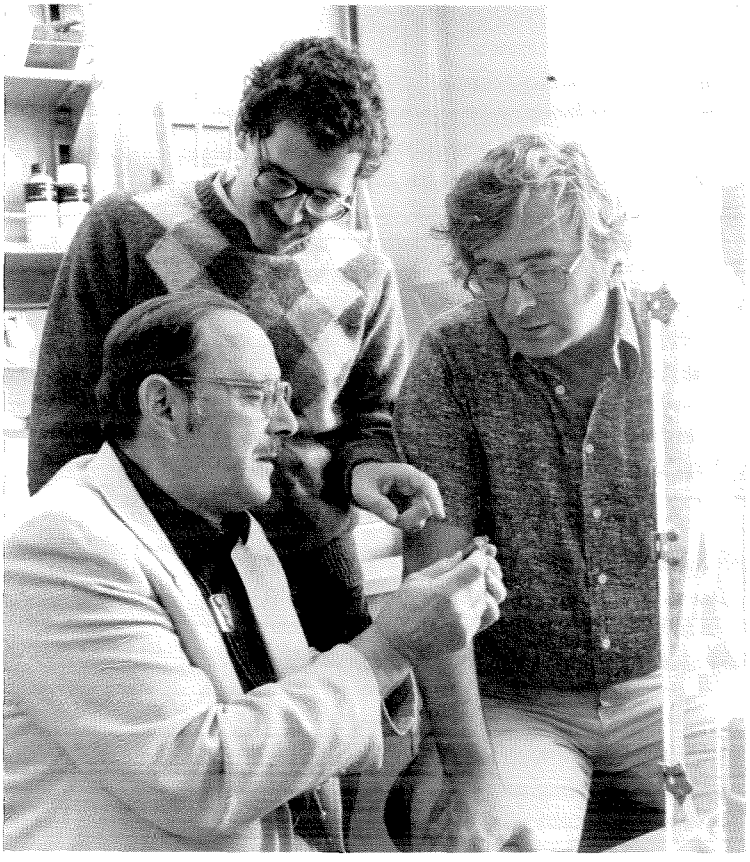
The Ripple Effect

What happens when people with ideas come together in an environment that encourages communication?



All it takes for a discussion is three geologists and a rock. The geologists are (left to right) Gerald Wasserburg and Edward Stolper of Caltech, and David Walker, a Fairchild Scholar from Harvard.

THE ripple effect of a stone in a pond is a homely metaphor for describing what goes on when an idea strikes a research medium. But that is how science begins, and the Sherman Fairchild Distinguished Scholars program makes it happen at Caltech many times more often than it otherwise would.

David Walker, for example, is a senior research associate at Harvard University, holder of the Clarke Medal of the Geochemical Society, and well known to fellow geologists for his imaginative scientific ideas. More particularly, he is known for his development of new experimental approaches to understanding the genesis of rocks, especially those of igneous origin. Walker is currently spending six months at Caltech as a Fairchild Scholar and working with his former student Edward Stolper, assistant professor of geology, to understand the circumstances under which anomalous chemical variations occur in particular magmas and those in which they do not. They want to find out if the Soret effect is the cause of this variation and, if so, under what conditions it operates.

The Soret effect, which is concerned with the diffusion of heat and mass in liquids, is an obscure enough phenomenon that geologists are seldom aware of it. But petrologists like Walker are increasingly interested in finding out why the composition of lava from one volcano differs from that of another or, for that matter, why there are anomalies within the chemical variations in the lavas from the same volcano. As a first step in that direction, Walker and Stolper hope to be able to demonstrate experimentally that the Soret effect is of sufficient magnitude and that it works at a geologically reasonable rate.

Walker has already done initial studies at Harvard of the Soret effect on silicate liquids. Now he and Stolper, whose current interest is in infrared spectroscopy, will try to characterize the different molecular arrangements of water in magmas to find out how they fit into the overall thermal diffusion scheme in molten lava. Neither infrared spectroscopy, however, nor the electron

microprobe that Walker usually uses to analyze major and trace elements in magmas is capable of discriminating the isotopes of some of those elements. For that, they will depend on the expertise of Gerald Wasserburg, Caltech's MacArthur Professor of Geology and Geophysics, whose laboratory is noted for isotopic analysis of many materials — lunar rocks, meteorites, and oceanic basalts, for example.

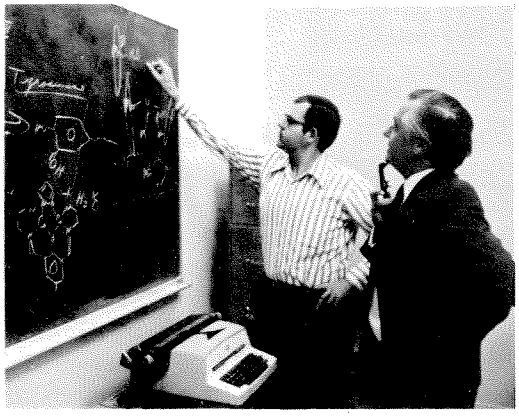
As research with immediate geological relevance goes, coming to understand the Soret effect may be a relatively minor undertaking. It is, however, an excellent example of how all good science starts. Someone's idea drops — or is thrown — into the right mental "pond," where it begins to create a thousand ripples for others to note and analyze and build upon. Volcanism is one of the major processes going on in the earth, and it has wide-ranging long- and short-term effects, many of which are not well understood. Walker, Stolper, and Wasserburg are scientists getting together in an environment that encourages communication. Out of their ideas and interaction may come one more piece for solving the terrestrial puzzle.

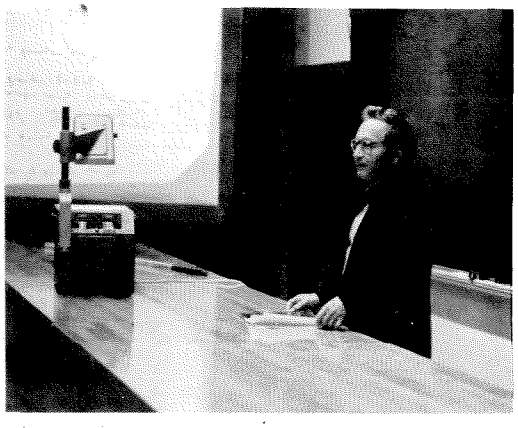
Getting people like that together for a reasonable period of time is not always easy, financially at least, for today's university. In fact, ever since the springs of research dollars began drying up in the late 1960s, colleges across the nation have been facing some very stringent financial conditions. Caltech has probably suffered less severely than many a less prestigious or less science-oriented institution. Nevertheless, a dozen years of diminishing research grant funds and rising costs have taken a considerable toll. With a "mild recession" blanketing the economy and the probability of still further cuts from Washington, the outlook for the future of federal grants makes past problems seem relatively mild.

One partial solution is, of course, to persuade the private sector — industry, foundations, and individuals — to dig more deeply into its financial pockets to support the basic research that is the foundation upon which science and engineering at Caltech are built. Many institutional and individual efforts are made in that direction, and fortunately some of them succeed beyond all expectation. Caltech has greatly benefited, for example, from its early foresight in asking the Sherman Fairchild Foundation to underwrite a program that over the last nine years has financed the visits of some 200 distinguished scholars to the Institute — including that of David Walker. This pilot program has made it possible for Caltech to stoke the creative fires of its faculty and students without having to enlarge its permanent staff. And while the fiscal benefits of such a program are substantial, the intellectual ones are impressive — and probably even more important to those fortunate enough to interact directly with the visitors.

The Fairchild Program is somewhat different from most visiting scholar programs in that, for example, applications are rarely received for it, and invitations to participate are extended only after considerable thought and review. In addition, the scholars have no formal responsibilities while they are at Caltech. Both the Caltech community and the visitors find that this freedom plus the chance to interact in many situations with other distinguished scientists make for a high order of stimulation. If communication is the lifeblood of an educational enterprise, how many transfusions does a visiting scholars program offer? At a very basic level, some counting can be done. In 1980-81, for example, 21 different Fairchild Scholars were in residence for periods varying from three months to a full year. Between October and May, the *Caltech Weekly Calendar* announced 22 departmental seminars to be led by them, one scholar spoke for the Caltech Y "Evening Spotlight Series," one gave a Watson Lecture, and two former Fairchild Scholars returned to the campus and gave seminars.

Much more numerous interactions take place



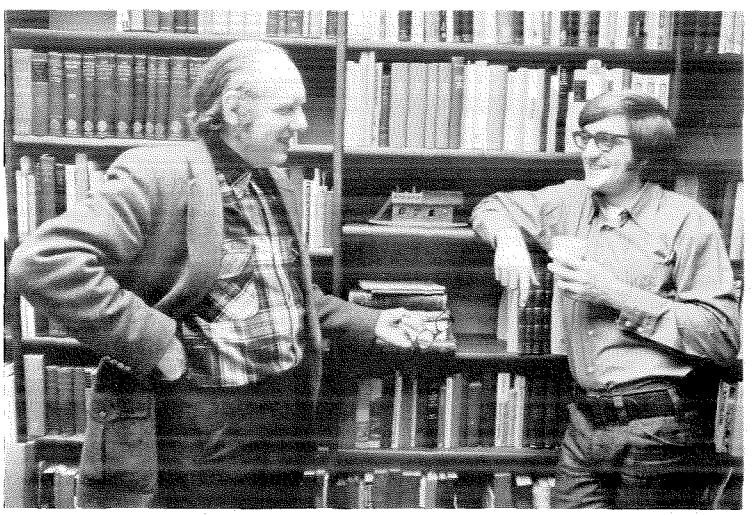


Three Nobel prizewinners have been among Caltech's Fairchild Scholars: Hans Bethe (left), Sir George Porter (center right, with Robert Gagne, who was at that time a Noyes research instructor in chemistry), and Philip Anderson.

on a less public and formal basis, with hundreds of one-on-one or -two or -three encounters in an office, or a lab, or a hallway. In seismology, for example, there is a long tradition of everybody in the department gathering every morning and afternoon for coffee and conversation, and that includes visitors. "I don't know how many ideas for new research have come out of those coffee klatsches," says Clarence Allen, professor of geology and geophysics, "but it's a lot, and the level and diversity of the ideas of people as creative as the Fairchild Scholars we've had is incredible."

"Incredible" is a hard word to quantify; by definition, Fairchild Scholars are already distinguished in their fields or show unusual promise of becoming so. It would seem that we should expect creative thought processes from them. But another way to look at it is to note some of the ways they have been recognized by their peers. A once-over-lightly look at their credentials recently revealed that 120 of the 200 scholars who have visited Caltech since 1973 are citizens of the United States. Of those, more than half are members of the National Academy of Sciences or of the National Academy of Engineering — or both. Sixteen hold named professorships at their home institutions. Three are Nobel laureates. Of the scholars from foreign countries, 20 are listed as members of the equivalents of our National Academies in their own countries. One Fairchild Scholar is unique in being the only scientist/astronaut in the Apollo lunar exploration program, and he has gone on to become United States Senator Harrison Schmitt from New Mexico.

But what have they done for Caltech? "Stretched our minds," says Roger Noll, Institute Professor of Social Sciences and chairman of the division of the humanities and social sciences.



William Riker (left) in a 1974 visit to Caltech as a Fairchild Scholar with Morris Fiorina, who was assistant professor of political science at that time. Riker is currently president of the American Political Science Association, and Fiorina became a full professor in 1977.

"It's easy in a small place like Caltech to become very cloistered. We need to have some external force continually pushing our minds in new directions. In the Fairchild program, we bring in a steady flow of brilliant new people, and it's a challenge to understand what they're doing and learn about it. Moreover, they often have a profound effect on our developing programs."

One of the people who did that for the Caltech social scientists was William Riker, a political science professor who is University Dean of Graduate Studies at the University of Rochester and president of the American Political Science Association. Riker was a Fairchild Scholar in 1973-74. "He is generally regarded as the father of the research methods that have since become known nationally as the 'Caltech School' of political science," says Noll. "He is one of the first people who thought about political science in a scientific way and used tools of economics and mathematics to model political processes. His visit to Caltech was instrumental in getting our program started.

"Subsequent Fairchild Scholars in the areas of economics and political science — Theodore Anderson, Richard Easterlin, G. S. Maddala, and Vernon Smith, for example — have continued to enlarge our perspectives and enrich our program. This year, Donald Brown of Yale has been with us. He is a highly creative thinker in mathematical economics and cooperative games. We have also had several historians, among them Charlotte Erickson, Allan Bogue, Allan Lichtman, and Peter Payne. These scholars have been instrumental in helping us build a bridge between social science and history and in making Caltech today unsurpassed in the world in the field of quantitative, social scientific history. For the future, we intend to invite scholars in philosophy and literature to help us achieve national distinction in those disciplines."

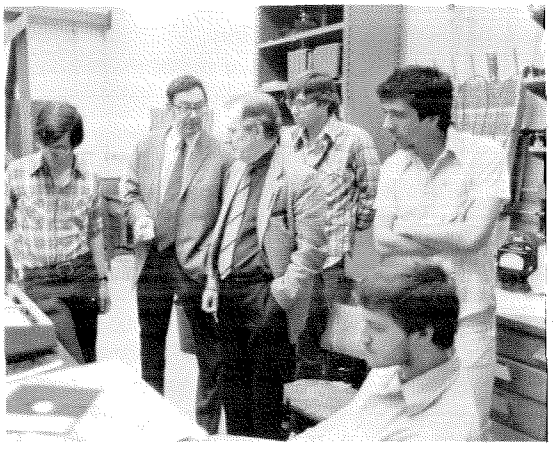
Noll points out that many Fairchild Scholars also become advocates of the Institute, helping, for instance, in the placing of graduates. Since John Ledyard, professor of economics at Northwestern University, was here in 1977-78, four Caltech social science PhDs have been hired there, and two excellent Northwestern undergraduates have come to Caltech for graduate study in economics.

"The Fairchild program leads to an enormous expansion of what we do," says Harry Gray, Beckman Professor of Chemistry and chairman of the division of chemistry and chemical engineering, "and this takes place in several ways. Those who come tend to talk about their research with faculty members here, and that is the inspiration

for many a new approach to a problem — for them and for us." Gray and Carl Ballhausen, professor and head of physical chemistry at the University of Copenhagen, collaborated on a book on molecular electronic structures while Ballhausen was here as a Fairchild Scholar in 1979. Ballhausen also worked on a problem dealing with the coupling of vibronic electronic states, and presented his results in a seminar to the division.

The model of interaction that Gray is also closely acquainted with is that of the Fairchild Scholar acting as a "kind of glue" to get existing separate groups together and doing joint experiments. Exactly this happened with his group and that of Sunney Chan, professor of chemical physics and biophysical chemistry, when Bo Malmström, professor of biochemistry and head of the department of biochemistry and biophysics at the University of Göteborg, Sweden, arrived in the fall of 1980. Malmström's work has been mainly on the structure and function of enzymes, with emphasis on metal-ion-containing protein systems and the role played by the metal ions in enzymatic activity and biocatalysis. Much of this is in the same general area that Gray and Chan are interested in. Malmström, says Gray, "came off the plane with liquid nitrogen tanks of his copper enzymes. He rolled up his sleeves the first night he was here, with a bunch of our students around. We literally started talking about experiments from the first hour, and the next day people were starting to work."

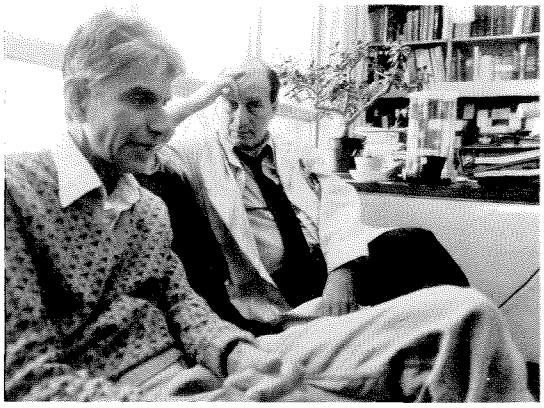
Chan points out that this isn't likely to happen in the normal course of things; it takes someone from the outside to look at the separate things different groups are doing and put them together. For example, one of the projects undertaken during Malmström's stay was an investigation of the reactions of nitric oxide with tree and fungal laccases. These copper-containing enzymes, which the Gray group has been studying recently, catalyze the reduction of dioxygen to two molecules of water. At the time of Malmström's arrival, Chan's group had just completed a study of the reactions of nitric oxide with cytochrome *c* oxidase (an oxygen-reducing metalloprotein important in the energetics of cellular respiration), which greatly clarified the structure of the metal centers in this enzyme and their functional roles in electron transfer, energy conservation, and activation of dioxygen. Malmström, whose interests include both cytochrome *c* oxidase and the laccases, realized that a similar study with the laccases might help to elucidate the structure and function of the metal centers in these proteins as well. The results, which turned out to be quite different from those with cytochrome *c* oxidase, have led to a better understanding of the mechanism of dioxygen reduction by the laccases.



Bo Malmström came from Sweden as a Fairchild Scholar in 1980, and in early 1982 he was back for a visit with the group he had worked with. Top (right to left) graduate students Craig Martin and Robert Kanne with Sunney Chan of the chemistry faculty and Malmström. Left, Martin, Kanne, and Malmström are joined by chemist Harry Gray and graduate students Gary Campbell and David Blair (seated).

Incidentally, Malmström's period of being a Fairchild Scholar took place two years after an invitation was first extended to him. That offer got lost in the mail, so a rather bewildered chemistry division wondered why he didn't respond. The delay turned out to be fortunate, however, and when he finally did arrive, both the state of his science and that of the Gray and Chan research groups were at a point where collaboration was most profitable. Two interesting interruptions occurred during Malmström's visit. Because he is chairman of Sweden's Nobel Prize committee for chemistry, he had to make flying trips home in October (to participate in the final selection process) and December (to attend the presentation ceremony).

The research done while he was here (and continued since) included not only the laccase-nitric oxide work previously mentioned, but also a systematic study of the spectroscopic properties of a large number of copper-containing proteins, supplied by both Malmström's group in Sweden and



A conference between Fairchild Scholar Obaid Siddiqi and biology professor Seymour Benzer, at the right.

Gray's group here at Caltech. Several papers are currently being written as a result of this collaboration, and one paper has already been published, appearing in *Biochemistry* (1982, *20,* 5147) under the names of Gray, Malmström, and Chan, but the names ahead of theirs are those of graduate students Craig Martin, Randall Morse, and Robert Kanne.

In the biology division, an interesting Fairchild Scholar/Caltech faculty interaction has been that between Seymour Benzer, Caltech's Boswell Professor of Neuroscience, and Obaid Siddiqi, head of the molecular biology unit at the Tata Institute of Fundamental Research in Bombay, India. Each worked earlier in molecular biology; each has switched to neurobiology; each uses the fruit fly *Drosophila melanogaster* as his research organism. Benzer changed from bacteriophage to Drosophila several years before Siddiqi, and has done important research on the genetics of behavior through the isolation and characterization of mutant species of the fly. Siddiqi started working with Drosophila about ten years ago, largely through the influence of Benzer and his work. He has studied neural physiology of temperature-sensitive paralytic mutants, but more recently he has become interested in how an organism perceives smell.

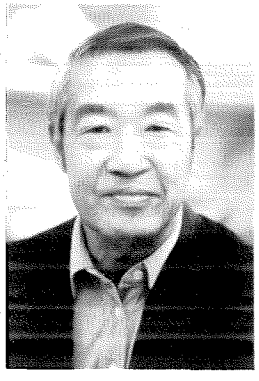
Drosophila seems to be an excellent organism on which to do this work. First, a lot has already been done on the smell mechanism of insects (in the hope of learning to control them). Second, building on the extensive work already done on mutant strains of Drosophila at Caltech, he should be able to manipulate the genetics of the smell receptors so as eventually to dissect their anatomical and functional organization and relation to behavior in response to various specific odor molecules. Siddiqi is doing both electrophysiology and biochemistry on this problem, and he and Benzer constantly discuss the results and work out new paths to try.

One of the many Fairchild Scholars who have visited the engineering and applied science division is Hiroshe Inose, a professor of engineering at the University of Tokyo, who has taken back to Japan the first draft of a book that he wrote with John Pierce, professor of engineering emeritus at Caltech. Inose arrived last September and left in November, but in that short time he and Pierce were able to put together *Information, Technology, Civilization: The Intersection.* The book will be used as a basis for discussion at an international meeting of the Club of Rome that will be held in Tokyo in October 1982.

Not all Fairchild Scholars come from academia, and one who did not was John Lambe, who was for some years principal staff scientist for the Ford Motor Company. While here as a visitor, he worked with the research group of Thomas McGill, professor of applied physics, and the outcome has been the development of long-term collaboration in the area of electronic transport in very small structures.

Not all Fairchild Scholars have been men. One woman scientist was Lynn Margulis, a biologist from Boston University, who crossed divisional lines to work with the geology division at Caltech in 1977. She has been interested in the origins of life, particularly its evolution in the Precambrian era. It was her interest in tracing this history through study of evidences of life forms found in rocks that led her to geology. While she was here, she testifies, she also learned to use the gel electrophoretic apparatus in the laboratory of fellow biologist Elias Lazarides, the high-speed film equipment in the laboratory of Theodore Wu, professor of engineering science, and the scanning electron microscope under the direction of Caltech's Ruddock Professor of Biology, Jean-Paul Revel. "With these tools," she wrote after returning to Boston, "we made unprecedented discoveries at a rate I have never been able to work at previously in my career. To set up this quality equipment at Boston University would probably have cost over a million dollars and, of course, was unthinkable." Margulis also gave

Two Fairchild Scholars who have visited the division of engineering and applied science are Hiroshe Inose (left) and John Lambe.



a lecture, "Life on the Early Earth," on the evening Athenaeum series.

Another woman Fairchild — in 1980 — was Alexandra Bellow, professor of mathematics at Northwestern University, who is a world leader in her field of martingale theory and theory of liftings. She later wrote to the Fairchild Program at Caltech that working with Caltech mathematicians in the areas in which the Institute excels — analysis, combinatorics, and number theory — helped her devise new techniques for attacking the problems she was studying here — ergodic theory and measure theory. Having no teaching or administrative duties, she "luxuriated," she says, in having an uninterrupted block of time for mathematical work. "Uninterrupted," however, needs some qualification, because in the three months she was here she also gave several colloquium lectures at Caltech, two at UCLA, and one at UC San Diego, and she spoke at a conference honoring the 85th birthday of mathematician Einar Hille at UC Irvine.

It has been eight years since February1974 when Stephen Hawking stunned the astrophysical world with a paper in which he proposed that black holes — contrary to Einstein's classical laws of gravitation — actually emit a steady stream of particles and eventually explode. That September he arrived in Pasadena to spend a year at Caltech as a Fairchild Scholar from Cambridge University, discussing his ideas and developing his theories in interaction with the relativistic astrophysicists and other physicists at the Institute. Among that group was a constellation of brilliant scientists, including three other Fairchild Scholars brought here in roughly overlapping periods under the aegis of Kip Thorne, now Kenan Professor of Theoretical Physics. Those three were Edwin Salpeter, professor of physics at Cornell University, who has made major contributions to theoretical particle physics; Werner Israel, professor of physics at the University of Alberta, Canada, who is famous for his pioneering work in the physics of black holes; and Robert Dicke, Brackett Professor of Physics at Princeton, who is known for his theoretical interpretation of blackbody radiation as a remnant of the big bang that created the universe, for the Brans-Dicke Theory (which stimulated tests of relativity), and for tests of the equivalence principle (the fundamental assumption in Einstein's theory that gravity acts the same way on all matter). Before Hawking returned to England, he formulated a new principle of physics which says that every singularity in spacetime (including the big bang) produces particles in a completely thermally random manner.

Four distinguished physicists who were at Caltech as Fairchild Scholars during 1974-75 were (top, left to right) Robert Dicke, Werner Israel, Edwin Salpeter, and Steven Hawking. At the Institute this spring and working in the same general field is Fairchild Scholar Marcus Grisaru (lower picture, left) with visiting associate Anders Karlhede and research fellows Warren Siegel, Richard Grimm, and Sylvester Gates.

Research in this field has not stood any more still than time has. Hawking's principle has come to be generally accepted, but some of his later formulations are more controversial. Several people at Caltech are trying to understand his concept of spacetime foam, for example. "Spacetime foam" is Hawking's somewhat whimsical name for the very complicated and turbulent way spacetime looks when viewed from a very short distance — 10^{-33} cm (the Planck length), for example — which is in considerable contrast to its smooth appearance on a large scale.

A current Fairchild Scholar now consulting with a group of Caltech's theoretical physicists is Marcus Grisaru, professor of physics at Brandeis University, who works on a theory called supergravity, which may represent a long step toward the unification of those two seemingly contradictory theories, the general theory of relativity and quantum theory. Physicists' and astrophysicists' attempts to find a completely consistent quantum theory of gravity now build on this work, which may be the essential element in attempts to unify the fundamental forces — and eventually to understand the nature and origin of the universe.

Usually, the ripple effect has no such cosmic implications. A child tossing a stone in a pond can cause it — and so can a scientist expressing an idea to another scientist. The Sherman Fairchild Distinguished Scholars program is boosting the number of ripples at Caltech. □ – *J.B.*