SURFing

The SURFers who hang around Caltech all summer are not engaged in a fruitless search for the perfect wave in Pasadena. The 46 young men and women who are participating in the Summer Undergraduate Research Fellowship program this year are doing independent research — work that is expected to make a genuine contribution to the field and result in a scholarly publication. And they are receiving support to do it.

This is the third year of SURF, which is funded by donations from Samuel P. Krown, a life member of The Associates, and from the Caltech Prize Scholarship Fund, established by an anonymous donor in 1976. The initial idea of using some of these funds to encourage creative research, promote interaction between undergraduates and faculty, and improve the undergraduate program came from Fred Shair, professor of chemical engineering, and Harold Zirin, professor of astrophysics and director of Big Bear Solar Observatory. President Marvin Goldberger has been an enthusiastic supporter of SURF since its inception.

During the program's first three years William Schaefer in chemistry, Bernard Minster in geology, and Shair, respectively, have volunteered to administer it. Carmen Longo of the Office of Student Affairs has helped keep the program running smoothly.

Teaching in the framework of research has always been a cornerstone of Caltech's philosophy of undergraduate education. But the SURF program goes several steps farther than the more usual situations where a student is hired as a small piece of a professor's grant or to work around the lab as part of a financial aid package. SURF students are chosen primarily on perceived research potential, and they, working with their faculty sponsors, must develop project proposals themselves. These are reviewed by faculty familiar with the field, and the final decision is made by a special committee of the Faculty Committee on Scholarships and Financial Aid.

SURF students are expected to carry their projects to completion during the ten-week summer period, and at the end of that time present written and oral reports. The oral reports are given at a daylong conference run along the lines of a technical meeting. Each participant receives a copy of the conference proceedings. SURF participants are also invited to attend weekly luncheon seminars during the summer at which faculty present overviews of their own research fields; attendance at these seminars has been practically 100 percent.

Few students, nationwide, have such an opportunity for involvement in research from start to finish — from proposal to publication — until graduate school.

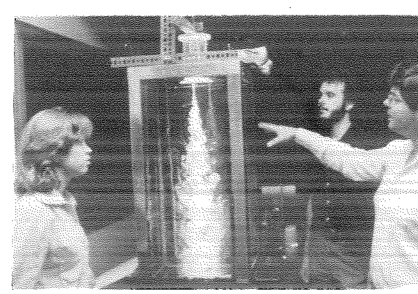
During the summer of 1981 students each received $2300 for what is considered full-time employment. While this amount may not be competitive with that from some industrial summer jobs, it is sufficient to live on and to enable students to save for their expected contributions to academic-year expenses. Shair hopes that the student stipends can increase with increases in the cost of living. Essentially all of the money for SURF goes to the students; such expenses as laboratory supplies and computing are covered separately through faculty research grants. This structure serves to place the student research closer to the mainstream of faculty interest.

Shair hopes SURF can be expanded to include as many Caltech undergraduates as are capable and eager for such an experience. Based on insights gained over the past three years, he believes that the optimal SURF program would involve about 70 students and 60 faculty members each year. Enthusiasm for SURF among faculty and students and the desire to expand it have stimulated an attempt to have the program endowed. In the meantime, it is still growing, and the 46 SURFers in 1981 represent the largest SURF program to date. In the following pages six of these students discuss their research at midpoint and what the program has meant.

KELLEY SCOTT
Sophomore, Engineering and Applied Science

The aim of my SURF project is to obtain a three-dimensional view of the structure of turbulent jet flow. Knowledge of this structure can be applied to understanding such problems as jet noise and the mechanisms of mixing and chemical reactions. The completed "picture" of the flow can be assembled from a series of slices in much the same way that a few cross sections of a boat can convey the idea of an entire vessel.

Working with Paul Dimotakis, associate professor of aeronautics and applied physics, I planned to photograph successive slices of jet flow using laser-induced fluorescent dyes, a laser sheet, and a stepping motor/mirror combination to place the sheet in the desired positions in sequence throughout the flow. Sounds simple? I had problems just saying it at the beginning of the summer. As I learned more about what this plan was actually going to entail, I started to realize that those photographs were a long way down the line in terms of what had to be done to get there. Poor me — I was so naive.



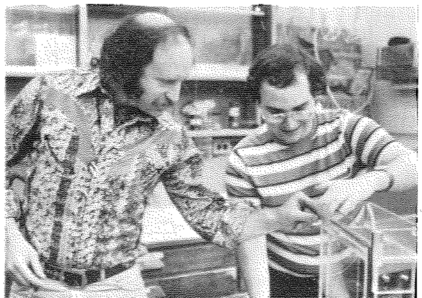
When the time came that I needed my first piece of equipment, I asked, "Where do I get one of those?" I discovered that *I* was supposed to wire the thing together. Since I had never done any electrical work at all, this came as a bit of a shock. So I learned some basics in that area. Soon I had to find another part of the system. I was a little wiser by this time; "What do I have to put together now?" I wondered. It turned out that I didn't just need to put something together this time: I had to design it too. Things have been progressing along this line to the point that I've tried my hand at wire wrapping, designing and building control panels with the appropriate switches and connections, studying different computer systems, photography, optics, and learning basic business practices, along with other odds and ends associated with a research project.

GARY MOCKLI
Junior, Biology

My SURF project has allowed me to work in the developmental biology laboratory of Professor of Biology Eric Davidson this summer, studying specific RNA transcripts found in the mature sea urchin oocyte. Such transcripts are stored in the egg before fertilization and are believed to play a major role in the early development of eukaryotic (all but the most primitive) organisms.

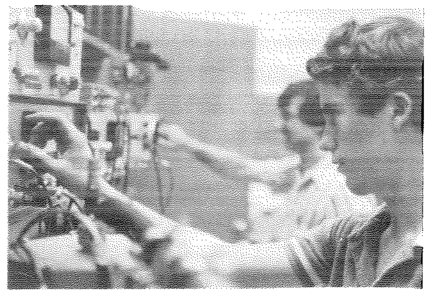
Several factors make the sea urchin an excellent choice for the study of early eukaryotic development. For example, large quantities of eggs can be easily obtained, and also sea urchin embryos have very distinct developmental stages. Fertilization of many eggs at one time makes it possible to collect large numbers of embryos at the same stage simultaneously. Thus it is simple to make comparisons between the varieties and concentrations of the transcripts found in the mature oocyte and in the early stages of development.

I am using recombinant DNA technology to examine these transcripts. Recombinant DNA is an area of biology that I had not previously encountered, and I have been able to learn a great deal about it this summer. In fact, because of the SURF experience I am seriously considering this field of research as a career. I intend to continue working in Professor Davidson's lab, both term-time and summer during my remaining two undergraduate years, to gain still more experience in both recombinant technology and developmental biology.



RICHARD POGGE
Junior, Physics

As a physics major with a strong interest in astrophysics, I would find it very difficult (or rather, impossible) to find summer employment in an astrophysically related field that would actually get me looking through a telescope. The SURF program has given me a chance to do real astrophysical research for not just one, but two summers.



The value of the program lies in the experience it gives. Suddenly, science is stripped of the comforting veils of elegant theory and "plug-and-crank" formulas, and the student can see what research is really like — more questions than answers, error sneaking in from practically everywhere, noisy data, cloudy nights, and equipment that won't work the way it does in the Phys 1 demonstrations. But it also lets the student see the beauty as well — the data that conform well to theory, the clear, moonless night when everything works, and the sense of pride that comes from seeing your name among the authors of a paper to be published. This is something no number of hours in the classroom can give.

I am working this summer in the field of infrared astrophysics with Gerry Neugebauer, professor of physics and director of Palomar Observatory, Tom Soifer, senior research associate in physics, and other members of the infrared group. The Carnegie Institution of Washington has granted me 38 nights of observing time on the 61-centimeter (24-inch) telescope on Mount Wilson. The time is being used to make a long-term monitoring of the unusual quasar, BL Lacertæ.

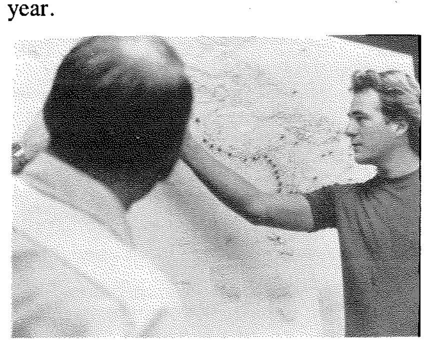
BL Lacertæ is a strong radio source that is also a strong optical and infrared source. It is unusual in that its spectrum exhibits neither emission nor absorption lines — only a continuum. In addition, the continuum is highly polarized, indicating perhaps some sort of synchrotron emission mechanism. The object is known to vary in its emitted flux on time scales of about one day, but lately it has been very dim and quiet. Since it is a bright source at both infrared and visual wavebands, it is possible to study it from the 61-cm telescope.

My observing program consists of watching BL Lacertæ with an infrared detector with filters for 2.2 micron and 1.6 micron wavelengths, and simultaneously monitoring the visual flux with a photomultiplier tube sampling around 5500 Å wavelengths. The three wavelengths will allow me to determine whether the changes in intensity (if any) are accompanied by broad spectrum color changes, giving some insight into the emission process.

This sort of "hands on" experience is beyond value for me. Sitting at the back of this big metal and glass "light bucket," counting photons all summer, and then "dancing with the data" (as Professor of Theoretical Astrophysics Roger Blandford says) to make some sense out of it all will perhaps educate me more in practical science than anything else I'll do during my remaining undergraduate years at Caltech.

JOHN KING
Senior, Chemical Engineering

I think one of the best things about undergraduate education at Caltech is the opportunity for us to get involved in doing research. The SURF program is the perfect chance to spend a substantial amount of time working on our own projects. I was able to begin working in chemical engineering during the summer after my freshman year and continued during subsequent summers as well as the school year.



My time was mostly spent working on studies of atmospheric flow and pollutant transport using a tracer gas technique developed by Professor of Chemical Engineering Fred Shair. In one such study we are now working on the final versions of a paper on the characterization of upslope flows. After a release made from a chemistry building at Caltech, we followed the tracer into the mountains and saw it move through Altadena, Henniger Flats, and on up to Mount Wilson. The data from this study provides an accurate characterization of flow velocities and dispersion associated with this important ventilating mechanism. My SURF project this summer involves an investigation into the safety of a liquid natural gas facility proposed for Point Conception. This will be based on some new data from a study we conducted in the Santa Barbara Channel region last summer.

Because of the SURF program I have been able to spend a lot of time working on my own projects like this. I'm sure that the experience provided by working independently on a research project will be very valuable when I enter graduate school.

STUART GOODNICK
Junior, Physics

Caltech prides itself on the large number of research opportunities available to undergraduates, and the SURF program is certainly the best example of the Institute's encouragement of student scientific work. The greatest benefit of this program is not so much the quality of the research but the chance it gives students to find out what a career in science is actually like; professional science bears little resemblance to undergraduate academics.

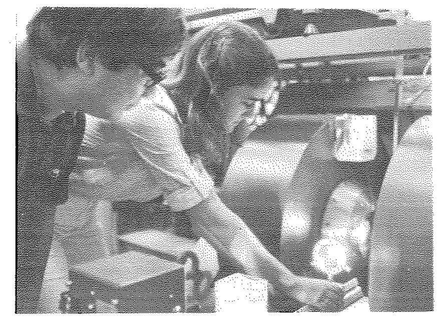
I am working on a project in theoretical nuclear physics; in particular I'm attempting to improve a simple kinetic model of a proton-nucleus scattering process. The original first approximation of this scattering, published in 1980, describes the proton collisions with the individual nucleons in terms of Boltzmann two-body collisions. Even though this description relies upon gross approximations, the theoretical energy cross sections calculated from it closely match the experimental data within the intermediate energy range. In other words, when a 90 MeV proton collides with a large nucleus, the kinetic model can roughly predict the likelihood that the energy of the emergent particles is in the range of 30-60 MeV. My current research involves refining this model by considering Pauli blocking for nucleons being scattered below the Fermi energy of the nucleus and by considering the effects of the coulombic interaction on each individual collision within the nucleus.

This project has been very different from regular class work where a certain amount of information is set forth for you to learn. Here I must decide what specific things I need to learn at every step, and then I have to go dig them out. My adviser, Associate Professor of Physics Steve Koonin, helps by pointing me in the right direction and suggesting ideas for further research. Working as a physicist with professional physicists has given a realistic perspective to my desire to embark on a scientific career. To me this is the greatest value of the SURF program.

LYNMARIE THOMPSON
Junior, Chemistry

When I was deciding where to go to college, I remember thinking that one of Caltech's important assets was that undergraduates could get involved in research. At the time I thought that I'd like to make a career of scientific research, but it worried me that I couldn't know ahead of time what it was really like. With the SURF program I can really immerse myself in a project, which is in many ways better than trying to fit research in during the year (with at least five other classes). I can learn some science as well as something no lecture or textbook could teach me: the kind of thinking and learning that research involves — and the frustrations and rewards.

My specific interests are in biophysical chemistry, and I have joined the research group of Sunney Chan, professor of chemical physics and biophysical chemistry; they work on determining the structure of cytochrome *c* oxidase, a mitochondrial enzyme that catalyzes the last step of cellular respiration. My project's goal is to study heme-sensitized photo oxidation so that this process might be used to map the structure of the oxygen-binding site of the enzyme. To get a better understanding of how this reaction might work I am trying to determine the relative rates of photo oxidation with different sensitizers, specifically porphyrin rings with different metal centers in different oxidation and spin states. (Heme is a porphyrin ring with a Fe II center.) This is done by monitoring production of the excited singlet state of oxygen ($^1O_2$), which is an indication that photo oxidation is taking place. $^1O_2$ reacts with an ammine (TMP) to form a nitroxide radical (TEMPO), which because of its lone electron gives an electron spin resonance signal. The intensity of the signal is proportional to the concentration of TEMPO, which depends on the amount of $^1O_2$ produced. Thus, plotting signal intensity versus irradiation time gives the rate of photo oxidation for a particular sensitizer.



So far I've learned some very specific, detailed science that complements the broader learning I've done in classes. I've also gained some familiarity with the lab, techniques, and instruments that will be useful in later research. One of the most important things I've discovered about research is that everything takes twice as long as expected because lots of things go wrong.

Besides the expected slowness and mistakes of inexperience, things take longer than I'd expect because all the details involved are not apparent until I start doing the experiment. New problems and questions arise even as I try to just set up and standardize the experiment — the lamp setup varies, requiring a daily control: room light also affects the reaction; solutions are contaminated by hard-to-clean syringe tubes; variance in diameter of capillary tubes can affect the signal intensity by as much as 30 percent.

It's easy to feel sometimes that I'm not getting anywhere, since until now I've done nothing but prepare for the "real" experiment. However, through these preparations I am improving the data and learning how to think about the problems so that later I'll be able to iron them out more quickly.

I'm glad that the SURF program has given me this opportunity to learn about scientific research.