RESEARCH CORPORATION QUARTERLY BULLETIN
A FOUNDATION FOR THE ADVANCEMENT OF SCIENCE
SPRING 1976

File w/ Technology Transfer

Basic Research as a Major Contributor to the National Economy; Report of Science Board Shows Possible Danger Signals

Keeping a finger on the pulse of science in the United States is a responsibility assigned by Congress to the National Science Board. The readings are presented in the annual reports of the Board, the most recent of which has just been published as *Science Indicators–1974*.[1] "Indicators such as these," states the report, "can provide early warnings of events and trends which might impair the capability of science–and its related technology–to meet the needs of the Nation."

Several early warnings in the report deal with decreasing support for basic research through 1974. (Since 1974 there have been slight increases, but the total is still below that of the late 1960s.) This trend has directly affected Research Corporation for as other support has declined the foundation has been called upon to help fill the gap. But even in its narrow area of special interest–support of academic basic research in the physical sciences–Research Corporation's limited resources fall far short of meeting the challenge. A great deal of research has already been lost and the talents of many young investigators in their most creative years have gone untapped.

The long-range impact of this is made clear in *Science Indicators–1974* as it links the results of basic research in advancing technology with the contributions of technological progress to the economic health of the U.S. The following, measured in constant 1967 dollars, are some of the trends which portend future problems:

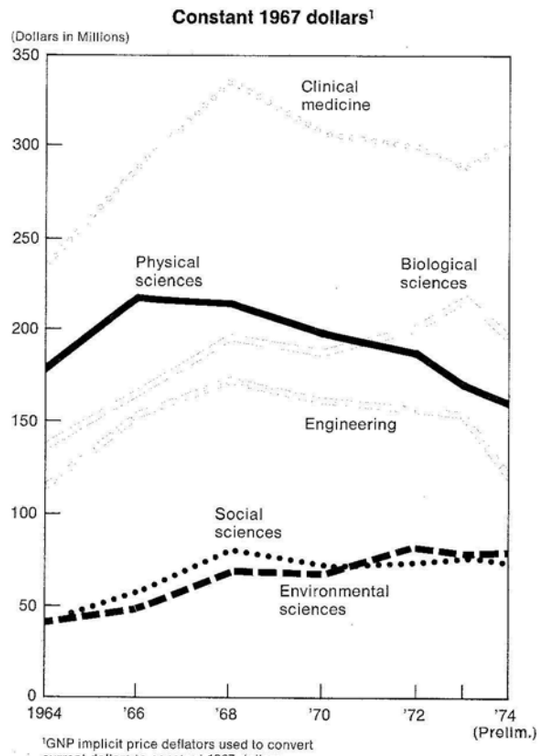
- Reductions in U.S. expenditures for *industrial research and development*–which has been a major factor in advancing the nation's productivity, economic status and standard of living.
- Reductions in total expenditures for *basic research*–upon which industry relies increasingly for new and advanced technologies–and even greater decreases in expenditures for *industrial basic research.*
- Reductions in support for *industrial basic research in the physical sciences*–the disciplines to which roughly half of industrial basic research expenditures are allocated.
- Reductions in expenditures for *basic research in colleges and universities*–the institutions which perform an increasing share of all basic research and upon which industry depends increasingly for published research reports.
- Reductions in expenditures for *basic research per scientist in doctorate-granting universities and colleges*–the institutions which account for over 90% of all academic basic research expenditures–with still greater decreases per scientist in *basic research in chemistry and physics.*

RATIONALE FOR WARNINGS

Following are excerpts from *Science Indicators–1974* which give the background and rationale for these early warnings:

Research and development is increasingly the basis and impetus for technological innovation in industry, the results of innovation being new and improved products, processes and services. These are the elements of technological progress, through which many of the advances

Estimated Federal Basic Research Expenditures in Universities and Colleges, by Field of Science, 1964-74



[1]GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

[1] *Science Indicators—1974,* Report of the National Science Board, 1975. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $4.60. Stock Number 038-000-00253-8.

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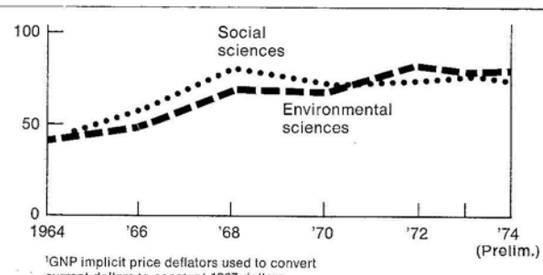

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in the nation's productivity, economic status and standard of living take place.

By far the largest share of U.S. industrial R & D expenditures goes for development activities; in 1974 they accounted for 79% of the total, compared with 18% for applied research and 3% for basic research.

Total industrial R & D expenditures, measured in constant 1967 dollars, were 11% lower in 1974 than in 1968-69, the years of highest funding, a reduction to almost the 1965 level. Basic industrial research expenditures were down 31% in 1974 from the peak level of 1966, dropping to about the 1961 level. Physical science basic research in industry, which accounts for about one-half of industrial basic research expenditures, received about 30% less in 1973 than in the 1967-69 peak years.

In constant 1967 dollars, the nation's total expenditures for basic research were down almost 13% in 1974 from the peak year of 1968. Federal expenditures for basic research, which accounted for the majority of the total, were down about the same amount, and federal support for the physical sciences declined even more—about 25% from 1969 to 1974. While the federal contribution to basic research expenditures increased from 59% to 68% over the 1960-74 period, and the universities' own support increased from 6% to 11%, industry support declined from 28% to 15%.

One important indicator of the relationship between basic research and technology is the extent to which new technologies or innovations depend upon results from basic research. A study of 277 innovations produced in the U.S. from 1953 to 1973[2] sought to establish the modes by which the technology was acquired; citing multiple sources, the innovating firms named applied research in 74% of the cases, basic research in 39% and technology transfer in 28%, much of the latter, of course, being based on prior research. The basic research figure is probably further understated because the data apply only to the period between conception and realization of the innovation, thus excluding prior research. This would indicate that industrial innovation, as represented by major technological advances, depends heavily upon basic research—a dependency which has increased over the years.

Another study of 179 major advances in technology [illegible] the U.S. from 1953 to 1973[2] sought to establish the modes by which the technology was acquired; citing multiple sources, the innovating firms named applied research in 74% of the cases, basic research in 39% and technology transfer in 28%, much of the latter, of course, being based on prior research. The basic research figure is probably further understated because the data apply only to the period between conception and realization of the innovation, thus excluding prior research. This would indicate that industrial innovation, as represented by major technological advances, depends heavily upon basic research—a dependency which has increased over the years.

Another study of 179 major advances in technology occurring in the U.S. between 1950 and 1973[3] examined the patent documentation associated with each to determine the source cited as the origin of the invention. Comparing the 1950-61 and 1962-73 periods, the number of

UNIVERSITY CONTRIBUTIONS

Throughout the 1960-73 period, industry's contributions to published research reports decreased while those of colleges and universities increased. By 1973 academic institutions were responsible for almost 75% of the publications in 13 scientific fields, while industry contributed about 10%. Between 1960 and 1973 university research reports in chemistry increased from 59% to 75% and in physics from 50% to 72%; industry research reports in chemistry decreased from 25% to 18% and in physics from 28% to 16%.

Universities and colleges perform an increasing share of the nation's basic research—more in 1974 than industry, the federal government, federally funded research and development centers administered by universities, and nonprofit institutions combined. Over the 1960-74 period, the academic institutions' share of total basic research expenditures increased from 37% to 54%, while over the same period the share performed by industry decreased from 32% to 16%.

Basic research is concentrated in academic institutions awarding doctorate degrees in the sciences and engineering, the 280 universities in this category in 1974 accounting for 92% of academic basic research expenditures. Between 1969 and 1974 there was a large increase in the number of institutions awarding these doctorates and in the number of scientists and engineers at existing institutions. This, together with the drop in real expenditures for basic research, resulted in a reduction of 27% in constant 1967 dollar expenditures per scientist and engineer in the 1966-74 period. In chemistry it is estimated that the reduction amounted to 32%, and in physics 39%.

SOURCES OF SUPPORT

With basic research the foundation upon which technological advances and future economic well-being will build, and with industry relying increasingly on scientists in academic institutions to perform basic research, tomorrow's economic growth may depend on increased support of academic basic research today. The physical sciences, which are of particular importance to industry, need special attention.

On the basis of past performance, the federal government and industry appear to be the major possibilities for the needed additional support. Unfortunately, federal obligations for basic research in colleges and universities have dropped even further since 1974, a total reduction

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Did you get your copy of the 1975 Annual Report?
A mix-up in the mailing house resulted in a number of copies of the 1975 Annual Report not being mailed. If you did not get your copy, please write and we will send one promptly. Our apologies to those we missed.

Three Appointed to Advisory Committees

Charles A. Arrington, Jr., and Thomas Erber have been named members of the Cottrell Program Advisory Committee, which evaluates grants proposals and advises on grants policy for Research Corporation's programs supporting basic research in the physical sciences. Guillermo Arroyave has been appointed to the Williams-Waterman Program Advisory Committee, which has parallel responsibilities for the foundation's public health nutrition program in Latin America and the Caribbean.

Dr. Arrington, Chairman and Associate Professor of Chemistry at Furman University, augments the expertise of the Cottrell Commitee in physical chemistry. A graduate of Furman with a B.S. in chemistry, he received his Ph.D. from Harvard University in physical chemistry, and was a Postdoctoral Fellow in the Department of Chemistry at the University of California.

Dr. Erber, Professor of Physics at Illinois Institute of Technology, succeeds Walter R. French, Jr., Head of the Department of Physics at Nebraska Wesleyan University, who completed a five-year term on the Cottrell Committee. Dr. Erber earned his B.S. in physics at Massachusetts Institute of Technology and M.S. and Ph.D. degrees in physics at the University of Chicago. He has been a member of the physics faculty at I.I.T. since 1957.

Dr. Arroyave, Chief of the Division of Physiological Chemistry at the Institute of Nutrition of Central America and Panama, Guatemala, succeeds Nevin S. Scrimshaw, Head of the Department of Nutrition and Food Science at M.I.T., who had served on the Williams-Waterman Committee since 1961. A graduate of San Carlos University, Guatemala, Dr. Arroyave earned his Ph.D. in biochemistry at the University of Rochester. He has been on the INCAP staff since 1961.

QUARTERLY BULLETIN **SPRING 1976**
Research Corporation, 405 Lexington Avenue, New York, N.Y. 10017

A foundation for the advancement of science, Research Corporation has a dual mission in serving educational and scientific institutions. Through its Grants Program it supports basic research in the natural sciences and basic and adaptive research in public health nutrition. Through its Patent Program it speeds the practical application of scientific discovery through technology transfer.

GRANTS PROGRAM

Cottrell College Science Grants support academic research programs in the natural sciences at private undergraduate institutions.

Cottrell Research Grants support basic research in the physical sciences and engineering in graduate institutions and public undergraduate universities.

Brown-Hazen Grants support work directly related to mycology, stressing research, training in research and medical applications. (Program nearing termination.)

Williams-Waterman Grants support research programs for the combat of nutritional diseases, particularly in the developing nations of the Western Hemisphere.

PATENT PROGRAM

Services contributed without cost to educational and scientific institutions include evaluating faculty and staff inventions, accepting assignment of those which appear to be useful and marketable, applying for patents through qualified counsel, licensing issued patents to industry, and defending against infringement when necessary.

Royalties received from patents assigned to the foundation are apportioned among the inventor, his institution and Research Corporation, with the institution's patent policy determining the inventor's share. The foundation's share is used to help support its programs of technology transfer and grant-making.

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Grants of $650,000 Made for Basic Research in Physical Sciences

Grants totaling $650,334 were made by Research Corporation in February for basic research, primarily in the physical sciences, in colleges, universities and scientific institutes. Twenty-two Cottrell College Science Grants amounting to $159,463 were awarded to 20 private, predominantly undergraduate institutions, and 58 Cottrell Research Grants totaling $490,871 were made to 50 graduate institutions and public undergraduate universities. The grants varied in amount from $350 to $24,000, with most in the $5,000 to $10,000 range.

In both programs applications for grants are judged on the scientific originality and significance of the research proposed and the demonstrated competence or promise of creativity of the principal investigators. Additional factors in the college program, which is directed to privately supported undergraduate institutions, are the degree of student involvement in the research, the suitability of the problem to a research-oriented teaching program and the overall academic atmosphere in which the work will be conducted.

Cottrell College Science Grants

MARY M. ALLEN, Wellesley College
Organic carbon utilization by blue-green algae—$6,100

WILLIAM R. BARTLETT, St. John's University, Minnesota
Stereoselective synthesis of the boll weevil sex attractant—$4,400

KEITH BECK, Elmhurst College
Synthesis and investigations of multistriatin and some analogs (two-year program)—$6,784

GEORGE M. BODNER, Stephens College
^{13}C NMR studies of the σ-donor/π-acceptor character of arsenic and antimony ligands in $LNi(CO)_3$ derivatives—$4,000

BRUCE C. and BARBARA J. BYRNE, Wells College
Ultrastructural and genetic analyses of behavioral mutations in *Paramecium aurelia—$8,950*

CLARENCE W. CLARK, Morehouse College
Molecular studies on the nature of R-factor replication in *Salmonella typhimurium* and *Proteus mirabilis*—$5,600

MICHAEL J. COLLINS, St. John's University, Minnesota
A calorimetric investigation of the acceptor properties of some lanthanide shift compounds—$3,000

MICHELE A. CRAYTON, Hamline University
The extracellular polysaccharides of Platydorina caudata Kofoid: I. Nature of the sulfated polysaccharide and the sulfation process—$5,950

ANATOL EBERHARD, Ithaca College
Anaerobic studies with luminous bacteria (two-year program)—$12,000

MICHAEL T. FLOOD, Beloit College
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MICHAEL T. FLOOD, Beloit College
Preparation and properties of saturated ligand transition metal complexes of low oxidation state (two-year program)—$10,000

WILLIAM C. HARRIS and LON B. KNIGHT, JR., Furman University
Computer-assisted matrix isolation experiments: Vibrational spectra and

DAVID PEAK, Union College, New York
Theory of diffusion-controlled multistate kinetics—$4,300

FRANCIS X. SMITH, King's College, Pennsylvania
Synthesis of rotaxanes with fluorescent end groups—$2,000

JOSEPH L. SNIDER, Oberlin College
Absolute measurements of solar rotational speeds using an atomic-beam technique (two-year program)—$12,735

KIM D. SUMMERHAYS, University of San Francisco
Pictorial investigation of Fermi-contact nuclear spin coupling: An application of multidimensional computer graphics—$2,280

SUZANNE P. VARIMBI, Rosemont College
Ambident nucleophilicity of thioketones—$4,000

LAUREN R. WILSON, Ohio Wesleyan University
The synthesis, structure, and reactivity of heavy metal complexes for protein structural studies—$4,400

Cottrell Research Grants

RICHARD D. ADAMS, Yale University
Investigations of the ligand behavior and reactivity of metal coordinated sulfonium cations and sulfur ylides—$8,959

NEAL R. ARMSTRONG, Michigan State University
Investigations of the redox pathways of tocopherol and bioquinones in aqueous micelle solutions—$10,000

JAMES M. BAILEY, Southern Illinois University
Structural organization of RNA tumor virus RNA—$11,500

B. GEORGE BARISAS, St. Louis University
Fluorescence correlation spectroscopic studies of model membranes—$12,000

PHILIP N. BORER, University of California, Irvine
Production and isolation of short helical fragments of natural double stranded nucleic acids—$8,000

ALAN BRENNER, Wayne State University
The chemistry and catalytic activity of supported transition metal carbonyls—$19,000

DAVID A. CHURCH, Texas A&M University
Angular momentum transfer in ion-surface collisions—$10,000

GERALD E. COHN, Illinois Institute of Technology
Spin label investigations of photodynamic action on biological membranes—$5,000

DONALD J. CREIGHTON, University of Maryland Baltimore County
Enol-keto tautomerase: Catalytic mechanism and stereochemistry—$6,405

LOUIS J. DE HAYES, University of California, Riverside
Electron transfer and oxidative addition/reductive elimination reactions of vanadium, molybdenum and rhenium complexes—$4,200

KENNETH T. DOUGLAS, Duquesne University
Mechanism of acyl transfer *via* acyl coenzyme A derivatives—$8,750

JERRY P. DRAAYER, Louisiana State University
Nuclear structure physics—Theoretical investigations focusing on the physics of heavy-ion induced excitation processes—$5,500

RUSSELL S. DRAGO, University of Illinois
Intervalence electron transfer rates—$5,000

REGINALD J. DUFOUR, Rice University
Angular momentum transfer in ion-surface collisions—$10,000

GERALD E. COHN, Illinois Institute of Technology
Spin label investigations of photodynamic action on biological membranes—$5,000

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RUSSELL S. DRAGO, University of Illinois
Intervalence electron transfer rates—$5,000

REGINALD J. DUFOUR, Rice University
Observational studies of the chemical composition and evolution of gassy galaxies—$6,500

GARY R. DUKES, University of Alabama
Structural effects on kinetic reactivity and thermodynamic stability of transition metal complexes—$8,200

Geologist's Quake Theory Leads to Environmental Quality Award



David M. Evans, geologist, discovered the cause of unusual Denver earthquakes and pointed out other hazards of underground pollution; he was honored as the 1976 winner of the NAS Award for Environmental Quality.

David M. Evans, the engineering geologist who produced the landmark study that established the cause of Denver-area earthquakes and who documented the dangers of pumping wastes deep underground, was named 1976 winner of the National Academy of Sciences Award for Environmental Quality. The Award and honorarium of $5,000, presented at the NAS Annual Meeting in Washington April 26, was established in the Academy by Research Corporation to honor its founder, air pollution control pioneer Frederick Gardner Cottrell.

The presentation to Mr. Evans grew out of a series of strange events that began in April 1962 at the Colorado School of Mines' then-new geophysical observatory. Suddenly the instruments began recording the jiggling lines that marked a small earthquake—in an area that had been remarkably free of tremors since a quake in 1882.

"This is what happens when you install a sensitive seismograph," commented the Observatory Director, Maurice Major. "You discover that a supposedly earthquake-free area *does* have earthquakes." It was not a matter of new equipment, however, for a check with the long-established Regis College Seismological Observatory nearby revealed it was recording the same shocks—the first ever to have epicenters in the Denver area.

Incredibly, the next five years were to witness hundreds more earthquakes including some that were, if not violent, very perceptible. Equally obvious were the cracked foundations and broken windows that followed. In 1966 Mr. Evans proposed in a key paper the cause of the Denver basin disturbances. The paper explored a relationship between the tremors and the pumping of liquid wastes by the Army into a 12,045-foot disposal well at Denver's Rocky Mountain Arsenal. In a lucid scientific statement Mr. Evans presented all known factual data and a discussion of the fluid mechanics that would cause fault movement when pressure is increased.

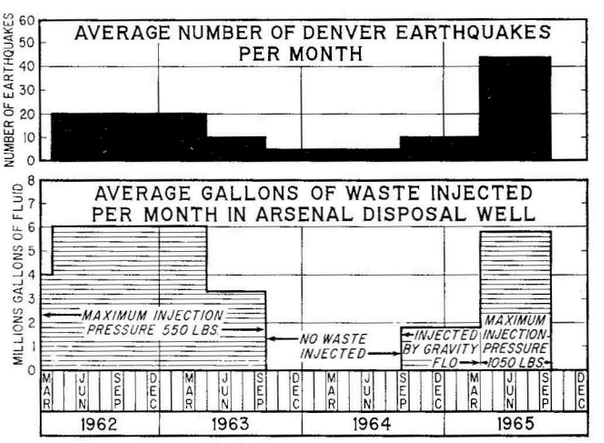
Between 1962 and 1965 the Army had pumped millions of gallons of wastes, the result of agricultural chemical manufacturing, into an injection well drilled in 1961 after other disposal methods began to contaminate local groundwater. The liquid, under pressure, had permeated crystalline basement rocks, reducing their strength to resist strains in the earth's crust and unleashing seismic energy.

Confirmed by a U.S. Geological Survey study and amplified by leading geologists and geophysicists, Mr. Evans' work has led to improved siting of reservoirs and injection wells to insure that the interaction of liquids and underlying fault zones will be harmless. Basic research stimulated by his papers is proving even more provocative. An experiment with oil field injection wells drilled near a Colorado fault has demonstrated that the wells can be used to turn seismic activity on and off. The question is whether man might someday produce small controlled earthquakes to relieve stress and forestall more violent events.

In related work, Mr. Evans has become an active spokesman on the hazards of underground pollution. Without careful control of underground wastes, he has shown, noxious fluids can move along aquifers and faults to poison ground water at points far removed from where they are pumped into wells or allowed to sink into the soil. Wastes that have been disposed of in this manner include cyanides, carbolic acid, radioactive substances and organic chemicals from the manufacture of drugs and pesticides. In writing extensively on the topic, Mr. Evans has alerted millions to the need for a better understanding of the subterranean environment.

A 1936 graduate of the Colorado School of Mines, David M. Evans was a naval officer in World War II, has served as a District Geologist for Honolulu Oil Corp. and as Chief Geologist for Sharples Oil Corp. Following a decade as a consulting geologist, he returned to the Colorado School of Mines in 1967 to become Director of the Potential Gas Agency of the Mineral Resources Institute, resigning in 1974 to resume geological consulting activities. Mr. Evans has helped guide several professional, conservation and government groups dedicated to geology and pollution control.

Previous winners of the Research Corporation-sponsored award have included Arie J. Haagen-Smit, W. Thomas Edmondson, G. Evelyn Hutchinson and John T. Middleton. Dr. Haagen-Smit, the 1972 NAS awardee, was recipient of a National Medal of Science award in 1973.



Direct relationship between Denver earthquakes and waste disposal at the Rocky Mountain Arsenal was revealed in 1966. The graphs above, reprinted from The Mines Magazine, *compare earthquake frequency with disposal gallonage and pressures.*

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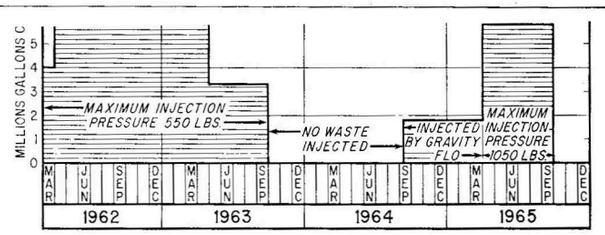

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5

CHARLES M. GRISHAM, University of Virginia
Magnetic resonance studies of the functions of divalent metals in membrane systems—$12,700

WILLIAM P. HALPERIN, Northwestern University
Thermal and magnetic properties of liquid and solid ^{3}He—$17,900

STEPHAN S. ISIED, Rutgers University
Intramolecular electron transfer across amino acids and polypeptides—$10,000

PETER A. JACOBI, Wesleyan University
Synthetic approaches to the cytotoxic germacronolides—$4,000

ROBERT C. KERBER, State University of New York at Stony Brook
Stable complexes of unstable inorganic species—$4,200

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Amine oxidases: Biochemical and magnetic resonance investigations—$8,000

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New applications of analytical chemistry to archaeology—$7,000

ROMAN LAUBERT, New York University
Penetration of swift molecules through solid targets—$6,000

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The rate of heating ions and electrons in a multidipole plasma—$9,500

EDWIN A. LEWIS, University of Alabama
Thermodynamics of histone interactions and assembly of the chromatin complex—$10,000

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Reversible conformational transitions in bacterial proteins: Studies on the α subunit of tryptophan synthetase from *E. Coli*—$11,000

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Fluoroxy fluorination of N-acylaminoaromatic compounds—$2,262

DONALD R. PAULSON, California State University, Los Angeles
A geometrical test for the structure of the triplet states of 1,3-dienes—$7,000

JOHN D. PETERSEN, Kansas State University
The use of saturated organic bridging ligands to mediate electron transfer and light induced electron transfer reactions between transition metal centers—$7,000

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The effects of electron correlation energy on chemical reaction pathways—$4,000

JAMES G. PRUETT, University of Pennsylvania
Quantum state reaction rates—$8,500

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The light-induced proton pump of the purple membrane—$7,000

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Gas phase phosphorescence—A probe of intersystem crossing—$9,500

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Heavy metal binding proteins—$10,000

REX E. SHEPHERD, University of Pittsburgh
Reduction of H_2O_2 by biologically related complexes of the iron triad—$17,000

MARILYN STOCKTON, Dartmouth College
Electron concentrations and electron temperatures in high pressure discharges—$10,000

RUSSELL TIMKOVICH, Illinois Institute of Technology
Enzymatic mechanism of bacterial cytochrome oxidase—$10,100

BAYLOR B. TRIPLETT, Stanford University
Study of mixed valence hyperfine structure with low temperature Mössbauer experiments—$10,000

RICHARD A. TUFT, Worcester Polytechnic Institute
Multiple scattering from dense optical media—$11,000

MICHAEL J. WEAVER, Michigan State University
Investigations of reactivity patterns and mechanisms for some heterogeneous electron-transfer reactions of metal complexes—$7,600

BERNARD A. WEINSTEIN, Purdue University
Investigation of the pressure induced metallic phase transition in tetrahedral semiconductors—$5,300

E. L. WOLF, Iowa State University
Photoemission and tunneling studies of A15 superconductors—$7,300

S. D. WORLEY, Auburn University
Applications of photoelectron spectroscopy to chemical problems—$8,500

STEVEN W. YATES, University of Kentucky
Nuclear spectroscopic studies of high-spin phenomena in the platinum region—$10,000

Corporate Funding for Cottrell Grants

Two of the Cottrell Research Grants made in February were funded by industrial firms which have entered into continuing programs with Research Corporation for support of basic research in the physical sciences. The grant to Richard D. Adams of Yale University has been designated as a Pennwalt Corporation Grant, and that to Richard R. Schrock of Massachusetts Institute of Technology as a Schering-Plough Corporation Grant. Like a similar grant made last October to Lawrence C. Davis of Kansas State University—a National Starch and Chemical Corporation Grant—these named awards were the first made under multi-year programs being funded by the donor companies through Research Corporation.

Grants of this type are handled—up to the final stage—by the usual procedures for Research Corporation's grants programs: initial screening of applications by the foundation's Regional Directors of Grants, refereeing by "outside" scientists, consideration and recommendation by the program's scientific advisory committee, and approval by the Board of Directors. After Board approval, and with the explicit approval of the applicants, proposals judged by the staff to be in the general field of scientific interest of a donor corporation are identified for

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company funding, and these grants are designated by the donor's name.

Industrial support for basic research is being sought by