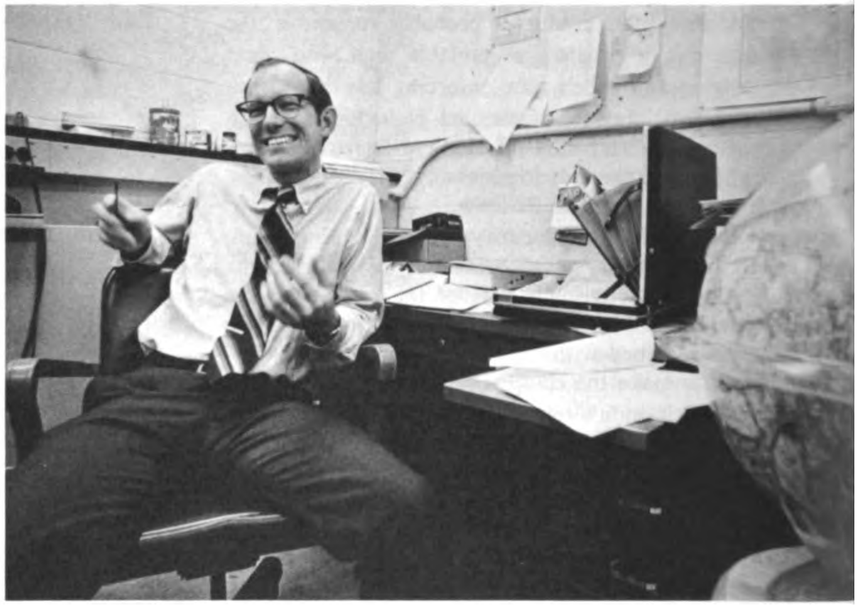
*INTERVIEWED BY*
*LEIGH BUCHANAN BIENEN*

# The Young Scientists

*Photographs by*
*Richard A. Hesel '67*



## *Jason Morgan*
## *Geophysics*

Our research cruise this summer from Panama to Acapulco and San Diego included myself, five undergraduates, and one graduate student. In addition, there were five Navy scientists and 25 merchant marine crew members. We were on a new 215-foot ship designed for general oceanographic research and were mainly concerned with measuring the ocean bottom. Two areas along the Central American coast were surveyed in detail. We also did some dredging and coring of the ocean floor. Dredging is scooping up sediment and rock fragments in a bucket at the end of a five-mile wire rope. For coring, a three-inch pipe with a thousand-pound weight on it is sunk into the ocean floor. Then it is pulled up, filled with mud. The samples are examined, and by the species of shells and the kind of rocks obtained, it is possible to tell the age of the sediment. Several of us will be occupied with analyzing the data from the cruise throughout most of the fall and winter.

In a typical day on board, you spend half of a watch, or four hours, monitoring the instruments, that is, writing down the time and the magnetic and bathymetric readings. The machines work around the clock. The magnetometer is towed 700 feet behind the ship. When the dredging and coring begin, everyone, including some of the crew, helps manipulate the heavy equipment. Coring takes three hours, dredging, six. Then there is preparation for data collection and the putting away of the results.

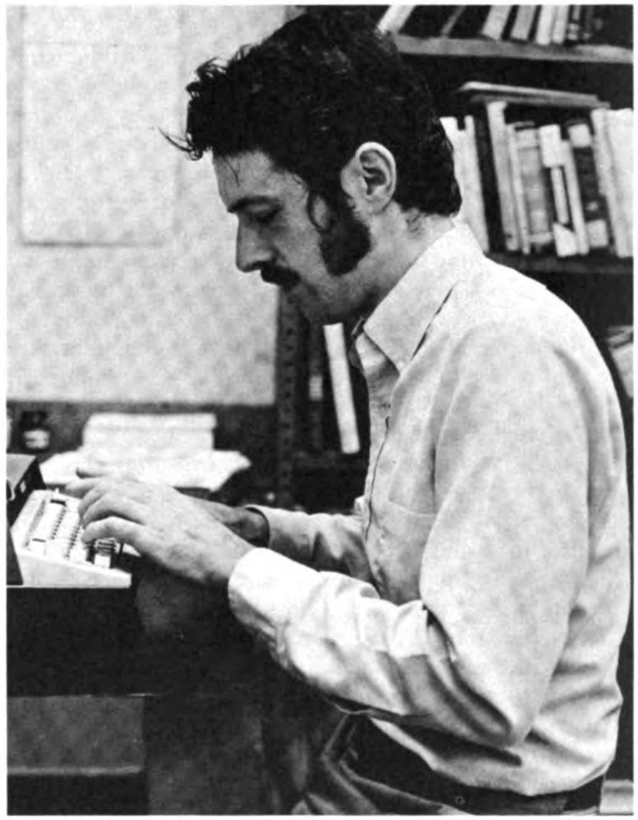
This was the largest summer oceanographic cruise Princeton has participated in, and student participation was high. There are some advantages to *not* being at an oceanographic institute, surprisingly enough. When you have a ship of your own, it's necessary to keep it constantly in operation. So you end up going to sea more often than you might wish for your own research interests. And continuous cruising means the processing of enormous volumes of data. There is an advantage to having several months to sit back and think about the findings of a cruise. The other side of this is, of course, that there is no ship available should you like to go to some far-off place without making elaborate preparations long in advance.

My thesis on gravitational waves led me into geophysics. On a post-doctoral fellowship in geophysics I started to work on convection currents in the earth's mantle. My particular part of that project was to work out a theoretical model compatible with observations on oceanic trenches. We were trying to estimate the size of the sinking mass on the basis of our information about convection currents in oceanic trenches. This is a subject to which I've returned on and off since then. Particularly I've been able to do more on this since the Geophysical Fluid Dynamics Laboratory moved to the Forrestal Campus a few years ago.

I plan to be occupied with this subject for some time to come. In collaboration with Fred Vine, I'm in the middle of writing a book titled *Sea Floor Spreading and Continental Drift.* Actually, the book is about neither subject, but about plate tectonics—a new term incorporating the other two. Plate tectonics adds precision to the earlier model. It now looks like all of the undersea mountain building, earthquakes, volcanic piling and other tectonic activity occur only on boundaries between crustal plates. The book will be a general undergraduate textbook and should be out a year from now.

Of course, these highly specific and detailed analyses all point to the development of some general theory about the history of the earth and its forming. Like everyone else, I try my hand at this. Sea floor spreading is just another example of continental drift. One thing I hope we'll get from the Apollo flights is measurements accurate enough to be of some theoretical use on the subject. With the laser-corner reflector equipment now set up on the moon, it is claimed that distances from the moon to a point on earth can be measured to an accuracy of around ten centimeters. This is a degree of precision that has never been achieved before with surface land measurements. With such data, it would be possible to see evidence of continental drift over a few years. The Atlantic is estimated to be widening at the rate of about two centimeters a year. The Pacific trenches are spreading at the rate of around ten centimeters a year. Accurate measurements of this over a long period would be of enormous help in the formulation of some sort of detailed theoretical model for continental drift.

## *Henry S. Horn, Biology*



Ecology is the branch of biology dealing with interrelations of plants and animals with their environment. The field has been traditionally divided into plant and animal ecology. And recently there has been a distinction made between population ecology and the ecology that studies the organization of the whole community, its physical and biological components. There isn't a single textbook that covers both adequately. One thing ecologists do is examine patterns: biological patterns, patterns man has created, and physiographic patterns. Physiographic patterns are the patterns imposed by geography, weather, and soil differences. Biological patterns occur as organisms compete with each other for space and food. The lowest natural level is the plants, or sessile beasts. These constitute a resource for the next level of beasts, who in turn compete with one another for sustenance and themselves provide food for their predators at the next level. This causes further patterns of biological organization. People fit into the environment in several ways. First, man has in many places obliterated that whole first layer of plants and replaced it with asphalt and concrete. Man also changes ecological patterns with husbandry, fertilizers, and by dumping wastes into natural waters.

The public recognition of man's role and responsibility in the environment has not yet come about. The subject is talked about in the news media and on the campuses. But people just sit around and agree with one another. It is a mistake to assume that public recognition of the problem is widespread. One encouraging sign is the naming of the President's Council on Environmental Quality with Russell Train, a Princeton man ['41], as its head. But we are not yet moving towards any real solution of environmental problems.

I am against the wholesale banning of pesticides, perhaps even of DDT. People are beginning to learn to appreciate lawns with dandelions and sorrel. The verdict is certainly in on DDT, that DDT has widespread and disastrous effects. But pesticides should be considered as prescription drugs for the environment. If the prescription is continually reviewed, then I see no reason against continuing its use. The problem is that use is continued indefinitely, and where it is not necessary for reasons of public health or for protecting food supply. Also, there is no monitoring of the effects of prolonged use.

The research I've just finished is an examination of the growth patterns of trees in forests, how growth is affected by the pattern of leaf distribution in the tree. My theory starts by distinguishing two extreme types of leaf distribution in trees: a mono-layer, in which all the leaves are packed into a single layer with no gaps between adjacent leaves, and a multi-layer, with leaves loosely scattered through many layers. From a horrendous formula, I calculate how fast each kind of tree will grow in an open field or deep in the forest. It turns out that a multi-layered tree will grow faster than a mono-layered one in an open field. In forests where saplings grow up in the shade, the mono-layered species grow more quickly. This accounts for changes in forest composition as the forest grows older.

My field work has confirmed the theory for forests around Mammoth Cave, Ky.; for the Giant Sequoia groves of California; for the tropical rain forest of Costa Rica; and here in Princeton at the Institute, Herrontown and Stony Ford Woods. By measuring all the trees in the forest and determining their ages, it is possible to tell which species are invading and which are senile. For example, one plot in the Institute Woods was a field only 30 or 50 years ago; it has a senile growth of gray birch trees. They are being invaded by red maple, hickories, oaks, and a host of other species. The gray birch have about four or five leaf layers; the red maple have around two and a half; and the beech around one and a half. The multi-layered trees are being invaded by mono-layered trees.

The largest numbers of leaf layers I have ever observed is on the dawn redwood, *Metasequoia*, in Prospect Garden. This particular tree has ten distinct layers. This species was known only from fossils until around 1941, when a Chinese forester discovered a whole valley full. He shipped seeds to arboretums all over the world, and now there are specimens of this prehistoric tree in several places.

There is still some work that I want to do with trees, to relate the shapes of whole trees and their patterns of development to the patterns of growth and layering I have already observed. The detailed measurements I've made could be used to predict the growth and productivity of a forest and could be used in forest management.

# *W. Todd Wipke, Chemistry*

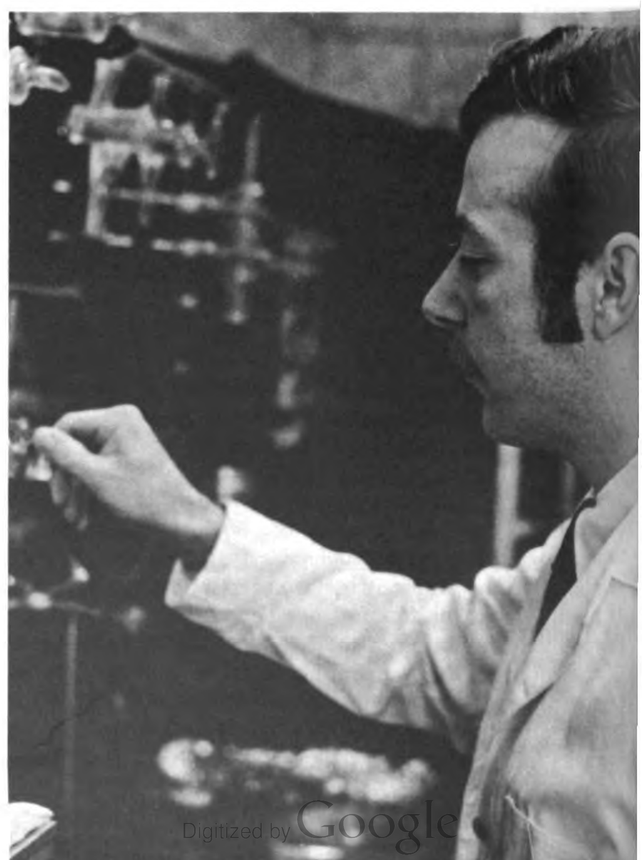
As a graduate student at Berkeley, I started thinking about using computers to solve problems in chemistry. I programmed a computer to generate molecular structures. I asked the computer to find all possible compounds having a three-ring structure with eleven carbon atoms. The computer generated all possible molecular structures that met the given constraints. There turned out to be 265 distinct permutations. Some of these molecules could not possibly exist chemically, some are commonly found, and for some it is unknown whether or not they exist. But the important thing was that with this comprehensive list we were assured of not overlooking any possibilities. No one before had thought of applying computers to this kind of problem in chemistry.

I also began working on the photochemistry of dienes, a class of polyunsaturated compounds. It was known that the enrichment of milk by vitamin D was due to a photochemical reaction of ergosterol, a diene held in a curved "C" shape. The light-induced reaction occurs between the ends of the diene that are close to each other, across the mouth of the "C". We wondered how the diene would react if the ends were held apart as in an "N"-shaped, transoid structure. We found that under certain conditions the dienes were transformed into highly strained structures. In fact, the chemical structure of the final product was so strained it reacted with *water* at room temperature!

After two years in the army, I decided I needed to do post-doctoral research in chemistry. When I got to Harvard, I went right back to the line of thinking I had been working on at Berkeley. I began working on what now interests me: computer simulation of organic synthesis. I began by writing down many of the principles and heuristics, or rules of thumb, which chemists have used successfully in organic synthesis. One large part of the problem was putting information in terms the computer could understand. Today's computers come from the manufacturer well-trained for mathematics but poorly trained for chemistry. First, the computer had to be taught basic principles of organic chemistry. I gave the computer mechanistic information about how reactions occur instead of an empirical collection of facts. The machine was also given the criteria for discarding chemical impossibilities. Finally, the computer was given a target molecule to synthesize. The program works "backward" to predict the immediate chemical precursors of the target molecule. This process continues until the target molecule is broken down into commercially available chemical building blocks. At each successive stage of molecular construction, the computer worked out all possible combinations. The computer had to be instructed at each stage of the process, to be told how to evaluate its results as it went along. A chemist had to interact with the computer and guide it through the problem-solving maze. This, in turn, required that the chemist be able to communicate with the computer in his own terms.

The chemist's language is pictures. The computer was taught to read standard graphic symbols for molecular structures and to give out its results in the same form. I developed the programs and techniques that allowed chemists to put their problems directly on computers. For the first time, any chemist could pick up a pen, draw his familiar picture of a molecule, and the computer was able to recognize the chemical properties of that molecule.

Although the computer's level of chemical expertise is only around that of a second-year graduate student, it has produced meaningful and interesting results on some moderately difficult research problems. One interesting aspect of this research has been that many chemists have had new ideas for research suggested to them by the computer results. In our laboratory now we are trying to synthesize compounds by the routes predicted by the computer. These routes often involve reactions under unusual circumstances. We program the chemical mechanism and the computer applies it wherever possible. Sometime a familiar chemical reaction will be predicted



under unfamiliar circumstances. In this sense the computer can "predict" a new reaction.

There is a great deal of general interest now in the problem-solving process. Our work on computer-assisted design of organic synthesis might be considered a simulation of how organic chemists go about solving problems of synthesis in the laboratory. What we hope will come out of this is a clearer understanding of the basic principles of organic design, an opening up of a whole new branch of chemistry. Computers are not going to go away. If chemistry does not keep up with these developments, it will be chemistry that suffers. This implies some adjustment of undergraduate curricula. I don't see how people can grow up in a world where so many things are influenced by computers and know nothing about them.

## *Henry Arbarbanel, Physics*

I'm one of those people who wanted to be a scientist since he was ten years old. In fact, I always wanted to be a theoretical physicist, although for a long time I didn't have any idea what that meant. So my undergraduate career didn't sway me one way or another, except to confirm my prejudices. Princeton appealed to me for graduate work because there were no required courses or grades. Princeton was and still is quite free. Access to professors is extremely easy. Faculty members leave their doors open when they are in their offices. People are here to be talked to.

After a post-doctoral year at Princeton I went to Stanford. There I worked on field theory and problems of proton-proton scattering. We asked whether or not one could take a certain kind of field, satisfy some general physical requirements, such as causality, and still describe an interesting result. The answer was no, because the specific requirements were satisfied only when there was no causality. This result removed these fields from real theoretical interest. If the results had been positive, they would have provided the theoretical foundation for a great deal of work already done on the subject. The other problem I worked on that year did have positive results. We tried to provide a theoretical basis for the relationship between proton-proton scattering and electron-proton scattering. We wanted to describe precisely the apparent connection, graphically visible, between these two scattering processes. The theory we developed is testable at the Soviet high-energy accelerator near Moscow or at the National Accelerator Laboratory scheduled to open in Illinois. Experiments such as this typically take a year to plan, and a year to run. Then you need one or two years to analyze the data. So the results won't be in for a while. One of my colleagues at Stanford bet a Russian physicist ten kilograms of Beluga caviar (about 22 pounds, or $1100 worth) that our results would be proved correct by the Russian experiments. So I have more than the usual professional interest in the outcome.

After Stanford, I returned to Princeton as an assistant professor and became interested in two separate research problems. One involved our work with soft mesons. The other problem concerned the properties of integral equations for high-energy scattering (variants on the Bethe-Solpeter equations). This is what I've been working on for the past few years. We have come up with a model for the behavior of inelastic electron-proton scattering that has opened the way for further theoretical investigations. The soft meson problem is distinctly different. Here the interesting result was that certain semi-classical findings of non-relativistic quantum mechanics, which have been known for 20 years, could be given proper relativistic formulation. That's significant because non-relativistic theories have always been patently irrelevant to high energy physics. Now these old results are no longer completely *ad hoc* in the realm of very high energies.

Last year, I was a faculty fellow at Stevenson Hall and supervised a student-taught, non-credit seminar to which 12 extraordinarily devoted sophomores came every week to listen to each other lecture on classical mechanics. The class was my idea, but the students carried it through completely on their own. I did nothing else but sit in the back and ask some hard questions.

Learning physics provides intellectual discipline. Physics also passes on information about the way the physical world has been variously described by scientists. We start with Newtonian mechanics because it is not an intense abstraction from everyday life. The growing anti-scientific attitude in the U.S. bothers me because I see science as an exciting subject of intellectual inquiry. To the question of relevance, I reply, of course it's not relevant to social problems or to international politics. And, why should it be? Physics is as good a place as any to develop intellectual capacity. It's unfortunate that physics is regarded as totally research-oriented by most students. The community would be as well served by people bringing intellectual vigor to the classrooms. There is still a vast unfulfilled need for well-trained high school physics teachers. Training for this sort of career is unfortunately systematically ignored by most universities.