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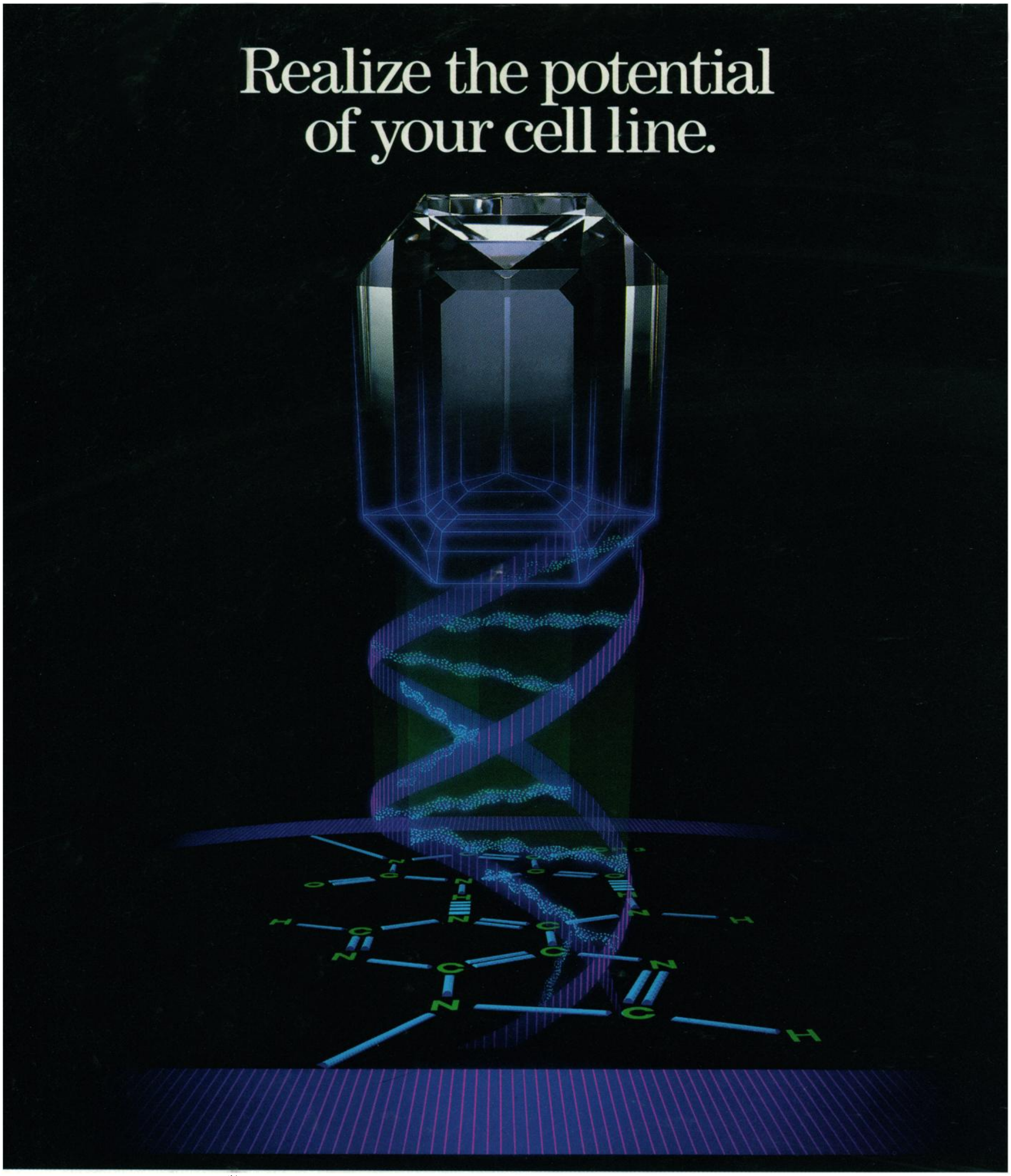

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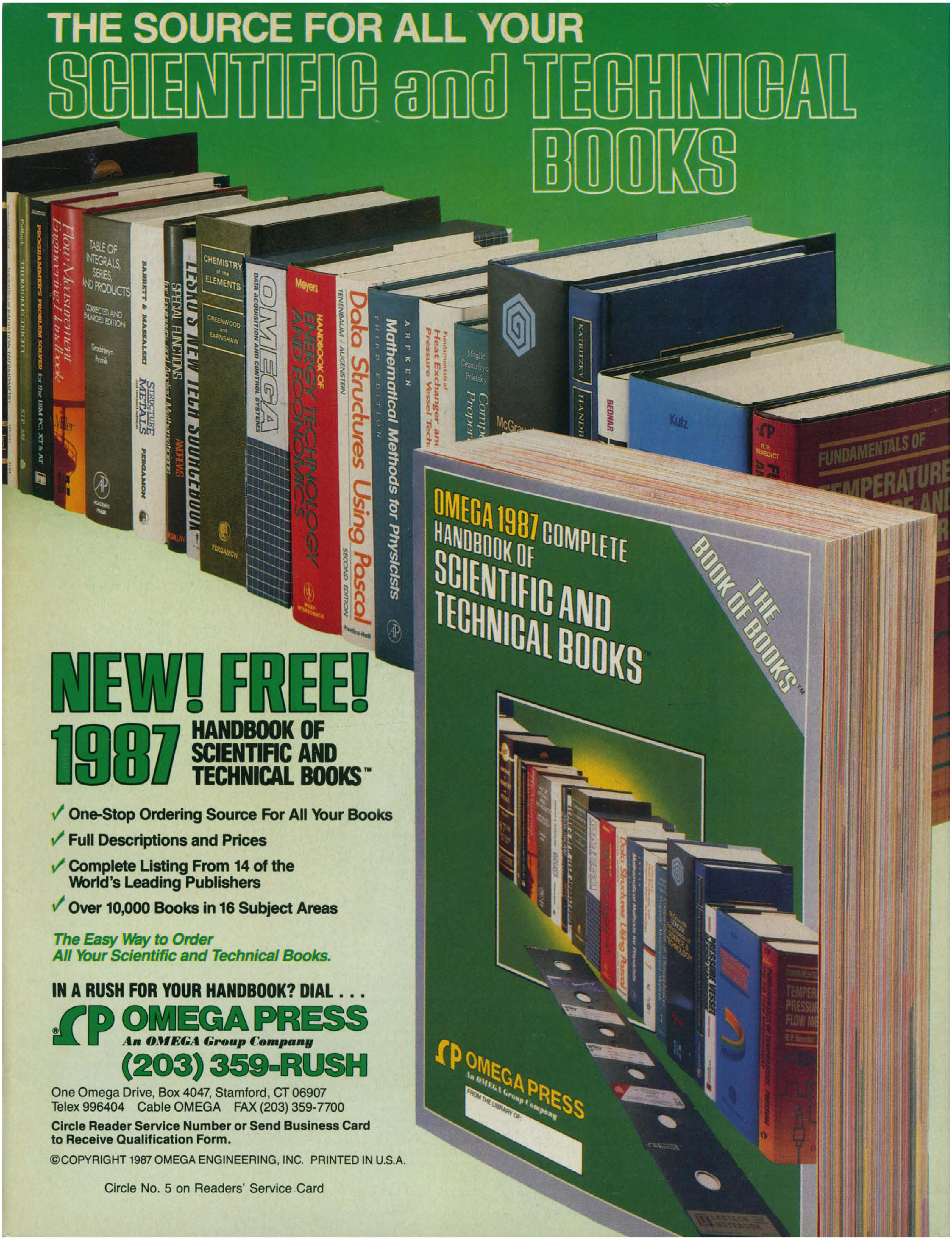
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COVER Laser spectroscopy of samples in diamond-anvil high-pressure cell. The excitation argon-ion laser (tuned to wavelength of 488 nanometers) is focused by a lens at upper right corner to a 100-nanogram hydrogen sample at a pressure of 30 gigapascals. The optical arrangement is used for Raman scattering, Brillouin scattering, ruby fluorescence, and laser heating at high pressures. See page 605. [Photography by Linda Mao, Fairfax, VA]

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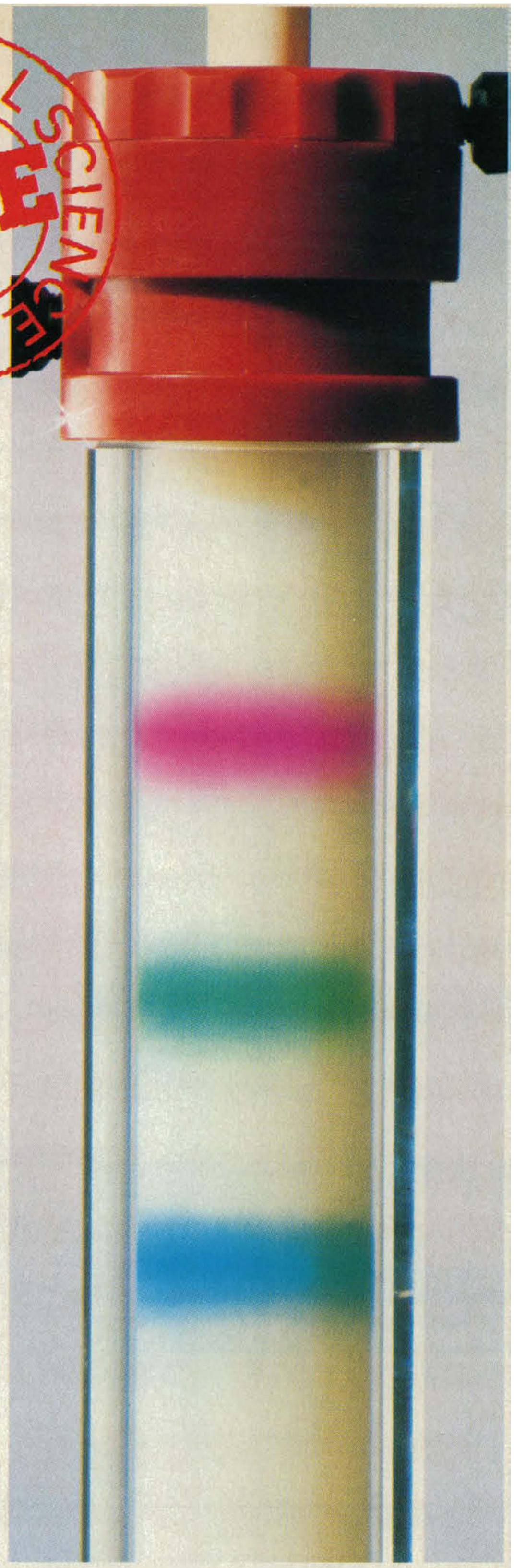

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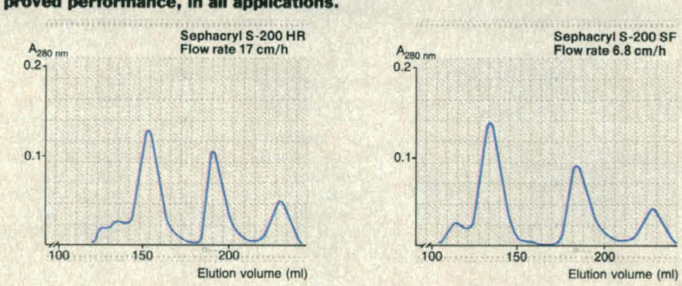

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This Week in SCIENCE

More from comet Halley: polymers in space

SPACECRAFT Giotto flew by comet Halley in March 1986; on board was the Positive Ion Cluster Composition Analyzer, a heavy-ion analyzer, that measured at close range the positive ions present in the comet's coma (pages 626 and 628). Peaks in the spectrum between 40 and 120 atomic mass units (amu) were regular (appearing at 14- or 16-amu intervals), symmetric with nearly constant widths, and showed decreasing intensities with increasing mass. According to Mitchell *et al.* and Huebner, this spectral pattern is best accounted for by a polymer of formaldehyde $(H_2CO)_n$ called polyoxymethylene. (Hydrogen, oxygen, and carbon are, together with nitrogen, the most abundant and chemically active elements in space.) This polymer has a long repeating chain; it can break up into shorter pieces and it can bond to other ions. It may be one of the constituents of cometary dust that can bind small grains into larger ones. Its presence was predicted but has not previously been shown. It is the first polymer that has been identified in space.

Chernobyl's signature in Greenland ice sheet

WITHIN the Greenland ice sheet there is a new and definitive stratigraphic marker for 1986—a layer of radioactive cesium that was deposited in polar glaciers shortly after the nuclear reactor at Chernobyl exploded and burned in April (page 633). The cesium traveled quickly in a radioactive cloud in the troposphere where residence times are at most a few weeks. (In the stratosphere, residence times are typically more than a year.) Davidson *et al.* collected ice and snow samples from the ice sheet; cesium-134 and cesium-137 were concentrated in a single 10-centimeter-wide band slightly below the surface. Because the cloud dispersed fairly evenly throughout North America within weeks of the accident, it is likely that glaciers throughout the Arctic have a similar cesium band. Such a band should help in dating ice cores, in calculating rates of snow accumulation, and in defining features of long-range atmospheric transport.

Nonprotective antibody in malaria infections

ADULTS living in regions where malaria is endemic become less susceptible to infection as they age; the form taken by the protective immunity is unknown (page 639). Hoffman *et al.* report that the presence of antibodies to the sporozoite stage of the malaria parasite does not affect susceptibility to reinfection or the speed with which such an infection might develop. In Saradidi, Kenya, individuals have heavy exposures to the parasites throughout their lives. Local men were treated with antimalaria drugs (that freed them of current infections). Daily observations were then made and subjects were monitored for antibody to the parasites and for the development of new infections for more than 3 months. Of the 83 adults participating in the complete study, 72 percent became reinfected during the study period regardless of their prior sporozoite antibody status; they received on average one bite each day from an infected mosquito (and hundreds of bites daily from mosquitoes that did not carry the parasite). Unless vaccines can induce much higher antibody titers than those induced naturally, antibody will not be the key to prevention under these intense conditions of exposure. Protection might come from some other immunogen of the parasite or from some other host response.

Astrocytes and nerve regeneration

INJURED axons in the spinal cord and brain typically regenerate only over short distances; one of the impediments to their regrowth is reactive astrocytes, the star-shaped cells that are prominent in the mammalian central nervous system (page 642). Liuzzi and Lasek show that the astrocytes do not act as a physical barrier to axon growth; instead, they activate certain physiologic "stop" pathways within the axon that serve during development to stop axon growth once a target has been reached. Dorsal root sensory axons of rats were crushed and then allowed to regenerate; others were directed into a cul-de-sac to prevent them from elongating. Those confronted with a physical barrier accumulated cytoskeletal proteins and other structures normally transported to the growing tip of the axon; those that confronted astrocytes accumulated few cytoskeletal structures. Promotion of axon regeneration after central nervous system injury must therefore focus on removal of both the physical and the physiologic barriers to regrowth.

Moth pheromones

FEMALE insects ready for mating release multicomponent sex pheromones into the wind; males downwind from the females respond with characteristic courtship moves (page 650). Linn *et al.* have found that it is the blend of components in the mixture that determines the effectiveness of the released chemicals. Synthetic pheromone preparations containing one, two, or three components were tested in field studies of Oriental fruit moth (OFM) males. Those mixtures consisting of just the right blend of the three components as they exist in the natural OFM pheromone were most effective in eliciting wing fanning, walking, and flight upwind (signs of sexual activation) by male OFM moths. Flight tunnel tests of these and two other species of moths—cabbage loopers and red-banded leaf rollers—had earlier established the importance of the blend in male responsiveness. The mechanism by which a male detects chemical signals from a female is unclear; however, the precision and speed with which he can detect both the quality and the quantity of constituents in the blend are likely to directly affect his mating success.

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SCIENCE

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Research Applications of Lasers

Laser light comes in many sizes, shapes, and colors. The most powerful lasers produce intensities as high as 10^{16} watts per square centimeter, one trillion times the intensity at the surface of the sun and enough to cause fusion reactions. Pulses that are 6×10^{-15} second in duration, consisting of three optical cycles, are now available from dye lasers, and wavelengths shorter than 100 angstroms have been generated by x-ray lasers. Such lasers are interesting objects of study in their own right, but the lasers that operate within the limits are the workhorses: commercially available and approaching turn-key reliability. Lasers are increasingly used as tools for scientific research; with them it is possible to open new avenues of inquiry. In this issue of *Science* are three articles—in geophysics, atomic physics, and chemical physics—that present several ways in which lasers are employed as tools in the laboratory.

Hemley, Bell, and Mao describe some of the uses of lasers in laboratory geophysics. Inside the earth, planetary matter is subjected to pressures that approach several million atmospheres and temperatures in the thousands of degrees. Because direct observation is not possible, an understanding of internal structures and transformations can only be achieved by simulation of these extreme conditions. Small amounts of minerals or their constituents are sandwiched between diamond surfaces and subjected to large static pressure, the latter communicated by the calibrated fluorescence of a ruby chip. An infrared laser beam, passing unhindered through the transparent diamond, may heat the tiny sample, thus raising the compressed environment to high temperature. A visible-wavelength laser can probe the sample for Raman and Brillouin resonances, which reveal the subtleties of the dynamics of the earth and other planets. Raman spectra disclose the remarkable phase transitions of minerals under pressure, and Brillouin scattering permits a quantitative measure of the elastic and acoustic properties important in seismic studies.

Itano, Bergquist, and Wineland describe laser spectroscopy of ions held captive in an electromagnetic trap. In these experiments, quantum states are studied with extraordinary precision; from the results we learn more about atomic clocks and fundamental physics. Confined to a small space and freed from the perturbing influence of neighbors, single atomic ions exhibit quantum-mechanical resonances that are exceedingly narrow in comparison with the broad spectral lines of denser matter. A precisely tuned laser can further constrain the atomic motion by radiation pressure. Lasers that are under strict frequency stabilization can be used to record high-resolution spectra of the isolated ion. In other experiments, this trapped performer can be made to execute quantum jumps, abruptly fluorescing and then going dark.

Jankowiak and Small review experiments that reveal much about the properties of solids at temperatures near absolute zero. In particular they discuss "hole-burning" spectroscopy as a means of extracting harmony from chaos. Amorphous materials, glasses and polymers for example, are disordered on a microscopic scale, and this disorder is reflected in the broad optical absorption spectrum of a collection of guest molecules. The confusion caused by this disorder can be cleared away by carefully exciting a limited group of molecules to higher energy states with a narrow-band laser. These chosen few molecules, now absent from the ground state, are represented by "holes" in the spectrum. This select group can be watched closely: the holes will fill up as the guests rush back to their places. The glass structure can change, however, before the guest molecules have returned, and persistent spectral holes are the result. Even at temperatures below 1 K this structural reorganization continues: no longer thermally activated, the glassy rearrangement instead occurs by quantum tunneling. With laser hole-burning spectroscopy, researchers can probe the time scales of these dynamic events over 15 orders of magnitude, obtaining new information about basic properties of an important class of materials, the disordered solids.

Perhaps the most exciting future role for lasers is in those applications at the limits of performance: electronic pulse generation with ultrashort laser pulses, long baseline laser interferometers for gravity wave detection, and the creation of "squeezed" states of light with exotic statistical properties, to name a few. In these explorations, grand discoveries await researchers equipped with the next generation of laser tools.—DAVID F. VOSS

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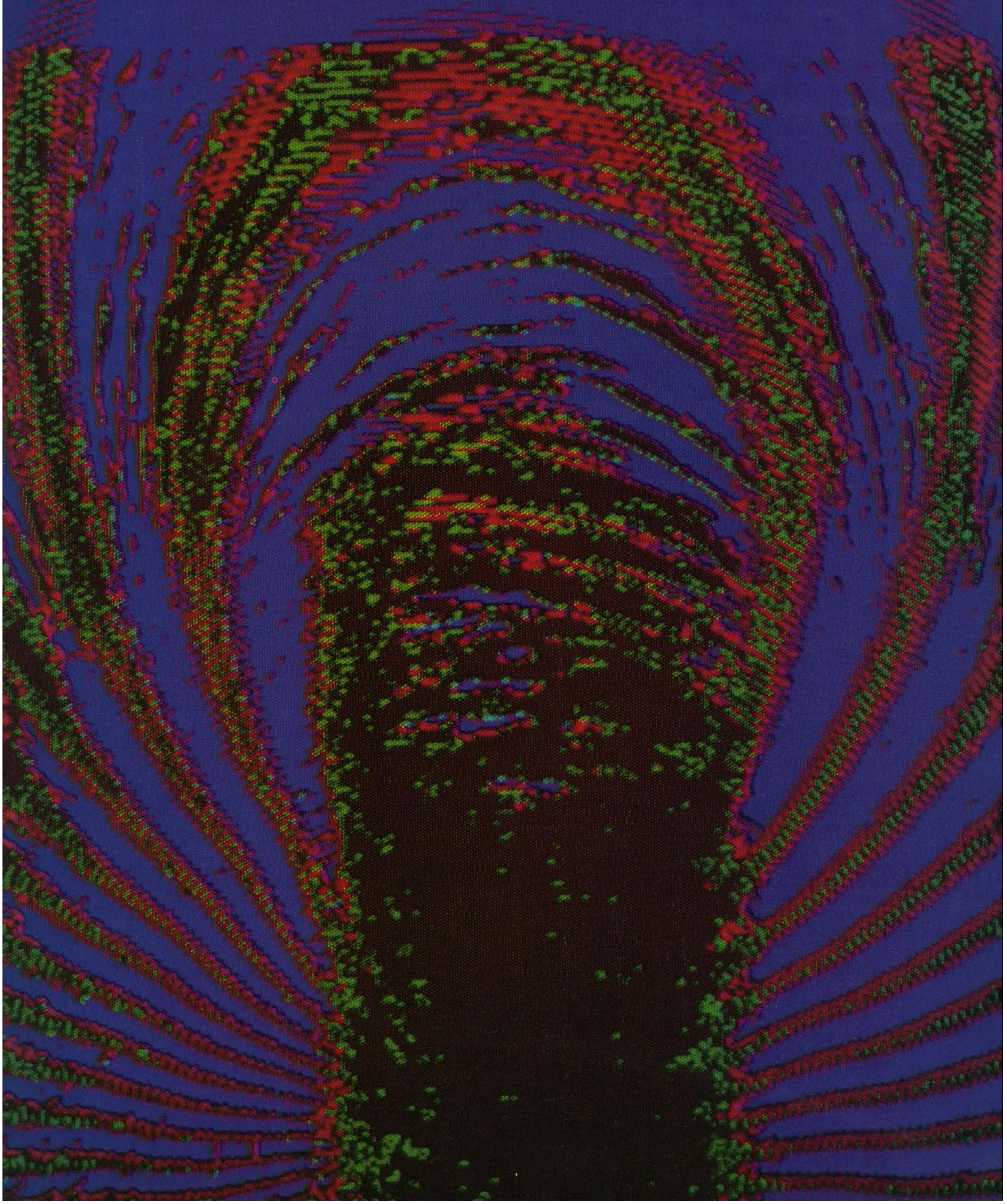
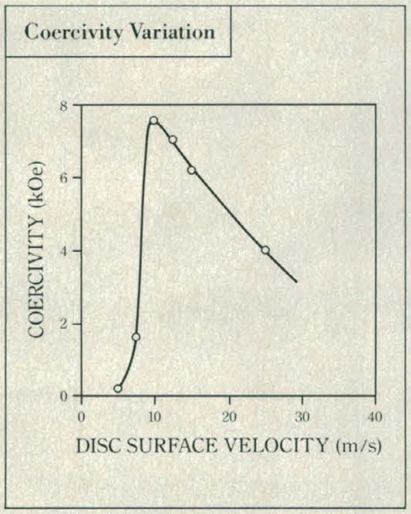
The Critical Interval



The Critical Interval

There has long been a need in the industrial world for low-cost, high-performance permanent magnets. Discoveries at the General Motors Research Laboratories have led the way toward meeting this challenge by the application of new preparation techniques to new rare-earth magnetic materials.



Coercivity of $Pr_{0.4}Fe_{0.6}$ plotted as a function of disc surface velocity.

Color-enhanced transmission electron micrograph of melt-spun $Nd_{0.4}Fe_{0.6}$ having 7.5 kOe coercivity.

TWO properties characterize desirable permanent magnets: large coercivity (magnetic hardness or resistance to demagnetization) and high remanence (magnetic strength). Higher-performance magnets are required to reduce further the size and weight of a wide variety of electrical devices, including d.c. motors. Such magnets are available, but the cost of the materials necessary to produce them severely limits their use. The research challenge is to select, synthesize, and magnetically harden economically attractive materials of comparable quality.

Prominent among alternative materials candidates are alloys composed of iron and the abundant light rare earths (lanthanum, cerium, praseodymium, neodymium). Investigations conducted by Drs. John Croat and Jan Herbst at the General Motors Research Laboratories have led to the discovery of a method for magnetically hardening these alloys. By means of a rapid-quench technique, the researchers have achieved coercivities in Pr-Fe and Nd-Fe that are the largest ever reported for any rare earth-iron material.

Drs. Croat and Herbst selected praseodymium-iron and neodymium-iron based upon fundamental considerations which indicate that these alloys would exhibit properties conducive to permanent magnet development. These properties include ferro-magnetic alignment of the rare earth and iron magnetic moments, which would foster high remanence, and significant magnetic anisotropy, a crucial prerequisite for large coercivity.

That these materials do not form suitable crystalline compounds, an essential requirement for magnetic hardening by traditional methods, presents a major obstacle. Drs. Croat and Herbst hypothesized that a metastable phase having the necessary properties could be formed by cooling a molten alloy at a sufficiently rapid rate. They tested this idea by means of the melt-spinning technique, in which a molten alloy is directed onto a cold, rotating disc. The cooling rate, which can be varied by changing the surface velocity of the disc, can easily approach 100,000°C per second. The alloy emerges in the form of a ribbon.

THE researchers found that variations of the cooling rate can dramatically affect the magnetic properties of the solidified alloys. In particular, appreciable coercivity is achieved within a narrow interval of quench rate.

Equally remarkable, synthesis and magnetic hardening, two steps in conventional processing, can be achieved simultaneously.

"X-ray analysis and electron microscopy of the high coercivity alloys reveal an unexpected mixed microstructure," states Dr. Croat. "We observe elongated amorphous regions interspersed with a crystalline rare earth-iron compound."

Understanding the relationship between the coercivity and the microstructure is essential. The two scientists are now studying the extent to which the coercivity is controlled by the shape and composition of the amorphous and crystalline structures.

"The development of significant coercivity is an important and encouraging step," says Dr. Herbst, "but practical application of these materials requires improvement of the remanence. Greater knowledge of the physics governing both properties is the key to meeting the commercial need for permanent magnets."

TECHNOLOGY UPDATE: 1987

Subsequent to the research reported above, Drs. Croat and Herbst added boron to neodymium-iron as a glassifier to increase the formation of the elongated amorphous regions they had observed in the material. They reasoned that shape anisotropy, and thus coercivity, was related to the presence of these amorphous micro-needles.

They discovered that the addition of boron promoted the formation of a previously unknown ternary compound: $Nd_2Fe_{14}B$. Its atomic magnetic moments are arranged so that this compound has a large magnetization. At the same time, the researchers found that, compared with neodymium-iron, coercivity had risen from 8 to 20 kOe, and that the magnetic energy product had increased by a factor of seven.

On March 31, 1987, General Motors dedicated a new Delco Remy plant in Anderson, Indiana for the production of magnetic material and finished magnets made from $Nd_2Fe_{14}B$ under the commercial name MAGNEQUENCH.

General Motors

GM

MARK OF EXCELLENCE

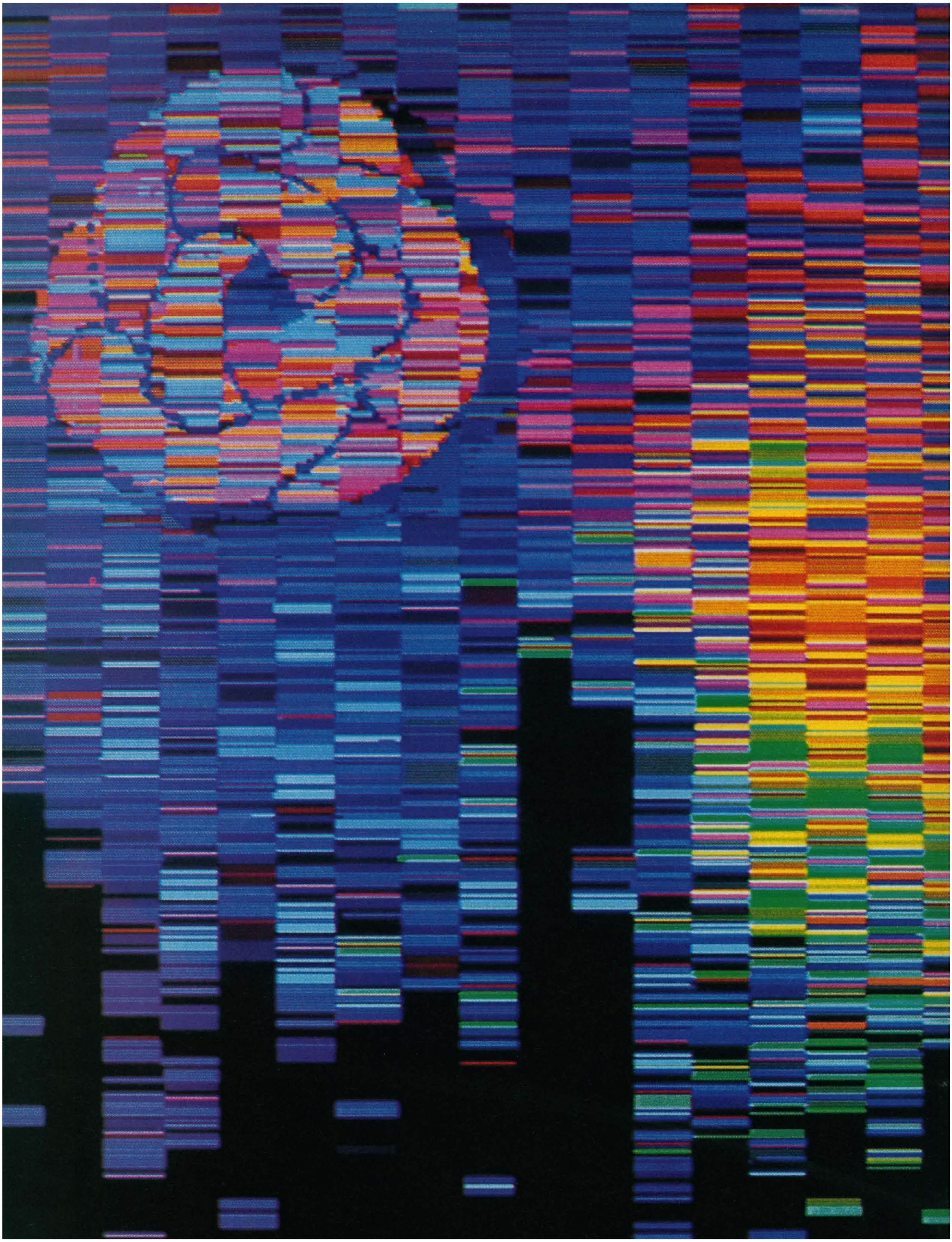
THE MEN BEHIND THE WORK

Dr. John Croat and Dr. Jan Herbst did their original work on rare-earth magnetic materials when both were Staff Research Scientists in the Physics Department at the General Motors Research Laboratories.

Dr. Croat (right) holds a Ph.D. in metallurgy from Iowa State University. In 1984, he joined GM's Delco Remy Division to stabilize the melt-spinning process for the commercial production of MAGNEQUENCH materials. He is currently Chief Engineer at the Indiana plant.

Dr. Herbst received his Ph.D. in Physics from Cornell University. He is now a Senior Staff Research Scientist and Manager of the Magnetic Materials Section in the Physics Department of the GM Research Laboratories. His research interests also include photo-emission theory, the physics of fluctuating valence compounds, and superconductivity.

Dr. Croat joined General Motors in 1972; Dr. Herbst in 1977.



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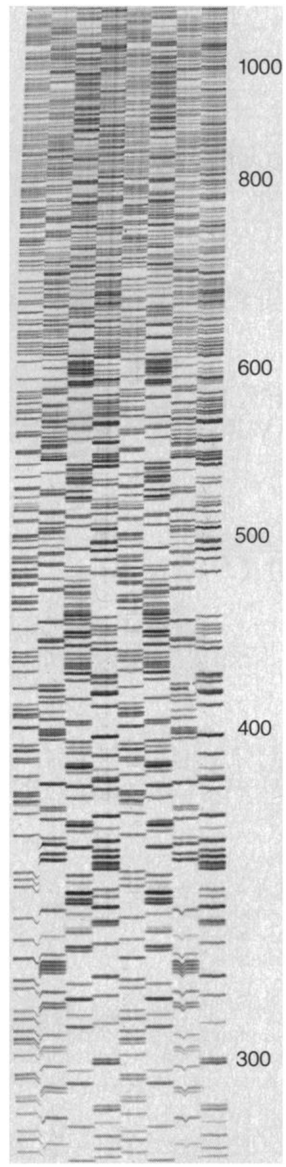

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1. Tabor, S. and Richardson, C.C., *Proc. Nat. Acad. Sci., USA* **84**, No.14, 4767-4771 (1987).

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Robotic Hands Page 3

Recent Robotic Hand Research

Presently, there are two disparate approaches to gripper construction, with correspondingly different design goals. The two types are industrial hands and omni-hands. Industrial hands are fairly simple, uni-function, one or two DOF grippers which are currently being used for such jobs as welding and assembly-type functions. Omni-hands are complex, multiple DOF hands.

Anthropomorphic hands are supplemented by sophisticated hardware and feedback control and offer many advantages; a large range of motion and the ability to pick up objects and manipulate delicate parts without causing damage to them. Maintaining a stable grasp, high costs, and complexity of control relegate this hand to the status of a research tool for the present. The complexity of the additional degrees of freedom inherent in the Omni-hand is illustrated in Figure 1.

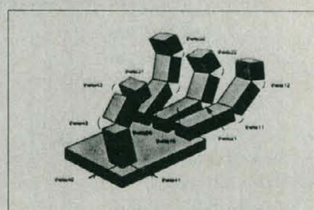
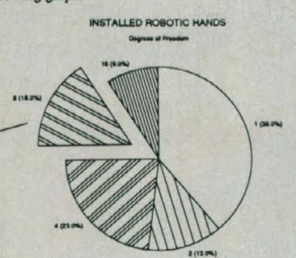


Figure 1: Angle Definitions of Hand Geometry

Until concurrent work in decision-making, task strategy, and vision systems is developed, the potential of this hand cannot be realized. The decreasing cost of producing a functional hand with more than one degree of freedom is speeding acceptance by industry as illustrated in the following graph.



The cost figures are based on a three fingered hand, each finger supporting three DOFs. Lower acquisition costs will allow an increase in the number of degrees of freedom employed in industrial hands. Placing the control for the hand on the arm so as to reduce the weight on the hand itself also lowers cost. The hand-object system was modelled as a rigid body system, in which a heuristic for a stable grasp is a grasp that, when altered by an external force, seeks to produce a motion or force to return the system to stability.

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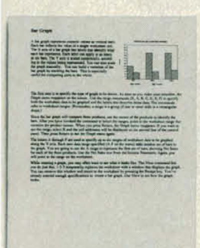

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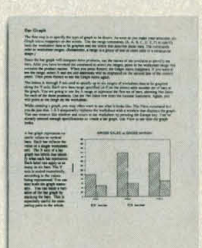

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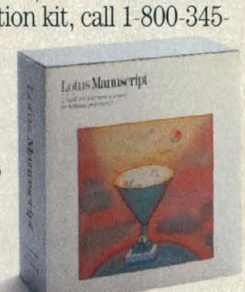

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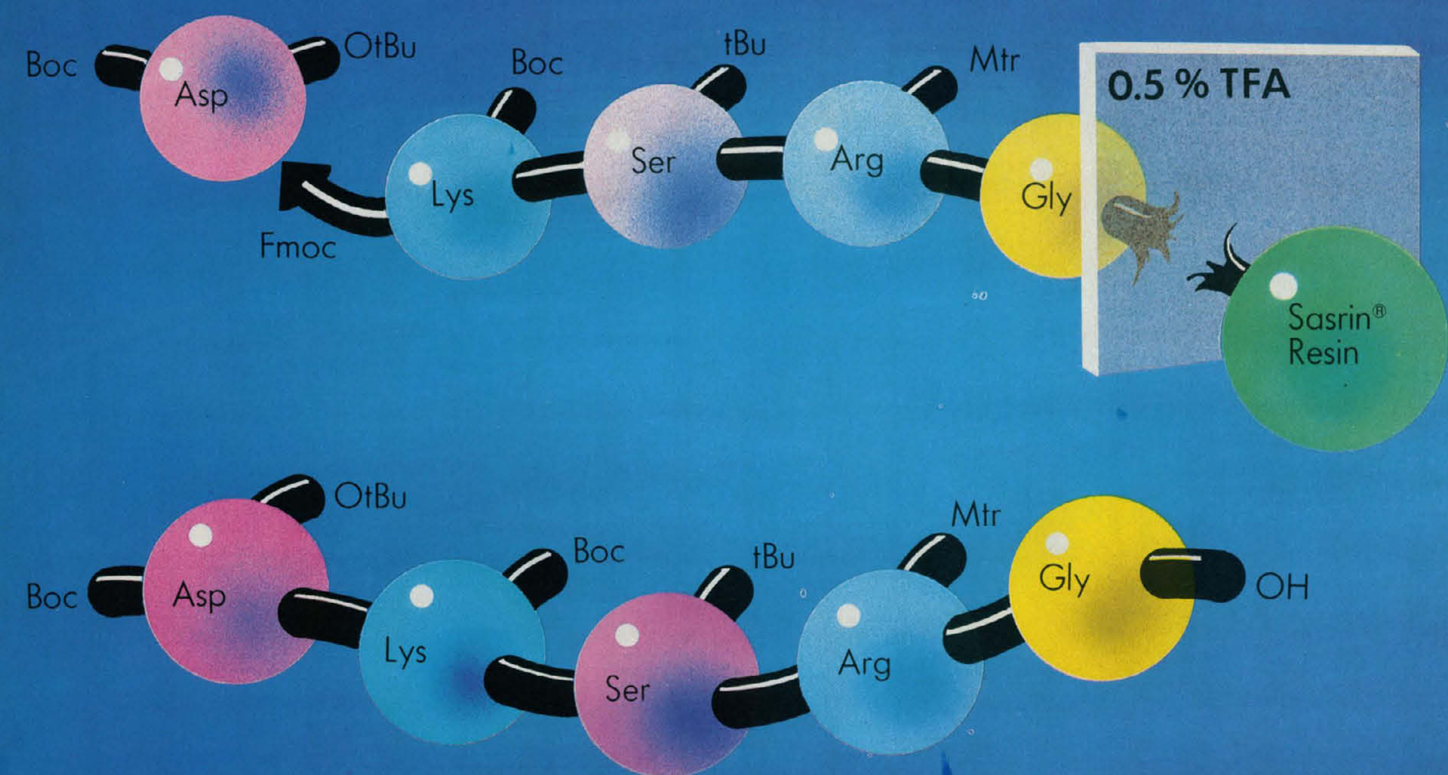

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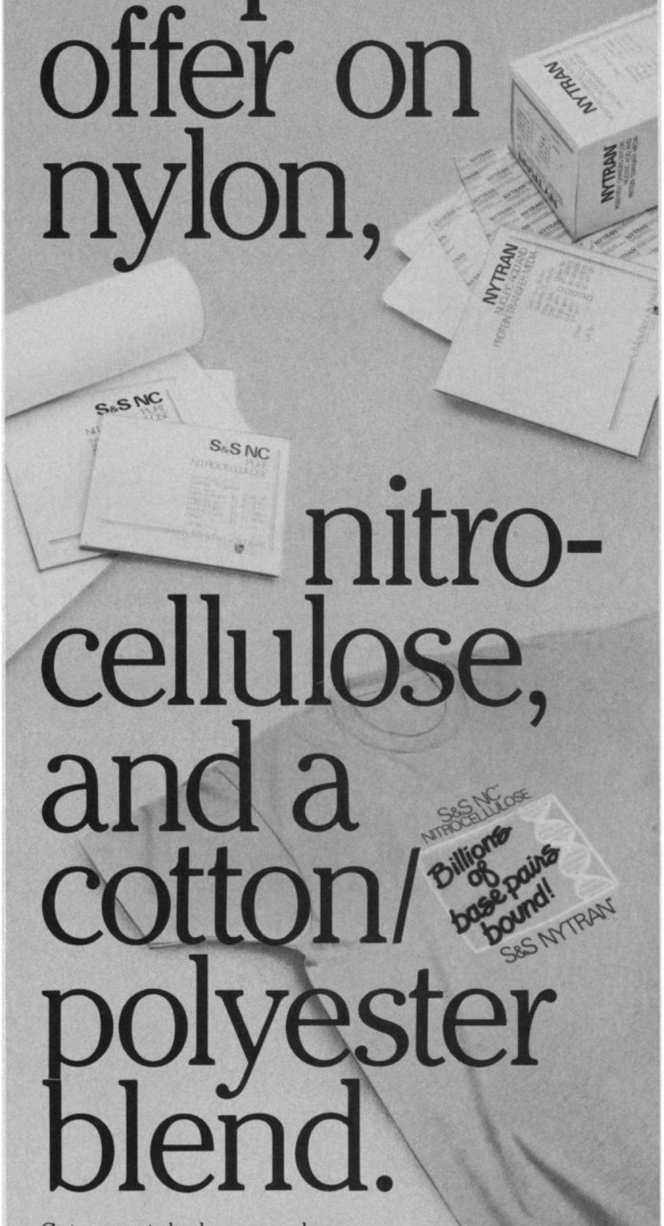

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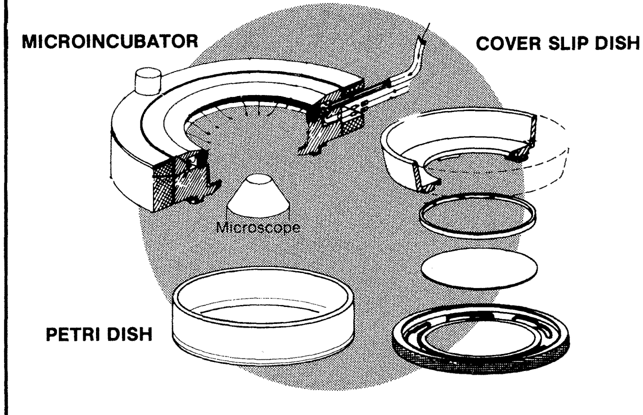

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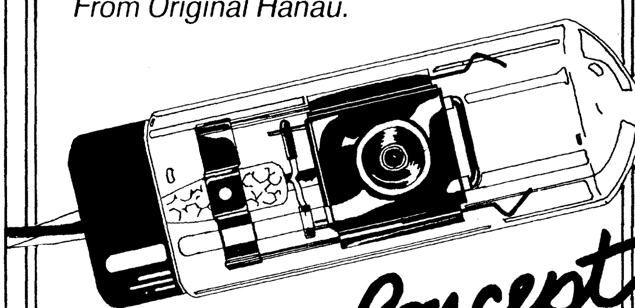

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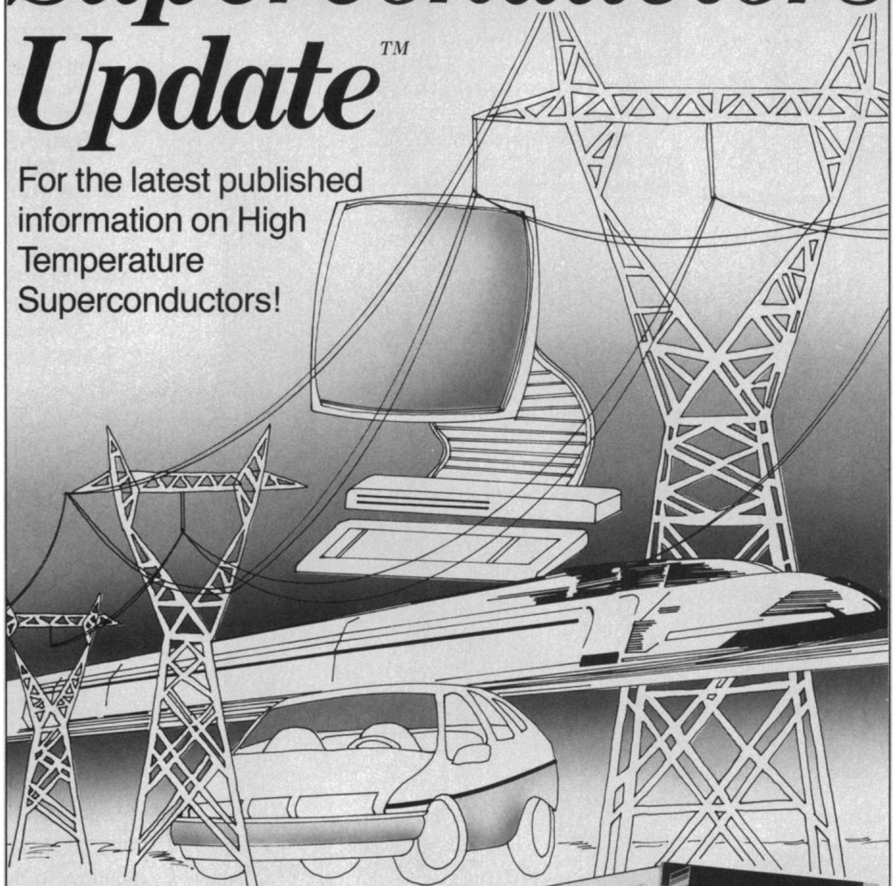

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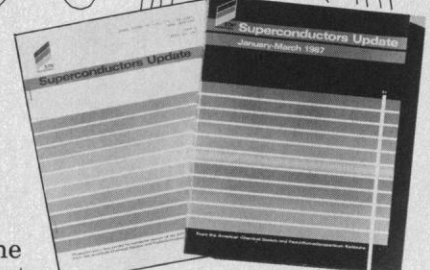

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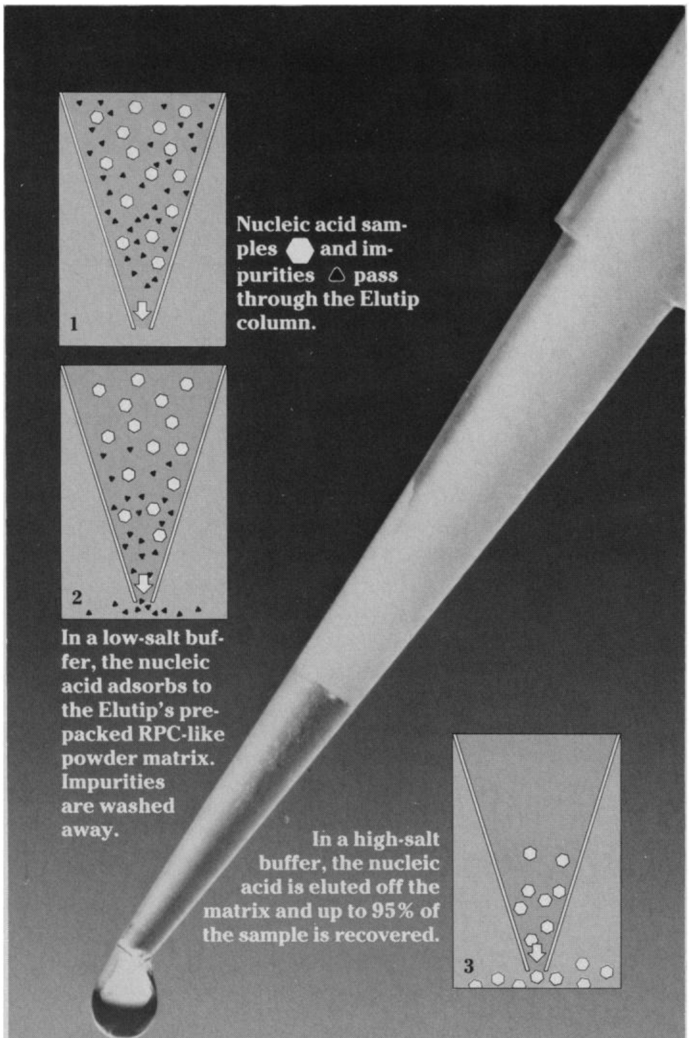

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Receptors and Cell Activation

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Cosponsored by the National Heart, Lung, and Blood Institute and the American Heart Association - Celebrating 40 Years of Partnership in Progress

The symposium is the tenth in the series of "Frontiers in Basic Sciences That Relate to Heart, Lung, and Blood Diseases." It is the third in a commemorative series of conferences honoring the Centennial of the National Institutes of Health and the 40th Anniversary of the National Heart, Lung, and Blood Institute (NHLBI). The Frontiers in Basic Sciences symposia are conducted by the NHLBI to capitalize on and transfer the progress in basic science disciplines to clinical research problems. Leading experts in the field will present their views on the state of the science, the problems facing current understanding, and anticipated future developments in receptors and cell activation.

The symposium will be cochaired by Dr. Michael A. Beaven of the National Heart, Lung, and Blood Institute and Dr. Alfred G. Gilman of the University of Texas Health Sciences Center, Dallas. Presentations will be structured around the following topics: receptors-structure and regulation, GTP binding regulatory proteins and signal transduction, intracellular signals, and effector systems. Presentations by noted experts will be followed by open discussion.

For further information and registration materials, please contact: Dr. Elliott C. Kulakowski, Senior Scientific Advisor, OPPE, National Heart, Lung, and Blood Institute, Building 31, Room 5A03, Bethesda, Maryland 20892, (301) 496-6765.

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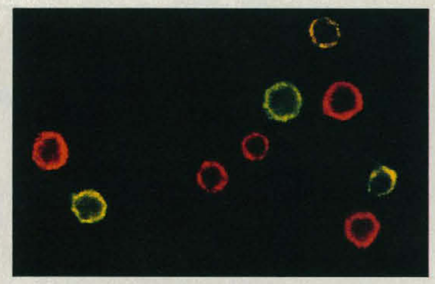

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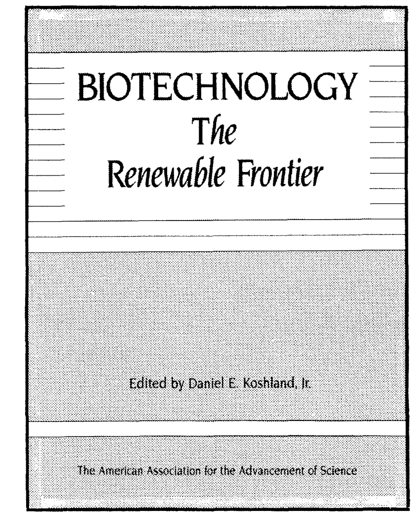

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