay alive, the cell dies, releasing the virus' offspring to invade another cell and continue the cycle.

Some viruses are more or less benign, not noticed by their hosts; others are virulent. All attack only the cells of certain systems: flu and cold viruses target primarily the respiratory system; rabies virus, the muscles and nerve cells. Researchers have not known exactly how the rabies virus accomplishes this targeting; if they did, they could interfere with the process. Now *Thomas Lentz* at the Yale Medical School has shown how a rabies virus seeks out muscle cells.

In a way, the muscle cell seeks out the rabies virus. On the walls of these cells are certain proteins that recognize and receive only acetylcholine, a chemical substance that communicates between nerves and muscles. Each molecule of protein has only a certain number of receptors with which it can bind to acetylcholine. In fact, snake venom and poisons such as curare paralyze by the simple expedient of binding to the same receptors on the protein that acetylcholine normally does, thus using up all the available binding sites and preventing acetylcholine from carrying a stimulus from a nerve cell to a muscle cell. Lentz found that the rabies virus works the same way.

The coat of the rabies virus is studded with spikes. The heads of the spikes are modified to match exactly the acetylcholine receptor on a muscle cell; when the head and receptor touch, they stick avidly. With acetylcholine receptors covered with rabies viruses, the muscles can receive no stimulus from nerves and the patient is to some extent paralyzed. Rabies is lethal because once the virus takes over the muscle cells and releases its offspring into the bloodstream, the offspring head straight for the nervous system. New muscle cells will replace the ones killed by viruses, but nerve cells do not reproduce: after age two, humans have all the nerve cells they ever will. Rabies eventually invades so many nerve cells that the body loses voluntary control. Ultimately, the rabies virus moves to the brain.

Lentz has synthesized peptides that imitate the spikes on the rabies virus; he has found that his synthetics also bind avidly to acetylcholine receptors. The hope is that these synthetics could protect muscle cells from the rabies virus by tying up all their acetylcholine receptors. The rabies virus also has a generic resemblance to viruses that cause autoimmune diseases and to other slow viruses that account for many other illnesses. This kind of basic research may eventually lead to protection from these maladies.

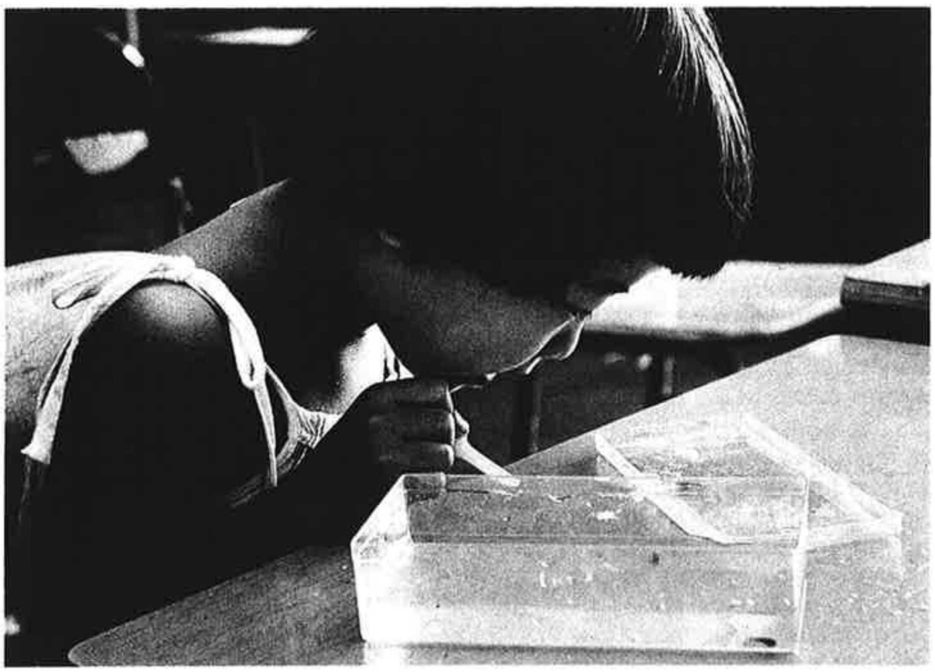
Science and Engineering Education

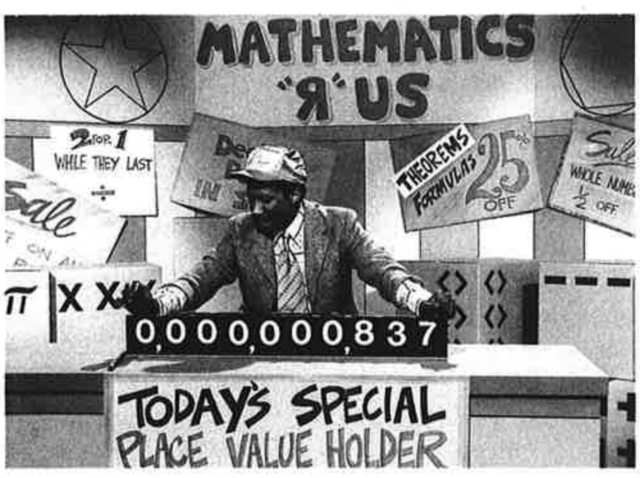
NSF has always supported the "pipeline" of training for careers in science and engineering—largely through fellowships for graduate and postdoctoral students and awards to develop high-quality teaching materials at the high school level. The scientists of the future, however, are now in grade school, and many will lack the experience and motivation they need unless the quality of early general education is greatly improved.

Because these early years are critical, NSF's efforts include support for award-winning television series (aimed at bringing children to school with a healthy interest and background in science and mathematics), and for programs that provide hands-on experience through museums, clubs, and other nonschool activities.

Following this are programs that add to the quality of education in the schools through improved instructional materials and workshops that help to prepare teachers and maintain their skills. These particularly focus on the status and prestige of science teaching as a profession.

The Foundation also plays a key role in a nationwide awards program launched by President Reagan in 1984. Administered through the National Science Teachers Association, the Presidential Awards for Excellence in Science and Mathematics Teaching honor 2 outstanding science and math instructors from each state, the District of Columbia, and Puerto Rico each year. The prestigious award, and a $5,000 grant for materials and training, are based on outstanding performance in the classroom, student progress, and professional endeavor.





Students entering the scientific and engineering disciplines in college are aided by the College Science Instrumentation Program (mentioned above). Ultimately, the most talented go on to graduate and postdoctoral fellowships—and to research apprenticeship as part of NSF's many disciplinary research programs.

These and other education-related programs are a key part of NSF's ongoing mission to promote the progress of science in this nation.

Presidential Teaching Awardees. NSF Director Erich Bloch honors science teacher Almodovar Fonseca-Rivera from Puerto Rico. In second photo (left to right), Nebraska science teacher Roger Rea, Ohio math teacher Ruth E. Hubbard, and Kentucky science teacher Sister Mary Ethel Parrott join 1985 Nobel Prize winning chemist Jerome Karle and his wife, chemist Isabella Karle.

OREGON MUSEUM OF SCIENCE & INDUSTRY

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MODEL SECONDARY SCHOOL FOR THE DEAF, WASHINGTON, DC

Special Research Communities

Cutting Across Disciplinary Boundaries

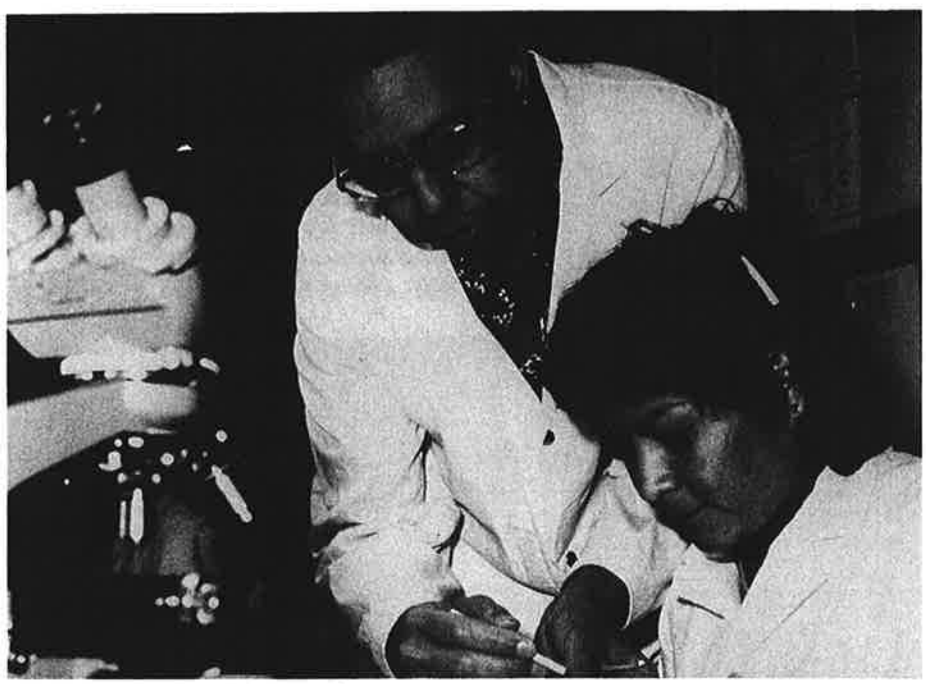
Several program clusters at NSF cut across disciplinary research boundaries. Focusing on special research communities, some of these program clusters are designed to improve the involvement of small high-technology firms, women, and minorities in NSF research activities. Addressing special problems associated with the nation's scientific and engineering infrastructure is another focus for these programs—for example, the Experimental Program to Stimulate Competitive Research involves states that are relatively less successful in competing for federal research funds. Supporting the U.S. scientific and engineering community in international cooperative science activities is yet another program cluster; it increases access to unique research environments and facilities abroad and provides other benefits for U.S. researchers.

As part of a government-wide initiative to convert scientific research results into technology, NSF's Small Business Innovation Research (SBIR) program provides seed money to small high-technology firms for high-risk research projects. The goal is to attract private-venture capital to commercialize research findings, and results have been encouraging. Several firms have been successful in leveraging NSF research investments of $200-$300,000 into multimillion-dollar venture capital commitments; these will further develop research results into commercial products or systems in areas such as genetic technology, electronics, and materials science.

Increasing the number and research capability of minority scientists and engineers and strengthening institutions with significant minority enrollments are the goals of another set of NSF programs that cut across disciplinary lines. Several researchers funded under these programs have made important contributions in mathematics, electronics, and polymer science. Providing equipment and instrumentation to minority institutions enables them to establish facilities for special research programs. The laboratory for monoclonal antibody technology at Nashville's Tuskegee Institute is an example. Another is a multidisciplinary research instrumentation laboratory at the University of Puerto Rico at Mayaguez. It is unique in the Caribbean region.

Other key NSF goals include helping female scientists and engineers become engaged in research as independent investigators and providing opportunities for female Ph.D.s to begin or resume research after a career interruption. Through these efforts, women who are established researchers in their fields act as mentors and counselors to science and engineering students. As a result, female scientists who had not previously considered submitting research proposals to NSF are now doing so in increasing numbers and with growing success.

Several states are making major attempts to provide additional resources to their academic institutions as a result of the Experimental Program to Stimulate Competitive Research (EPSCoR). Catalyzing state and industry attention,



Biologist Don C. Ahshapanek instructs a student at Haskell American Indian Jr. College.

BOB KRAMER

VPW awardee. Biologist Gillian Cooper-Driver is one of the 1985 grantees under NSF's Visiting Professorships for Women (VPW) program. Through this program, female Ph.D.s can begin or resume research in their fields and also act as mentors to science and engineering students.

NSF grants have leveraged funding and heightened awareness of the need to strengthen capabilities in academic science and engineering research. In Montana, South Carolina, Arkansas, Maine, and West Virginia, research talent has been developed in such areas as geology, marine sciences, physics, and chemistry. Broadening the base of research funding in these states has allowed university leadership to redirect scientific activities and participate more fully in the national research and development enterprise.

Started in FY 1985, NSF's Industrialized Countries Exchange Program is providing opportunities for younger U.S. scientists and engineers to gain research experience and professional contacts in the countries of Western Europe and Japan. Special science and technology initiatives with India and China offer other opportunities for U.S. researchers to investigate monsoons, minerals, and other phenomena that are unique to those regions. Joint research activities with foreign scientists are available to U.S. scientists and engineers in more than 30 countries that have co-operative science agreements. These programs are important as a means for cost and resource sharing as well as access to foreign scientific and technological development.

Anatomy professor Eldridge Johnson examines a specimen.

Guayule processing in Mexico, an example of an international program supported by NSF.

Small Business Innovation Research. This line electron beam apparatus was supported by NSF's Small Business Innovation Research program.

NSF Awards: People Who Met The Challenges

1985 Vannevar Bush Award winner Dr. Hans Bethe.

1985 Waterman Award winner Dr. Jacqueline Barton.

Vannevar Bush Award

The National Science Board, NSF's governing body, grants the prestigious Vannevar Bush Award, named for the engineer and World War II science administrator who prepared the presidential report recommending establishment of the National Science Foundation. The honorary award recognizes individuals who have made outstanding contributions to the nation through public service activities in science and technology.

In 1985, the award was presented to *Hans Albrecht Bethe*, professor emeritus at Cornell University, a theoretical physicist whose contributions have ranged over a lifetime.

Bethe's research has focused on the behavior of the nuclei of atoms. His most famous work, in 1938-39, solved an old problem. Earlier theories had held that hydrogen and helium, 98 percent of the universe, were made during the so-called big bang phase of creation. But no one could account for the origin of all the rest of the elements, that important 2 percent from which we are made. Bethe's explanation was that the whole periodic table of the elements was made either in the fiery cores of stars or in the split seconds of their explosive deaths. Subsequent work provided precisely detailed support for his theory, which now is the basis for scientists to understand the behavior of our sun and the evolution of stars.

In 1942, Bethe was one of the small team that studied the feasibility of the atomic bomb, and later he held a central position on the Manhattan Project. Bethe's current work focuses on supernovas, the end stages of massive stars; recently he has been an outspoken proponent of the nuclear test ban treaty. Bethe has won, among other important awards, the U.S. National Medal of Merit, in 1946, and the Nobel Prize in Physics, in 1967.

Alan T. Waterman Award

This award, named for NSF's first director, is presented each year to a researcher under 35 years of age and not more than 5 years beyond receipt of the doctoral degree, whose research shows excellence and innovation. This year the award went for the first time to a woman, *Jacqueline K. Barton*, an inorganic and biophysical chemist at Columbia University.

Barton, whose early training at a girl's school had to be supplemented by science courses at a nearby boy's school, is also a Sloan Foundation Fellow and a Presidential Young Investigator. Her work has focused on the relationship between the structure of a molecule of DNA and its function. The DNA molecule, the familiar double helix that controls what proteins the body makes, can spiral either to the left or to the right. Which direction it takes determines what biological processes it controls. Barton designed certain metal-containing molecules that attach to the DNA molecule in such a way that distinguishes a left-handed DNA molecule from a right. Knowing this will allow scientists to design new pharmaceutical agents which could affect the way DNA controls life processes. The experimental tools Barton developed are necessary to bridge the fields of molecular biology and inorganic chemistry.

3

Senior Staff Appointments in FY 1985

John Moore, previously Associate Director and Senior Fellow of the Hoover Institution in Stanford, California, became NSF's Deputy Director. Dr. Moore has also been serving as Chief International Affairs Officer, assessing NSF's programs in international science.

William J. Merrell, Jr. was nominated to be the new Assistant Director for Astronomical, Atmospheric, Earth, and Ocean Sciences. (He was sworn into office at the start of fiscal year 1986.) Dr. Merrell came from Texas A&M University, where he was an Associate Dean and Director of the Division of Atmospheric and Marine Sciences.

Richard Nicholson, former Staff Director of NSF, is now the Assistant Director for Mathematical and Physical Sciences. Dr. Nicholson also served previously as head of NSF's chemistry division.

Nam Pyo Suh, formerly a Professor of Mechanical Engineering at the Massachusetts Institute of Technology, was sworn in as the new Assistant Director for Engineering.

Organizational Changes

The major organizational change in FY 1985 was in the Engineering Directorate. Four engineering divisions and one office were abolished, and five new divisions and one new office were established.

The *Engineering Directorate* was reorganized partly to adjust to a diverse and fast-moving discipline: the modern field of engineering has anywhere from 30 to 40 different subfields; it is in general an area that has changed with extraordinary rapidity. The directorate was also reorganized to accommodate the increasing interdependence of science and engineering. Much of engineering, especially that involving complex systems such as the turbulent flow of fluids, has traditionally been driven by experience and innovation, where a design was based less on theory and more on what seemed to work. This latter approach is increasingly ineffective; as a method of solving problems, it is relatively inflexible. The most flexible approach is founded on basic scientific principles.

The new divisions and office are:

—Engineering Science Division in Chemical, Biochemical, and Thermal Engineering;

—Engineering Science Division in Mechanics, Structures, and Materials Engineering;

—Engineering Science Division in Electrical, Communications, and Systems Engineering;

—Division for Science Base Development in Design, Manufacturing, and Computer Engineering;

—Division for Fundamental Research in Emerging and Critical Engineering Systems;

—the Office of Cross-Disciplinary Research.

The Engineering Directorate has also instituted a new program designed to fund more high-risk/high-return projects. These projects are either those whose outcome is uncertain but whose success would be a significant contribution, or those whose subjects do not fall into any standard categories. The new program does not bypass the peer review system; however, proposals that got mixed reviews and therefore were declined funding might, under this program, get a second chance.

The *Science and Engineering Education Directorate* also changed its organization, creating three divisions and two offices:

—The Division of Materials Development and Informal Science Education deals primarily with the improvement of instructional materials and techniques, the application of advanced teaching technology, and science education programs in museums, the media, and other nonacademic settings.

—The Division of Research Career Development handles graduate, minority graduate, and certain international fellowships, along with the Presidential Young Investigators program.

—The Division of Teacher Preparation and Enhancement administers such activities as the Presidential Awards for Excellence in Science and Mathematics Teaching, the Honors Workshops for Precollege Teachers, and similar teacher development efforts.

—The Office of College Science Instrumentation manages the College Science Instrumentation Program, described earlier, and the Office of Studies and Program Assessment maintains a database and reports on the status of precollege science and math education.

Finally, there were realignments in the *staff offices* that report to the NSF Director. The Office of Audit and Oversight merged with the Office of the Controller to become the Office of Budget, Audit, and Control. The Foundation's computer services division moved from the Directorate for Administration to become the Office of Information Systems, under the Foundation's Director; two offices that boost small business involvement in science and technology moved from the Office of the Director to the Directorate for Scientific, Technological, and International Affairs.

Policy Notes

NSF funds proposals for research and equipment according to the proposals' excellence. The judgment of excellence is made through and guaranteed by the system of peer review, through which thousands of scientists and engineers outside the Foundation evaluate proposals on an ad hoc basis and advise NSF staff as to which should be supported. Recently, however, a number of universities have obtained millions of dollars for academic projects directly from Congress, thus bypassing the merit-based review system.

An ad hoc committee set up by the National Science Board, called such appeals to Congress a dangerous precedent. The committee's report[1] said that the merit review process is the most reliable guarantor of excellence. Direct appeals, the report noted, make science dependent on special interest politics, seriously undermining its objectivity, integrity, and automomy.

"The question facing American universities today is this," the report stated: "Will they retain responsibility for the excellence of U.S. science and engineering, or will they cede it to purely political processes? The choice is in the hands of the science and engineering community. The trend is in the wrong direction."

The report concluded that universities resort to direct appeals because so many of their facilities are deteriorating. The study recommended that the National Science Board, the National Academies of Science and Engineering, and the White House Office of Science and Technology Policy jointly call a conference of all interested parties (which took place in the summer of 1985), and that NSF set up a formal group to examine the merit review process.

Within a month of the report, NSF established an advisory committee of 10 scientists, engineers, and educators; the group is headed by Norman Hackerman, Chairman of the Scientific Advisory Board of the Robert A. Welch Foundation in Houston. At this writing the Hackerman Committee (which will disband in May 1986) is evaluating the present merit review system, assessing any inequities that might result from it, and preparing a final report on findings and recommendations.

In 1985 NSF also considered the question of funding facilities rather than equipment or specific projects, an issue raised in prior years. The policy adopted is that the primary responsibility for providing facilities to house researchers lies with colleges and universities. Although NSF will consider funding facilities in certain compelling cases, in general it will fund projects first, equipment second, and facilities third.

[1]*Report of the National Science Board Committee on Excellence in Science and Engineering,* Feb. 22, 1985

Senior Foundation and Board Officials

Erich Bloch
Director

Before becoming Director of the Foundation in August 1984, Mr. Bloch was Vice-President for Technical Personnel Development at the IBM Corporation, which he joined in 1952 as an electrical engineer. In 1985, Mr. Bloch was awarded the National Medal of Technology by President Reagan, an award made for his part in pioneering developments related to the IBM/360 computer that "revolutionized the computer industry."

John Moore
Deputy Director

Dr. Moore became NSF's Deputy Director in June 1985. He is on leave of absence from the Hoover Institution at Stanford University, where he was Associate Director and Senior Fellow. Previous positions include economics professor and associate director of the Law and Economics Center at Emory University, and research professor and associate director at the University of Miami's Law and Economics Center.

Roland W. Schmitt
Chairman
National Science Board

Dr. Schmitt is Senior Vice-President for Corporate Research and Development at the General Electric Company, where he has been employed since 1951. He is a member of GE's Corporate Executive Council, President of the Industrial Research Institute, and also serves on the National Academy of Engineering Council.

Charles E. Hess
Vice Chairman
National Science Board

Dr. Hess has been Dean of the College of Agricultural and Environmental Sciences at the University of California, Davis, since 1975. He is also Associate Director of the California Agricultural Experiment Station and has served on numerous state, national, and international advisory boards and commissions in horticulture and forestry.

Moving Ahead

The present state of science and engineering will surely determine the future. But at present our country is not adequately supporting basic researchers, is not investing sufficiently in up-to-date equipment, and is not training enough young researchers.

For the future, if our country is to remain economically competitive, it must redress these inadequacies. In particular it must fund those areas where international competition is most fierce, and in general it must continue to fund the best basic research.

Both competition and potential progress are great in fields created by a new cooperation between science and engineering. Biotechnology, for example, will drastically improve agriculture's ability to feed the world and medicine's ability to prevent or treat disease. Fiber optics and semiconductor devices are altering what is possible in communications and computer science. The combination of computer science, cognitive science, and artificial intelligence should provide the technologies for improving education. New computer architectures will increase the already enormous speed of computing, making possible science that was previously impossible. New materials and composites of materials will be designed so that their properties match their uses; thus they will be lighter, stronger, cheaper, and less likely to corrode.

Basic research also has, and always has had, intrinsic cultural value, and it often has surprising practical applications as well. In physics, the study of the most fundamental constitutents of nature combined with that of the infinite, or nearly infinite, universe should produce new understandings of why matter behaves as it does and how space and time are linked. In mathematics, the most abstruse and unworldly theories are increasingly invaluable in describing complex systems, such as the weather, that do not obey simple laws of cause and effect. Earth scientists will put satellites in the skies to chart the land and its movements. Behavioral scientists are learning more about the chemical foundations of emotions, drives, and learning.

By supporting both research of high intrinsic value and research that will contribute to our competitiveness, the National Science Foundation continues to invest in our nation's future through its ongoing commitment to excellence.

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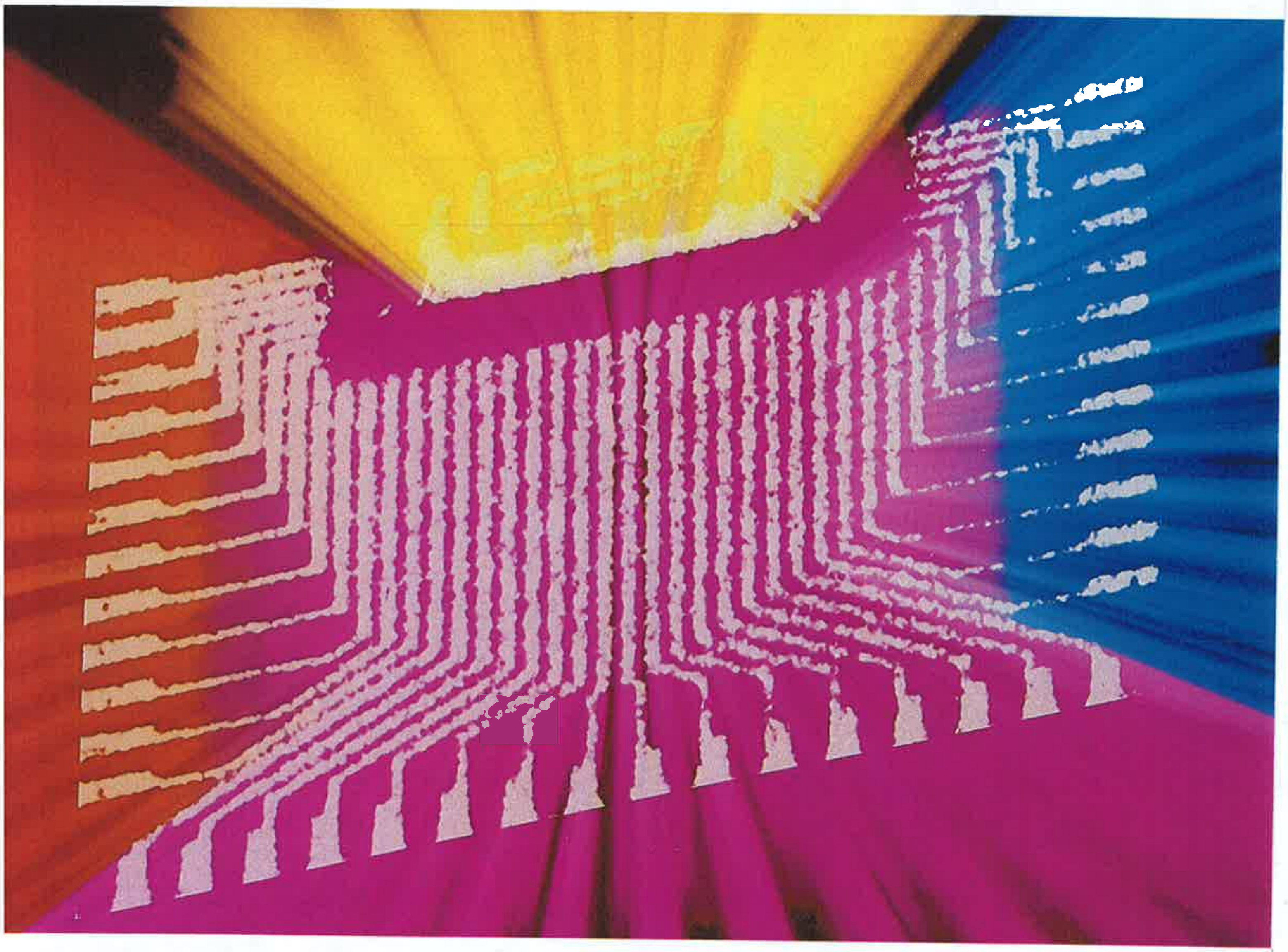

Appendix A

National Science Board Members and NSF Staff

(Fiscal Year 1985)

NATIONAL SCIENCE BOARD

Terms Expire May 10, 1986

Jay Vern Beck, Professor Emeritus of Microbiology, Brigham Young University, Provo, UT
Peter T. Flawn, President, University of Texas, Austin, TX
Mary L. Good, President and Director of Research, Signal Research Center, Des Plaines, IL
Peter D. Lax, Professor of Mathematics, Courant Mathematics and Computing Laboratory, New York University, New York, NY
Homer A. Neal, Provost, State University of New York at Stony Brook, Stony Brook, NY
Mary J. Osborn, Professor and Head, Department of Microbiology, University of Connecticut Health Center, Farmington, CT
Donald B. Rice, President, The Rand Corporation, Santa Monica, CA
Stuart A. Rice, Dean of the Division of Physical Sciences, The James Franck Institute, University of Chicago, Chicago, IL

Terms Expire May 10, 1988

Warren J. Baker, President, California Polytechnic State University, San Luis Obispo, CA
Robert F. Gilkeson, Chairman of the Executive Committee, Philadelphia Electric Company, Philadelphia, PA
Charles E. Hess, Dean, College of Agricultural and Environmental Sciences, University of California, Davis, CA
Charles L. Hosler, Vice President for Research, Pennsylvania State University, University Park, PA
William F. Miller, President and Chief Executive Officer, SRI International, Menlo Park, CA
William A. Nierenberg, Director, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA
Norman C. Rasmussen, McAfee Professor of Engineering, Massachusetts Institute of Technology, Cambridge, MA
Roland W. Schmitt, Senior Vice President, Corporate Research and Development, General Electric Company, Schenectady, NY

Terms Expire May 10, 1990

Perry L. Adkisson, Deputy Chancellor, Texas A&M University System, College Station, TX
Annelise G. Anderson, Senior Research Fellow, The Hoover Institution, Stanford University, Stanford, CA
Craig C. Black, Director, Los Angeles County Museum of Natural History, Los Angeles, CA
Rita R. Colwell, Vice President for Academic Affairs and Professor of Microbiology, University of Maryland, Adelphi, MD
Thomas B. Day, President, San Diego State University, San Diego, CA
James J. Duderstadt, Dean, College of Engineering, The University of Michigan, Ann Arbor, MI
K. J. Lindstedt-Siva, Manager, Environmental Sciences, Atlantic Richfield Company, Los Angeles, CA
Simon Ramo, Director, TRW Incorporated, Redondo Beach, CA

Members Ex Officio

Erich Bloch, Director, National Science Foundation, Washington, DC
Thomas Ubois, Executive Officer, National Science Board, National Science Foundation, Washington, DC

NATIONAL SCIENCE FOUNDATION STAFF

(As of September 30, 1985)

Director, Erich Bloch
Deputy Director, John H. Moore
Senior Science Advisor, Mary E. Clutter
Director, Office of Equal Opportunity, Brenda M. Brush
General Counsel, Charles Herz
Director, Office of Legislative and Public Affairs, Raymond E. Bye
Controller, Office of Budget, Audit, and Control, Sandra D. Toye
Director, Office of Advanced Scientific Computing, John W. Connolly
Director, Office of Information Systems, Constance K. McLindon
Assistant Director for Astronomical, Atmospheric, Earth, and Ocean Sciences (Acting), Albert L. Bridgewater
  Deputy Assistant Director for Astronomical, Atmospheric, Earth, and Ocean Sciences, Albert L. Bridgewater
  Director, Division of Astronomical Sciences, Laura P. Bautz
  Director, Division of Atmospheric Sciences, Eugene W. Bierly
  Director, Division of Earth Sciences, James F. Hays
  Director, Division of Ocean Sciences, M. Grant Gross
  Director, Division of Polar Programs, Peter E. Wilkniss
Assistant Director for Biological, Behavioral, and Social Sciences, David T. Kingsbury
  Head, Office of Biotechnology Coordination, Robert Rabin
  Director, Division of Behavioral and Neural Sciences, Richard T. Louttit
  Director, Division of Biotic Systems and Resources, John L. Brooks
  Director, Division of Information Science and Technology, Charles N. Brownstein
  Director, Division of Cellular Biosciences (Acting), Bruce L. Umminger
  Director, Division of Molecular Biosciences, James H. Brown
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Assistant Director for Engineering, Nam P. Suh
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Director, Division of Administrative Services, Troy T. Robinson

Appendix B

Financial Report for Fiscal Year 1985

(In thousands of dollars)

Research and Related Activities Appropriation

Fund Availability

Fiscal year 1985 appropriation	$1,306,012	
Unobligated balance available, start of year	2,053	
Adjustments to prior year accounts	3,638	
Fiscal year 1985 availability		$1,311,703

Obligations

Astronomical, Atmospheric, Earth, and Ocean Sciences:		
Astronomical Sciences	$82,764	
Atmospheric Sciences	95,064	
Earth Sciences	45,962	
Ocean Sciences	121,276	
Arctic Research Program	7,961	
Subtotal, Astronomical, Atmospheric, Earth, and Ocean Sciences		$353,027
Biological, Behavioral, and Social Sciences:		
Molecular Biosciences	$60,927	
Cellular Biosciences	52,385	
Biotic Systems and Resources	58,121	
Behavioral and Neural Sciences	44,378	
Social and Economic Sciences	28,751	
Information Science and Technology	8,948	
Subtotal, Biological, Behavioral, and Social Sciences		$253,510
Engineering:		
Chemical, Biochemical, and Thermal Engineering	$29,178	
Mechanics, Structures, and Materials Engineering	23,310	
Electrical, Communications and Systems Engineering	25,805	
Design, Manufacturing and Computer Engineering	17,464	
Emerging and Critical Engineering Systems	34,961	
Cross-Disciplinary Research	19,910	
Subtotal, Engineering		$150,628
Mathematical and Physical Sciences:		
Mathematical Sciences	$47,730	
Computer Research	39,124	
Physics	115,795	
Chemistry	87,563	
Materials Research	106,976	
Subtotal, Mathematical and Physical Sciences		$397,188
Scientific, Technological, and International Affairs:		
Industrial Science and Technological Innovation	$13,436	
International Coöperative Scientific Activities	12,422	
Policy Research and Analysis	5,146	
Science Resources Studies	4,140	
Research Initiation and Improvement	8,600	
Subtotal, Scientific, Technological, and International Affairs		$43,744
Advanced Scientific Computing		$41,396
Program Development and Management		$71,951
Subtotal, obligations		$1,311,444
Unobligated balance available, end of year		$197
Unobligated balance lapsing		$62
Total, fiscal year 1985 availability for Research and Related Activities		$1,311,703

U.S. Antarctic Program Activities Appropriation

Fund Availability		
Fiscal year 1985 appropriation	$110,830	
Unobligated balance available, start of year	68	
Adjustments to prior year accounts .	2	
Fiscal year 1985 availability ...		$110,900
Obligations		
U.S. Antarctic Research Program ...	$11,156	
Operations Support	99,685	
Subtotal, obligations		$110,841
Unobligated balance available, end of year		$59
Total, fiscal year 1985 availability for U.S. Antarctic Program Activities		$110,900

Special Foreign Currency Appropriation

Fund Availability		
Fiscal year 1985 appropriation	$2,800	
Unobligated balance available, start of year	37	
Adjustments to prior year accounts .	22	
Fiscal year 1985 availability ...		$2,859
Obligations		
Special Foreign Currency	$2,830	
Unobligated balance available, end of year	2	
Unobligated balance lapsing	27	
Total, fiscal year 1985 availability for Special Foreign Currency Program ..		$2,859

Science and Engineering Education Activities Appropriation

Fund Availability		
Fiscal year 1985 appropriation	$82,000	
Unobligated balance available, start of year	31,450	
Adjustments to prior year accounts .	37	
Deferred in FY 1985	(31,450)	
Fiscal year 1985 availability ...		$82,037
Obligations		
Research Career Development	$27,298	
Materials Development, Research, and Informal Science Education .	22,726	
Teacher Preparation and Enhancement	25,188	
Studies and Program Assessment ..	1,748	
College Science Instrumentation ...	4,996	
Subtotal, obligations		$81,956
Unobligated balance available, end of year		$44
Unobligated balance lapsing		$37
Total, fiscal year 1985 availability for Science and Engineering Education Activities		$82,037

Trust Funds/Donations

Fund Availability		
Unobligated balance available, start of year	$2,791	
Receipts from nonfederal sources ..	6,138	
Fiscal year 1985 availability ...		$8,929
Obligations		
Ocean Drilling Programs	$7,601	
Miscellaneous Program Activities ...	119	
U.S.-Spain Scientific and Technological Program	83	
Subtotal, obligations		$7,803
Unobligated balance available, end of year		$1,126
Total, fiscal year 1985 availability for Trust Funds/ Donations		$8,929

SOURCES: Fiscal Year 1987 Supplementary Budget Schedules and Fiscal Year 1987 Budget to Congress.

Table 1. Astronomical, Atmospheric, Earth, and Ocean Sciences, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Astronomical Scis., Nat'l. Research Centers	265	$82.76
Atmospheric Sciences, Nat'l. Research Centers	549	95.06
Earth Sciences	652	45.96
Ocean Sciences	717	121.28
Arctic Research	68	7.96
Total	2,251	$353.02

SOURCE: Fiscal Year 1987 Budget to Congress-Justification of Estimates of Appropriations (Quantitative Program Data Tables).

Table 2. Biological, Behavioral, and Social Sciences, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Molecular Biosciences	891	$60.93
Cellular Biosciences	784	52.38
Biotic Systems and Resources	761	58.12
Behavioral and Neural Sciences	798	44.38
Social and Economic Sci.	542	28.75
Info. Sci. & Tech.	121	8.95
Total	3,897	$253.51

Table 3. Engineering, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Chemical, Biochemical, and Thermal Engineering	534	$29.18
Mechanics, Structures, and Materials Engineering	365	23.31
Electrical, Communications and Systems Engineering	393	25.81
Design, Manufacturing and Computer Engineering	188	17.46
Emerging and Critical Engineering Systems	455	34.96
Cross-Disciplinary Research	50	19.91
Total	1,985	$150.63

Table 4. Mathematical and Physical Sciences, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Mathematical Sciences	1,167	$47.73
Computer Research	352	39.12
Physics	528	115.80
Chemistry	1,045	87.56
Materials Research	834	106.98
Total	3,926	$397.19

Table 5. Science and Engineering Education, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Research Career Development	142	$27.30
Materials Development, Research, and Informal Science Education	98	22.72
Teacher Preparation and Enhancement	260	25.19
Studies and Program Assessment	13	1.75
College Science Instrumentation	234	5.00
Total	747	$81.96

Table 6. Scientific, Technological, and International Affairs, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Industrial S & T Innovation	194	$13.43
Internat'l. Coop. Sci.	625	12.42
Policy Research and Analysis	67	5.15
Sciences Resources Studies	38	4.14
Research Initiation and Improvement	71	8.60
Total	995	$43.74

Table 7. U.S. Antarctic Program, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
U.S. Antarctic Research Program	135	$11.15
Operations Support	11	99.69
Total	146	$110.84

Table 8. Advanced Scientific Computing, Fiscal Year 1985

(Dollars in Millions)

	Number of Awards	Amount
Advanced Scientific Computing	45	$41.39

Appendix C

Patents and Inventions Resulting from Activities Supported by the National Science Foundation

During fiscal year 1985, the Foundation received 117 invention disclosures. Allocations of rights to 58 of those inventions were made by September 30, 1985. These resulted in dedication to the public through publication in 11 cases, retention of principal patent rights by the grantee or inventor in 43 instances, and transfer to other government agencies in 4 cases. Licenses were received by the Foundation in 61 patent applications filed by grantees and contractors who retained principal rights in their inventions.

PATENTS ISSUED IN FY 1985:

NUMBER	TITLE	INSTITUTION
4,243,433	Forming Controlled Inset Regions by Ion Implantation and Laser Bombardment	Stanford University
4,282,057	Vapor Growth of Mercury Iodide for Use as High Energy Detectors	Purdue University
4,385,830	Direct Measurement of Vorticity by Optical Probe	Cornell Research Foundation
4,464,359	(2′-5′)-Oligo (3′-Deoxyadenylate) and Derivatives Thereof	Research Corporation
4,468,297	Degradation and Detoxification of Halogenated Olefinic Hydrocarbons	University of California
4,478,694	Methods for the Electro-synthesis of Polyols	SKA Associates
4,481,531	Microchannel Spatial Light Modulator	Massachusetts Institute of Technology
4,483,785	Electrically Conductive and Corrosion Resistant Current Collector and/or Container	University of Utah Research Foundation
4,485,265	Photovoltaic Cell	Harvard University
4,485,473	Mode Locking of Travelling Wave Ring Laser by Amplitude Modulation	Cornell Research Foundation
4,487,637	Purification of Niobium	Cornell Research Foundation
4,487,829	Production and Use of Monoclonal Antibodies Against Adenoviruses	Massachusetts Institute of Technology
4,487,840	Use of Silicon in Liquid Sintered Silicon Nitrides and Sialons	Cornell Research Foundation
4,489,001	Acidic Phallotoxin Derivatives and Methods of Preparation	Cornell Research Foundation
4,496,419	Fine Line Patterning Method for Submicron Devices	Cornell Research Foundation
4,499,007	Stabilization of Conductive Polymers in Aqueous Environments	Massachusetts Institute of Technology
4,503,555	Semiautomatic Optical Scanning Apparatus Utilizing Line Integration	University of California
4,512,964	Method for Forming Nitric Oxide from Ammonia	Massachusetts Institute of Technology
4,521,308	Rotary Support for Vacuum Filtration Apparatus	University of California
4,537,990	Method for Growing Single Crystals of Urea	Cornell Research Foundation

Appendix D

Advisory Committees for Fiscal Year 1985

(Addresses effective as of September 30, 1985)

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Texas Education Society
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(All in university anthropology departments unless otherwise listed)

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William T. Sanders
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Museum Studies
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Field Museum of Natural History

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