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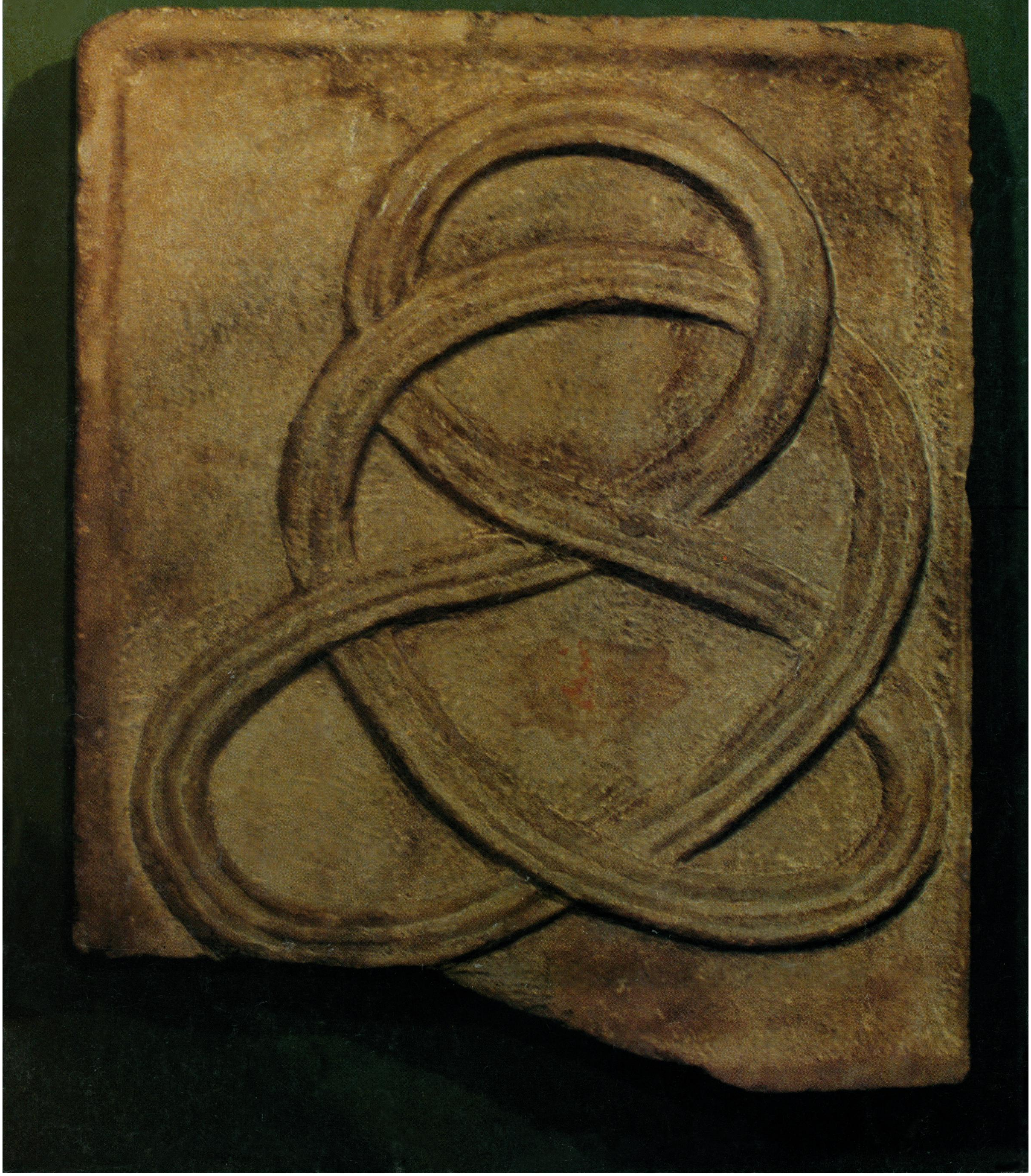

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COVER

Knot with six crossings is depicted in this Roman bas relief from about the third century A.D. The identical knot form was observed in electron micrographs of DNA and the information from it can be used to postulate mechanisms of genetic recombination. See page 171. [From the private collection of Ilya Prigogine, Center for Statistical Mechanics and Thermodynamics, University of Texas, Austin 78712]

Near-earth asteroids

Eighty-three near-earth asteroids (NEA's) are known, but where they came from is a mystery (page 160). NEA's are small orbiting bodies with paths that cross or come near to the orbit of Earth. McFadden *et al.* used reflectance spectra and albedo measurements to analyze the mineral compositions of NEA's and compared these with the compositions of planets, satellites, and the main-belt asteroids in orbits between Mars and Jupiter. Several NEA's have mineral compositions similar to those of asteroids near Kirkwood gaps (the dynamically unstable regions of the main belt where few asteroids are detectable), and one is similar to a main-belt asteroid from a stable region. Some NEA's may, therefore, have escaped from the main belt into new orbits near Earth. Some of these and other NEA's have compositions similar to meteorites. More source regions are being sought to account for NEA's with other mineralogies. Mercury, Mars, the moon, and satellites of planets of the outer solar system have so far been ruled out.

Spring bloom of phytoplankton

Satellite data have been used by Brown *et al.* to study the spring bloom of phytoplankton in the Atlantic Ocean along the East Coast of the United States (page 163). During the month-long study, periodic measurements were made of pigment concentrations (an indication of the amount of phytoplankton in the water) and sea-surface temperatures. These measurements were confirmed from a ship. Several details of the bloom were elucidated: the contribution of phytoplankton in the open ocean to the total biomass was much larger than expected; the continental slope region was found to be as productive as the nearshore shelf region; and the blooming seemed to occur immediately after strong winter winds had ceased. The combination of satellite and ship data offers new opportunities for studying biological variability in the world's oceans.

Interleukin-l and thrombosis

A major goal in the therapy of thrombosis is inhibition of the metabolism of arachidonic acid in platelets (page 174). When damage occurs in the blood vessel wall, platelets respond by adhering to the injured area, aggregating, and forming a plug that may block blood flow. Arachidonic acid, an abundant fatty acid in both platelets and cells of the vessel wall, is a precursor of prostacyclin and other prostaglandins in these cells. Prostaglandins promote platelet aggregation while prostacyclin inhibits it. Rossi *et al.* found that interleukin-1, a modulator of the immune system, induced synthesis of prostacyclin in two types of cells found in the vessel wall. If this occurred in the body, it would make available an inhibitor of platelet aggregation.

Snake venom and calcium currents

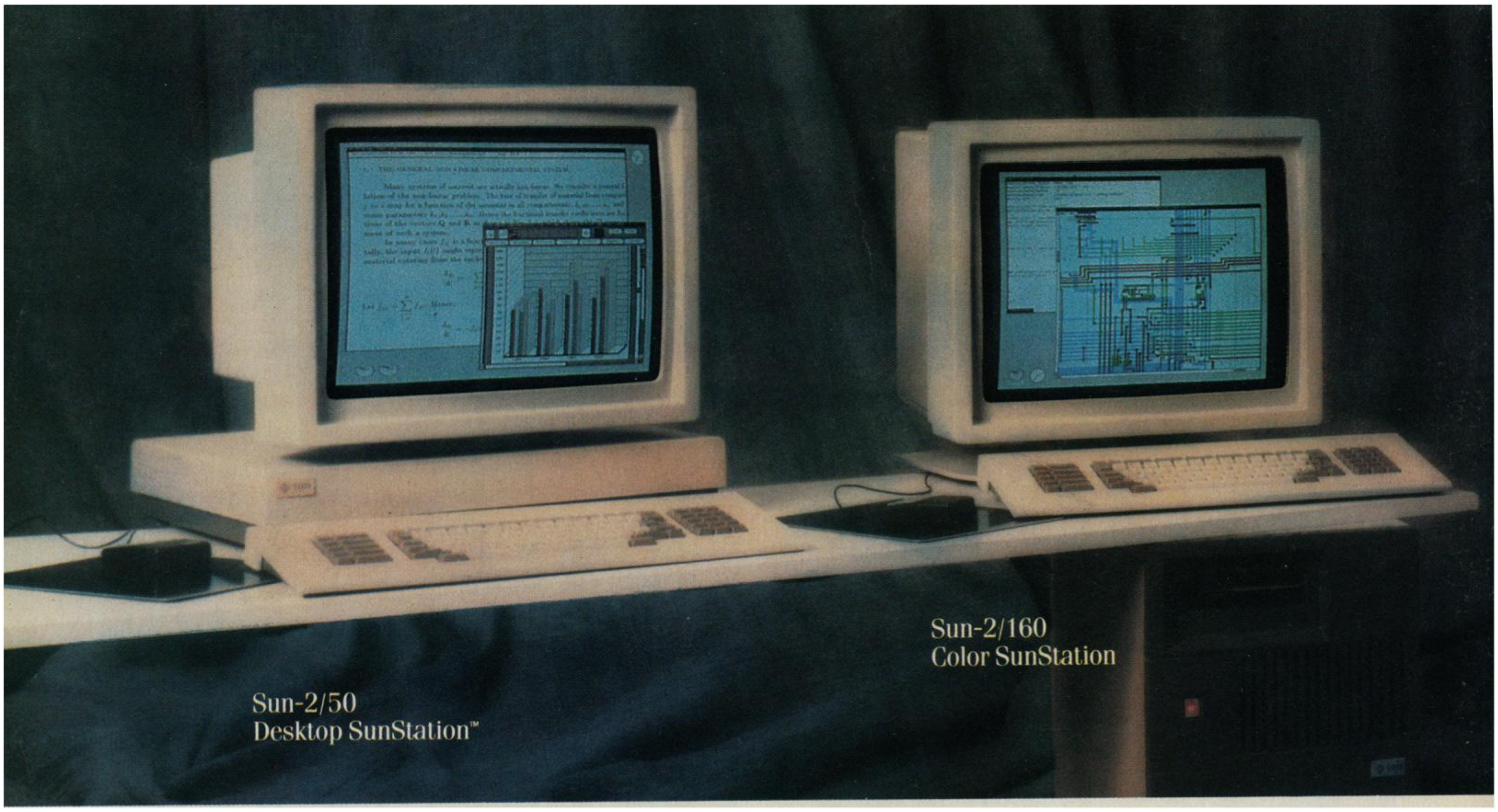
Atrotoxin, a component of the venom of the rattlesnake *Crotalus atrox*, may be useful for isolating and studying the proteins that help regulate calcium currents and electrical conductance in heart cells (page 182). Atrotoxin competes with known inhibitors of calcium activity, apparently by binding to the same protein to which the inhibitors bind, and it disrupts the normal functioning of heart cells. Hamilton *et al.* found that calcium currents increased in heart cells within 30 seconds after atrotoxin was added to the medium. The toxin was specific for calcium activity and did not alter sodium or potassium conductance in these excitable cells.

Antigen switching in sleeping sickness

Trypanosomes that cause sleeping sickness evade host immunity by periodically switching their surface glycoproteins (antigens) from one type to another (page 190). Esser and Schoenbechler found that 5 days into an infection in mice, parasites with two antigen types could be detected. Parasites with one type on their surfaces enter the host's blood stream when a tsetse fly bites. After 6 days, only 15 percent of the parasites still have the initial surface glycoproteins, and new ones predominate. The switch is not induced by host immune responses to the new antigens, since it takes place even in mice that have lost the ability to produce antibody. An understanding of the sequence in which surface markers appear may be one step in the eventual control of the parasite.

Delayed insecticide resistance

Bacillus thuringiensis (BT), a biological insecticide, has been used successfully in pest control for more than 20 years, but now resistant insects have been found (page 193). Insects readily develop resistance to chemical insecticides, but the long grace period for BT suggested that resistance to it might not be possible. However, McGaughey found that Indianmeal moths growing in grain storage bins treated with BT were much more resistant to BT than were those in untreated bins. Moths could also be made resistant in the laboratory if they were fed BT-treated food: the first generation had a low (19 percent) survival rate, but by the fourth generation, survival was high (82 percent); by the 15th generation, the concentration of BT needed to kill these moths was 100 times that of the original. Resistance proved to be a stable, recessive genetic characteristic passed along to subsequent generations reared in the absence of BT. The potential of field-crop pests for developing resistance to BT may be less than that of pests in storage bins because BT is less stable outdoors. In the field, plant-feeding pests would probably not be exposed to BT for the successive generations required to allow resistance to develop.



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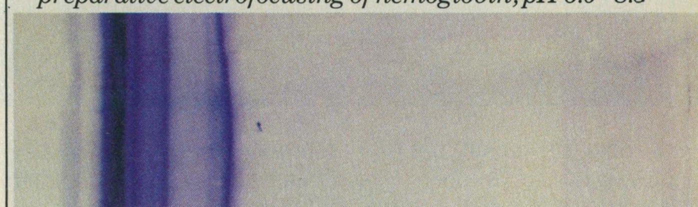

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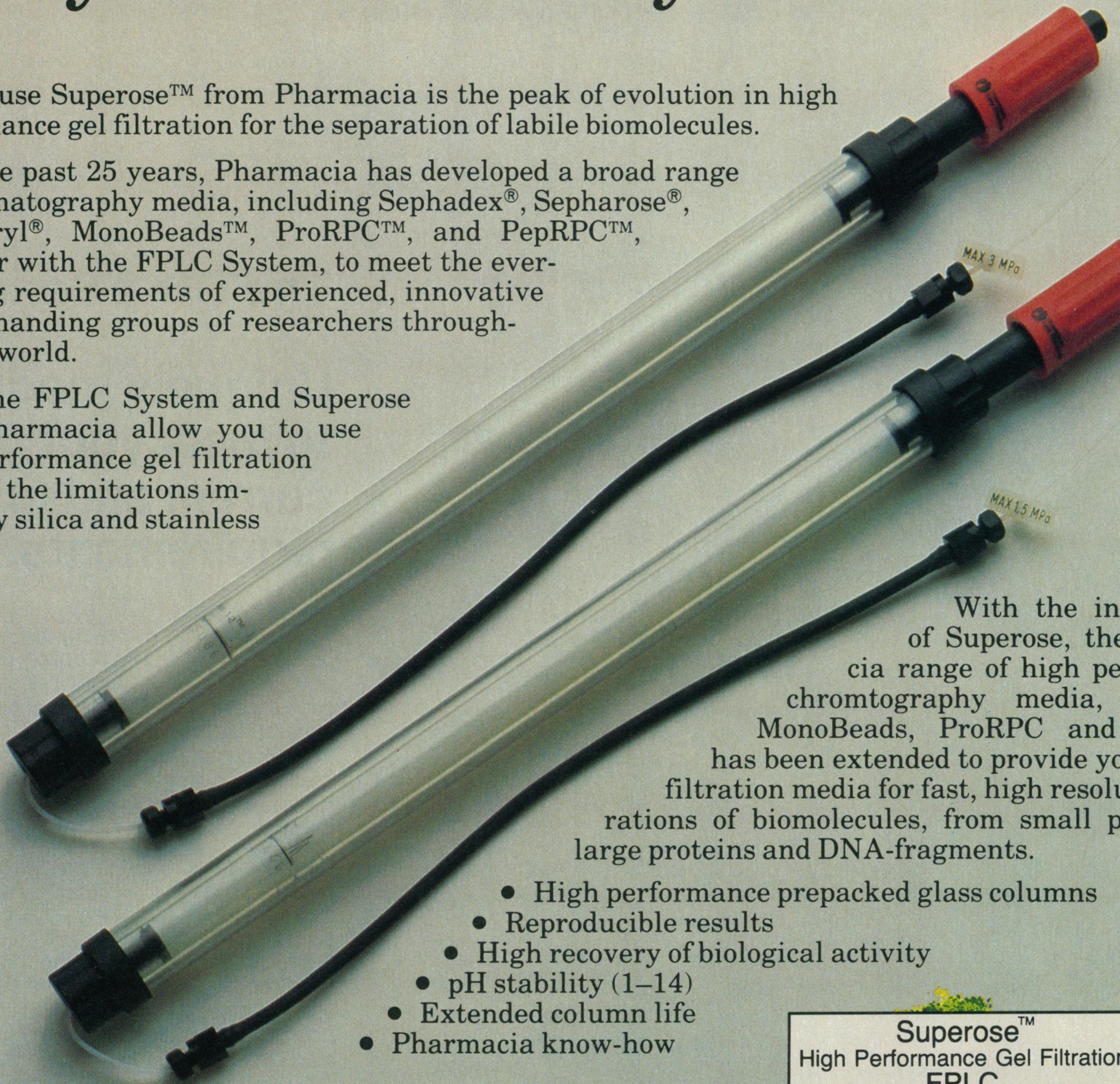

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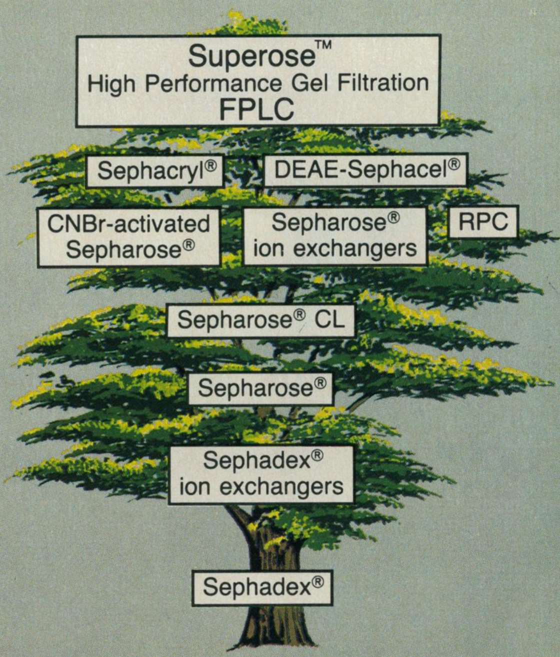

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biotics or of herbicide-resistant weeds as a result of using herbicides.

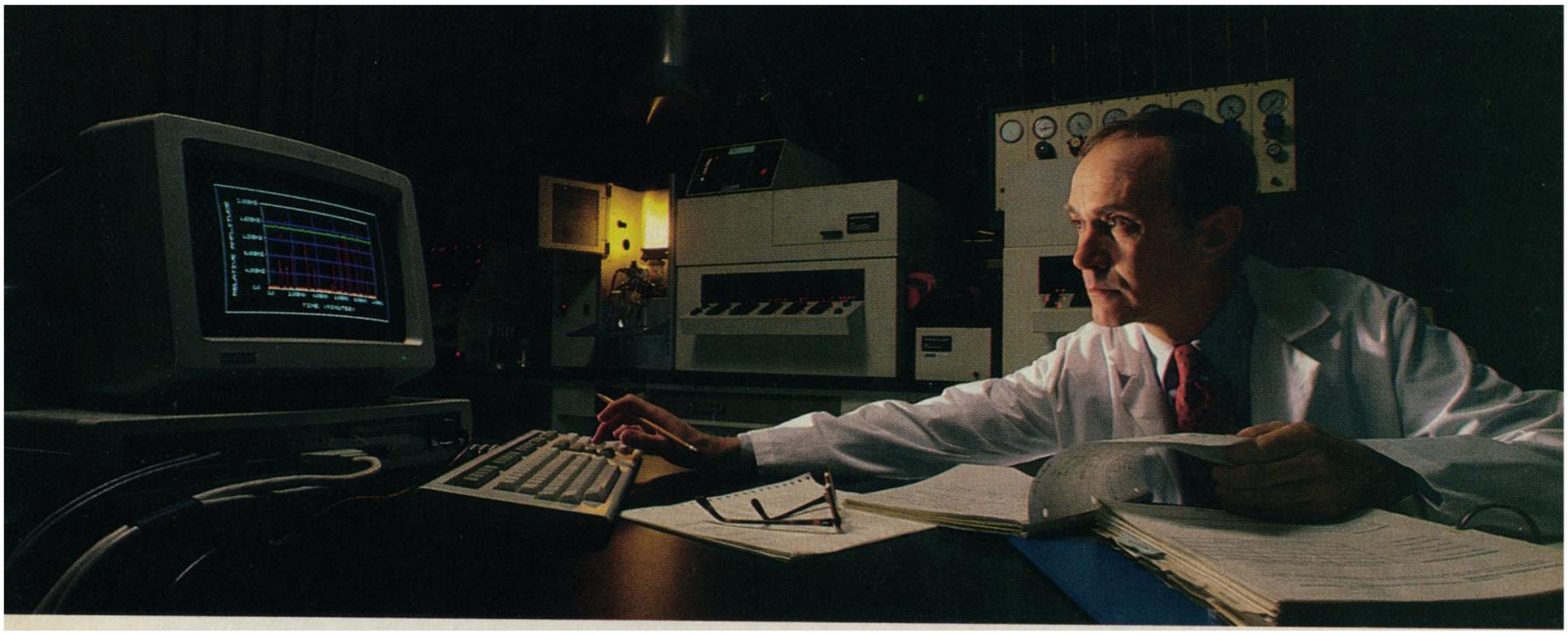
As stated by Colwell *et al.*, it would be desirable to have quantitative values associated with risk, rather than terms such as "unlikely" and "seems very small." At this time, however, one can place no reasonable number on the risks being discussed. Their comparison with quantitation of the negative effects of drugs or pesticides is not helpful. Measuring LD_{50} is quite different from determining the probability of potential damage, in a wide range of environments, of a novel organism, whether produced by a conventional cross or genetic engineering. Even with a traditional breeding cross, can anyone now or in the near future quantitate, from greenhouse experiments, the chance that an undefined problem will occur? Current plant breeding is carried out with no quantitative risk assessment data, but with confidence from long and extensive experience that the risk "seems very small." We know too little about the biochemistry, molecular biology, and genetics of interacting biological systems to quantitate reliably the chance of a problem, especially if field experience with analogous organisms has not revealed a problem. Breeders have always been concerned about unexpected problems, and standard field testing in several locations over several seasons is the accepted way to determine these. Problems have occurred in a few instances, but none has reached the magnitude of those caused by importation of organisms such as the kudzu vine or the gypsy moth.

Will quantitative risk assessment for recombinant organisms be reliable, and is the information to be obtained worth the cost? Such an effort was never required for conventional breeding or microbial inoculant experimentation. Why should it be necessary for genetically engineered organisms? Colwell *et al.* criticize the statement that the task of designing relevant tests to determine the safety of recombinant organisms a priori is enormous. Rather than refute it, however, they say only that ecologists have never had sufficient resources to predict ecological outcomes. They do not suggest a specific program or predict a time scale for how long it might take to build a scientific basis for quantitating risk. Meanwhile, handwringing over recombinant DNA technology without specific plans for feasible and effective risk assessment provides no convincing basis for treating genetically engineered organisms differently from the way we treated earlier products of plant breeding or microbial selection.

To demonstrate how difficult it would be to devise laboratory tests to indicate what will occur in the field, we can take the example of *Rhizobium*, a bacterium that fixes nitrogen on the roots of legumes. *Rhizobium* cultures have been produced commercially for almost a century, and there has been tremendous incentive to devise a laboratory or greenhouse assay to determine which strains are the best under field conditions. Numerous laboratories have put extensive effort into this problem for many decades, but no assay is yet available. Will it be possible in a reasonable time frame to devise tests for organisms less understood than *Rhizobium*? Colwell *et al.* support the view that it is extremely difficult to devise a relevant laboratory or greenhouse test to predict potential danger quantitatively. They state, "The forces that actually control a species in nature are, however, frequently elusive and can only be detected through intensive field manipulation."

Colwell *et al.* suggest that crop plants genetically engineered for desirable properties, such as insect resistance, herbicide resistance, and stress tolerance, have the potential to transfer these traits to related species, thereby creating new or more invasive weeds. This argument can also be made for traditional breeding, in which these properties are routinely added to our crops (and may also be transferred to other plants that can breed with crops). A reason for not being concerned that transfer to other plants will cause a serious problem is the fact that each added gene function generally adds a load to the physiology of the plant. As we develop crops to suit our needs, especially under intensive farming conditions, plants lose their adaptability to grow and flourish in the wild. Very high yielding corn, wheat, or soybeans have not caused weeds to become more invasive to nonagricultural habitats merely because the crops were bred for increased resistances. A recent report (*3*) discusses the potential for generating problem weeds as a result of field testing genetically engineered crop plants, and it comes to the same conclusion as I did in my article.

Colwell *et al.* state that it is a contradiction to develop microorganisms that fulfill certain intended functions yet do not survive or compete to some degree. If a microorganism is to be beneficial it must be maintained for a sufficient period in the soil or on the plant. On the basis of efficacy considerations, but not safety concerns, this issue is the greatest problem for scientists developing useful strains such as *Bacillus thuringiensis* or



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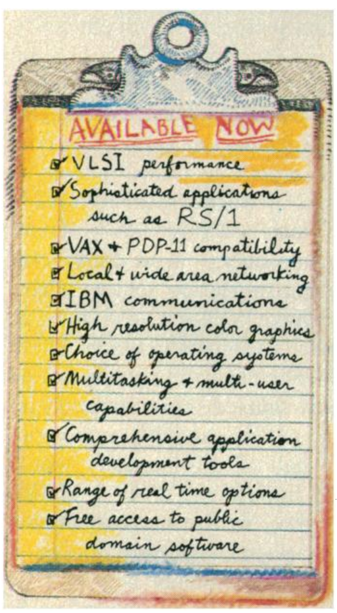

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nitrogen-fixing bacteria. A microorganism cannot be manipulated too dramatically or its effect on the plant will be minimal. On the other hand, it is not necessary that every member of the population of the added microorganism disappear from the site within a short period after the beneficial effect has been obtained. There are many cases in which *Rhizobium* strains were added to fields as long as a decade ago, and still can be found in the soil in small numbers. This is probably true for most of the commercial and experimental soil inoculants added to our environment over the past century. Problems have not occurred. In many cases, the microorganisms were genetically altered. If a foreign gene is added to such organisms, it is difficult to imagine how the chance for a problem will increase.

Colwell *et al.* state that the article made "little mention of the potential of engineered microorganisms to transfer plasmids containing novel genes to other microorganisms in the environment." In fact, it was stated that "microorganisms intentionally and unintentionally added to the environment have naturally exchanged genes with other microorganisms." To elaborate further, however, there is increasing evidence that a tremendous amount of gene transfer occurs naturally, not only among related genera, but also between unrelated microorganisms and even between kingdoms. In rare cases, a new phenotype predominates because of certain selective conditions. This is evolution. What scientists create through genetic engineering is minuscule and ecologically insignificant compared to what occurs continually and randomly in nature.

The negative response of regulatory agencies to requests by academic and commercial researchers who wish to release recombinant organisms for small-scale field testing has been frustrating, but a major benefit is evolving. Disciplines that normally have not been interacting are debating issues of common scientific interest. This can only aid science and the public's perception of science. Meaningful evaluation of the potential for problems associated with the use of recombinant organisms requires a balanced perspective and appreciation of practices that have been used in agriculture for decades or centuries. Field testing is the only way to prove that recombinant organisms are safe, and it is "extremely unlikely" that such tests would cause serious health or environmental problems.

WINSTON J. BRILL

Agracetus, Middleton, Wisconsin 53562

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Reusable Oil Plants?

Philip H. Abelson is correct in observing that "current trends of increased energy efficiency and of [oil] substitution" are encouraging (Editorial, 3 May, p. 531). However, a closer examination reveals information that may temper excessive optimism.

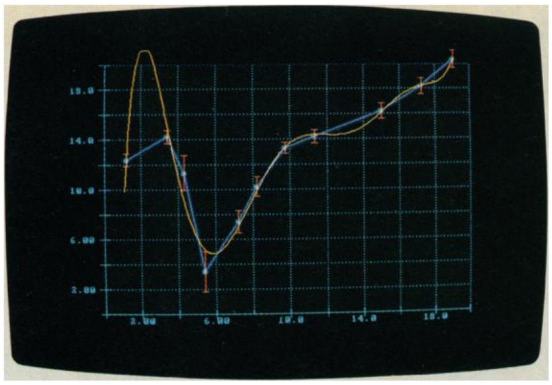
The statistical picture since 1978 (1979 to 1984) shows that coal provided 54 percent, nuclear 20 percent, oil 12 percent, hydro 11 percent, and everything else about 2 percent of the 4 quads of domestic energy production increases. Combined with improving national energy efficiency (measured as a 16 percent decline in total energy needed per constant dollar of gross national product), the trends are in the right direction.

It is also important to note that utilities are directly responsible for reducing total U.S. oil consumption by one-third since 1978, while increasing total electric output. Unlike oil reductions in the transportation sector, in which efficiency improvements for new vehicles are the driving force, utility oil savings have come about because of the addition of new non-oil generation (primarily coal and nuclear, which account for over 60 percent and 25 percent, respectively, of all capacity installed since 1978). There is a dangerous energy wild card here. Unlike the transportation sector, where the guzzlers have been replaced, most of that oil capacity remains in place. There is about 100,000 megawatts electric of oil capacity now unused, comprising virtually all of the excess capacity on the grid. Using only half of this capacity would increase oil imports by over 1 million barrels per day. In the current climate these power plants represent the most likely source of significant new electric power. They involve no capital risk, public controversy, or regulatory uncertainty, as do large coal and nuclear plants. It is highly improbable that this much generation in the form of small-hydro, wind, and wood can be built in the next two decades.

MARK P. MILLS

Science Concepts, Inc., 1825 I Street, NW, Washington, D.C. 20006

Erratum: In the article "Hughes Institute poised for growth" by Barbara J. Culliton (News and Comment, 7 June, p. 1178), Raymond Gesteland's name was spelled incorrectly.



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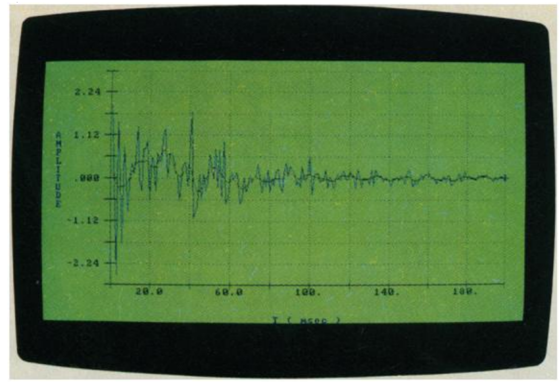
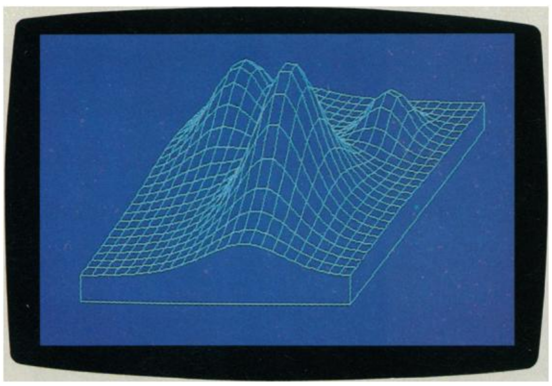


New color graphics enhance comparison of experimental data with filtered data.



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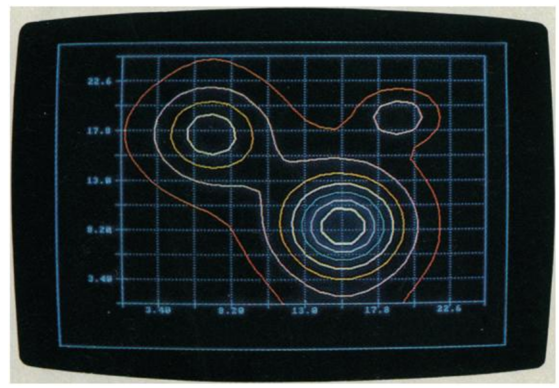

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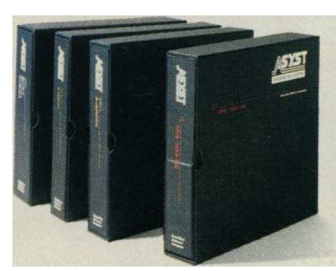

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Engineering Education

The technological superiority of the United States is fast vanishing. The country is experiencing enormous trade deficits, has become a debtor nation, and is probably sliding toward a crisis a few years hence. One hope for minimizing future economic problems is high technology. Scientific competence is a useful ingredient in technology, but it is overshadowed in importance by engineering skill.

For several years, industrial employers have found it difficult to meet their needs for engineers. There has been a bulge in engineering enrollments and a corresponding shortage of professors. The universities have been unable to attract enough native-born graduate students. These problems led to an in-depth study by a committee organized by the National Research Council (NRC). The study is nearing completion, and a summary has been released.*

The tone of the report seems unusually objective. If anything, the tenor may be on the optimistic side. For example, while noting the shortage of qualified professors, the report points to the high quality of students and to the satisfaction expressed by employers regarding new holders of baccalaureate degrees. Nevertheless, there are problems. One of these is the scarcity of expensive new equipment. Instrumentation for science and engineering has been improving rapidly for decades. When available, sensors and transducers coupled with chips make it possible to follow in detail fast-changing and complex phenomena. A related problem is computerization. Few universities have the resources to obtain state-of-the-art equipment.

All university educators face difficult decisions in choice of curricula for undergraduates. Four years seem too short a time to provide both breadth and depth. In engineering a tiny fraction of students take advanced degrees. The main employer, industry, places little monetary value on holding an advanced degree. The average bachelor of engineering in 1984 could expect an annual entry salary of almost $26,000. There was little incentive to take a low-paying graduate fellowship to work 4 years with inferior equipment. One consequence is that 40 percent of graduate students in engineering are foreigners. The NRC report recommends increasing graduate stipends for native-born students to a level half that of entry-level salaries.

Science and engineering share a problem in the fact that there are two tiers of universities. The prominent research universities are well equipped, and their professors have time to engage in or direct research. Young professors at the second-tier schools find it difficult to maintain competence at the cutting edge of science or engineering. The NRC report recommends that special provision be made for these professors through new engineering research centers funded by the National Science Foundation. Another recommendation is the fostering of co-op or intern programs in which undergraduates receive some of their training at industrial sites.

One of the concerns expressed in the NRC report is the need for continuing education. With science and technology evolving rapidly, there is danger of obsolescence for the engineer. Effective international competition requires familiarity with other cultures and tastes. Advancement into management is facilitated by knowledge of financial matters, marketing, and ability to communicate. At present, few universities participate in continuing education of engineers.

Our problems in international balance of payments include high labor costs, a nonsymmetrical trading relation with Japan, strong dollars, and a tardiness in adopting robotics and quality control. Excellence in high technology cannot be expected to overcome all these handicaps. But unless the United States finds ways of achieving such excellence, its economic problems will surely go from bad to worse.—PHILIP H. ABELSON

*Committee on the Education and Utilization of the Engineer, *Engineering Education and Practice in the United States* (National Academy Press, Washington, D.C., 1985).


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