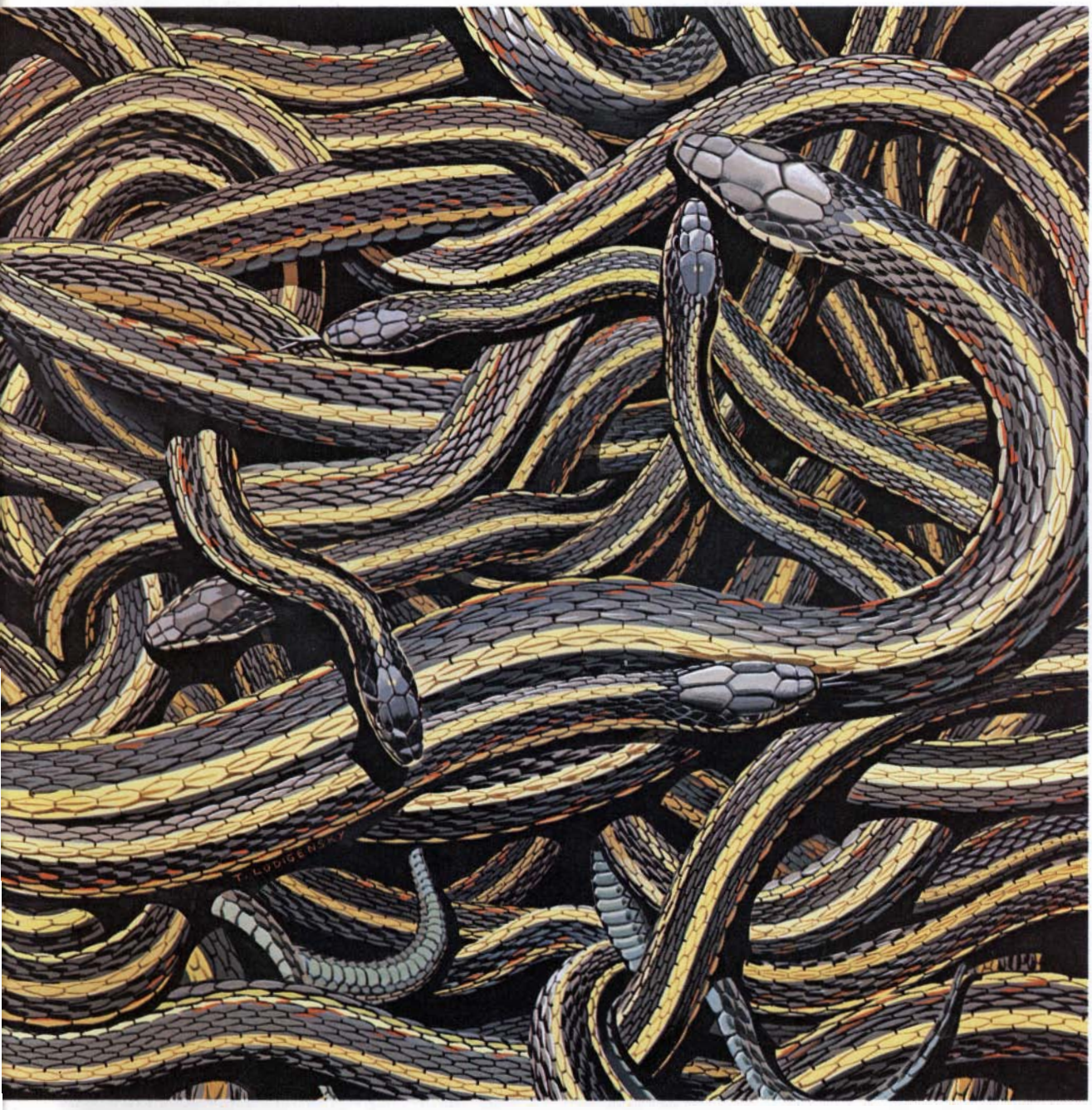
SCIENTIFIC AMERICAN



SNAKE MATING BALL

$2.00

November 1982

The Mercedes-Benz 240 D Sedan: the most pedigreed four-cylinder automobile in the world.

This $24,000* sedan uniquely blends hard-nosed diesel efficiency and masterful over-the-road performance with quality that is the subject of legend. It is no mystery why resale value after three years has been calculated at 86 percent.

History records a powerful reason why the 240 D is a four-cylinder automobile apart: its 2.4-liter overhead camshaft engine is *40 years* more refined than the most refined domestic diesel passenger car power plant. In fact, it descends directly from the engine installed in the first diesel passenger car ever produced for sale.

10 cars, 7,000,000 miles

Pedigree tells. No automobile engine may have so often documented such staggeringly high mileage as the four-cylinder Mercedes-Benz diesel.

One survey revealed that ten American-owned and -driven Mercedes-Benz four-cylinder diesels had between them rolled up well over seven *million* miles.

Perhaps less astonished than the average layman by such claims are the engineers of Mercedes-Benz. It is they who specify machining tolerances as fine as one-hundredth of a millimeter for vital 240 D engine parts.

They also implanted a tiny *ball pin* in each cylinder's precombustion chamber–diffusing injected fuel, aiming to make this engine as smooth-running as it is long-running.

One automotive tester punished the 240 D under extreme conditions and concluded that "...once you're at 80 it'll stay there till you run out of fuel–which will probably be quite a few hours later." The 240 D outruns every sedan in its price class in fuel efficiency. Imagine: a $24,000 sedan capable of 32 est. hwy. and 27 EPA est. mpg.** A happy economy.

Allergic to mediocrity

The 240 D's pedigree extends beyond that jewel of an engine.

The 51 years of design refinement invested in its fully independent suspension system can be *felt* in limpetlike roadholding and a supple ride. The 240 D is neither a galumphing luxury car nor a testy "sports sedan"–simply one of the best-mannered five-passenger automobiles extant.

There doesn't seem to be a commonplace engineering idea in the car. Even its power steering system is a technological feat: it works *progressively* to feed in extra steering force only when you need it, as in parking. Crucial steering "feel" never deserts you.

Steering to brakes to suspension, every system in the 240 D is harmonized with every other. Such superb tune and balance do not just happen. The engineers spent *seven years* developing the 240 D.

Quality is standard

The real glory of the 240 D's beautifully padded, carpeted, wood-trimmed interior is the seats. Your body may never have been so well cared for in an automobile before. The time to judge them is not in the showroom but after a nonstop eight-hour drive.

You can choose a four-speed manual 240 D or a version fitted with a four-speed, torque-converter *automatic* transmission that can also be shifted by hand. Air conditioning, electronic cruise control, and a central vacuum locking system head a long list of built-in amenities.

The 240 D epitomizes what so many car makers today are scrambling to achieve: quality of fit, quality of finish–quality, period. It is so solidly built that there are 4,786 individual welding points in the body shell. It is so well finished that between the body metal and surface paint are *six* layers of protection.

The 240 D also epitomizes the rational Mercedes-Benz order of priorities. Paramount is safety. The car incorporates *more than 120* individual safety features. Many could be omitted and few buyers might be the wiser. But then, the 240 D would not deserve its pedigree as a Mercedes-Benz.

*Suggested retail price p.o.e. New York. West Coast prices slightly higher.

**Use EPA estimated mpg numbers for comparison. Actual mileage may vary, depending on speed, trip length, and weather. Actual highway mileage probably lower.

Engineered like no other car in the world

Established 1845 **SCIENTIFIC AMERICAN** November 1982 Volume 247 Number 5

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN (ISSN 0036-8733), PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK, N.Y. 10017. SECOND-CLASS POSTAGE PAID AT NEW YORK, N.Y., AND AT ADDITIONAL MAILING OFFICES. AUTHORIZED AS SECOND-CLASS MAIL BY THE POST OFFICE DEPARTMENT, OTTAWA, CANADA, AND FOR PAYMENT OF POSTAGE IN CASH. SUBSCRIPTION RATE: $21 PER YEAR IN THE U.S. AND ITS POSSESSIONS; $27 PER YEAR IN ALL OTHER COUNTRIES. POSTMASTER: SEND ADDRESS CHANGES TO SCIENTIFIC AMERICAN, 415 MADISON AVENUE, NEW YORK, N.Y. 10017.

SCIENTIFIC AMERICAN

CORRESPONDENCE

Offprints of more than 1,000 selected articles from earlier issues of this magazine, listed in an annual catalogue, are available at 75 cents each. Correspondence, orders and requests for the catalogue should be addressed to W. H. Freeman and Company, 660 Market Street, San Francisco, Calif. 94104. Offprints adopted for classroom use may be ordered direct or through a college bookstore. Student sets of 10 or more Offprints are collated by the publisher and are delivered as sets to bookstores.

Editorial correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York, N.Y. 10017. Manuscripts are submitted at the authors' risk and will not be returned unless they are accompanied by postage.

Advertising correspondence should be addressed to C. John Kirby, Advertising Director, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York, N.Y. 10017.

Subscription correspondence should be addressed to Subscription Manager, SCIENTIFIC AMERICAN, P.O. Box 5969, New York, N.Y. 10017. The date of the last issue on your subscription is shown in the upper right-hand corner of each month's mailing label. For change of address notify us at least four weeks in advance. Please send your old address (if convenient, on a mailing label of a recent issue) as well as the new one.

Name

New Address

Street

City

State and ZIP

Old Address

Street

City

State and ZIP

THE COVER

The painting on the cover shows one aspect of the reproductive behavior of the red-sided garter snake, a species indigenous to western Canada (see "The Ecological Physiology of a Garter Snake," by David Crews and William R. Garstka, page 158). In the painting the snakes have just emerged from the den in which they spend the winter. A female is shown trying to leave the vicinity of the den; her body, some two feet long, crosses the painting almost horizontally, then curves upward and toward the left. Her progress is impeded by a welter of courting males that form a "mating ball" around her. The males are all smaller than the female. One male is shown succeeding in his courtship: his body is aligned with that of the female and his chin is pressed onto her back. When he and the female start to copulate, the unsuccessful males immediately return to the opening of the den and wait there for another female to come out.

THE ILLUSTRATIONS

Cover painting by Ted Lodigensky

Page	Source	Page	Source
53–60	George V. Kelvin	143–156	Jerome Kuhl
63	Patricia J. Wynne	158	Bianca Lavies, © 1975 National Geographic Society
64–69	Walken Graphics	160–164	Patricia J. Wynne
71	Andrew Tomko	166	Andrew P. Halpert and William R. Garstka
72	Andrew Tomko (*top*), Patricia J. Wynne (*bottom*)	168	Patricia J. Wynne
73	Andrew Tomko	173	Barry Stark, Northern Illinois University
74–75	David L. Jones, U.S. Geological Survey (*top*); Andrew Tomko (*bottom*)	174–178	Allen Beechel
76–77	Todd Pink	183	National Archives and Records Service
78–79	Andrew Tomko	184–186	Ilil Arbel
80–81	Todd Pink	188–189	U.S. Bureau of Mines
82	Andrew Tomko	191–192	Ilil Arbel
83–84	Todd Pink	194	Arthur Eisenkraft
129	Richard J. Feldmann, National Institutes of Health	198–199	Michael Goodman
130–140	Alan D. Iselin	202–204B	Arthur Eisenkraft

Authentic professional achievement almost always involves an element of danger. Those who depart from tradition must be aware that even professionally responsible actions can open the door to the danger of additional professional liability exposures.

Professional liability insurance from the CNA Insurance Companies helps professionals face this danger squarely and sensibly. For more than a quarter of a century, CNA has been committed to providing the liability protection professionals must have to function courageously and creatively.

Our professional liability specialists work closely with association representatives to establish proper coverages and to keep them updated as changing situations require. CNA even shares loss data and loss expense information to help association members understand their premium base.

Learn how CNA's professional liability insurance can help you and the members of your professional group deal with liability exposures squarely and sensibly. Ask your independent insurance agent or your association executive to contact Vice President, Professional Liability, CNA, CNA Plaza, Chicago, Illinois 60685.

"COURAGE CONSISTS NOT IN BLINDLY OVERLOOKING DANGER, BUT MEETING IT WITH THE EYES OPEN."

Jean Paul Richter

CNA Professional Liability Insurance protects professional group members including ▫ Doctors ▫ Attorneys ▫ Architects ▫ Engineers Accountants ▫ Corporate Directors and Officers ▫ School Boards ▫ Hospitals ▫ Medical Clinics ▫ Publishers ▫ Broadcasters

INSURANCE FROM CNA

BIT BY BIT, OUR INFORMATION SYSTEMS

WE BUILD UNDERSTANDING INTO COMPUTERS.

At McDonnell Douglas, we use technology to help people solve problems.

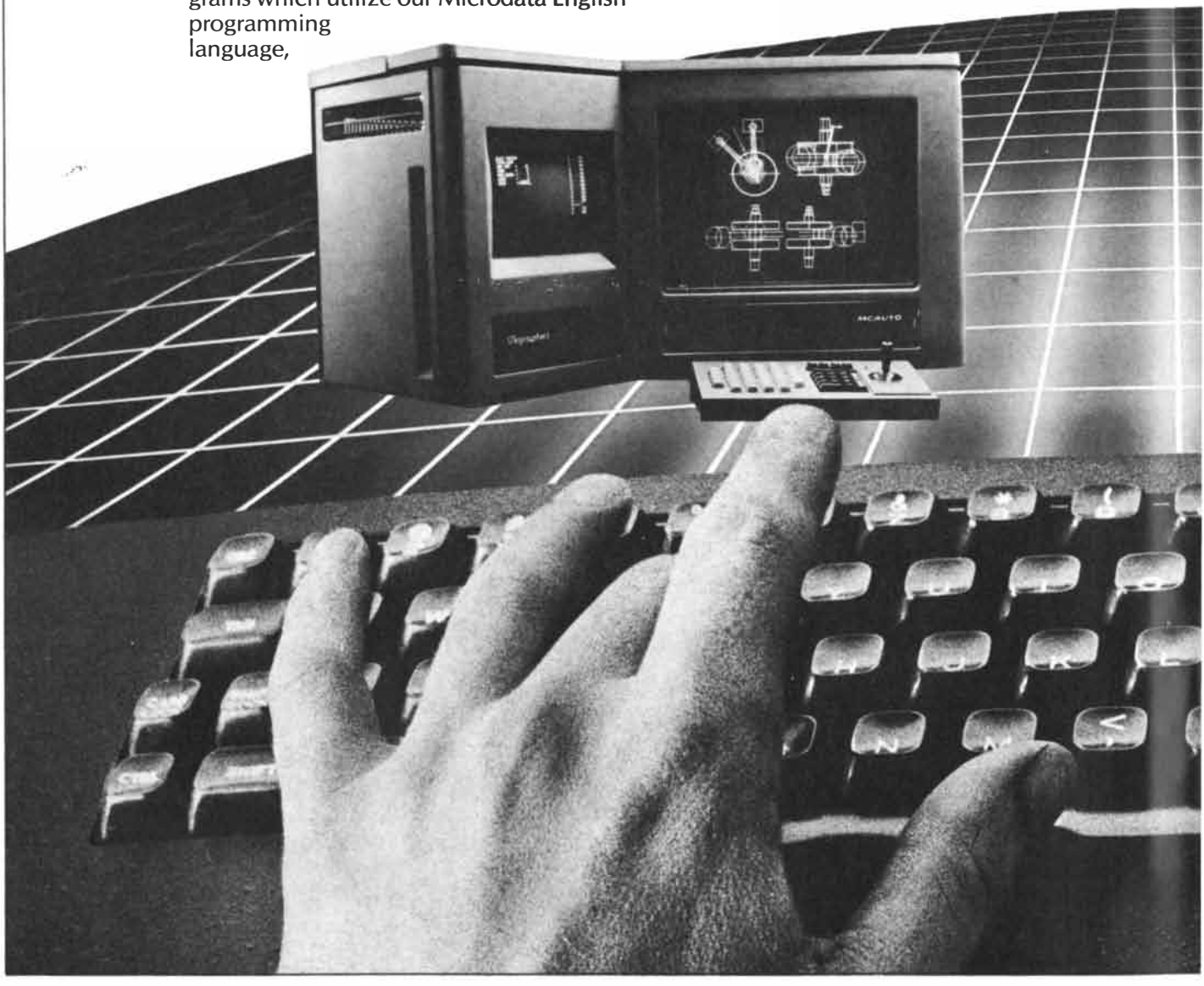
For instance, a small plumbing company is growing rapidly. That's good. But there are problems: The accounting department needs help handling accounts receivable, accounts payable, inventory control, payroll. It's time to invest in a computer system, but no one in the company knows the first thing about computers.

Up steps Microdata Corporation, a McDonnell Douglas subsidiary, with a Reality® business computer that's easy to use, even if you aren't a computer professional.

Microdata specialists do the professional work for you. They offer packaged programs which utilize our Microdata English® programming language, allowing people to use everyday words and phrases in talking with the computer. The plumbing company finds that, with Microdata, the transition to computers is fast, easy, painless—and productive.

CREATING NEW JOBS WITH AUTOMATION.

Four years ago a small Oregon manufacturing firm was locked in stiff competition. Costs were rising. They installed a Unigraphics™ system from McDonnell Douglas Automation Company, MCAUTO,® to automate design and manufacturing. The result is proof of the *human benefits* of technology. Design and production time were cut by 70%; prototype parts were produced in days instead of weeks. Costs dropped. Sales climbed. The company tripled its workforce to meet demand for



ARE RESHAPING YOUR WORLD.

their new products. They made the intelligent decision for their people and their business—MCAUTO.

A HEALTHIER FUTURE FOR HEALTH CARE.

Hospital paperwork and reporting increase the cost of essential health care services. Now one out of every six hospitals in America is fighting the problem with data services from MCAUTO.

One urban hospital was threatened—its very survival was in doubt—because of the high cost of delayed reimbursements. Then they started using a MCAUTO system for patient accounting, record keeping and billing. Their expenses dropped. Cash flow jumped by more than $18 million.

This is one way MCAUTO shifts the burden of information handling from hospital staff to computer. Nurses return to nursing, managers to managing. Everyone benefits from more efficient health care.

Everyone benefits when information flows. Individuals and organizations increase productivity.

And higher productivity means a better life for all.

MCDONNELL DOUGLAS

LETTERS

Sirs:

Roger Revelle ["Carbon Dioxide and World Climate," by Roger Revelle; SCIENTIFIC AMERICAN, August] gives what appears to be a rather balanced review of the CO_2-climate question, but he fails to point out that most of the predictions of the computer models used to study the problem are basically at odds with reality. For instance, citing the modeling work of James E. Hansen and his colleagues, he notes that the greatest warming from increasing atmospheric CO_2 is predicted to occur in northern latitudes. However, Hansen's own data for this region (*Science,* Vol. 213, No. 4511, pages 957–966; August 28, 1981) show that the average temperature of northern latitudes has been decreasing at a mean rate of more than .1 degree Celsius per decade since 1935—a period over which the models clearly predict it should have been warming. And there is no evidence for any recent change in this trend. Indeed, satellite observations of variations in Northern Hemisphere seasonal snow cover reported by Kenneth F. Dewey and Richard R. Heim, Jr., of the University of Nebraska at Lincoln indicate that there has been an overall increase in snow-cover area from 1966 to 1980....

The primary reason the global temperature appears to have risen slightly in recent years is that southern latitudes seem to exhibit a warming trend. However, as Revelle notes by reference to the work of Hermann Flohn, this is the one region of the globe where CO_2 effects are projected to be smallest—again just the opposite of what actual measurements indicate....

In sum, Revelle presents the standard story of a close-knit group of climate modelers that is promulgating serious consequences for the earth if atmospheric CO_2 is allowed to increase at currently projected rates. However, the above observations and several recent empirical studies indicate that the climate warming predicted by these modelers has been overestimated by a full order of magnitude. In spite of attempts by this group and their representatives in the National Academy of Sciences to deny it, the contrary story told by real-world data cannot be contained much longer.

SHERWOOD B. IDSO

Institute for Biospheric Research, Inc.
Tempe, Ariz.

Sirs:

Roger Revelle's excellent article was paradoxically both timely and ill-timed.

Timely because CO_2 has been of enormous concern to a growing body of scientists, and ill-timed because since he wrote his article the great eruption of El Chichon in March and April has penetrated the tropopause and injected a vast amount of volcanic dust and sulfur dioxide into the stratosphere. Preliminary reports on the size and extent of this cloud from lidar measurements indicate that it is probably even denser than the 1963 Mount Agung eruptions.

Dr. Revelle has correctly stressed man's inability to quantify the climatic warming effect of CO_2 precisely. I would also stress man's inability to quantify the cooling effect of the El Chichon dust/aerosol cloud precisely. Nevertheless, the offsetting effects of these two events—one gradual and continuous, the other sudden and discontinuous—are obvious. The capriciousness of nature in "interfering" with man's models of climatic variation ought not go unnoticed. Volcanic dust/aerosol clouds are negative feedbacks that retard CO_2 warming. Their effect can be determined only after the eruption. The eruptions are not predictable. The temperature variations shown in the article reveal pronounced and sudden drops in 1882–85, 1914–18 and 1962–64. These dates correspond with the Krakatoa eruption, the Mount Katmai eruption and the Mount Agung eruption.

The purpose of this letter is not to disagree with Dr. Revelle but rather to point out that any CO_2 warming effect may indeed be masked by the cooling effect of the El Chichon aerosol cloud, which is expected to persist for several years. In addition the trend in mean annual Northern Hemisphere temperatures has been inconclusive rather than a warming one in the 1970's. Although Northern Hemisphere cooling seems likely in the short term, the addition of CO_2 to the atmosphere will ultimately be felt. The problem deserves the attention Dr. Revelle and *Scientific American* have given it.

DONALD R. WIESNET

Chief, Land Sciences Branch
National Oceanographic and
Atmospheric Administration
Washington, D.C.

Sirs:

I find it easy to sympathize with Sherwood Idso, because I have lived in the time of two scientific conflicts where almost all the "knowledgeable" experts were on one side and the truth was on the other. But neither the fact that the Bull of Altamira dated back to the Paleolithic nor the facts of continental drift are good analogues. Idso's "recent empirical studies" actually support the models he criticizes.

In one of these studies Idso has compared the seasonal cycle of changes in the flux of solar radiation at the earth's surface with the corresponding short-term response of surface temperature. From this study and similar ones he calculates that a change in downward radiation at the surface of 1 Wm^{-2} (watt per square meter) will bring about a nearly immediate surface-temperature change of .2 degree Celsius. The same kind of calculation has been used for empirical validation of a number of CO_2-climate models. For example, Veerabhadran Ramanathan has shown that if the surface were at radiative equilibrium, if the atmospheric temperature remained unchanged and if there were no changes in thermal fluxes caused by other processes, an instantaneous doubling of atmospheric CO_2 would increase the downward radiative flux at the surface by 1 to 1.5 Wm^{-2} and the surface temperature would rise by about .2 degree, in close agreement with Idso's observations.

In spite of Idso's claims there is no known experimental analogue to indicate how this direct radiative response to a change in CO_2 concentration will affect the climate when all processes are acting. As a result theoretical climatic models must be used.

It is known that on time scales longer than a few weeks the lower atmosphere (the troposphere) is closely coupled to the surface through convective and other air motions as well as radiative processes. With increased CO_2 the troposphere and the surface will become warmer because infrared radiation will be trapped in the troposphere. Model computations indicate that for a doubling of atmospheric CO_2 the net change in radiative flux to the surface will be more than 4 Wm^{-2}, and the surface temperature will rise by about one degree, provided the quantity of water vapor in the atmosphere remains fixed. But the concentration of water vapor in the air will rise with rising temperature, resulting in more trapping of infrared radiation in the troposphere. Model computations indicate that with this positive feedback the surface temperature will rise by about two degrees. Several other positive feedbacks are likely. For example, if clouds rise with increasing tropospheric temperature so that the temperature and the outgoing infrared radiation from the cloud tops remain constant, the temperature near the surface will rise. Similarly, the melting of snow and ice caused by CO_2-induced warming will lower the earth's reflectivity, resulting in more absorption of solar radiation and hence further heating.

Computations of the combined effects of tropospheric warming and these positive feedbacks give an estimated global temperature increase for a doubling of CO_2 of 3 ± 1.5 degrees, more than a tenfold amplification of the relatively

small, direct-radiative influence on surface temperatures computed by Ramanathan (and also by Idso) from non-equilibrium radiative-transport considerations.

Idso states, and I pointed out in my article, that observed atmospheric temperature changes over the past 100 years do not positively confirm the model studies. I described the close correlation obtained by James E. Hansen and his colleagues between these observations, when the data are averaged on a global basis, and temperature changes computed from a model that took into account increased CO_2, fluctuation in volcanic aerosols, ocean thermal inertia and a small variation in the sun's luminosity. But as Michael C. MacCracken points out in a forthcoming article, there are several weaknesses in this correlation, notably the discrepancy between the model computations and the latitudinal distribution of observed temperature changes. Equilibrium models predict an amplification of the CO_2-induced warming at high northern latitudes, but the observations do not show this. Instead they indicate an average cooling in the latitude zone between 23.6 degrees north latitude and 90 degrees of about .5 degree C. from 1935 to 1970, followed by a warming of about .2 degree after 1970. Idso's claim that the observed increase in snow-covered areas in 1966–1980 indicates continued cooling is probably incorrect. In previously very cold regions a slight warming will lead to more snowfall because the air is capable of holding and then giving up more moisture.

Several climatic factors, for example the extent of cloud cover, the response of the hydrologic cycle and the behavior of the oceans, may not be satisfactorily accounted for in present models. We must conclude that until a warming trend that exceeds the noise level of natural climatic fluctuations becomes clearly evident, there will be considerable uncertainty and a diversity of opinions about the amplitude of the climatic effects of increased atmospheric CO_2. If the modelers are correct, such a signal should be detectable within the next 10 or 15 years.

As for the letter from Donald R. Wiesnet, I agree with him except for one thing. As I have pointed out above, average temperatures north of 23.6 degrees north apparently rose about .2 degree C. between 1970 and 1980. As Wiesnet implies, however, this may be only climatic "noise." It is interesting to note that 1981 was the warmest year on record in the Northern Hemisphere.

ROGER REVELLE

Professor of Science and Public Policy
University of California, San Diego
La Jolla

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

NOVEMBER, 1932: "The speed records at the recent National Air Races were made possible by years of engineering. When Major James H. Doolittle established a world's land-plane speed record of 296.287 miles per hour, his Wasp engine employed a supercharger the impeller of which was traveling at a rate of 27,600 revolutions per minute, or 460 revolutions per second. Jimmie Haizlip, Captain Roscoe Turner and Jimmie Wedell, who finished one-two-three in the race across the continent earlier in the week, flew Wedell-Williams ships with Wasp Junior engines, employing superchargers with an average impeller speed of 400 revolutions per second. The supercharger is the development of Dr. S. A. Moss. All the leading planes in the race were racers of an extreme type but are forerunners of commercial design."

"When we try to interpret something about which we know so little as the effect of the sun's eclipse on the propagation of radio waves, the best we can do is to start with such theories as we may have and try to carry these theories somewhat further by establishing new facts. In equipping an expedition to make radio observations of the total eclipse of August 31 it was intended particularly to follow out a suggestion made by Dr. Irving Langmuir, who wished to obtain more data regarding the theory that from the sun there is a corpuscular or electronic emission traveling at a rate of 1,000 miles per second. For the test a radio frequency of 8,655 kilocycles was selected. The outstanding result of the observations was that this normally strong signal almost totally disappeared during the two hours preceding the optical eclipse of the sun, which in accordance with the calculations of the astronomers would be the time during which the corpuscular or electronic eclipse would take place. Therefore it was felt that the correctness of the theory of the electronic eclipse was proved."

"Einstein's mathematical deductions have shown us the possibility of a four-dimensional and even a five-dimensional world. His calculations show that the universe is not infinite, although it has no definite bounds; that space is warped by the presence of matter; that two parallel lines may meet in such a warped space, and that a straight line may ultimately return to its starting point. Are the Einstein theories so contrary to our everyday logic? Do we have to give up any attempts to visualize his new world and to trust only his mathematical deductions? As a matter of fact, some of the most radical conceptions of non-Euclidean (or Riemannian) space can be reproduced before our eyes by means of an artificial 'warped' space. It is simply a paper strip the ends of which are glued together to form an endless band. One end before it is glued must be turned halfway around. Our world may represent some such space. The paper strip may simply correspond to directions in which objects, including rays of light, must travel. Such a world will be finite but endless, because nothing, even rays of light, will ever be able to get out of it. We must not denounce new theories only because they do not always agree with our understanding of things as we see and feel them on the earth. Our everyday logic is not an all-powerful criterion of scientific theories."

NOVEMBER, 1882: "A general system of electric distribution is needed, not for electric lighting only but for hundreds of other purposes of which we now dream little. Motors that could work sewing machines already exist and would be used literally by the millions if the source of electricity were but at hand. If we have a system of electric distribution, lifts for elevators will be multiplied. An electric lift is both simpler and cheaper than a hydraulic lift, which will probably be eliminated entirely at no distant date. The locomotive steam engine is irrevocably doomed. Why should we employ an enormous and expensive lumbering mass of metal, loaded with boiler and coal and burning four pounds of coal per horse power per hour, to pull our trains when we might equally well pull them by electric motors of one-tenth part of the total weight, drawing their supplies of electricity electrically from a large and far more economical stationary engine at one end of the line?"

"The most striking feature in the study of the Tertiary period is the gradual and orderly succession of higher types of mammalia. We find the placental mammals becoming increasingly specialized as we approach the frontier of history. The living orders appear in the Eocene, the living genera in the Miocene, a few living species in the Pliocene and the rest in the Pleistocene. The most specialized of all animals, namely man, cannot be looked for until the higher mammalia by which he is now surrounded were alive. We cannot imagine him in the Eocene age, at a time when animal life was not sufficiently differentiated to present us with any living genera of placental mammals. Nor is there any probability of his having appeared on the earth in the Miocene, because of the absence of higher placental mammals belonging to living species. Nor in the succeeding Pliocene age can we expect to find man on the earth, because of the very few living species of placental mammals then alive. It is not until we arrive at the succeeding stage, or the Pleistocene, when living species of mammalia begin to abound, that we meet with indisputable traces of the presence of man on the earth."

"The Municipal Council of Paris having voted a grant of 1,000 francs to the Academy of Meteorological Ascension for the purpose of making experiments in aerial photography, a balloon ascent was lately made by members of the academy. They carried with them an apparatus for taking instantaneous photographs. This had six lenses pointing in different directions in order to embrace the whole of the horizon. The balloon rose 200 meters. A telephone was afterward fitted up in the car to enable the occupants to communicate with their friends below."

"Dr. G. M. Hammond, in a recent communication on the proper method of executing the sentence of death by hanging, cites a number of authorities and cases all going to show that the practice of jerking the body by the neck with a view to dislocation is wrong, useless and barbarous. The main object of the executioner should be to adjust the noose in such a way as to close the windpipe at once, so as to produce immediate asphyxia. The condemned person should be raised from the place on which he is standing by pulling on the rope, which should pass over a pulley fixed to a beam above, and he should be allowed to hang for 30 minutes. The rope should be soft and flexible, so as to fit closely to the neck. Carried out in this manner, an execution by hanging will be effectually and mercifully performed. It would be better with persons weighing under 150 pounds to attach a weight to the feet, so as to ensure a sufficient degree of traction on the cord. It is supposed by many that the dislocation of the neck produces instant death; such, however, is by no means certainly the case. There are instances on record in which the vertebrae of the neck have been dislocated and recovery has taken place. Moreover, even when death does occur, it is no more instantaneous than when asphyxia is accomplished, and there is no greater freedom from convulsions."

If it's the best telecommunications system on earth, why on earth change it?

If you've ever tried to make a telephone call anyplace else on earth, you know what you've got in America. The best telecommunications system in the world.

But now you've heard the Bell System is on the verge of major changes. Changes in how we're organized. Changes in the way you can choose to do business with us.

Why change something that works?

There's a very good reason. The telecommunications business itself has changed.

For most of our history, the Bell System has had one overriding goal: universal service. Dependable telephone service at reasonable rates for everyone who wanted it.

Bolstering that goal were government policies determining that telephone companies would operate differently from most American companies. Within many areas of the country, we were to be the exclusive supplier of telecommunications services. And since the Bell System didn't operate in a competitive market, its rates and profits were strictly regulated by the government. But today the goal of universal service has been achieved. Over 96% of American households have telephone service.

Now regulators and legislators in this country are looking more to the marketplace and competition, rather than to regulation, to decide who will provide competitive services and equipment and how they will be priced. In part, this stems from an increasing sentiment in this country for the deregulation of major industries.

But perhaps most important is the fact that technology has changed the future of telecommunications. We are about to enter a new era–the Information Age. The technology of communications gradually has merged with that of computers. The marriage of these two technologies offers the potential for an impressive array of new customer services. However, the blending of these two technologies has also blurred the boundaries between a traditionally regulated industry–communications–and the unregulated data-processing industry.

The combination of all these factors has led to a rethinking of public policies on telecommunications. These changes will require some changes in the Bell System. But we can assure you that your telephone service will still be the best telecommunications system on earth.

Along with your local Bell telephone company, we'll be telling you about any changes as they occur. In ads like this.

In each of these ads you'll find a telephone number. That number is an important part of our "Let's Talk" program.

This program has been set up by the Bell System to help you understand exactly what the changes at the Bell System will mean for you right now. And in the future.

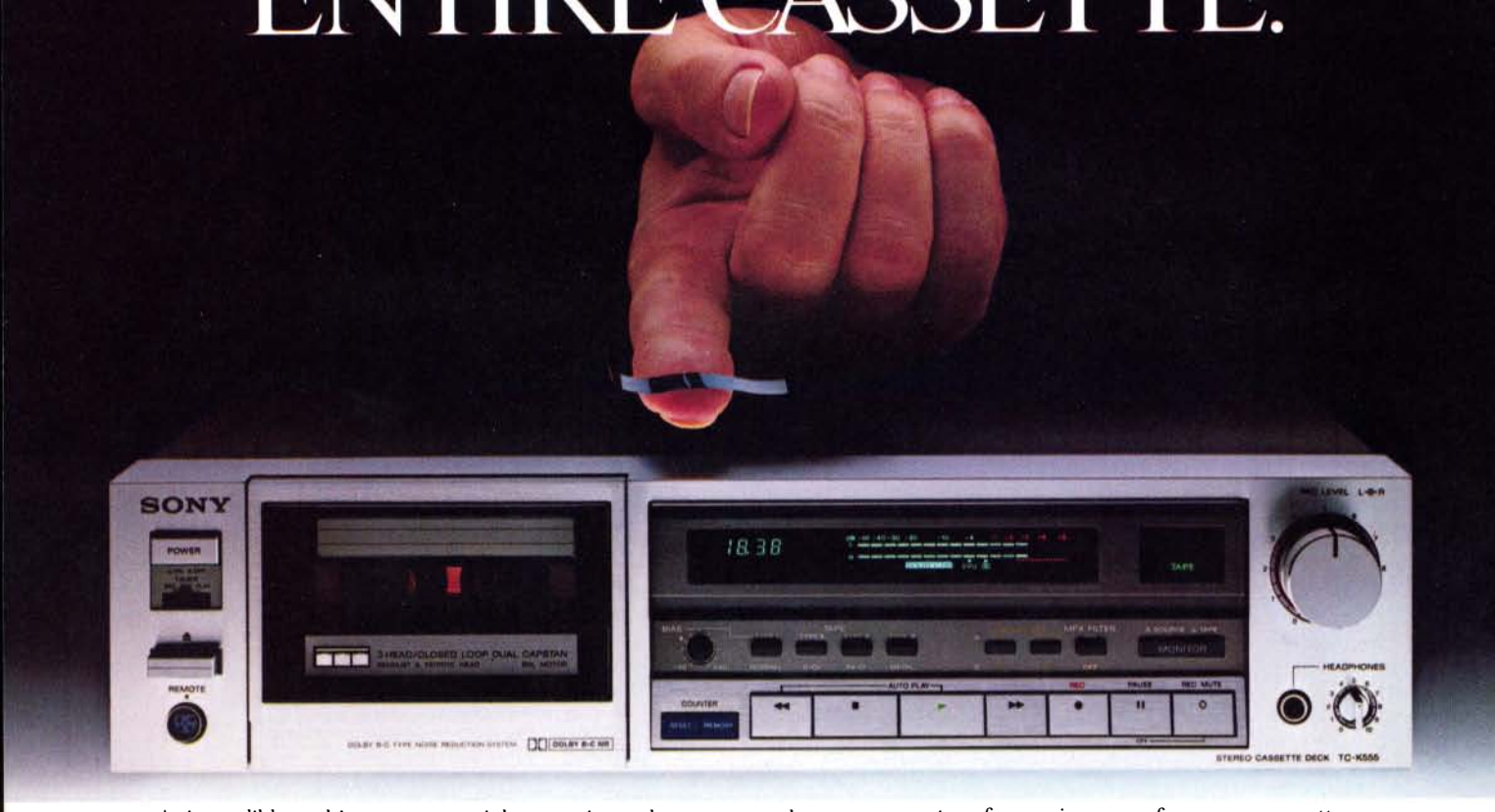
Call us. At 1 800 555-5000.

There'll be somebody to talk to. Somebody to help you. To answer your questions. To get you information.

So call us. **Let's talk.**

Bell System

SONY CAPTURES MORE MUSIC ON THIS MUCH TAPE THAN MOST RECORDERS DO ON AN ENTIRE CASSETTE.



As incredible as this statement might sound, it's absolutely credible.

Most cassette recordings just aren't faithful to the way the music was originally intended. Simply because they're made on two-head machines. And two-head machines compromise both the dynamic range and frequency response of the music. So you can listen to an entire cassette and never hear the most brilliant highs of a flute. Or the deep, rich, resonant lows of a bass.

The new Sony TC-K555 is without compromise.

Because there are three separate heads—one to erase, one to record and one to play back—each is optimized for its own specific function. So you hear the highest highs and the lowest lows. Or, to put it another way—you hear more music.

Now, others offer three-head decks, but only Sony offers a unique, Independent Suspension system. This remarkable system allows for incredible precision and consistency in head alignment and prevents the significant high-frequency loss caused by the alignment errors so prevalent in other systems.

And the K555 also includes closed-loop dual capstan drive for superior tape tension and reduced modulation noise. This results in not only crisper, cleaner, more precise sound, but exposes more tape to the heads. And the more tape exposed to the heads, the more music exposed to your ears.

The head design is equally unique. It's a combination of Sendust and Ferrite for maximum performance no matter what tape type.

And of course, three heads also give you the added benefit of instantaneous off-the-tape monitoring. It's one more assurance that the quality of the recorded music will be faithful to the quality of the original.

Other outstanding features: everything from Dolby's newest, most advanced noise reduction system, Dolby C,* to a state-of-the-art linear time counter which measures elapsed tape time in minutes and seconds, instead of inches.

So if sound is as important to you as it is to Sony, insist on the cassette deck that captures more music on an inch of tape than most decks can on a mile—the K555 from Sony.

FEATURES AND SPECIFICATIONS: Linear Counter of actual elapsed time. 16-segment Peak-Program Meters with maximum recording level indication. Optional RM-50 remote control, RM-80 wireless remote, RM-65 synchronizer. S/N ratio 61dB (type III tape, Dolby off). Wow & flutter 0.04% (WRMS). Frequency response 25Hz—18kHz ±3dB (metal tape). *Dolby is a registered trademark of Dolby Laboratories. Sony Corp. of America, Sony Drive, Park Ridge, NJ 07656. © 1982 Sony Corp. of America. Sony is a registered trademark of the Sony Corp.

SONY. The one and only.

THE AUTHORS

RANDALL FORSBERG ("A Bilateral Nuclear-Weapon Freeze") is director of the Institute for Defense and Disarmament Studies in Brookline, Mass. Her B.A. in English (1965) is from Barnard College. Since 1968 she has done theoretical and practical work on the nuclear arms race between the U.S. and the U.S.S.R. From 1968 to 1974 she was on the staff of the Stockholm International Peace Research Institute (SIPRI). Since 1972 she has been the author of the section on U.S. and U.S.S.R. nuclear weapons in the annual SIPRI volume on world armaments and disarmament. From 1974 to 1980 she was a graduate student in political science at the Massachussetts Institute of Technology. In 1980 she founded the Institute for Defense and Disarmament Studies. Forsberg wrote the first draft of the "Call to Halt the Nuclear Arms Race," which has become the central organizing document of the current Nuclear Freeze Campaign.

JOHN R. BEDDINGTON and ROBERT M. MAY ("The Harvesting of Interacting Species in a Natural Ecosystem") are biologists with an interest in the dynamics of natural populations. It is an interest that each of them arrived at by an unusual route. Beddington is a member of the faculty of the University of York. He is currently on leave and serves as senior fellow of the International Institute for Environment and Development in London and director of its Marine Programme. His B.Sc. and M.Sc. are from the London School of Economics and Political Science. His undergraduate training was in economics; his graduate work was in the philosophy of science and mathematical statistics. He then went to the University of Edinburgh, where he earned a doctorate for work on the population dynamics of the red deer in Scotland. Since obtaining his Ph.D. in 1973 he has been at York. May is Class of 1877 Professor of Zoology and chairman of the University Research Board at Princeton University. Born in Australia, he received his B.Sc. and Ph.D. from the University of Sydney in theoretical physics. After getting his doctorate he spent two years as Gordon Mackay Lecturer in Applied Mathematics at Harvard University before returning to Australia to join the Sydney faculty of physics. May moved to Princeton in 1973.

DAVID L. JONES, ALLAN COX, PETER CONEY and MYRL BECK ("The Growth of Western North America") are geophysicists with a common interest in what is called microplate tectonics. Jones is geologist with the Western region of the U.S. Geological Survey. His B.S. (1952) is from Yale University; his M.S. (1953) and Ph.D. (1956) are from Stanford University. His main scientific interests are the structure and paleontology of the rocks of the Pacific coast of western North America. Cox is dean of the School of Earth Science at Stanford. His bachelor's degree and doctorate in geophysics are from the University of California at Berkeley. Since earning his Ph.D. in 1959 he has worked for the U.S. Geological Survey or for Stanford, sometimes in combination. Coney is professor of geosciences at the University of Arizona. His B.A. (1951) is from Colby College; his Ph.D. in geology (1964) is from the University of New Mexico. Among his scientific interests are the regional tectonics of mountain systems, plate motion and the tectonics of Mexico and Alaska. Beck is professor of geology at Western Washington University. His bachelor's degree and master's degree in geology are from Stanford. After receiving his master's degree he worked for the Standard Oil Company of California and the U.S. Geological Survey before returning to get his Ph.D. at the University of California at Riverside in 1969; he went to Western Washington in the same year.

MARK PTASHNE, ALEXANDER D. JOHNSON and CARL O. PABO ("A Genetic Switch in a Bacterial Virus") are molecular biologists who did the work that is the basis of their article while all three were at Harvard University. Ptashne is professor and chairman of the department of biochemistry and molecular biology at Harvard. He was graduated from Reed College with a B.A. in chemistry in 1961. His Ph.D. in molecular biology was given by Harvard in 1968 and he has remained there since, becoming professor in 1971 and chairman in 1980. Johnson is postdoctoral fellow at the University of California at San Francisco. His bachelor's degree (1974) is from Vanderbilt University. He did graduate work in Ptashne's laboratory, earning his doctorate in 1980. Pabo is assistant professor of biophysics at the Johns Hopkins University School of Medicine. He also did graduate work with Ptashne, getting his doctorate in the same year as Johnson; he moved to Johns Hopkins this year.

KENZO ISHIKAWA ("Glueballs") is research physicist at the City College of the City University of New York. A native of Japan, he received his education in physics there, obtaining his B.S. at the Tokyo Institute of Technology in 1971 and his Ph.D. from Tohoku Uni-

A map of the Council of Scientific and Industrial Research Institutions published in the Special Report "Science and Technology in India" in the August issue of *Scientific American* showed the location of the various laboratories and research centers and did not reflect the official map of India.

No political significance was intended by any of the boundaries in the cartographers' drawing, commissioned by the author of the Report.

The map was not shown to the organizations that sponsored the Special Report.

The unintentional discrepancy is regretted.

Michael Frenchman
Author of Report

TEST DRIVE YOUR DISTRIBUTED CONTROL DREAM MACHINE.

Only Fisher offers 24 locations in North America and additional locations worldwide where you can get your hands on a distributed control system. Come put PRōVOX® instrumentation through its paces. Just a few minutes with a process control simulation and you'll know this is distributed control made as easy as it should be.

Easy-to-use interactive software gives you more flexibility than other systems. You customize the color graphics to display your process your way, not in some rigid, uncompromising format. And human engineering will put you at home with our system fast. When you see how expandable and cost effective PRōVOX is, you'll understand why Fisher is the leader in putting technology to work.

This is another example of why Fisher Controls is your total process control resource. Around the world, your Fisher representative can provide control room instrumentation, field measurement instruments, control valves and regulators. He can also help with application engineering, education and after-sale service. So call him to test drive your distributed control dream machine. Fisher Controls, P.O. Box 14755, St. Louis, Missouri 63178. (314) 694-9900.

FISHER®

THE NEW LOOK OF TOTAL PROCESS CONTROL.

CIMAR
CUTS THROUGH THE

GM

BEST OF ALL...IT'S A CADILLAC.

RON '83
IMPORT MYSTIQUE.

HOW CIMARRON '83 BEATS THE IMPORTS AT THEIR OWN GAME

	CIMARRON '83	AUDI 5000S	BMW 320i	VOLVO GL	SAAB 900S SEDAN
FRONT-WHEEL DRIVE	STANDARD	STANDARD	NOT AVAILABLE	NOT AVAILABLE	STANDARD
ELECTRONICALLY FUEL-INJECTED ENGINE*	STANDARD	STANDARD	STANDARD	STANDARD	STANDARD
FIVE-SPEED MANUAL INCLUDING OVERDRIVE	STANDARD	STANDARD	STANDARD	STANDARD 4-SPEED	STANDARD
TACHOMETER WITH FULL INSTRUMENTATION	STANDARD	EXTRA COST	STANDARD	STANDARD	STANDARD
POWER-ASSISTED RACK AND PINION STEERING	STANDARD	STANDARD	RACK AND PINION ONLY	STANDARD	STANDARD
EPA PASSENGER COMPARTMENT VOLUME	89 CU. FT.	90 CU. FT.	82 CU. FT.	89 CU. FT.	89 CU. FT.
TUNGSTEN HALOGEN FOG LAMPS	STANDARD	NOT AVAILABLE	EXTRA COST	NOT AVAILABLE	DEALER INSTALLED OPTION
ALUMINUM ALLOY WHEELS	STANDARD	STANDARD	EXTRA COST	STANDARD	STANDARD
AIR CONDITIONING	STANDARD	STANDARD	EXTRA COST	STANDARD	STANDARD
ELECTRONICALLY TUNED AM/FM STEREO RADIO	STANDARD (may be deleted for credit)	EXTRA COST	EXTRA COST	DEALER INSTALLED OPTION	DEALER INSTALLED OPTION
LEATHER-WRAPPED STEERING WHEEL	STANDARD	STANDARD	EXTRA COST	DEALER INSTALLED OPTION	NOT AVAILABLE
LEATHER SEATING AREAS	STANDARD	EXTRA COST	NOT AVAILABLE	STANDARD	NOT AVAILABLE
MSRP**	$12,215 (F.O.B.)	$13,665 (P.O.E.)	$13,440 (P.O.E.)	$13,905 (P.O.E.)	$13,555 (P.O.E.)

*Some Cadillacs are equipped with engines produced by other GM divisions, subsidiaries or affiliated companies worldwide. See your dealer for details. All imports shown are 1982 models.

**Manufacturer's Suggested Retail Price including dealer prep (where applicable) as of 9/23/82. Tax, license, destination charges and optional equipment additional. Destination charges vary by location and may affect comparison. Level of standard equipment varies.

Bold new performance. In '83 Cimarron sports a snappy new 2.0 liter electronically fuel-injected engine with a 5-speed manual transmission. (3-speed automatic is available.) Plus an exclusively tuned Touring Suspension, front-wheel drive and more.

Bold new look. There's a strong new grille treatment and tungsten halogen fog lamps. A proud new hood medallion. And crisp, new aluminum alloy wheels.

Plus Cadillac touches... Like body-contoured, leather-faced front bucket seats with lumbar support.

Air conditioning. Full instrumentation including tach. All standard. And available features like a new electronically tuned AM/FM stereo cassette radio with 5-band graphic equalizer.

Extraordinary value. Compare Cimarron '83 to any import in its class. Feature for feature. Sticker for sticker. Most of all, compare performance with a demonstration drive. See a Cadillac dealer soon.

versity in 1976. In 1977 he came to the U.S. as research physicist at the University of California at Los Angeles. He left in 1980 to serve in the same capacity at the Deutsches Elektronen-Synchrotron (DESY) laboratory in Hamburg. He returned to the U.S. earlier this year. In addition to the subject of Ishikawa's article, his scientific interests include gauge theories, the decay of the proton and magnetic monopoles.

DAVID CREWS and WILLIAM R. GARSTKA ("The Ecological Physiology of a Garter Snake") are biologists who share a particular interest in the physiology and behavior of snakes. Crews is associate professor of zoology at the University of Texas at Austin. His bachelor's degree (1969) is from the University of Maryland at College Park. He received his Ph.D. from Rutgers University in 1973. From 1973 to 1975 he was research associate at the University of California at Berkeley. In 1975 he moved to Harvard University; he left Harvard for Texas earlier this year. Garstka is assistant professor of biological sciences at the University of Alabama at Huntsville. His B.A. is from the University of California at Los Angeles. After eight years as a laboratory technician he went to Harvard, where he obtained his doctorate in 1982 for work on chemical communication among garter snakes.

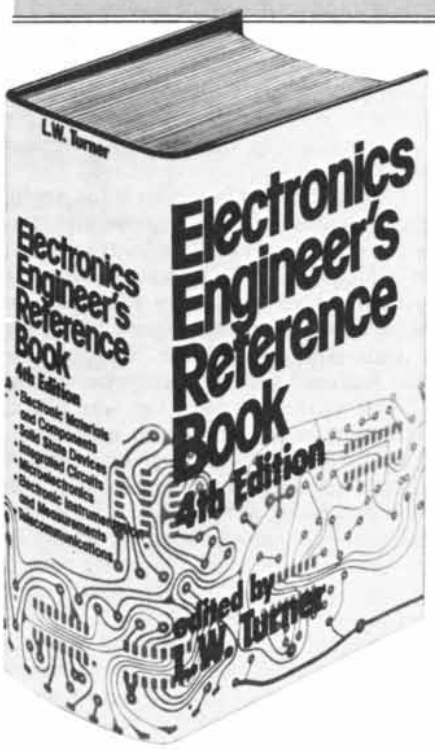
THOMAS D. ROSSING ("The Physics of Kettledrums") is professor of physics at Northern Illinois University. His B.A. is from Luther College; his Ph.D. in physics, granted in 1954, is from Iowa State University. After getting his doctorate he served for three years as research physicist at the UNIVAC division of the Sperry Rand Corporation. In 1957 he joined the faculty at St. Olaf College in Northfield, Minn.; he remained at St. Olaf until 1971, the last six years as chairman of the physics department. At the end of the period he went to Northern Illinois. He writes: "Although most of my research has been in solid-state physics, I have taught courses in musical acoustics for 25 years, and in recent years this has become my main area of research."

EDWARD R. LANDA ("The First Nuclear Industry") is a hydrologist with the water resources division of the U.S. Geological Survey. He received his undergraduate education at the City College of the City University of New York, from which he got his B.S. in geology. From 1970 to 1975 he attended the University of Minnesota, where he earned three degrees: his M.S. and his Ph.D. in soil science and his M.P.H. in radiological health. Landa's current work is on uranium mill tailings and the wastes left by radium extraction.

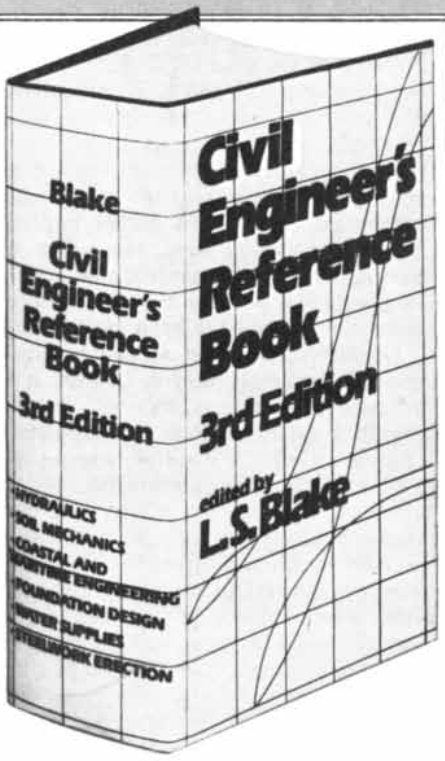
Take 1 of three Engineer's Reference Books for only $2.95

when you join any one of our three Professional Engineering Book Clubs—*the Electrical and Electronics Engineering Book Club, the Professional Civil Engineering Book Club* or the *Professional Mechanical Engineering Book Club.* Whichever club you join, you simply agree to buy 3 more books—at handsome discounts—within the next 12 months.

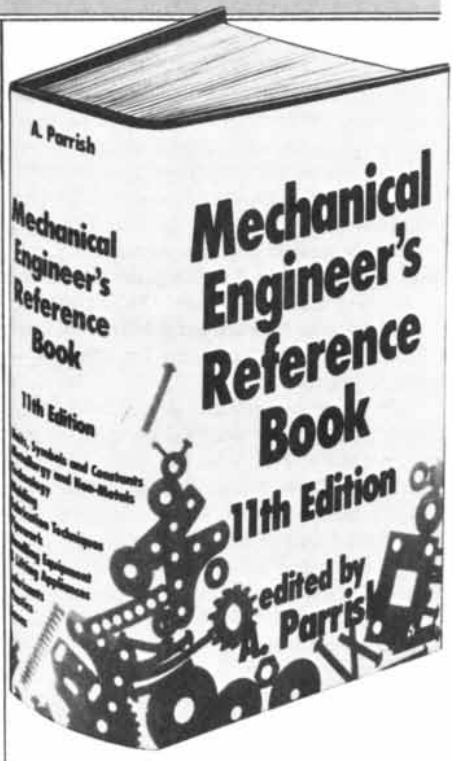
Each of the Professional Engineering Book Clubs provides a convenient and inexpensive way to improve your professional skills. The books we offer keep you up-to-date about new concepts, techniques and systems which are constantly being developed. Whichever field in engineering is your specialty—Electrical and Electronics, Civil or Mechanical—you can be sure that we have the ideas and answers to help you stay on top of your profession. So take the Engineer's Reference Book of your choice and join one of our three clubs.



44145-3. Electronics Engineer's Reference Book. *Edited by L.W. Turner.* Completely rewritten and updated. Includes chapters on electronic materials and components, solid state devices, integrated circuits, microelectronics, telecommunications, electromagnetic and nuclear radiation, sound and video recordings, and much more. 27 sections written by 62 contributors. 1600 pages.
Publisher's Price: $78.00



38250-3. Civil Engineer's Reference Book. *Edited by L.S. Blake.* Latest edition of this engineering classic. Concise chapters on mathematics and statistics, site investigation, hydraulics and surveying, soil and rock mechanics, sewage disposal, contract management and insurance. Current practices in design, structures and use of materials. Thousands of diagrams, charts, formulas, graphs and illustrations. 1800 pages.
Publisher's Price: $84.00



61655-3. Mechanical Engineer's Reference Book. *Edited by A. Parrish.* Revised and updated. Comprehensive description of theory and design data and fabrication of materials. Chapters on thermodynamics, fluid mechanics, metallurgy, lubricants, computers, productivity measurement, instrumentation and much more. Extensive symbols and abbreviations. Thousands of charts, diagrams, formulas and illustrations. 20 sections contributed by 37 engineering consultants. 1700 pages.
Publisher's Price: $79.95

4 Good Reasons to Join

1. The Finest Books. Of the hundreds and hundreds of books submitted to us each year, only the very finest are selected and offered. Moreover, our books are always of equal quality to publishers' editions, *never* economy editions.

2. Big Savings. In addition to getting the Engineer's Reference Book of your choice for only $2.95 when you join, you keep saving substantially up to 30% and occasionally even more. (For example, your total savings as a trial member—including this introductory offer—can easily be over 50%. That's like getting every other book free!)

3. Bonus Books. Also, you will immediately become eligible to participate in our Bonus Book Plan, with savings of up to 70% off the publishers' prices.

4. Convenient Service. At 3-4 week intervals (16 times a year) you will receive the Book Club News, describing the Main Selection and Alternate Selections, together with a dated reply card. If you want the Main Selection, do nothing and it will be sent to you automatically. If you prefer another selection, or no book at all, simply indicate your choice on the card, and return it by the date specified. You will have at least 10 days to decide. If, because of late mail delivery of the News, you should receive a book you do not want, we guarantee return postage.

If reply card has been removed, please write to **Professional Engineering Book Clubs, Dept. ___-AF2 Riverside, N.J. 08075 to obtain membership information and an application.**

METAMAGICAL THEMAS

"Default assumptions" and their effects on writing and thinking

by Douglas R. Hofstadter

A father and son were driving to a ball game when their car stalled on the railroad tracks. In the distance a train whistle blew a warning. Frantically the father tried to start the engine, but in his panic he couldn't turn the key, and the car was hit by the onrushing train. An ambulance sped to the scene and picked them up. On the way to the hospital the father died. The son was still alive but his condition was critical, and he needed immediate surgery. The moment they arrived at the hospital he was wheeled into an emergency operating room, and a surgeon came in, expecting a routine case. On seeing the boy, however, the surgeon blanched and muttered, "I can't operate on this boy—he's my son."

What do you make of this grim riddle? How could it be? Was the surgeon lying or mistaken? No. Was the dead father's soul somehow reincarnated in the surgeon's body? No. Was the surgeon the boy's true father and the dead man the boy's adoptive father? No. What, then, is the explanation? Think it through until you have figured it out on your own—I insist! You'll know when you've got it, don't worry.

When I was first asked this riddle a few years ago, I got the answer within a minute or so. Still, I was ashamed of my performance. I was also disturbed by the average performance of the people in the group I was with—all educated, intelligent people, some men, some women. I was neither the quickest nor the slowest. A couple of them, even after five minutes of scratching their heads, still didn't have the answer. And when they hit on it, their heads hung low.

Whether we light on the answer quickly or slowly, we all have something to learn from this riddle. It reveals something deep about how "default assumptions" permeate our mental representations and channel our thoughts. A default assumption is what holds true in what you might say is the "simplest" or "most natural" or "most likely" possible model of whatever situation is under discussion. In this case the default assumption is that the surgeon is a man. The way things are in our society today that is the most plausible assumption. But the critical thing about default assumptions (well revealed by this story) is that they are made automatically, not as a result of consideration and elimination. You did not explicitly ponder the point and ask yourself: What is the most plausible sex to assign to the surgeon? Rather, you merely let your past experience assign a sex for you. Default assumptions are by their nature implicit assumptions. You were not aware of having made any assumption about the surgeon's sex, because if you had been, there would not have been any riddle.

Usually reliance on default assumptions is extremely useful. In fact, it is indispensable in enabling us—or any cognitive machine—to get around in this complex world. We simply cannot afford to be constantly distracted by all kinds of theoretically possible but unlikely exceptions to the general rules or models we have built up by induction from many past experiences. We have to make what amount to shrewd guesses, and we do it with great skill all the time. Our every thought is permeated by such shrewd guesses—assumptions of normalcy. The strategy seems to work pretty well. For example, we assume that the stores lining the main street of a town we pass through are not just cardboard facades, and for good reason. Probably you are not worried about whether the chair you are sitting on is going to collapse. Probably the last time you used a saltshaker you did not consider that it might be filled with sugar. Without much trouble you could name dozens of assumptions you are making at this very moment, all of which are *probably* true rather than *definitely* true.

This ability to ignore what is highly unlikely—without even considering whether or not to ignore it—is part of our evolutionary heritage, coming out of the need to be able to size up a situation quickly but accurately. It is a marvelous and subtle quality of our thought processes. Once in a while, however, this marvelous ability leads us astray. Sexist default assumptions are a case in point.

When I wrote my book *Gödel, Escher, Bach: an Eternal Golden Braid,* I employed the dialogue form, a form I enjoy very much. I was so inspired by Lewis Carroll's dialogue "What the Tortoise Said to Achilles" that I decided to borrow his two characters. Over a period of time I developed them into my own characters. As I proceeded I found I was naturally led to bring in some new characters of my own. The first one was the Crab. Then came the Anteater, the Sloth and various other colorful individuals. Like the Tortoise and Achilles, the new characters were all male: Mr. Crab, Mr. Sloth and so on.

That was in the early 1970's, and I was quite conscious of what I was doing. Yet for some reason I could not get myself to invent a female character. I was upset with myself, yet I could not help thinking that introducing a female character "for no reason" would be artificial and therefore distracting. I did not want to mix sexual politics—an ugly real-world issue—with the ethereal pleasures of an ideal fantasy world.

I racked my brains about it for a long time. I even wrote an apologetic dialogue on this very topic, an intricate one in which I myself figured, discussing with my own characters the question of sexism in writing. Apart from my friends Achilles and the Tortoise, the cast featured God as a surprise visitor, and as in the old joke she was black. Although corny, it was an earnest attempt to grapple with some problems of conscience that were plaguing me. The dialogue never got polished, and it was not included in my book. A series of reworkings, however, gradually turned it into the "Six-Part Ricercar" with which the book concludes.

My pangs of conscience did lead me to make a few minor characters female: there were Prudence and Imprudence (who argued briefly about consistency), Aunt Hillary (a conscious ant colony) and every other member of the infinite series Genie, Meta-genie, Meta-meta-genie and so on. I was particularly proud of this gentle touch, but no matter how you slice it females got the short end of the stick. I was not altogether happy with it, but that's the way it was.

In addition to the book's dialogues being populated with male characters, it was filled with default assumptions of masculinity, the standard "he" and "his" always being chosen. I made no excuse for this. I gave my reader credit for intelligence; I assumed he would know that often occurrences of such pronouns carry no gender assumptions but simply betoken a "unisex" person.

Over a period of time, however, I have gradually come to a different feeling about how written language should deal

Profile by Andrew Hargrave

Metallgesellschaft streamlining its worldwide operations.

Metallgesellschaft (MG) ranks as the 17th largest West German corporation according to the latest Fortune listing. Its worldwide sales rose to DM 11.3 billion in the year ended September 30, 1981, 20 percent up on the previous year. However, profits declined slightly from their relatively modest level, to DM 34 million, a reflection of the worldwide economic recession. For MG is an international concern, involved among others in non-ferrous metals and ores which bore the brunt of the recession.

The MG Board regards the current situation as temporary, but also as a challenge. Its strategy is to simplify as well as update a complex product, sales and services pattern which has grown up during the 101 years of MG's existence. At the same time, it still intends to stick to the original concept of its founder, British-born William Merton: To marry technology, ingenuity and cash through long-term contracts with producers rich in raw materials but lacking these essentials of development.

The strategy is in the process of being implemented. "Once it bears fruit," says an executive board member, "we'll no longer be a diffuse conglomerate but a highly effective and competitive force."

Headquartered in Frankfurt, in the heart of West Germany, Metallgesellschaft is still a highly diversified corporation, its business ranging from the exploration, mining, processing and marketing of non-ferrous ores and metals to energy utilization and conversion, plant engineering, metal fabrication, automotive components, chemicals and transportation.

MG is directly represented in over 30 countries with one in six of its total staff of around 27,000 employed abroad. A substantial proportion of the Group's activities is based on high technology which is reflected in the large ratio – two in five – of white-collar staff. Its international character is further underlined by the high proportion of income generated outside West Germany, 58 percent of total worldwide sales in 1980/81.

Karl Gustaf Ratjen, Chairman

As the corporation's success in times good and bad is based on the appreciation of situations and developments which are global rather than domestic in character, an essential ingredient is the quality of the people it employs. At the same time, the "thinkers" – managers, scientists, technologists, researchers, engineers, geologists, chemists, marketing and financial specialists – carefully selected to carry out the strategic objectives of the corporation, also have to act as a team. Compatibility of action – a viable interface in all activities – is one of MG's top priorities.

They are "a unique combination of raw materials knowledge allied to specific sector or project work, academic and/or top management training and international experience." They must be able to identify and develop natural resources, with the application of high technology but also at low cost, as much as construct financial models and marketable products.

The strategy of "slimming," in terms of both personnel and products, has included running down or even closing works such as the Frankfurt works of the old-established metal fabrication unit of Vereinigte Deutsche Metallwerke (VDM) earlier this year with 1,700 jobs. Others are being trimmed or offered for sale or equity participation.

In other sectors and geographical areas, including the United States, the plans are for expansion. There is to be increasing concentration on sectors where MG expertise is expected to yield dividends – non-ferrous ores and metals, energy production, utilization, conversion and conservation as well as plant engineering.

In all these operations the associate company Lurgi, well known and respected worldwide as an innovator, designer and constructor of process plant in the energy, metals, chemicals, petrochemicals and environmental field, is playing a key role. In 1980/81, Lurgi achieved "a marvelous result, its best ever", according to Metallgesellschaft executive board chairman, Karl Gustaf Ratjen. He warned though that this happy situation reflected the abundance of orders of earlier years rather than current ones. MG's strategic concept also provides for as complete a "package" in individual projects as possible, covering the whole sequence of operations from raw material exploration, mining, processing, smelting to marketing and finance so as to ensure a high degree of operational control, even though in almost every case MG is associated with a partner or partners to take account of local interests and susceptibilities as well as to spread risks.

Many of these packages involve North American locations and/or associations through equity participation, licensing, exchange of knowhow, etc. That is why a high-powered trading unit is being built up in New York to provide the international backup to MG's – and Lurgi's – advanced process technology.

Indeed, technology is believed by MG to be the ace in its deck, a matter of high priority in its strategic concept. Raw material exploration, mining, processing and trading, are generally very capital intensive and, at the same time, risky. Technological knowhow limits costs and is consequently of utmost significance not only to MG but its partners in enterprise, often developing or newly independent countries.

The quality of feasible as well as potentially profitable "packages" is also vital in terms of bringing into production natural resources lying idle because of remoteness and lack of infrastructure in the country concerned. The absence of skills normally available in advanced industrial countries is as much an obstacle to development as that of an efficient transportation network and services.

This is a problem which the industrialized world is increasingly having to face as existing, more accessible raw material resources dry up and scarcity threatens. It is one that Metallgesellschaft has to confront head on by the very nature of its business.

GERMAN INNOVATION

Moving ahead in North America.

The streamlining of the complex Metallgesellschaft structure is taking place within five corporate divisions – natural resources, manufacturing, plant engineering and contracting, chemicals and transportation – as well as several operating sub-divisions. And even after the "diffuse conglomerate" has been streamlined into what an executive calls "a competitive force," MG will, by the very nature of its business, remain a fairly complex organization requiring coordination at all levels between the corporate and operating divisions as well as foreign branches, representative offices and minority holdings in 60 centers, in over 30 countries spread over five continents.

The trend certainly is for further internationalization, with emphasis on North America where MG links go back to 1887, only six years after the birth of the company. It was then that the founder William Merton set up in New York, in partnership with his brother Henry and a US banking associate, the American Metal Company, forerunner of the present Amax Corporation. AMC, like MG, dealt in the exploration, mining, smelting and trading of non-ferrous metals until it was confiscated during World War I. The same happened to the new MG offshoot, the Ore & Chemical Corporation in World War II, with the important difference that this time it was recreated under the same title in 1951.

Today MG and its associate companies, Lurgi, VDM and Karl Schmidt – especially Lurgi – have a firm and growing foothold in the North American market through Metallgesellschaft Corporation, both as explorers, producers and traders in metals and as organizers, often in partnership with domestic interests, of funding projects.

At present nearly 1,000 of Lurgi's 5,500 employees work abroad, including hundreds in North America. In the US, Lurgi's subsidiary, American Lurgi, was converted into the full-blown Lurgi Corporation in October 1979.

There were several options to strengthen Lurgi's US presence, including participation in a large US concern, the takeover of a smaller one or the establishment of an entirely new company. In the event, the decision to combine the process knowhow of the parent in Frankfurt with US project management, strongly oriented toward American markets (North, Central and South), prevailed. The temporary collapse of oil prices and the new US Administration's decision to free natural gas prices have certainly not helped the new Lurgi setup. One of Lurgi's strongest lines, perhaps the strongest – coal gasification, liquification and the production of coal-based chemicals – is linked to the comparative prices and availability of energy sources and fuels. Its major expansion over the past decade owes as much to its advanced technology as to its reputation as an engineering constructor.

However, the presence of vast natural resources in oil and gas substitutes, including oil shale, tar sands as well as coal, make North America an ideal market place for Lurgi technology in the longer term.

An example is the demonstration plant based on the Lurgi-Ruhrgas (LR) process of converting shale and sands into crude oil and gas. The plant delivered to Getty Oil at Bakersfield operates on the basis of diatomite, and has been running satisfactorily since the end of last year. The introduction of commercial versions will surely come when, as expected, crude prices rise once again. Another important contract awarded to Lurgi is a major synfuel (SNG) project for American Natural Gas, a subsidiary of American Natural Resources.

The range of Lurgi's substantial order book (valued at over DM 4 billion) shows the wide ramifications of its technological base. It includes methanol plants in Indonesia, Malaysia and East Germany; coal-based direct reduction iron ore plants in South Africa and New Zealand; a pesticide project in the Soviet Union; a fatty acid/alcohol plant in the Philippines as well as others involving dust filtering, coal gas desulphurization and effluent disposal.

Altogether, 85 percent of Lurgi's contracts (in value) originate outside West Germany, no less than 55 percent in the less charted waters of OPEC, developing countries and Eastern Europe. Put another way, nearly half the total order book originates in Australasia, China and Southeast Asia as well as Australia and New Zealand. The opportunities are high but so are the risks. The varying levels of skills and infrastructure and, above all, the financing of projects which, in spite of the plethora of development aid available from national and international agencies, depends in the final analysis on the financial viability of the borrowing country.

Lurgi is designing and building plant in more than 70 countries and is directly represented in 23. It runs about 100 pilot plants in Frankfurt, the nerve center of Lurgi as well as MG, has installed around 30 large demonstration plants, such as Bakersfield, all over the world and employs nearly 400 qualified research people, almost 10 percent of the total staff in Frankfurt – scientists, technologists, including chemists, physicists, geologists, mineralogists, engineers, mathematicians, environmental experts.

Lurgi's experience in energy technology goes back at least 60 years and one of its outstanding practical demonstrations is the huge SASOL project in South Africa: for gasifying and liquifying cheap domestic coal (to make the country more independent from imported oil) to produce synthetic fuels and chemicals. After many years of successful operation of stage one at Sasolburg, stage two and three in Secunda have now been completed, working up to a throughput of 30–32 million tons of coal in all three stages together.

The attitude of the MG Board toward the present difficulties in the US – which include some shelvings and postponements of contracts – is that basically Lurgi's objectives are long-term and that its strong points in technology are precisely those which distinguish it from US competitors. In other words, MG as a whole is confident about the future of its North American operations.

Methane-Reforming Plant – Part of the World's largest Oil-from-Coal-Plant.

Metallgesellschaft at work around the world.

MITTERSILL

Up to a decade or so ago, the Puster Valley (Pustertal) in the Tyrolean Alps of Austria was a boon for mountaineers but little else. Although the existence of valuable tungsten deposits had been well known at heights of 1,500 meters to 2,500 meters above sea level, they had been virtually inaccessible until the building of a tunnel through the mountains. It was then that a Metallgesellschaft "package" was put together involving several divisions of the corporation as well as the Austrian metal concern Voest-Alpine, with a smaller stake for the specialist Teledyne Inc. of Los Angeles.

The opencast mine, developed by an MG team at 1,850 meters to 2,100 meters above sea level, is the first tungsten mine in Austria. MG is also responsible for the overall project management which includes the flotation plant at Mittersill about 7.5 miles away but at a level 1,000 meters below, producing a 30% ore concentrate.

The product is then ferried to a refinery (built by Lurgi) at Bergla, in Styria, a further 210 miles away where it is converted into tungsten powder.

The tungsten deposits, believed to be among the largest in the world, are estimated at 2.5 million tons of which about half is suitable for opencast mining. The eventual annual yield should reach 250,000 tons.

NANISIVIK

A lead-and-zinc mine, 430 miles north of the Canadian Arctic Circle, is a prime example how far exploring enterprise has to go in search of raw materials. Metallgesellschaft's annual purchases amount to about 800,000 tons of various concentrates. Thus prospecting, exploration and investment are to some extent guaranteed by internal disposal of the ore produced.

At Nanisivik, site of one of the first Arctic lead-and-zinc mines, a new community of 350 has been created together with such facilities as a school, health center, supermarket, police and airstrip.

In the mining company itself the Canadians, including the Government, have a majority stake, with MG Canada holding 11.25 percent of the shares. The Canadian subsidiary is also linked with the domestic exploration company Teck through a 20 percent holding in various projects, including molybdenum in British Columbia and copper-nickel in Ontario.

OK TEDI

Across the world, in the southern hemisphere, Metallgesellschaft is involved in what are believed to be among the largest copper deposits in the world, in Papua New Guinea. West Germany consumes 10 percent of the world's copper, and MG and its partners have an option to 50 percent of the mine's output. The $ 1.5 billion project, now in the course of development, will produce its first yield in 1984 when the "Gold Cap" is sheared off. The first copper is expected to be delivered in 1986.

MG leads the German section (which holds 20 percent of the Ok Tedi company's equity) of an international consortium which also includes the independent state of Papua New Guinea, BHP Minerals Pty. Ltd., Australia, one of the world's largest mining and mineral concerns, and Amoco Minerals Co, subsidiary of Standard Oil of Indiana. MG also played a majorrole in reviving the project abandoned by the U.S. Kennecott Corporation because of the risks associated with mining in the tropics many hundreds of miles from a road network, absence of infrastructure and political uncertainties about a young state.

The complex deal to finance the project (in which MG played a significant part) involves the Federal Government and development agencies as well as financial institutions in the U.S., West Germany, Australia, Britain, Canada and Austria.

SONG TOH

Metallgesellschaft had been a customer since 1953 of lead from a surface mine at Song Toh in the tropical rain forest near the Thai-Burma border. The owners, the Kleepbua family, lacked the resources – funds, and mining expertise – to exploit the considerable underground lead and zinc deposits in the area, all of which MG, with Federal Government backing, was prepared to supply.

Metallgesellschaft is a leading member of the London Metal Exchange

Today Song Toh is the biggest and most modern underground mining project in Thailand and probably in the whole of Southeast Asia, targeted to produce 22,000 tons of lead and zinc concentrates a year, 50 percent more than last year.

The project involves close cooperation with the Kleepbua family (which holds 51 percent of the equity) and other local interests, including Thai bank guarantees: also a step-by-step approach to problems of geology, mining technology, trading and financing to suit local customs, habits and traditions.

QSL

An example of a completely different kind is the new lead refining process QSL which combines the needs of environmental protection with the economical production of the metal. Recently inaugurated at MG's smelter at Duisburg, in the Ruhr, it was **L**urgi (the 'L' in QSL) which converted the ideas of the Canadian metallurgist Professor **Q**ueneau – who first approached Lurgi in 1952 – and Prof. **S**chumann into reality. The process, however, was patented in 1973; a pilot plant, with support from the Federal Ministry of Research and Technology, was followed by a demonstration plant.

To spread the cost of a full-scale commercial plant (the preliminaries had already cost $ 8.4 million), MG is associated in the $ 9.6 million project with the energy and raw materials corporation Preussag which also cooperates in providing the expertise for the practical application of this low-pollution, energy-saving (it saves 30 percent of the energy required per ton of lead produced) and generally economical leadmaking process. The project also demonstrates the capacity of the MG-Lurgi association to achieve a strong position in the market as a producer – in mines and smelters – as an engineer in plant construction, and as a trader in concentrates and metals.

Metallgesellschaft Services, Inc.
605 Third Avenue, New York, N.Y. 10158,
Tel.: (2 12) 4 90-21 42, Tx.: 621 095

Metallgesellschaft AG,
Reuterweg 14, D-6000 Frankfurt/Main,
Tel.: (6 11) 1 59-22 31, Telex: 4 125-0

with people of unspecified sex, or with supposedly specific but randomly chosen people. It is a subtle issue, and I do not claim to have the final answers by any means, but I have found some approaches that please me and that may be useful to other people.

What woke me up? Given that I was already conscious of the issues, what new element did it take to induce the shift? Well, one significant incident was the telling of that surgeon story. My own reaction to it and the reactions of my companions surprised me. Most of us manufactured all kinds of bizarre alternative worlds instead of imagining one in which a surgeon could be a woman. How ludicrous! The event emphasized for me how deeply ingrained our default assumptions are and how unaware of them we are. This seemed to me to have potential consequences far beyond what one might naively think. I am hardly one to believe that language "pushes us around," that we are its slaves, yet on the other hand I think we must do our best to rid language of usages that may induce or reinforce default assumptions in our minds.

One of the vividest examples of this came a couple of years after my book had been published. I was describing its dialogues to a group of people and said I regretted that the characters had all been male. One woman asked me why, and I replied, "Well, I began with two males—Achilles and the Tortoise—and it would have been distracting to introduce females seemingly for no reason except politics." Yet as I heard myself saying this a horrifying thought crept into my mind for the first time: How did I know that Carroll's Tortoise was really a male? Surely he was, wasn't he? I seemed to remember it very well.

And yet the question nagged at me. Since I had a copy of the Carroll dialogue ready to hand, I turned to it for verification. I was nonplussed to find that Carroll nowhere even hints at the sex of his Tortoise. In fact, the opening sentence runs: "Achilles had overtaken the Tortoise, and had seated himself comfortably upon its back." This is the only occurrence of "it"; from there on "the Tortoise" is what Carroll writes. "Mr. Tortoise" indeed! Was this entirely a product of my own defaults?

Probably not. The first time I had heard about the Carroll dialogue many years earlier someone—a male—had described it to me. This person very likely had passed *his* default assumption on to me. Hence I could claim innocence. Moreover, I realized, I had read a few responses in philosophy journals to the Carroll dialogue, and when I went back and looked at them, I found they too had featured a "sexed" Tortoise, in contrast to the way Carroll himself had carefully skirted the issue. Although I felt somewhat exonerated, I was still upset. I kept on asking myself: What if I had visualized a female Tortoise to begin with? Then what would *Gödel, Escher, Bach* have been like?

One thing that had dissuaded me from using female characters was the distractingly political way some books have of referring to the reader or briefly mentioned random people (such as "the student" or "the child") as "she" or "her." It stuck out like a sore thumb, and it made one think so much about sexism that the main point of the passage often went unnoticed. It seemed to me such a strategy might be too blunt and simplistic and could turn many people off.

And yet I could not agree with the attitude of some people, largely but by no means exclusively men, who refused to switch their usage on grounds of "tradition," "linguistic purity," "beauty of the language" and so on. To be sure, words such as "fireperson," "snowperson," "henchperson" and "personhandle" are unappealing, but they are not your only recourse.

In the introduction to Robert Nozick's *Philosophical Explanations,* an exciting and admirable book on philosophy, I came across the following footnote: "I do not know of a way to write that is truly neutral about pronoun gender yet does not constantly distract attention—at least the contemporary reader's—from the sentence's central content. I am still looking for a satisfactory solution." From this point on Nozick uses "he" and "him" nearly everywhere. My reaction was annoyance: could Nozick have really looked very hard? Part of my annoyance was undoubtedly due to my own guilt feelings for having done no better in my book, but some was due to my feeling that Nozick had failed to see a fascinating challenge here, one to which he could bring his philosophical insight and in so doing make a creative contribution to society.

As best I can remember, I first began seriously trying to "demasculinize" my prose in working on the dialogue on the Turing Test that eventually wound up as this column for May of last year. I wrote the dialogue with the sexes of the characters shifting fluidly in my mind, since I was modeling the characters on mixtures of people I knew. I always imagined the character I most agreed with more as being female than as being male, and the others vacillated.

One day it occurred to me that the beginning of the dialogue discussed Turing's question "Can you in principle tell, merely from a written dialogue, a female from a male?" The question applied so well to the very characters discussing it that I could not resist making some character "ambisexual"—ambiguous in terms of sex. Thus I named one of them "Pat." Soon I realized there was no reason not to extend this notion to *all* the characters in the dialogue, making it a real guessing game for readers. So were born "Sandy," "Chris" and "Pat."

Writing that dialogue was a turning point for me. Even though its total sexual equality had been motivated by my desire to give the dialogue an interesting self-referential twist, I found that I was relieved to have broken out of the all-male mold I had earlier felt locked into. I started looking for more ways to make up for my past default sexism.

It was not easy, and it still is not. For example, in teaching classes I find myself wanting to use "she" to refer back to an earlier unspecified person—a random biologist, say, or a random logician. Yet I find it does not seem to come out of my mouth easily. What I have trained myself to do rather well is to avoid gender-laden pronouns altogether, thus, like Carroll, "skirting" the issue. Sometimes I just keep repeating "the logician," or perhaps I just say "the person" or "that person." Every once in a while I say "he or she" (or "he" or "she"), although I have to admit I often simply say "they."

Someone who, like me, is trying to eliminate gender-laden pronouns from their speech altogether can try to rely on the word "they," but they will find themself in quite a pickle as soon as they try to use any reflexive verbal phrase such as "paint themselves into a corner," and what is worse is that no matter how that person tries they will find that they cannot extricate themself gracefully, and consequently he or she will just flail around, making his or her sentence so awkward that s/he wis/hes s/he had never become conscious of these issues of sexism. Obviously using "they" just takes you out of the frying pan into the fire, since you have merely exchanged a male-female ambiguity for a singular-plural ambiguity. The only advantage to this ploy, I suppose, is that there is/are, to my knowledge, no group(s) actively struggling for equality between singular and plural.

One possible solution is to use the plural exclusively, to refer, for example, to "biologists" or "a team of biologists," never just "a biologist." That way "they" is always legitimately referring to a plural. This, however, is a poor solution, since it is much more vivid to paint a picture of a specific individual. A body cannot always deal in plurals.

Another solution, somewhat more pleasing, is to turn an impersonal situation into a more personal one by using the word "you." This way your listeners or readers are encouraged to put themselves in the situation, to experience it vicariously.

Sometimes, however, this can backfire on you. Suppose you are talking about the strange effects in everyday life that statistical fluctuations can produce. You might write something like this: "One

THE FIRST KNOWN EXAMPLE OF A CAR EVALUATING ITS DRIVER.

Until now, timetables for routine automobile maintenance have overlooked one important and unpredictable factor: the person behind the wheel.

Obviously, someone who drives mostly on crowded city streets places different stresses on a car than someone who drives mostly on uncluttered highways. Differences in driving techniques (such as how hard one accelerates) are also a factor.

Which is why BMW engineers have developed the Service Interval Indicator—a computer-governed system based on the obvious fact that different people drive differently.

MAN AND MACHINE: IMPROVING COMMUNICATIONS.

With the aid of electronic sensors, the Service Interval Indicator monitors individual variations in driving habits and environments—as measured by engine speeds, the number of cold starts, and miles driven.

It then processes this information, and calculates when service is warranted—according to how the car is actually driven, not the dictates of an arbitrary schedule.

But BMW's aren't only engineered to evaluate their drivers.

They're also engineered to evaluate themselves.

TAPPING AN ALTERNATIVE SOURCE OF ENERGY: INFORMATION.

Another BMW innovation called Digital Motor Electronics constantly monitors the engine. It uses microprocessors to read all types of engine data—such as idling speed, air/fuel mixture, and throttle openings—and assures that fuel ignition occurs at the optimum moment.

And yet another BMW innovation monitors developments in other places. The On-Board Computer provides everything from outside temperature readings to anti-theft protection.*

The reason for this abundance of technology?

Simply that at BMW, one of our major preoccupations has always been heightening man's interaction with machine.

And all these improvements in communications are machine's latest contributions to that end.

THE ULTIMATE DRIVING MACHINE.

BMW, MUNICH, GERMANY.

*Optional on the 528e. Otherwise, all features discussed are standard on all 6-cylinder BMW's. ©1982 BMW of North America, Inc. The BMW trademark and logo are registered trademarks of Bayerische Motoren Werke, A.G

If you have an original, imaginative, innovative idea...

The Rolex Awards for Enterprise have one aim. To provide financial aid for projects which seek to break new ground in their particular sphere and which capture the spirit of enterprise shown by Rolex and Rolex owners.

These four Rolex Laureates are just some of the winners from the previous Rolex Awards for Enterprise.

From captive breeding to hormone research.

BILL LASLEY

So rapidly are the world's rain forests disappearing that many species of birds face extinction. Bill Lasley from America was

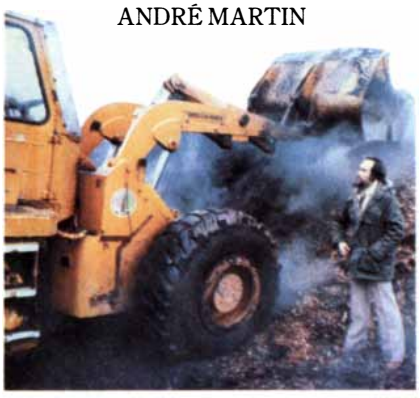
granted his Rolex Award for Enterprise to enable him to develop his ground-breaking research in the captive breeding of such species.

Bill Lasley's laboratory procedures now provide a basis for appraising and increasing the reproductive chances of a wide range of exotic species.

More recently Lasley has developed new methods of investigating estrogens, and the effect these hormones have on health and disease.

Safer forests; fertile land.

ANDRÉ MARTIN



Every year thousands of acres of land are ravaged by forest fires, and are then eroded by the elements.

André Martin from France has developed a method of clearing forests of fire-prone dead wood and scrub; then converting these forest wastes into organically rich humus which can be used to re-fertilise the land.

André Martin's Rolex Award for Enterprise is just reward for a highly original and practical solution to this environmental problem.

Save the Sperm Whale.

MILAN MIRKOVIC

Milan Mirkovic from Australia has created a unique method for growing the Jojoba plant. The Jojoba nut contains an oil almost identical in properties to that obtained from Sperm Whales.

Milan Mirkovic's idea involves the use of a special planting method which will help the Jojoba thrive in hot and arid deserts without the need for costly, traditional irrigation methods.

His Rolex Award for Enterprise will enable Milan Mirkovic to develop, refine and expand this brilliant idea which could save the Sperm Whale from possible extinction.

Recording European cave painting.

LUC DEBECKER

Luc Debecker is a Belgian living in Switzerland.

For ten years he has been painstakingly documenting the paleolithic cave paintings of Europe. When it is completed, Debecker's project will help us begin to understand how and why prehistoric man created these underground art galleries 40,000 years ago.

Luc Debecker's Rolex Award for Enterprise has allowed him to take time off from his job and buy essential equipment. Eventually he will publish a book of his findings and fascinating discoveries.

Your entry is now invited for the next Rolex Awards for Enterprise.

Enter The Rolex Awards for Enterprise and help make it a reality.

Originality; imagination, and innovation. Ideas displaying these qualities have always been at the heart of the success of Rolex themselves.

In 1926, Rolex perfected the Oyster case making possible the world's first truly waterproof wristwatch.

Then came the forerunner of all modern self-winding wristwatches, the Rolex Perpetual rotor mechanism.

Then the first wrist chronometer displaying both the day and the date.

Then the first specialised watch for deep-sea divers.

Achievements made possible by individual initiative, technical expertise and imagination. A policy Rolex will always pursue.

250,000 Swiss Francs for real help and assistance.

Rolex would now like to assist pioneers in their own fields of study with this third Rolex Awards for Enterprise.

Five self-motivated people with the imagination and initiative to start their own original projects will each receive an award of 50,000 Swiss Francs to further their ideas. In addition, each will receive a specially inscribed gold Rolex Chronometer.

The project should be in one of three categories:
Applied Sciences and Invention;
Exploration and Discovery;
The Environment.

A distinguished international committee has been specially selected to judge the entries.

Selection Committee

ANDRÉ J. HEINIGER (Chairman)
Chief Executive and Managing Director of Montres Rolex S.A., Switzerland.

ORIOL BOHIGAS GUARDIOLA
One of Spain's most important architects.

WALTER CUNNINGHAM
A former NASA astronaut.

PROFESSOR HEINZ HABER
German physicist and journalist.

PROFESSOR MOHAMED KASSAS
President of the IUCN and desert ecologist from Egypt.

MRS. PATRICIA KOECHLIN-SMYTHE
Former member of the British Equestrian Olympic Team, and Trustee of the WWF.

JOSÉ M. MAYORGA
A Spanish member of the Board of Trustees of World Wildlife Fund International.

PROFESSOR MICHIO NAGAI
Former Minister of Education, Culture and Science for Japan.

DR. RUY PEREZ TAMAYO
Head of Pathology at the Instituto Nacional de la Nutricion 'Salvador Zubiran', Mexico.

PAUL-EMILE VICTOR
French explorer and writer.

The entries will be judged on the basis of their general demonstration of the 'spirit of enterprise' plus their qualities of newness, originality, inventiveness, interest, feasibility, significance and the likelihood of completion.

How to apply.

Your entry must be completed in English on an Official Application Form and reach the Secretariat before the 31st of March 1983.

The Awards will be presented in Geneva at the end of April 1984.

To obtain an Official Application Form for The 1984 Rolex Awards for Enterprise together with the detailed Rules and Conditions, write to: The Secretariat, The Rolex Awards for Enterprise, P.O. Box 178, 1211 Geneva 26, Switzerland.

If you truly possess originality, imagination and initiative you will not let this opportunity pass you by.

THE ROLEX AWARDS FOR ENTERPRISE

ROLEX
of Geneva

day your mailman might have so much mail to sort down at the post office that it is afternoon by the time she gets started on her route." At the outset your avid reader Polly manufactures an image of her friendly postman sorting letters and a few moments later she is told the postman is a woman. Jolt! It is not just a surface-level jolt (the collision of the words "mailman" and "she"), although it is that too; it is really an image-image conflict, since you expressly invited Polly to think of *her own* mailman, who happens to be a man. Even if you had said "your letter carrier," Polly would still have been jolted. On the other hand, if you had asked Polly to think about, say, "Henry's letter carrier," then that "she" would not have caused nearly as much surprise, and maybe not any.

In teaching my classes I try always to use sex-neutral nouns such as "letter carrier" and "department head" (I avoid "chairperson"), and having done so I try my utmost to avoid using gender-specific pronouns to refer back to them. I have come to realize, however, that this is largely a show put on for my own benefit. I am not actively undermining any bad stereotypes simply by avoiding them. The fact that I am not saying "he" where many people would is not the kind of thing that will grab my students by the collar and shake them. A few people may notice my "good behavior," but they are the ones who are already attuned to these issues.

So why not just use an unexpected "she" now and then? Isn't that the obvious thing to do? Perhaps. But in many cases, as Nozick pointed out, it will seem so politically motivated that it will distract rather than enlighten. The problem is, once you have used a noun such as "letter carrier" that could apply to either sex, people will manufacture a mental "node"—a kind of hook in their minds on which they can hang various qualities. (If "node" means nothing to you, imagine a questionnaire with a number of questions requiring immediate answers.)

Now, it is naive to suppose that a few seconds after node formation the image is, or ever was, floating in a sexual limbo. It is next to impossible to build up more than the most fleeting, insubstantial image of a person without assuming he is a she, or vice versa. The moment that node is manufactured, unless you answer its questions, it will answer them itself. (Imagine that each blank in the questionnaire has a default answer entered in light pencil, easily erasable but to be used in case no other answer is provided.) And unfortunately—even for ardent feminists—those unconscious default answers are usually going to be sexist. (Women can be as sexist as the next guy.) For example, I have realized, to my dismay, that my defaults run deep, so deep that even when I *say* "letter carrier" and later "his or her route," I am often nonetheless *thinking* "his route." This is most disconcerting. It reveals that although my self-training may have succeeded quite well at the linguistic level, it has not yet fully filtered down to the *imagistic* level.

So have I not painted myselves into a corner? Am I not damned if I do and damned if I don't? After all, I have said that on the one hand the passive approach of merely avoiding sexist usages is not enough but that on the other hand the active approach of throwing in jolting stereotype violations is too much. Is there no successful middle path?

I have discovered, as a matter of fact, what I think is a rather graceful compromise solution to such dilemmas. Instead of dropping a nondefault gender into her lap *after* your reader has set up her default images of the people involved in the situation, simply do not let her get off the ground with her defaults. Upset her default assumptions explicitly from the word go.

I did this at the beginning of my May column on innumeracy, in which I retold an old joke. Usually the storyteller begins, "A professor was giving a lecture on the fate of the solar system, and he said...." The professor is almost always made out to be a male. This may reflect the sexual statistics for astronomers, but individuals are not statistics.

How could the story be improved—gracefully? Well, there is a delay, not a long one but still a delay, between the first mention of the professor and the word "he." It is long enough for the default male image to get solidly, even though implicitly, implanted in the listener's mind. So just don't let that happen. Instead make the professor a woman from the start. By this I certainly do not mean you should begin your story, "A woman professor was giving a lecture on the fate of the solar system, and...." That is horrible.

My solution was to give her sex away by her name. I invented the pseudo-Slavic name "Professor Bignumska," whose ending in "-a" signifies that its owner is female. To be sure, not everyone is attuned to such linguistic subtleties, so that for some people it will come as a surprise when a few lines down they read the phrase "according to her calculations." But at least they will get the point in the end.

What is worse is when people do not miss the point but rather reject the point altogether. In the French edition of *Scientific American* (*Pour la Science*) my "Professor Bignumska" was turned into "Monsieur le professeur Grannombersky." Not only was the sex reversed but clearly the translator had recognized what I was up to and had deliberately removed all telltale traces by switching the ending to a masculine one. I was disappointed. On the other hand, I was pleased to see that in the German edition (*Spektrum der Wissenschaft*) the professor's femininity remained intact: she was called "die namhafte Kosmogonin Grosszahlia." Not only her name but also her title has a feminine ending.

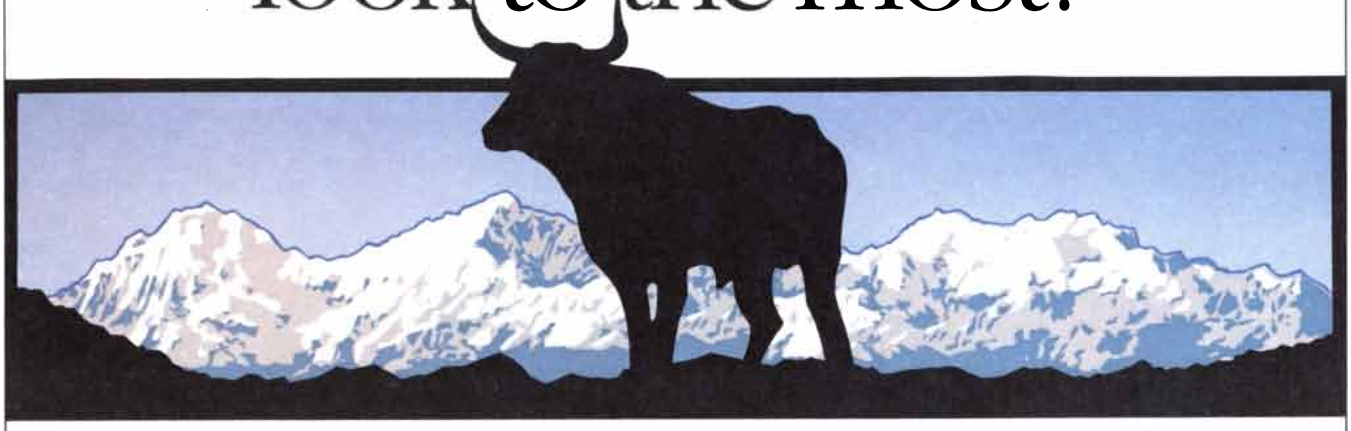
This practice of referring to members of some professions by explicitly feminine and masculine words certainly makes for trouble. What do you do when you are talking about a mixed group of actors and actresses? Unless you want to be verbose you have little choice but to refer to "actors." Why does a word such as "waiter," with its completely noncommittal ending, have to refer to a male? We are hard put to come up with a neutral term. Certainly "waitperson" is an awful concoction. "Server" is the best I have heard. On the other hand, it is nice to see "stewardess" and "steward" gradually being replaced by the general term "flight attendant."

All languages I have studied are in one way or another afflicted by these kinds of problems. Whereas we in English have our quaint-sounding "poetess" and "aviatrix," in French they have no better way of referring to a woman writer or professor than "une femme écrivain" or "une femme professeur," the default male gender being built into the nouns themselves. That is, "écrivain" and "professeur" are both masculine nouns. In order to enable them to refer to women you must treat them essentially as adjectives following (and modifying) the word "femme."

Another peculiarity of French is "quelqu'un," the word for "someone." It literally means "some one," and it calls for the masculine "un" no matter to whom it refers. This means, for example, that if an unfamiliar woman knocks at the door of Nicole's house and Nicole's young daughter answers the door, she is likely to yell to Nicole, "Maman, il y a quelqu'un à la porte" ("Mommy, there's someone at the door"). It is impossible to feminize the pronoun: "Maman, il y a quelqu'*une* à la porte." It would be even sillier to try to transform the impersonal "il y a" ("there is") into a feminine version, "elle y a." It just rings absurd. The masculine "il" is as impersonal as "it" in "It is two o'clock." Surely no one would suggest that we say "They are two o'clock."

In English we have some analogous phenomena. If a pair of strangers knock at Paul's door, his daughter may yell to him, "Daddy, someone's at the door." She will not say, "Sometwo are at the door." What this example illustrates is that the word "someone" does not carry with it strong implications of singularity. It can apply to a group of people without sounding odd. Perhaps by analogy "quelqu'un" is not as sexist at the

Who gives you investment ideas from the same source money managers look to the most?



Who else but Merrill Lynch.

People who know a business really well, soon learn who they can rely on for advice and information. In the investment business, it's the research team at Merrill Lynch.

For four years running, the Merrill Lynch research team has ranked first—by substantial margins—in the annual *Institutional Investor* poll of investment professionals.

But how does that help you if you're not investing millions at a time?

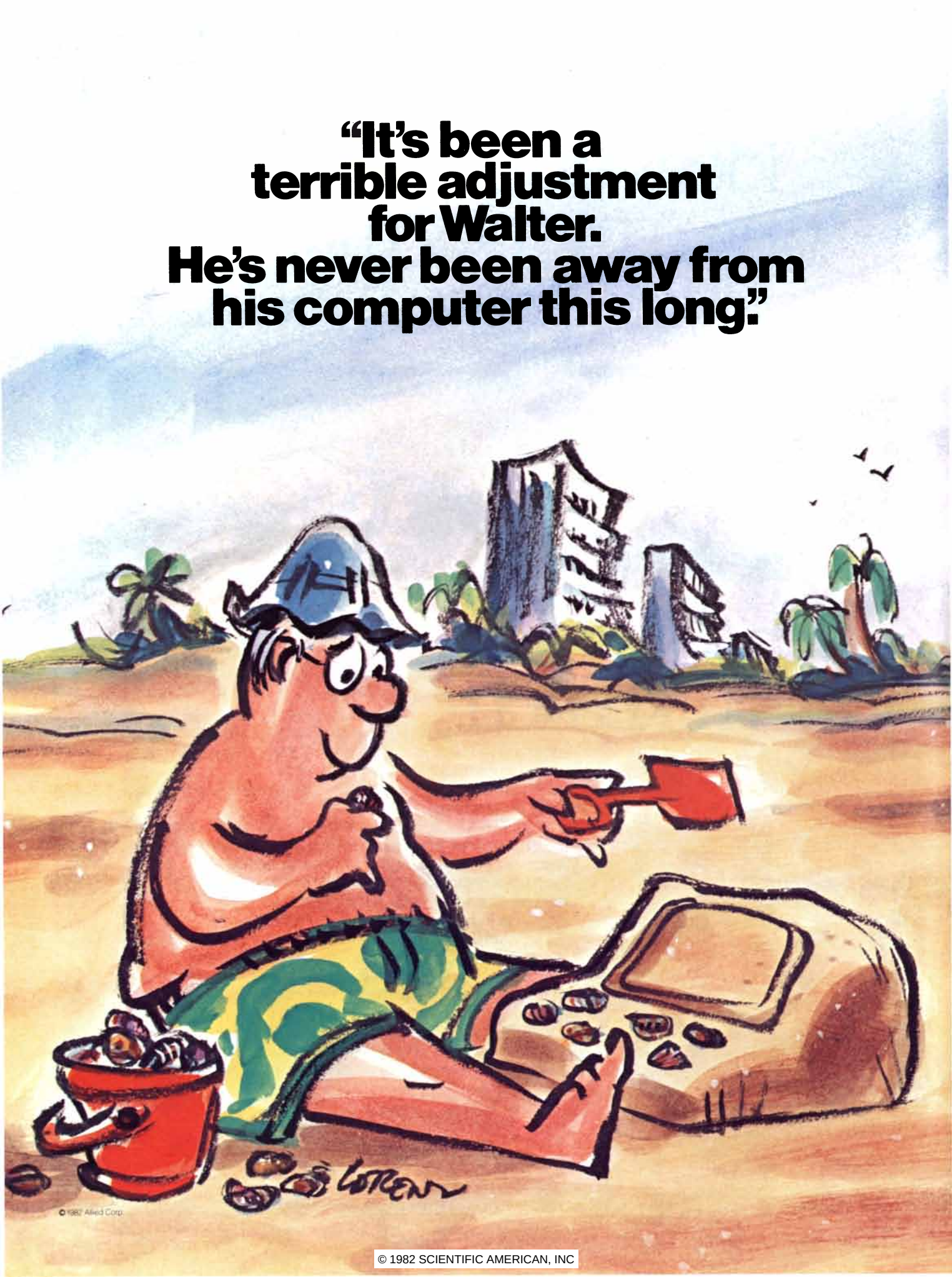
The key is your personal Merrill Lynch Account Executive. Our Account Executives have almost instant access to the full resources of Merrill Lynch research through a remarkable nationwide communications system. Current research opinions on some 1400 stocks are as close as their computer terminals.

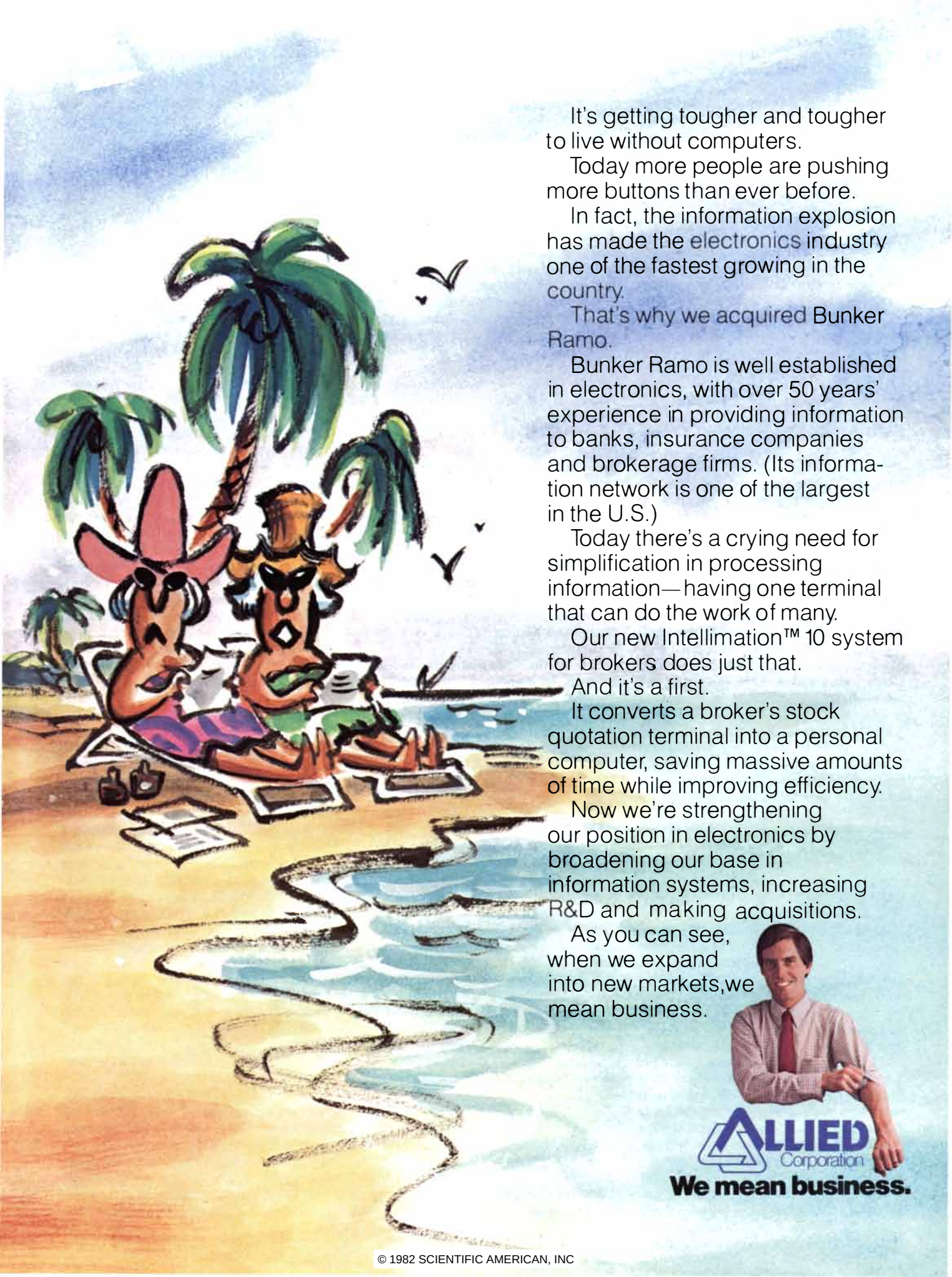
And our Account Executives can call on specialists in such fields as tax investments and corporate and municipal bonds to amplify their own knowledge of any particular type of investment that might be appropriate for you. No other financial services firm gives its Account Executives such strong and diversified backup support.

And that's one reason no one else can give you more help with more kinds of investments. No one else.

Merrill Lynch
Merrill Lynch, Pierce, Fenner & Smith Inc.
A breed apart.

"It's been a terrible adjustment for Walter. He's never been away from his computer this long."





It's getting tougher and tougher to live without computers.

Today more people are pushing more buttons than ever before.

In fact, the information explosion has made the electronics industry one of the fastest growing in the country.

That's why we acquired Bunker Ramo.

Bunker Ramo is well established in electronics, with over 50 years' experience in providing information to banks, insurance companies and brokerage firms. (Its information network is one of the largest in the U.S.)

Today there's a crying need for simplification in processing information—having one terminal that can do the work of many.

Our new Intellimation™ 10 system for brokers does just that.

And it's a first.

It converts a broker's stock quotation terminal into a personal computer, saving massive amounts of time while improving efficiency.

Now we're strengthening our position in electronics by broadening our base in information systems, increasing R&D and making acquisitions.

As you can see, when we expand into new markets, we mean business.

ALLIED Corporation

We mean business.

image level as its surface level would suggest. But that is hard to know.

Normally in French, to speak of a mixed or unspecified group of people, one uses the masculine plural pronoun "ils." Even a group whose membership has not yet been determined, but that stands a fair chance of including at least one male among 20 females, will still call for "ils." Female speakers grow up with this usage, of course, and follow it as naturally and unconsciously as male speakers do. Can you imagine the uproar if there were a serious attempt to reverse this age-old convention? How would men feel if the default assumption were to say "elles"? How would women feel? How would people in general feel if a group consisting of several men and one woman were always referred to as "elles"?

Curiously enough, there are circumstances where nearly that happens. There is a formalistic style of writing found in legal or contractual documents where the word "personnes" is used to refer to an abstract and unspecified group of people; thereafter the feminine plural "elles" is used to refer back to that noun. Since the word "personne" is of feminine gender (think of the Latin "persona"), this is the proper pronoun to use, even if the group being referred to is known to consist of males only.

Although this usage is grammatically correct, when it is dragged out over a long piece of text, it can give the reader a strange impression, since the original noun is so distant that the pronoun seems autonomous. One feels that the pronoun should at some point switch to "ils," and in fact sometimes it does. When it does not, it can make the reader uneasy. Perhaps this is just my own reaction. Perhaps it is merely the typical reaction of someone used to having a masculine default pronoun for an unspecified group of people.

We are all, of course, members of that collective group often referred to as "mankind," or simply "man." Even the ardent feminist Ashley Montagu once wrote a book called *Man: His First Two Million Years.* (I guess it was a long time ago.) Many people argue that this usage of "man" is completely distinct from the usage of "man" to refer to individuals, and that it is devoid of sexual implications. David Moser has astutely pointed out the weakness of this claim. He observes that in books you will find sentences in this vein: "Man has traditionally been a hunter, and he has kept his females close to the hearth, where they could tend his children." But you will never see such a sentence as "Man is the only mammal who does not always suckle his young." Rather, you will see "Man is the only mammal in which the females do not always suckle their young." So much for the sexual neutrality of the generic "man." I began to look for such anomalies and soon ran across the following gem in a book on sexuality: "It is unknown in what way Man used to make love, when he was a primitive savage millions of years ago."

Back to other languages. When I spent a few months in Germany working on my doctoral dissertation, I learned that the term for "doctoral adviser" in German is "Doktorvater," literally "doctor father." I immediately wondered: What if your Doktorvater is a woman? Is she your "Doktormutter"? Since that rang absurd to my ears, I thought a better solution would be to append the feminizing suffix "-in," making it "Doktorvaterin"—"doctor fatheress." It seems, however, that a neutral term just might be preferable.

Italian and German share an unexpected feature: in both the respectful way of saying "you" is derived from the feminine singular pronoun, the only difference being capitalization. In Italian it is "Lei," in German "Sie." Now, in German the associated verb has a plural ending, so that the connection with "she" is somewhat diluted, but in Italian the verb remains third person singular. Thus to compliment a man you might say, "O, che Lei è bello!" ("Oh, how handsome She is!"). Of course, Italians do not hear it in this naive way. To them it might seem equally bewildering that in English adding "s" to a noun makes it plural and adding "s" to a verb makes it singular.

One of the strangest cases is that of Chinese. In Mandarin Chinese there has traditionally been just one pronoun for "he" and "she," pronounced "tā" and written

This character's left side consists of the "person" radical, indicating that it refers to a human being, sex unspecified. Curiously, however, in the linguistic reforms carried out in China over the past 70 years or so, a distinction has been introduced whereby there are now separate written forms for the single sound "tā." The old character has been retained, but now in addition to its old meaning of "s/he" it has the new meaning of "he" (wouldn't you know?) and a new character has been invented for "she." The new character's radical is the one for "woman" or "female," so that it is

The new implication, not present in Chinese before this century, is that the "standard" type of human being is a male and females must be indicated specially as "deviant." It remains a mystery to me why the Chinese did not leave the old character as it was—a neutral pronoun—and simply manufacture *two* new characters, one with the female radical, as shown above, and one with the *male* radical, which would look this way:

(These three Chinese characters were created on a Vax computer with a character-designing program written by David B. Leake and me.) To give a corresponding (although exaggerated) example in English, can you imagine a political reform in which the word "person" came to mean "man" and for "woman" we were told to say "personess"?

The upshot is that in China there is no longer a truly gender-free pronoun in writing. Formerly you could write an entire story without once revealing the sex of its participants; now your intentions to be ambiguous are themselves ambiguous. In the case of the joke about the cosmologist with its default option, it is interesting to consider which way would be better for the sake of feminism. Would you rather have the storyteller leave the professor's sex unspecified throughout the story, so that people's default options would be invoked? Or would you rather have the storyteller forced to commit himself?

One of my pet peeves is the currently popular usage of the word "guys." You often hear a group of people described as "guys," even when the group includes women. In fact, it is quite common to hear women addressing a group of other women as "you guys." This strikes me as strange. Some people I have asked about it, however, have adamantly maintained that when "guy" is in the plural, it has lost all traces of masculinity. I was arguing with a woman about this, and she kept saying, "It may have retained some male flavor for *you,* but it has none in most people's usage." I was not convinced, but nothing I could say would budge her from her position. In the end I got lucky, because in a last-ditch attempt to convince me she said, "Why, I've even heard *guys* use it to refer to a bunch of women." Only after saying it did she realize she had just undermined her own claim.

Such are the subtleties of language. We are often simply too unaware of how our minds work and what we really believe. It is there for us to perceive, but too often people do not listen to themselves; they think they know themselves without listening to themselves. Along these lines I recently heard myself say-

ALL OVER THE WORLD
PEOPLE HAVE ONE THING IN COMMON.
THEY START THE EVENING WITH RED.

JOHNNIE WALKER® RED
SO SMOOTH, IT'S THE WORLD'S BEST SELLING SCOTCH.

SmithKline

SmithKline Beckman Corporation/World Headquarters

Eye Care. Improved visual health is one likely outcome of the unification of two world leaders in technology—SmithKline and Beckman Instruments—under the name SmithKline Beckman Corporation.

We entered ophthalmic research equipped with extensive chemical technology and unique capabilities in H_2 receptor technology. We are now exploring the potential for these technologies in a number of diagnostic and therapeutic applications.

Ongoing research is aimed at finding new pharmaceutical agents for controlling intraocular pressure—a principal factor in glaucoma. Above is an eye treated with sodium fluorescein for study of the flow dynamics of aqueous humor.

Converging

Beckman

One Franklin Plaza/Philadelphia, PA 19101

Physiological Monitoring. Precision instruments and associated products by SmithKline Beckman perform a remarkable variety of tasks in health care and research, speeding and simplifying procedures in hospitals and laboratories.

Many of these systems deliver instantaneous assessments of critical physiological parameters and supply indispensable information for medical diagnosis and therapy.

A Beckman rate nephelometer is the first high-speed clinical system for quantitation of body-fluid proteins *and* for therapeutic drug monitoring. The mobile, programmable system above measures metabolic and respiratory variables.

Look into SmithKline Beckman. And look into the future.

Technologies

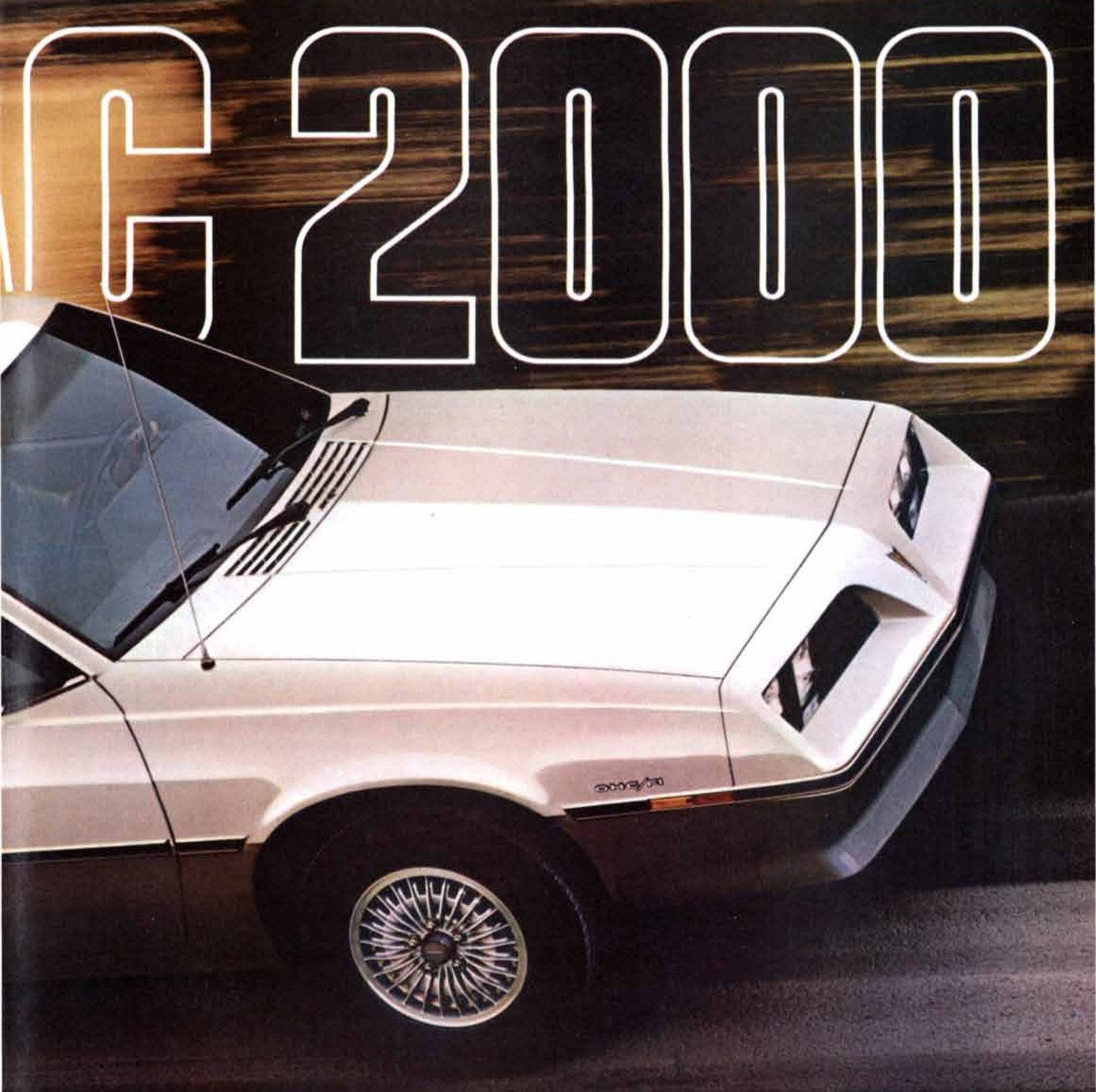
5-SPEED, OVERHEAD

Here's a combination that could only mean one thing: pure driving fun!

Check out the way the front-wheel drive takes you through the turns. The way the reclining front buckets hold you close. And the way the new standard 5-speed manual transmission with over drive takes you from 1st to fantastic...in a hurry.

To get you there with even more excitement,

PONTIAC WE B



CAM, FUEL INJECTION

our sleek and sporty Pontiac 2000 is equipped with an overhead cam 4-cylinder engine with Electronic Fuel Injection. And for responsive road handling, you get rack and pinion steering, MacPherson strut front suspension and semi-independent rear suspension.

Some Pontiacs are equipped with engines produced by other GM divisions, subsidiaries, or affiliated companies worldwide. See your Pontiac dealer for details.

GM

UILD EXCITEMENT

ing "chesspeople" to refer to those wood pieces you move around on a chessboard. I had overtrained myself to watch out for words that end in "man."

There simply is a problem with default assumptions in our society. It is manifested everywhere. You find it in proverbs such as "To each his own," "Time and tide wait for no man" and so on. You hear it when children (and adults) talk about squirrels and birds in their yards ("Oh, look at him running with that acorn in his mouth!"). You see it in animated cartoons, many of which feature some poor schlemiel—a sad "fall guy," a "schmo" with whom "everyman" can identify—whose fate it is to be dumped on by the world, and we all laugh as he is dealt one cruel blow after another. Why are women not in this role more often? Why are there not more "schlemielesses"—more "fall gals"?

One evening at some friends' I was reading a delightful children's book called *Frog and Toad Are Friends,* and I asked why Frog and Toad both had to be males. This brought up the general topic of female representation in children's television and movies. In particular we discussed the Muppets, and we all wondered why there are so few sympathetic female Muppet characters. I am a great fan of Ms. Piggy's, but still I think if she is the only major female character, something is wrong. She is hardly an ideal role model.

This general kind of problem is not limited to questions of sex, of course. It extends much further, to groups of any kind, large or small. The cartoons in *The New Yorker,* for instance, although they are innocuous in one sense, certainly do not do anything to promote a change in one's default assumptions about the roles people can play. How often do you see a black or female executive in a *New Yorker* cartoon (unless, of course, they are there because the point of the joke depends on it)? The same could be said for most television shows, most books, most movies.... It is hard to know how to combat such a monolithic pattern.

There is an excellent and entertaining book, which I discovered only after this article was nearly complete, that could be a giant leap for humankind in the right direction. It is *The Handbook of Nonsexist Writing,* by Casey Miller and Kate Swift (Barnes & Noble, 1980). I recommend it heartily.

One of the most eloquent antisexist statements I have ever come across is a talk delivered recently at a college athletes' banquet by Donald Kennedy, the president of Stanford. Thirty years ago Kennedy himself was an athlete at Harvard, and he reminisced about a similar banquet he had attended then. He mused: "It occurs to me to wonder: What would the reaction have been if I had predicted that soon... women would run the Boston Marathon faster than it had ever been run by men up to that point? There would have been incredulous laughter from two-thirds of the room, accompanied by a little locker-room humor."

Then he pointed out: "Yet that is just what has taken place. My classmates would be astonished at the *happening,* but they would be even more astonished at the *trends.* If we look at the past 10 years of world's best times in the Marathon for men and women, it is clear that the women's mark has been dropping, over the decade, at a rate about seven times faster than the men's record."

The case of swimming is even more remarkable. Kennedy recalled that in his day the Harvard and Yale teams were at the pinnacle of the nation in swimming, and both came undefeated into their traditional meet at the end of the season. "What would have happened if you had put this year's Stanford women into that pool?" asked Kennedy. "*Humiliation* is what. Just to give you a sample, *seven* current Stanford women would have beaten my friend Dave Hedberg, Harvard's great sprint freestyler, and *all* the Yalies in the 100. The Stanford women would have swept the 200-yard backstroke and breast stroke, and won *all* the other events contested.

"In the 400-yard freestyle relay there would have been a 10-second wait between Stanford's touch and the first man to arrive at the finish. Do you know how *long* 10 seconds is? Can you imagine that crowd in Payne Whitney Gymnasium, seeing a team of *girls* line up against the two best freestyle relay groups in the East, expecting the unexpected, and then having to wait *this long*—for the men to get home?"

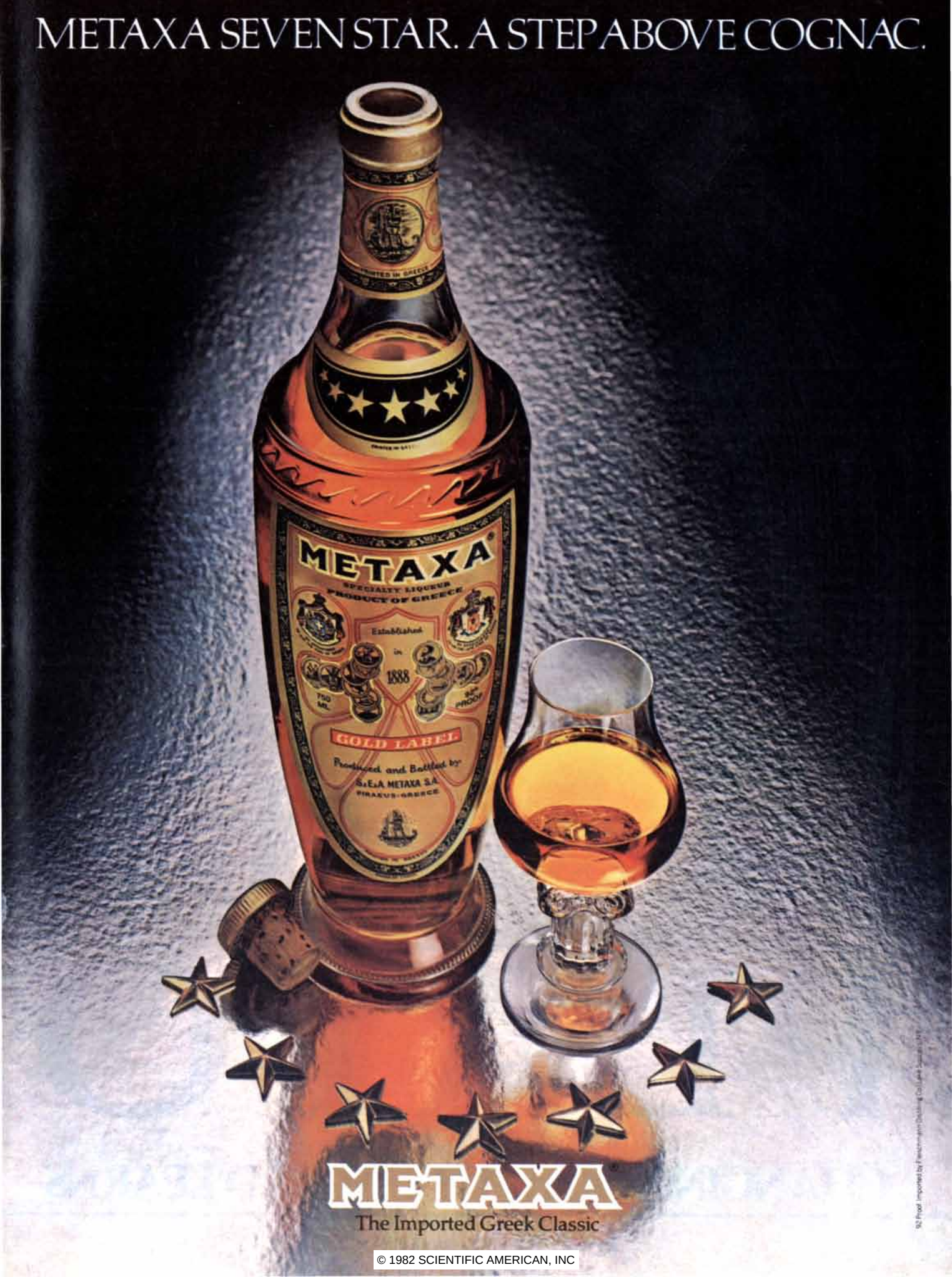
He painted a hilarious picture, but of course his point was dead serious: "I ask you: If conventional wisdom about women's capacity can be so thoroughly decimated in this most traditional area of male superiority, how can we possibly cling to the illusions we have about them in other areas?

"What, in short, is the lesson to be drawn from the emerging *athletic* equality of women? I think it is that those who make all the other, less objectively verifiable assumptions about female limitations would do well to discard them. They belong in the same dusty closet with the notion that modern ballplayers couldn't carry Ty Cobb's spikes and the myth that blacks can't play quarterback. Whether it is vicious or incapacitating or merely quaint, nonsense is nonsense. And it dies hard."

'Tis a point to ponder. Meanwhile,

他

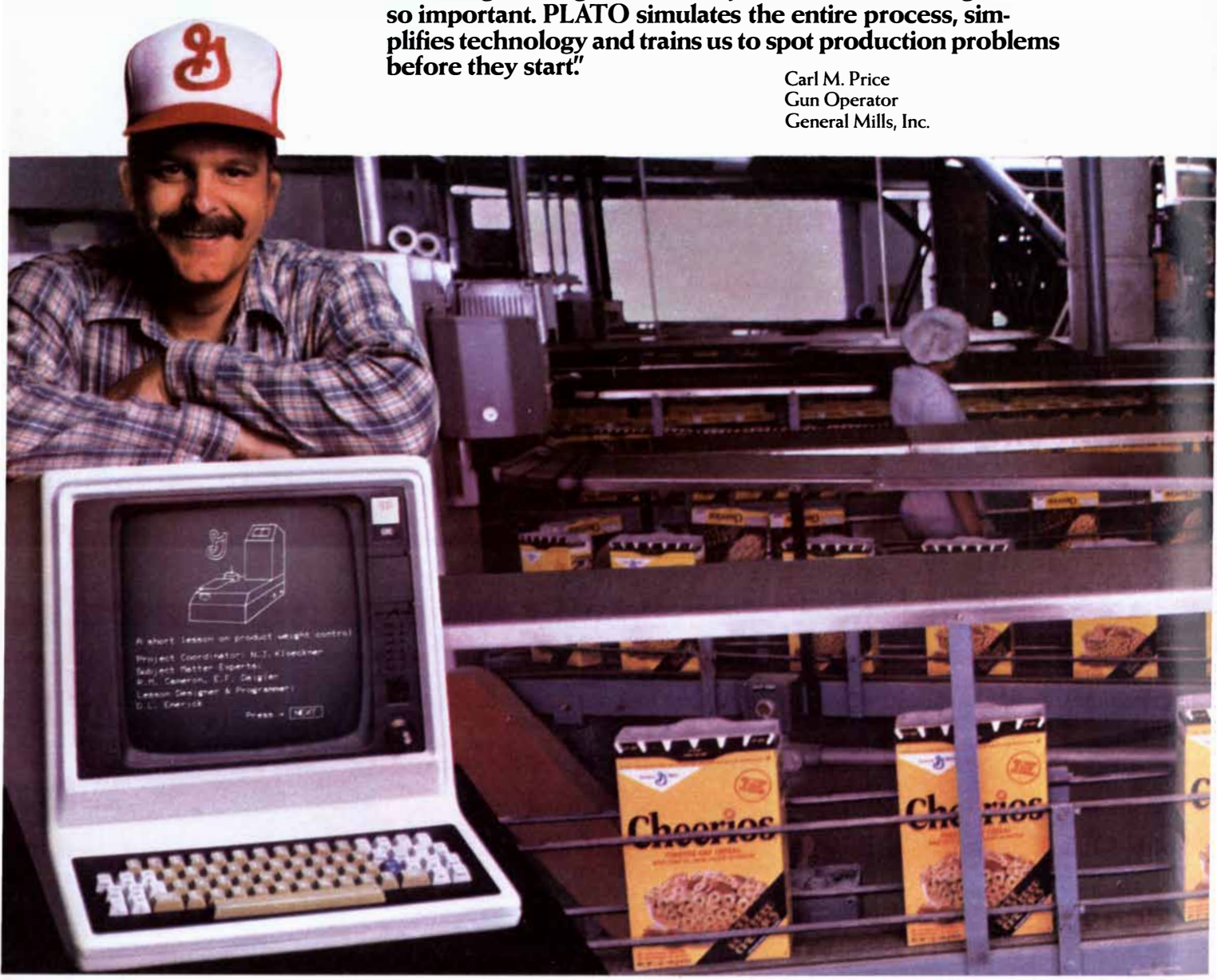
METAXA SEVEN STAR. A STEP ABOVE COGNAC.



Minimize downtime by training the way General Mills does.

"Every minute, 60 Cheerios packages come off this production line. Up in the control room, where I work, we see that things run right. That's why our PLATO training is so important. PLATO simulates the entire process, simplifies technology and trains us to spot production problems before they start."

Carl M. Price
Gun Operator
General Mills, Inc.



PLATO

CHANGING HOW THE WORLD LEARNS

Productivity and training go hand-in-hand at General Mills. That's why PLATO® computer-based training is now part of the company's operations training program in its package foods plants.

A major advance in training. PLATO training is interactive, individualized, self-paced training. It can simulate virtually any process whether it's a production line at General Mills or an assembly line at General Motors. So more people can be trained more uniformly and effectively at their own pace.

Use PLATO to meet your specialized needs. Production training, new hire development, sales training, systems conversion, employee redeployment—whatever the program, PLATO has over 7,000 hours of standardized courseware to meet the need. Or we can help you develop a special program for use at your location or any Control Data Learning Center.

Ask for an Executive Briefing. Learn how PLATO computer-based training can help your human resources reach their full potential and increase their productivity. *Call 800/328-1109 or write Control Data, Dept. HQV003-4, P. O. Box 0, Minneapolis, MN 55440.

*In Minnesota call collect 612-853-7518

CONTROL DATA

Addressing society's major unmet needs as profitable business opportunities

BOOKS

Electronic-watch marvels, spiders, poker, and archaeological tours of Mesoamerica

by Philip Morrison

ELECTRICAL AND ELECTRONIC CLOCKS AND WATCHES, by J. D. Weaver. Newnes Technical Books, Butterworth Publishers, 10 Tower Office Park, Woburn, Mass. 01801 ($29.95). Set apart those powerful statistical clocks, the sandglass and the sample of radioactive material. Other timekeepers, even the spinning earth, are all mechanical or electrical systems that periodically return to the same relevant state, to begin anew the next identical beat or turn. In theory such an oscillator is a perfect clock. Reality is not so tidy. There is no loss-free oscillator; every system loses energy. That energy must be refreshed—and the oscillator necessarily disturbed—if the beat is to endure. Of course, the earth-spin clock lasts out our brief time, even if our own clocks have found its limits. Each year earth spin loses a couple of milliseconds in the day, and it slows irregularly over the geologic epochs.

It was W. H. Shortt's clocks of the mid-1920's that were the first timekeepers to rival the spin of the earth, with an error of only a few milliseconds per day. They were electromechanical triumphs. Time was set by the steady beat of an invar pendulum swinging free in a sealed low-pressure enclosure. The master pendulum was kept alive by impulses fed in only once or twice per minute from a slave pendulum. An elegant feedback link both timed the slave and fed the losses of the master. They exchanged energy by mutual electromagnet impulses. All the slave-controlled magnet had to do was release a gravity arm beside the master pendulum, which through a jeweled contact delicately tweaked the master. All the master did was send a magnetic pulse by the fall of a second gravity arm that could drop only after the nudge on the master itself. That pulse kicked a light spring leaf on the slave pendulum only if the slave was running a little slow. If the slave was fast, its feeler would already have passed the place of interaction, and there would be no energy transfer until the slave slowed down.

Electrostatic clocks are old indeed, but they never were serious timepieces. The first current-using clocks go back to 1840; they did not rival the long-evolved ingenuities of straight clockwork. Their trouble is plain: the easy idea of closing a switch with the pendulum or the balance is inadequate. Switching is like friction, too sensitive to surface wear and corrosion. The electric impulse is not constant and periodicity fails. Nor is the smooth magnetic alternative workable. A coil and magnet can both detect the pendulum's position and feed it energy, but they cannot do so without loss. Some amplifier is needed; a switched-on current is the crudest of amplifiers, but it is too crude.

The first successful electric clocks were really hybrids. In 1907 a fully successful scheme appeared, later used for the slave pendulum of the Shortt clocks. It was called the Synchronome. Its energy source was electrical, all right, but the electric power was applied by a clever mechanical scheme. In effect the electrical part acted only to rewind the driving weight, by lifting a small gravity arm every dozen or so pendulum beats. Timekeeping was all the pendulum's work; even the transfer was mechanical, with that arm falling when it was tripped by the pendulum. After World War I the electric clock rose to domestic dominance, but in the somewhat disappointing form of the Telechron, a small synchronous motor controlled by the rotation frequency of the big generators of the power grid. These tethered slaves were everywhere, but they were facades, not timekeepers, displays of how carefully the engineers of the power stations had over the long run compared the big alternators to some fine Synchronome clock.

Clocks, but not watches, became fully electrical in 1927 at the Bell Telephone Laboratories. Warren A. Marrison's quartz-crystal clock (you can see it here in a fine period photograph, all storage batteries and a couple of relay racks of vacuum tubes) kept time with a big quartz rectangle, an inch square and half an inch high. From its first run it had the accuracy of the Shortt clocks. Within a few years quartz clocks improved by a factor of 10. The bigger error was then in the astronomers' ancient timepiece, the spinning earth. Today a commercial laboratory quartz clock right off the shelf keeps better time than our planet, and the very best units drift by only microseconds per day.

Precision timekeeping calls for two distinct insights. The first is evident; the invar pendulum bar exemplifies it. A faithful oscillator must remain physically the same as it returns again and again to its starting point. Any pendulum lengthens and shortens as its temperature changes, and its rate would then vary. The early 20th century found a neater solution for this weakness: invar is a nickel alloy that hardly changes in length with temperature. Modest attention to temperature control then yields a practically constant length. Indeed, improvement in quartz clocks also came first from attention to temperature stability. Marrison's quartz plate became a ring, a shape chosen because the resonant vibrational modes were insensitive to temperature. Aging remains a limit in quartz crystals, now grown synthetically with great care; internal strains in the quartz slowly relax over the years, causing small changes in elasticity and hence in frequency.

The second insight is as fundamental but less evident. The timekeeper that requires least interaction with the disturbing energy supply will likely perform the best; it better approximates the perfectly repetitive free oscillator of dream. A fine marine chronometer has a balance wheel that can retain a substantial fraction of its energy for 1,000 beats. A tuning fork can reach 10,000 vibrations, a free pendulum in low-pressure gas 100,000 swings and a good quartz crystal millions of vibrations before energy replenishment.

In late 1959 the Bulova Accutron appeared, the first electronically maintained watch of quality. Its timekeeper was a small magnet-tipped tuning fork made of an alloy with properties like those of invar. One transistor provided the amplification indispensable for driving the resonant fork magnetically. The counting of the fork vibrations, however, was mechanical. One tine bore a tiny jeweled finger. As the fork hummed the finger moved to advance tooth by tooth a little ratchet wheel with 320 teeth. That wheel drove the gear train. The watch "set new standards in domestic timekeeping," a minute a month under guarantee.

The chief limitation is interesting: it is gravity. The fork must move far enough for its motion to drive that tiny gear wheel. Such a sizable amplitude, although it is only a few tens of micrometers, limits the possible speed of motion; if the frequency were set really high, the energy of vibration would grow past practicality. But with low frequency,

GET YOUR HANDS ON A CHEVROLET THE COMPETITION CAN'T TOUCH.

That Chevrolet is Camaro, and it's flat outselling every other 2+2 sport coupe on the road today.*

Camaro. Designed and engineered with some of the newest performance technology you'll find on any road, anywhere. Including Ground Effects technology. A cockpit designed to link driver and machine together.

And now, Camaro is led by a new standard 5-speed, 5-liter** Z28 with the lowest aerodynamic drag coefficient of any production Chevrolet ever tested.

Get your hands on a hot-selling Camaro today. And experience what it's like to take hold of a Chevrolet that was chosen in February as Motor Trend's "Car of the Year."

*Source: Ward's Automotive Reports, Specialty Subcompact Segment.

**Some Chevrolets are equipped with engines produced by other GM divisions, subsidiaries, or affiliated companies worldwide. See your dealer for details.

GM Let's get it together... buckle up.

CHEVROLET CAMARO Z28

USA-1 IS TAKING CHARGE

Chevrolet

CAMARO · CELEBRITY · CAVALIER · CHEVETTE · CITATION · MALIBU · MONTE CARLO · CAPRICE · CORVETTE

some 300 beats per second, the fork length approaches a centimeter. Such a fork is large enough to feel gravity appreciably. Its motion is no longer pure, responsive only to the inner elasticity of its own steel; it gives a little under its own weight. The Accutron fork changed in rate about five seconds per day between the tines-up and tines-down positions; a watch in use is always turning with the wrist.

Transistors made possible good quartz domestic clocks but hardly watches; small size implies a high-frequency oscillation, at least an order of magnitude higher than that of the fork. Those rapid beats had to be counted electronically, which was no problem. The display is to be read, however, by the human eye, which can deal comfortably with at most one beat per second. The electronics to subdivide the swift oscillations (usually a series of bistable counters, each in turn dividing by two) would have to have a dozen stages or more. Allow a few transistors for each circuit and it is hard to imagine a fully electronic quartz watch with fewer than a dozen or two transistors inside. Such a transistor-packed watch did appear in 1969.

The first integrated-circuit watches came in about 1970. The floodgates then opened and the marvelous chips streamed out. The price has since fallen by a factor of 50 as the performance has improved: inexpensive accuracy of a minute a year is unremarkable. The typical watch of this style is all-electronic, with a button-size battery and an integrated-circuit chip equivalent to thousands of transistors, with oscillator, frequency division and logic enough to carry out an entire array of useful or entertaining tasks along with a visual display. All of them together drain only a few microwatts. The quartz crystal itself is a stiff little bar about a millimeter square and a centimeter long, resonant at 32,768 hertz, just 2^{15} flexures a second, bending barely a micrometer. The age effect reaches an accumulated error of about a minute for the first year, less thereafter: temperature variation produces a rate that is slow by 1/3 second per day for a change of 10 degrees Celsius, whether cooler or hotter. The trend is to megahertz crystals, with much better performance but requiring novel low-power logic.

All of this and more is found in J. D. Weaver's fascinating small book. The final chapter bravely attempts to explicate the cesium-beam quantum clocks that work now with an error rate of only nanoseconds a day to fix the official atomic time. His is an old and high tradition of technical exposition, that of the horologist, amateur and professional alike. With little mathematics and almost no concern for the quantitative elements of design, these collectors and craftsmen enjoy the step-by-step drawings and accounts of clever mechanisms and of still cleverer circuits, along with their practical realization, even when detail demands close study. Only a page or so is given to the chip, now the heart of the matter, small beyond much hope of repair, and past even description at this level. The simplifying talent falters a little before those fearful networks. Instead a piece of advice is prudently offered: "It is generally unwise to tamper with electronic watches, apart from changing batteries."

BIOLOGY OF SPIDERS, by Rainer F. Foelix. Harvard University Press ($30). "No recent author," Professor Foelix remarks, "has really attempted to pull together the various biological facts of a spider's life." This book, well translated by the author from its German original of 1979, offers up-to-date and frequently extraordinary information to fill that niche. The author spins clearly his matter-of-fact story of wonders, staying close to the evidence, hyperbole-free, even though he is surely a partisan, if not of spiders, then of arachnology itself. The status of spiders, all of them carnivores, abundant in every land, their prey mainly insects, is a worldwide evolutionary victory, won by a minority of only 30,000 species at the expense of the great insect mass. "Spiders have conquered all possible ecological niches on land"; it is their diverse ecology, from rain forest to sand dune, their ultrastructure, their powerful sensory arsenal and their intricate behavior that have been the topics of the more recent research. There remains much to learn; spider biochemistry and endocrinology are fast-growing, neurobiology is well on the way, genetics is still modest and sociality is a topic only of the past decade.

Ten chapters marshal all of this (with full references), from an account of functional anatomy to an effort to present a family tree, concededly on scanty evidence. If the widespread fierce little acrobats and artisans attract you at all, you will want to read this book. If fear is your reaction to these artful and venomous predators, the text of the book may prove remedial, although close-ups of eight turreted eyes, unsheathed fangs and little wary lovers may not at once draw you in.

That hairy spider is in fact wired for sound. Spiders collect most of their information with specialized mechanoreceptors. Internal nerve endings monitor the positions of leg and joint, and external hairs respond to touch, to air currents and to vibration of the substrate. For many spiders the web is not merely a snare but is an extension of the sensitive hairs of the body. Only the short body hairs and certain specialized adhesive hairs lack that triple nerve ending at the hair root able to monitor the hair's inclination. One subset of fine hairs is particularly sensitive; long and fine, mounted in membrane only half a micrometer thick, they quiver with the slightest current of air to offer directional information ("touch at a distance"). A blinded spider can still locate a buzzing fly accurately at a range of some inches. A couple of thousand narrow slits in the skin only a micrometer or two wide and much longer cover the extremities, some single, some in multiple arrays. These slits hold strain gauges capable of detecting a tiny compression of the cuticle. In groups they seem to act as filters, tuned to particular vibration bands at audio frequencies. There are plenty of taste hairs as well; spiders will discard old dead flies on one quick touch with a leg but will immediately accept fresh-killed ones.

Jumping spiders are more eye-minded; in the book one male is shown threatening its own mirror image. Their smaller eyes are motion sensors, like our own peripheral vision; their main eyes with large single lenses are capable of form perception. A spider of this kind begins to see something a foot or more away. If the object moves to half that distance, the spider turns to face it and begins to fix it with its main eyes, which have a movable retina. The image is held focused on the central retina; the retina scans the image across the 100 or so small and closely packed foveal cells. At one or two centimeters the keen-eyed spider leaps.

Such tested behavior makes a strong case for the sophistication of the vision of jumping spiders; their eyes are no mere simple light detectors but tiny imagers, the lenses with a focal length under one millimeter. There are four layers of retinal cells with differing sensitivities to color. Many jumping spiders are themselves colorful, which is certainly a hint, yet functional color vision has not been firmly proved. (It took decades to demonstrate color vision in the house cat.)

Then, of course, we learn of webs. The acoustic architectural design and the deft construction of webs by spiders sober and spiders stoned are well treated, if they are by now familiar marvels. What of the fiber itself? All spider species can secrete fiber, if only for egg sacs. It turns out to be a protein with properties not unlike a high grade of nylon. Here the scores of spigots from which the fluid runs to form the silk are well seen in micrographs. The glands have output valves under muscular control; ordinary spider silk therefore varies from a few micrometers in diameter to less than a micrometer. Many spiders own a special spinneret of a different form; on that surface they sport tens of

NO FOREIGN SEDAN CAN GIVE YOU THE ROOM OF THIS CHEVROLET WITH THE MILEAGE OF THIS CHEVROLET.

Chevrolet's 1983 front-wheel-drive Celebrity—a Chevrolet so precisely engineered it gives you twenty cubic feet more total room than the Datsun Maxima Sedan, seven more than Audi 5000.

Celebrity's front-seat leg room nearly equals some of America's biggest luxury cars; its trunk is more accommodating than a Rolls Royce. Yet Celebrity's aerodynamic shape, its standard electronically fuel-injected engine and automatic transmission give you better mileage ratings than some smaller foreign cars: 39 Est. Hwy., 24 EPA Est. MPG.*

Come try the room, the comfort, the quiet, the smoothness, the efficiency of our new-generation 5-passenger sedan. If you haven't seen your Chevrolet dealer, you're not ready to buy a new car.

Chevrolet's Celebrity.
Another reason why Chevrolet, America's sales leader, is USA-1.

GM

*Use estimated MPG for comparisons. Your mileage may differ depending on speed, distance, weather. Actual highway mileage lower. Some Chevrolets are equipped with engines produced by other GM divisions, subsidiaries, or affiliated companies worldwide. See your dealer for details.

USA-1 IS TAKING CHARGE Chevrolet

CELEBRITY · CAVALIER · CHEVETTE · CAMARO · CITATION · MALIBU · MONTE CARLO · CAPRICE · CORVETTE

thousands of tinier spigots, whose output is silk as fine as 100 angstroms in diameter, combed out of the spinning organ by a particular bristle comb and employed on the web as special entangling threads ("hackle bands"), an improved version of the thread sticky with beads of glue laid down by species that lack the fine fibers and remaining effective as a trap not for days after spinning but for weeks.

An injection of a powerful neurotoxin through the sharp tip of the fang is the first blow struck by most spider species. Spider digestion is always partly external; spiders have small mouths and filter-guarded throats, but the big meal is taken in drop by drop predigested with a good mix of digestive fluid vomited up before each ingestion. Some spiders suck on an insect thoroughly mashed with fang pliers; others merely punch fine holes in the dead prey, add the digestive substances and suck out the contents, a rich fluid diet. Internal digestion proceeds at leisure, the active gut packed away all over the interior of the spider, in some species even between the eyes.

The melodrama of love among the spiders is here, with some coolheaded comment. Not all small spider males need fear a big cannibal mate, although most males enjoy only a brief span after they have mated. A couple of dozen spider species are truly social; they cooperate, with conspecific aggression entirely absent. They join to attack large prey that have blundered into the web. They live longer in society, producing fewer eggs and together bringing food to spiderlings in the communal web, where up to 1,000 individuals may dwell in placidity. Spiders have two compact central ganglia of nerves up front, instead of the long chain of smaller ganglia typical of the arthropods. Short-term memory and learning have been demonstrated in these animals, generally regarded as being under stereotyped control by phylogenetically antique hard-wired programming. Those 30,000 neurons are not so few; recognition of the potential of microprocessors is perhaps not as new as we think.

POKER FACES: THE LIFE AND WORK OF PROFESSIONAL CARD PLAYERS, by David M. Hayano. University of California Press ($17.95). Bret Harte and Mark Twain are romantic witnesses to the glamor of Gold Rush gambling. Workaday California grew staid over the decades, and gambling became illegal there by an act of 1891. But an attorney general of the state, acting in wisdom or in irony, exempted the grand American game of draw poker, as a "game of skill." Today some 400 legal public cardrooms operate across the state. This lively book is an autoethnography of the principal tribe of the poker peoples of California, written after almost 10 years of devoted field work by a thoughtful anthropologist whose first field study had been carried out in the highlands of Papua New Guinea.

Professor Hayano, brought up in Chicago, must have remained something of a detached observer out there among tusked pigs and painters of faces. Here he "became the phenomenon," an ethnographer among his own people. He entered the cardrooms of Gardena as an enthusiastic social poker player, hoping only for relaxation from the hard work of research and teaching, and maybe a little easy money. Within a couple of years he had become an esteemed regular, called "The Arm" for his aggressive style of throwing chips into the pot. He came to realize that the thick description of the ethnographer could illuminate this subculture in which he was immersed, indeed submerged all night. It was the steady winners who most fascinated him, those few players who by night and by day managed to make a living and a career out of the capricious cards. His interest grew out of simple self-preservation into science; although his "recurrent fantasies of a full-time gambling life" have somewhat subsided, he views gambling behavior as a neglected concern of scholarship. This book is the first field report from deep within.

How unusual that culture is we gather from a page or two on his field-work ethics. His practice was to avoid the open notebook and direct public inquiries. But the cardroom itself encourages the incisive observation of others. One professional gambler who kept written notes on the mannerisms of frequent opponents had a page on Hayano more exhaustive and detailed than Hayano's own notes of the time.

On flat and fertile land in the hot sun half a dozen miles from Los Angeles International Airport the residential municipality of Gardena retains the commercial nurseries that recall its truck-gardening origins. Six large poker rooms have grown up there since the game was made legal in 1936, the largest concentration of such establishments in the world. The clubs, owned as corporations, several of them operated by veterans' organizations, are physically typical L.A. structures, big parking lot and lightly built one-story building. They hold restaurants and TV rooms but do not sell or serve liquor. Each large playing area has by law a maximum of 35 tables, eight players to a table; "a poker player can find action every hour and every day of the year except Christmas."

These are the sites of serious and unpublicized gambling, not the tinsel and television of the much larger and gaudier world of gambling Las Vegas. There are cardrooms in Las Vegas too, with unlimited stakes in some places and their own coterie of top pros, but they are inconspicuous among the tens of thousands of holidaymakers and the slot-machine-obsessed who fill the noisy casinos. A Gardena gambler does not buck the house, the proverbial house of infinite assets, corporate memory and even the undertone of violent sanctions. He or she (an important fraction of the players at Gardena are women) plays against the other players around the table. The house collects fees for time, at fixed moments by the clock, with a rate proportional to the stakes. It also organizes the groups of players, supplies chips for cash, maintains the restaurant; it is in fact a housekeeper without much interest in winning or losing at the game. The aim of the house is only to fill the seats at most tables most hours with players who will return.

Even the shills symbolize the difference between the casino and the cardroom: in Las Vegas these hirelings roll dice and "decorate the baccarat pit" on a small salary to create the impression of action. In Gardena there are props—proposition players—on a house salary but engaged to play and to pay the fees for game time with their own money. They are real gamblers with a little stake from the house, rather than paid actors. A Gardena showgirl, if she existed, would be an elderly and coiffured regular at a low-stakes table with a sternly calculating air toward the management of money.

The players form a complex, intense social world, a pyramid of involvement and dependence. Most of the quarter-million people who come in a year to the Gardena cardrooms spend something not far from the mean time and money there: a few score hours at $100 or $200 per year, like moviegoers. At the apex are the winners, the career pros. They spend their lives in the cardroom: there they eat, relax at the TV, meet friends, answer the telephone, on a 60-hour week (paying a table fee of $10 an hour), night and day. Some 100 people, mostly but not all of them men under 60, form this shifting group. Around them cluster a larger population of regulars and occasionals, winners and losers, but with outside income and less time to play at the tables.

It is those players, always at the higher-stakes and therefore more skilled tables, who together supply the economic base for the professionals. One may compute that around every career pro there are several dozen players who support him by modest losses for a few years. The scenes shift, even the pros drift away, the full-timers "sometimes become working regulars; regulars turn into twice-a-year occasionals;

THIS CHEVROLET IS SO VERSATILE IT'S PART WAGON, PART SCHOOL BUS, PART SNOWMOBILE, PART SPORTY CAR.

No import gives you the room and versatility of Chevrolet's front-wheel-drive, five-passenger Citation Hatchback.

There are 95 cubic feet of space inside a Citation. More than a Honda Accord, a VW Jetta, a Nissan Stanza DLX or Toyota Cressida. Yet Citation gives you small-car mileage along with its mid-size room: 42 Est. Hwy., 27 EPA Est. MPG.*

Chevy Citation is an agile car with a decidedly sporty feel. An electronically fuel-injected 2.5 Liter 4-cylinder engine is standard. Chevy's legendary F41 Sport Suspension is available on all Citation models as is—for the first time—the high-output 2.8 Liter V6. And, whichever way you go Citation, you get front-wheel-drive traction to help make winter a whole lot easier to pull through.

Chevrolet's versatile Citation. Any wonder it's outsold all other front-wheel-drives over the past three years combined?

Come drive it. If you haven't seen your Chevrolet dealer, you're not ready to buy a new car.

Citation 4-Door Hatchback: It does many things many cars can't.

*Use estimated MPG for comparisons. Your mileage may differ depending on speed, distance, weather. Actual highway mileage lower. Some Chevrolets are equipped with engines produced by other GM divisions, subsidiaries, or affiliated companies worldwide. See your dealer for details.

USA-1 IS TAKING CHARGE

Chevrolet

CITATION · CELEBRITY · CAVALIER · CHEVETTE · CAMARO · MALIBU · MONTE CARLO · CAPRICE · CORVETTE

and many occasionals, after a week's flurry of non-stop poker, vanish from the cardroom forever."

This is a complex yet narrow ecology. What is enduring adaptive behavior for a career pro in this consuming and precarious trade? It goes without saying that the pro knows the game, the probabilities and the precedents, all the rationalities of this demanding mix of incomplete information and chance. More than that, the player must know how to stretch the stakes, how to find the active opponent and the incautious one, when to save time and money by standing aside. The player monitors his opponents as players too. So much might be surmised; it would be explainable on the simpler theory of games, the extension of the model of the free market. Actually that is only the strategy of the game. A career player must also have a metagame strategy: the way to manage a career that pits chance against personality in multiple swift encounters.

It turns out that there the rational view fails most pros. They are engaged in constant examination of the long-run flow of events, looking for pattern in the patternless. Denying luck, they court it. Partly this is a matter of establishing an image among the others, an essential constituent of the game; partly it would appear to be a means of motivation, of self-struggle, "a constant battle with . . . inner forces as to play or not to play." Neither von Neumann alone nor game theory taken with psychology suffices for this demanding life: it requires an innovative adaptiveness, a steady struggle with feeling and survival, a personal philosophy under incessant examination. The outcome is a tentative half solution that transcends what can be demonstrated, like the one for most of us far from 52 cards.

Fraud? It is present but a small factor; covert collusion is its main agent, but in the long run that cannot help. Some form of mild collusion is usually present, through bonds of old debt and friendship, but it is offset by some "extra-heated rivalries," again beyond the bounds of simple maximization in the short run. Parasitism? The loan shark is always there, sitting at a card table or leaning on the rail, ready to stake a pro on tilt at a usurious 5 to 20 percent of "juice" per week but making no collateral demand. In Hayano's book there are popular songs, a wide gambling literature (little based on field work although often autobiographical and instructional), a glossary of terms of art, the posted rules of the Gardena rooms and an air of sympathy and insight that will please many readers. The book does not give space to the strategy of poker itself; here it is a life in society and not any game or gamester that is richly described. Players on tilt will always face the risk of Tap City, until the cards start running good, maybe after some Gardena miracle, that wildly improbable draw!

PLASTICS MATERIALS AND PROCESSES, by Seymour S. Schwartz and Sidney H. Goodman. Von Nostrand Reinhold Company, Inc. ($89.50). Beautiful and apt for its purpose, the familiar Ping-Pong ball remains a rare specimen of industrial archaeology. It is a sample of the first synthetic plastic, Celluloid, the invention of J. W. Hyatt in 1868, made to this day by gelatinizing cellulose nitrate with an alcohol solution of the natural terpene camphor. So plastic was the stuff thus prepared that it could easily be rolled and pressed into Victorian cue balls, enduring high collars and ribbons of silent films from Lumière to Valentino. Only a few knife handles and that long-standardized bouncing ball remain from Celluloid, along with that word plastic, now widely current and broad of meaning.

This hefty volume is a general introduction to the diverse and important substances we now call plastics and to their fabrication. There is no dearth of books on the industry, but they tend to fall between stools: they ignore molecules and aim at severe practicality, or treat polymers at some theoretical depth, or specialize in one family of ma-

terials or of processes, or give in to superficiality on facing the wide variety of topics. The big encyclopedias in many volumes shred their rich material too fine for any wide introduction. These authors, both experienced plastics engineers out of the aircraft industry as well as teachers, have successfully produced a work comprehensive enough to be generally useful without suppressing the detail requisite to understanding. It is no dictionary; even its large index did not help to find the material Tyvek starting from the name alone. But as a general reference good for understanding materials, design and fabrication over a wide range it is a book that belongs on the reference shelf of libraries and of interested (and well-heeled) readers. (Tyvek, a very tenacious neo-paper, is a "spunbonded high-density sheet" of polyethylene, as we learn from the long list of trade names for that polymer, one of about 50 trade-name lists by type of material in the volume.)

You can pick out about four book-length technical introductions between these covers. There is one book on thermoplastics, another on thermosetting materials, a third on fabrication processes (from fillers and films through injection molding to foam, reinforcement, fastening and joining, a trip through a production wonderland of clever and unexpected procedures in shop and factory) and an unusually clear fourth volume of background, with history, polymer chemistry, mechanical properties and their tests, the design of molds and fabricated parts, plastics identification and finally safety. A long tabular chapter to facilitate serious rational selection of materials and processes from this gourmand's menu looks useful; it is plainly the original work of the authors.

A plastic is here defined as a synthetic polymer of use in design and construction, not bioactive and only incidentally rubberlike. (Elastomers are another technology.) The chief products of this kind (data are as of the years 1978 to 1979) are the double-bonded carbon polymers, first polyethylene, then polyvinyl chloride, polystyrene and polypropylene. All of them are used by the millions of tons per year in the U.S., and all of them were well below $1 per pound for bulk resin as 1978 came in. Polyethylene means 10-mil film enough to cover entire counties for construction and packaging. Polyvinyl chloride (PVC) is the oldest and most versatile of the lot; it is processed by every known technique, as film, sheet, pipe, glues, finishes and molded parts. Polystyrene rose out of the capacity for the production of synthetic rubber in World War II; its ubiquitous forms are fine clear sheet, foamed products and alloys with other plastics. Polypropylene is woven into the expanses of carpet one now walks over indoors and out.

Such serviceable products in bulk do not exhaust the interest in these substances. Engineering plastics are those that can meet exacting specifications for strength and stability and other definable properties, not merely rough grading and low price. They are headed by the nylons, or polyamides, a family of polymers that resemble the proteins of life, their carbon chains linked by recurring nitrogen atoms. The newest members of this family appeared in 1974; they are still so proprietary that chemical characterization is vague. They are nylons whose chains are aromatic compounds: stable carbon rings. At costs of $1 per gram, these materials yield fibers of remarkable strength and heat resistance. Of the new fiber reinforcings discussed in the book these aramids plot better than glass and not far from the domains of exotic boron and graphite, "as strong as steel at 1/5 the weight." Then there are the familiar linkages with fluorine and silicon, far from the usual world of the organic chemist.

Monomer chemistry is outside the field of view here, except for a few general remarks; this is the world of polymers taken as resin or fiber, ready for end-use design and fabrication. In this treatment there is much even for the browser. Plastics are welded by schemes

that are appealing for their union of surprise and naturalness. Why not spin one thermoplastic part against another under pressure? In seconds "an excellent weld results." Ultrasonic welds are familiar by now, but what about the use of vibration heating at 60 cycles (or its octave), making possible big butt welds by frictional heating under sturdy clamps? Boats and gasoline tanks and similar structures are made by rotating a large mold while heating a charge of thermoplastic powder within. Rotate about two axes and you have a pickup top or a canoe complete in one step. The machines that spin those molds are big but far from clumsy.

Here glassblowing has its low-temperature, subtly programmed and large-size counterpart, with the piece automatically extruded and blown into a mold. Barrels of 55 gallons are by no means the largest products blow-molded. Then there is honeycomb, descended from the sandwiches of balsa faced with birch plywood that formed the skin of the famous Mosquito bomber of World War II. Nowadays the filling is an open honeycomb formed of fiberglass or impregnated paper, even of aluminum. It makes up into the strongest and lightest of panels, although not the cheapest or the simplest to join; the leading and trailing edges of the big 747 jet wing are made of various types of honeycomb, the state of this art.

THE COMPLETE VISITOR'S GUIDE TO MESOAMERICAN RUINS, by Joyce Kelly. University of Oklahoma Press ($35). ARCHEOLOGICAL MAP OF MIDDLE AMERICA, researched and compiled by George E. Stuart. National Geographic Society, Washington, D.C. ($3). These wintry months many readers plan trips toward the sun, and even more dream of them. Americans have hardly any better opportunity to sense the past of the New World than a visit during the sunny winters of Mesoamerica to those green uplands and greener plains where lie the manifold ruins of past cultures, cities built and carved since dim antiquity by gifted peoples innocent of wheat, horses, wheels or smelted iron.

The elaborately detailed volume by Joyce Kelly, a New Orleans painter and teacher, is a knowing and practical field guide to the ruins. She has compiled it from 20 years of inquisitive, acute and sympathetic visits. How to get there by private or hired car or jeep or by public transport down the long access tree, the site in its archaeological context, what a keen eye can actually see, the recent history of discovery and publication—all are given in an orderly, compact way for 119 sites and 41 active museums in five countries. Fine ink drawings and numerous photographs enliven the accounts, which are personal and detailed enough (broken stairs, sour oranges for

the picking, and the hours of shadow) to convince and offer genuine help to fainter-hearted travelers. Both the archaeology and the reconnaissance go up to 1979 or a little later; enthusiasm and friendship for the people of the land, ancient and modern, give the book its air of delighted witness to wonders.

In the current fashion there is even a rating system; rational enough, it offers the reader a dozen top-rated visits in Mexico and three outside it. The magnificent museum in Mexico City heads the list, as being beyond all ratings. Four stars of course mark the most famous of the sites—Chichén Itzá, Teotihuacán, Monte Albán and Mitla, Tikal, Copán—and the author's own favorite, green Palenque. There is much more. A reader can hardly put aside the image of the colossal Olmec heads; they are best seen near the old airport outside the busy city of Villahermosa, in a "unique park-museum." Three are there, sculptured boulders of basalt, 15 to 18 tons each, with other monuments, including huge floor mosaics. The Regional Museum of Tabasco is nearby, rich in La Venta work. (The site of La Venta itself is today an oil boom town, its mounds bulldozed.)

How could anyone resist white-plastered Tulum, perched on its cliff above the sapphire sea? Or the lake of Pátzcuaro far to the north in Michoacán, where the ruined city of Tzintzuntzan stands. Occupied when the Spanish came, it was home to outstanding craftsman in copper. Or Bonampak, where Mayan frescoes stand in brilliant color, known in the big museums only by copies? Bonampak lies like exquisite Yaxchilán in the land of the Lacandones, who have long venerated the ruins. The two related sites are easy to reach only by air. Or Izapa on the southernmost border of Mexico, seldom visited? It is a large site and an old one. Its position due west along the parallel from great Copán may be no accident but a fragment of the unsolved puzzle of Mesoamerican calendrics and geodesy. ("The caretaker's wife may come along with a bucket of water and offer to splash some on the monuments. Accept her offer.")

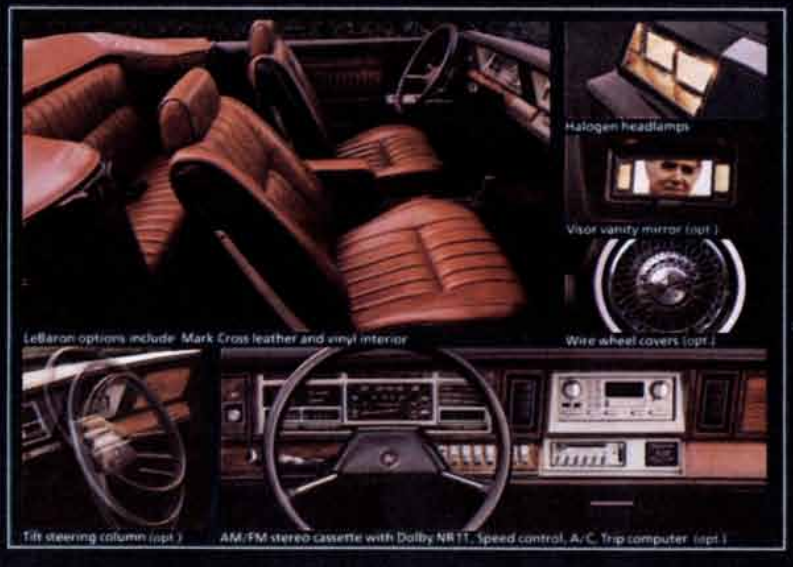
The National Geographic Society map is a good general one of Mesoamerica, its surface densely annotated with a capsule archaeology marking hundreds of sites. Its size and indications of relief complement the outline maps of the Kelly guide, not for roads and access but on a larger planning scale. (It does not extend north of the Valley of Mexico.)

A review is no place for individual advice. It is nonetheless difficult to avoid reminding the reader that from the Gulf of Fonseca north to the border of Mexico the countries are in a state of travail, from open civil war through the grades of threat and maneuver. A thoughtful traveler will need to reflect on each destination both in prudence and in equity.

THE 1983 CHRYSLER LEBARON SERIES.

They combine front-wheel drive, high mileage, room and luxury.
They are like no other cars in America, Europe or Japan.

Sedan & Convertible: 35 est. hwy. 27 EPA est. mpg.; Town and Country: 32 est. hwy. 24 EPA est. mpg. Use EPA est. mpg for comparison. Your mileage may vary depending on speed, trip length & weather. Hwy. & CA mileage lower.



Luxury starts with the LeBaron Coupe, equipped with more standard features than last year. Features that include:

- 5-speed manual transmission
- 2.2 liter engine
- Power rack-and-pinion steering
- Power front disc brakes
- Low-back bucket seats with console
- Padded landau vinyl roof
- Halogen headlamps
- Maintenance-free battery
- New instrument panel message center
- Electronic digital clock
- Luxury steering wheel
- Deluxe wheel covers
- 20 oz. cut pile carpeting
- Dual manual mirrors
- Warning chimes
- Crystalline pentastar hood ornament

Coupe only

44 EST. HWY. | 28 EPA EST. MPG.*

Coupe base price

$8,514**

**Base sticker price, excludes title, taxes, destination charges. †Whichever comes first. Limited warranties. Deductible may be required. ††"Dolby Laboratories. Buy or lease at your Chrysler-Plymouth dealer. Buckle up for safety.

LeBaron is built to such high standards of quality. Chrysler has the confidence to back each car with a 5 year/50,000 mile protection plan.

Now the Chrysler LeBaron Series is complete and there's a LeBaron for everyone. Each LeBaron is a unique statement of luxury. You get personal luxury in the coupe. The luxury of six-passenger room in the sedan. Functional luxury with the Town & Country. And the ultimate luxury, the LeBaron Convertible. It makes driving fun again.

Every LeBaron is pure driving pleasure. They perform with nimble responsiveness for a road-gripping, smooth ride because they're engineered with advanced front-wheel drive, rack-and-pinion steering and an iso-strut suspension system. And LeBaron's 1983 engine with an electronic combustion computer achieves more power with greater fuel efficiency than ever before.

LeBaron is built with the help of computers and robots in one of the world's most technologically advanced plants. A Quality Assurance Program of over 2,000 careful checks further assures LeBaron's quality. Quality so exceptional that Chrysler has the confidence to protect the engine and power train and the entire outer body against rust-through for 5 years or 50,000 miles†. See your dealer for details.

The Chrysler LeBaron Series. High mileage. Room. Luxury. Exceptional protection. All at a surprising price.

Chrysler

WE'VE RE-ENGINEERED THE AMERICAN LUXURY CAR.
THE NEW CHRYSLER CORPORATION. QUALITY ENGINEERED TO BE THE BEST.

Established 1845 SCIENTIFIC AMERICAN November 1982 Volume 247 Number 5

A Bilateral Nuclear-Weapon Freeze

In many of the current elections in the U.S. there is a referendum on whether to urge a halt in the production of new nuclear weapons and delivery systems. The nature of such a freeze is discussed here

by Randall Forsberg

The proposal of a bilateral nuclear-weapon "freeze" by the U.S. and the U.S.S.R. has excited wide public discussion in this country during the past year. The idea is to stop the nuclear arms race quite literally, by stopping the development and production of all nuclear-weapon systems in the two countries. Public interest (expressed, for example, by votes in numerous town meetings) brought the proposal in the form of an advisory resolution before the U.S. Congress. Whereas a vote on it was blocked in the Senate, it lost in the House in August by the narrow margin of 204 to 202. The proposal is now on the ballot as a referendum question in impending congressional and local elections in enough cities and states to put it before nearly a fourth of the country's population. Next to the depressed state of the economy, the nuclear freeze is said to be the warmest current issue in the country's politics.

First put forward in the "Call to Halt the Nuclear Arms Race" drafted by me and published in April, 1980, by several public-interest groups, the freeze goes beyond other arms-control measures proposed in the past 25 years to put a stop to the production, testing and, implicitly, development of nuclear weapons as well as their deployment. By the same simplicity that has given it wide popular appeal the freeze proposal responds directly to an ominous turn in the arms race. The bilateral freeze would preclude the production of a new generation of "counterforce" weapons by the U.S. and the U.S.S.R. These are weapons designed to attack the opponent's nuclear forces. In the ultimate scenario they would disarm the other nation and hold its population hostage. The quest for improved counterforce capability has driven the arms race far past the point where each contender can destroy the other's society and much else besides. The production of counterforce weapons would increase the risk of a nuclear war. Their deployment would put pressure on leaders to launch their weapons first in time of crisis, before they were attacked, and perhaps to place their nuclear forces in an automatic "launch on warning" status in peacetime. A freeze would prevent these dangerous developments.

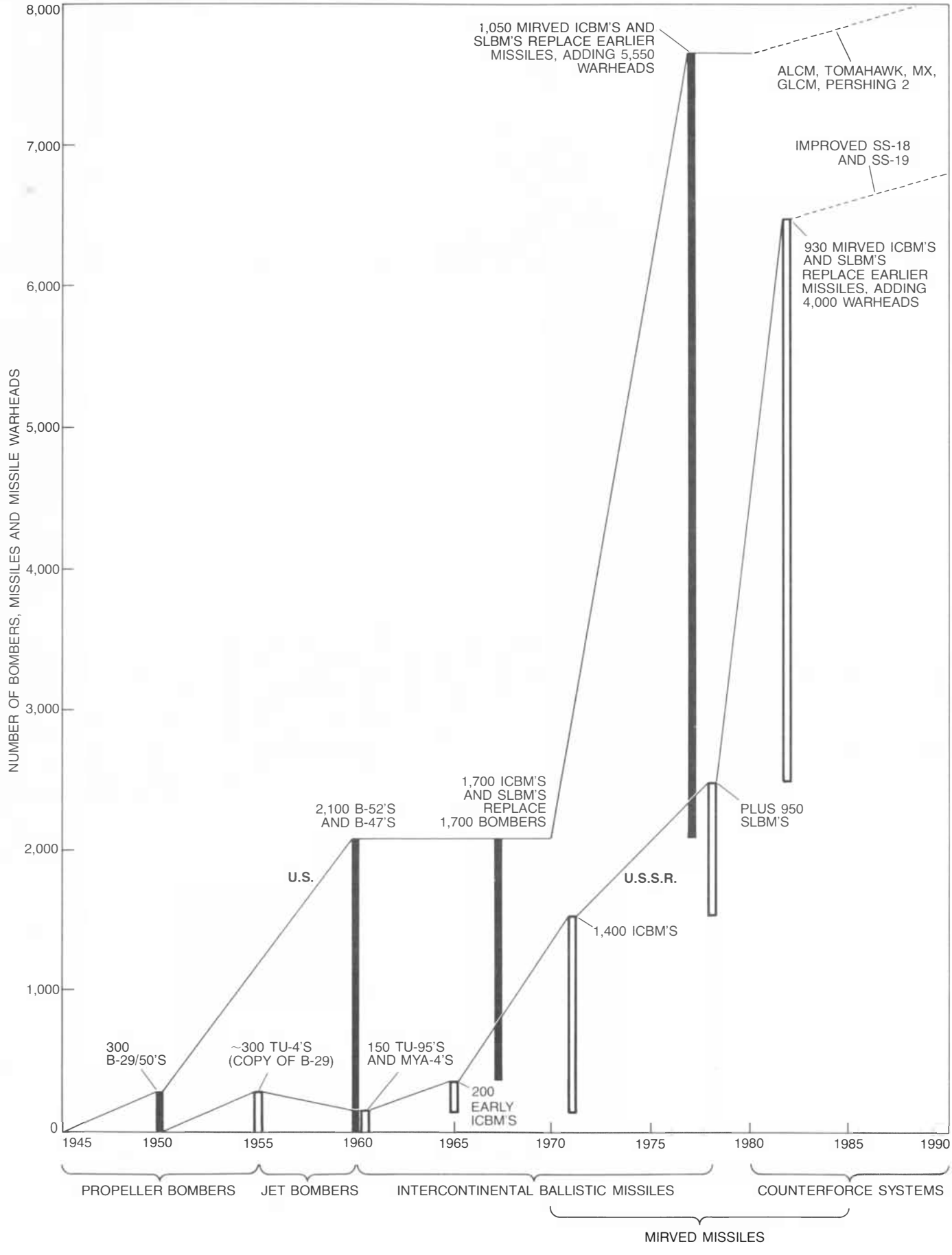
A freeze would help to accomplish other desirable goals. The U.S. and the U.S.S.R., by fulfilling the pledge they made in the 1970 Nonproliferation Treaty to stop the arms race, would help to brake the spread of nuclear weapons to countries that do not already have them. A freeze would create an opportunity for the nations of the world to make further progress in arms control and other global issues. It would also save billions of dollars.

The time is propitious for a bilateral freeze. Today the U.S. and the U.S.S.R. are closer to parity in nuclear arms than they have been at any time since World War II. The U.S.S.R. has advantages in some elements of nuclear weaponry, the U.S. has advantages in others. The most frequently cited statistics compare the numbers of "strategic" ballistic missiles and bombers and the numbers of nuclear warheads and free-fall bombs they carry. The U.S.S.R. has more strategic missiles: 1,398 land-based intercontinental ballistic missiles (ICBM's) compared with 1,052 for the U.S. and 950 submarine-launched ballistic missiles (SLBM's) compared with 520 for the U.S. In addition a recent buildup has brought the strategic force of the U.S.S.R. abreast of that of the U.S. in the arming of these missiles with multiple independently targetable reentry vehicles (MIRV's). The land-based ICBM's of the U.S.S.R. carry more warheads and larger ones. On the other hand, the U.S. has more warheads in total, owing to the larger number of warheads on its SLBM's. The U.S. also has many more intercontinental bombers, with much larger payloads, and a five-to-10-year lead in the new technology of small, long-range, low-flying cruise missiles [*see illustration on pages 54 and 55*].

More meaningful than comparisons of numbers of weapons is the fact that both countries have acquired enormous "overkill," that is, each has many times the number of weapons necessary to annihilate the other's urban population. Thus even if the U.S.S.R. destroyed all U.S. ICBM's, all U.S. bombers and all U.S. submarines in port, the U.S. would still have about 2,400 nuclear warheads on submarines at sea, completely invulnerable to such preemptive attack. This is several times the number needed to destroy the 300 largest cities and towns in the U.S.S.R., which have one-third of the population and three-fourths of the industry. Conversely, a U.S. attack on ICBM's, bomber bases and submarine ports in the U.S.S.R. would leave an estimated 1,200 strategic warheads, more than enough to inflict equivalent damage on U.S. urban centers [*see illustration on page 57*].

The bilateral freeze would preserve this parity. It would prevent the emergence of a new, destabilizing U.S. advantage in counterforce capability, projected in the buildup planned by the Reagan Administration [*see illustration on pages 58 and 59*]. And it would forestall the inevitable effort by the U.S.S.R. to match U.S. developments.

As spelled out in the "Call to Halt the Nuclear Arms Race," a freeze on both



HISTORY OF THE NUCLEAR-ARMS RACE between the U.S. and the U.S.S.R. is traced by these two curves. The vertical bars represent the total number of strategic delivery systems and missile warheads in each country's arsenal; the black bars are for the U.S. and white bars are for the U.S.S.R. A nuclear-weapon freeze would forestall the continuation of the arms race (*broken lines at upper right*).

sides would stop the following: the production of fissionable material (uranium 235 and plutonium) for nuclear weapons; the fabrication, assembly and testing of nuclear warheads; the testing, production and deployment of missiles designed to deliver nuclear warheads, and the testing of new types of aircraft and the production and deployment of any additional aircraft designed primarily to deliver nuclear weapons.

In order to achieve its promise as a new departure in arms control the freeze must be complete. One reason is to facilitate its verification. In all arms-control agreements to date the parties have relied primarily on "national" methods of verification, that is, methods that can be managed independently, without cooperation. This has meant principally surveillance by satellites. For this reason some have argued that the freeze should be limited to the deployment of large nuclear-weapon delivery systems, an activity that is confidently subject to satellite surveillance. Such a freeze would be better than none at all. There are, nonetheless, persuasive arguments in favor of a freeze that covers production as well as deployment and small systems as well as large.

If production is not banned, the military on both sides is likely to argue that missiles and bombers, warheads and bombs should continue to be produced, if only for storage in warehouses. Thus the 1963 Partial Test-Ban Treaty was followed by more vigorous testing underground than had ever been conducted aboveground, and the 1972 Anti-Ballistic-Missile Treaty has sheltered intensive developmental testing of those weapons. A "production but not deployment" race would continue the buildup

U.S. NUCLEAR WEAPON SYSTEMS

Number	Name	Warheads Carried: Number	Warheads Carried: Yield and Type	Deployed Warheads
INTERCONTINENTAL "STRATEGIC" OFFENSIVE FORCES				
Intercontinental ballistic missiles				
300	Improved Minuteman 3	3	335-kt. MIRV warhead	900
250	Minuteman 3	3	170-kt. MIRV warhead	750
450	Minuteman 2	1	1,500-kt. warhead	450
52	Titan 2	1	9,000-kt. warhead	52
Submarine-launched ballistic missiles				
304	Poseidon	10	40-kt. MIRV warhead	3,040
216	Trident 1	8	100-kt. MIRV warhead	1,728
Intercontinental bombers				
75	B-52D	4	100-1,000-kt. var.-y. bomb	300
255	B-52G,H	4	100-1,000-kt. var.-y. bomb	1,020
		+4	170-kt. SRAM missile	1,020
60	FB-111	2	100-1,000-kt. var.-y. bomb	120
		+2	170-kt. SRAM missile	120
STRATEGIC AIR DEFENSE				
Interceptor aircraft				
120	F-106	2	(1)-kt. Genie rocket	(240)
Antiaircraft missile				
(100)	Nike Hercules	1	(10)-kt. warhead	(100)
PATROL FOR STRATEGIC SUBMARINES				
Long-range antisubmarine aircraft				
230	P-3 Orion	(2)	(10)-kt. depth charge	(460)
Submarines				
17	Los Angeles SSN	(4)		
37	Sturgeon SSN	(4)		
13	Permit SSN	(4)	(5)-kt. Subroc missile	(276)
1	Lipscomb SSN	(4)		
1	Narwhal SSN	(4)		

U.S.S.R. NUCLEAR WEAPON SYSTEMS

Number	Name	Warheads Carried: Number	Warheads Carried: Yield and Type	Deployed Warheads
INTERCONTINENTAL "STRATEGIC" OFFENSIVE FORCES				
Intercontinental ballistic missiles				
580	SS-11	1	(1,000)-kt. (or 3 MRV)	580
60	SS-13	1	(1,000)-kt. warhead	60
150	SS-17	4	(200)-kt. MIRV warhead	(600)
(50)	SS-18	1	(10,000)-kt. warhead	(50)
(258)	SS-18	8	(550)-kt. MIRV warhead	(2,064)
(50)	SS-19	1	(1,000)-kt. warhead	(50)
(250)	SS-19	6	(550-kt.) warhead	(1,500)
Submarine-launched ballistic missiles				
18	SS-N-5	1	(1,000)-kt. warhead	18
374	SS-N-6	1	(1,000)-kt. (or 3 MRV)	374
290	SS-N-8	1	(1,000)-kt. warhead	290
12	SS-NX-17	1	(1,000)-kt. warhead	12
(192)	SS-N-18	(3)	(200)-kt. MIRV warhead	(576)
(32)	SS-N-18	(7)	(200)-kt. MIRV warhead	(224)
Intercontinental bombers				
30	Tu-95 *(Bear)*	2	1,000-kt. bomb	60
75	Tu-95 *(Bear)*	1	1,000-kt. bomb	75
		+1	(500)-kt. AS-3 *Kangaroo*	75
49	Mya-4 *(Bison)*	1	1,000-kt. bomb	49
ANTIBALLISTIC MISSILE				
32	*Galosh*	1	(100)-kt. warhead	32
STRATEGIC AIR DEFENSE				
Antiaircraft missiles				
2,000	SA-5 *Gammon*			
4,000	SA-3 *Goa*		Nuclear capability uncertain	(1,000)
3,000	SA-2 *Guideline*			
3,200	SA-1 *Guild*			
PATROL FOR STRATEGIC AND ANTISUBMARINE SUBMARINES				
Long-range antisubmarine aircraft				
50	Tu-95 *(Bear F)*		May carry nuclear depth charge	(100)
50	Il-38 *(May)*			
Submarines				
7	*Victor* 3	(4)	(15)-kt. SS-N-15	(28)
6	*Victor* 2	(4)	(15)-kt. SS-N-15	(24)
Surface ships				
2	Kiev	(4)	(15)-kt. SUW-N-1	(8)
2	Moskva	(4)	(15)-kt. SUW-N-1	(8)
1	Kirov	(16)	(15)-kt. SS-N-14	(16)
7	*Kara*	8	(15)-kt. SS-N-14	56
10	*Kresta* 2	8	(15)-kt. SS-N-14	80
30	*Krivak* 1/2	4	(15)-kt. SS-N-14	120

DELIVERY SYSTEMS AND WARHEADS currently deployed by the U.S. and the U.S.S.R. are listed. The numbers in parentheses are estimates. Overall the numbers given are conservative; they do not include aircraft and missiles held in reserve or stockpiled nuclear

on both sides, and along with it the confrontation, the cost and the growing destructive potential.

This line of reasoning suggests that any freeze agreement should incorporate objectives such as the production ban that, although they may be less independently verifiable, define the intent and interpretation of the more verifiable parts. A full statement of intent has force in other realms of domestic and international law.

In fact, as has been established by three decades of experience with demonstrated modes of verification, production activities are not hidden but are well known. The brochure *Soviet Military Power,* produced by the U.S. Department of Defense, gives a summary of what is known about the weapon-production complex in the U.S.S.R.:

"The military production industry includes 135 major final assembly plants involved in producing weapons as end products. Over 3,500 individual factories and related installations provide support to these final assembly plants."

A map in the brochure shows the military products manufactured in 14 regions of the U.S.S.R. Tables give the annual production of every type of weapon system, including small arms. This detailed information has been pieced together in spite of complete Russian secrecy about military production.

The production facilities for nuclear weapons are known at least as well as those for conventional weapons. Nuclear warheads are fabricated and assembled at just a handful of facilities in the U.S.S.R., which were identified in the 1950's, soon after they were established and years before the introduction of reconnaissance satellites. The closing down of these facilities could be moni-

INTERMEDIATE-RANGE "THEATER" OFFENSIVE FORCES				
Strike aircraft				
260	F-111 (land-based)	2	100-1,000-kt. var.-y. bombs, Bullpup or Walleye nuclear air-surface missiles or nuclear depth charges	(5,060)
380	F-15 (land-based)	2		
200	F-14 (carrier-based)	2		
150	A-6 (land/carrier)	2		
1,000	F-4 (land/carrier)	2		
20	F/A-18 (land/carrier)	2		
300	A-7 (land/carrier)	2		
170	F-16 (land-based)	2		
100	A-4 (land-based)	1		
BATTLEFIELD WEAPONS				
(300)	Pershing 1A MRBM	1	60-400-kt. var.-y. warhead	(300)
950	Lance SRBM	1	1-100-kt. var.-y. warhead	950
(1,000)	M-109 8-in. howitzer	1	<1-2-kt. var.-y. warhead	2,000
(1,000)	M-110 155-mm. howitzer	1	<1-2-kt. var.-y. warhead	2,000
300	Atomic demolition mine	1	1-to-100-kt. (diff. y.)	300
ANTISUBMARINE WEAPONS				
Carrier-based antisubmarine aircraft				
120	S-3 Viking	1	(10)-kt. depth charge	120
72	SH-3 helicopter	1	(10)-kt. depth charge	72
Surface ships with antisubmarine missile Asroc				
4	Virginia CGN	(22)	(1)-kt. Asroc missile	2,464
6	California CGN	(24)		
7	Truxtun CGN	(20)		
9	Belknap CG	(20)		
1	Bainbridge CGN	(24)		
1	Long Beach CGN	(24)		
10	Coontz DDG	(24)		
2	Kidd DDG	(16)		
30	Spruance DD	(24)		
9	Leahy CG	(8)		
23	Charles F. Adams DDG	(8)		
8	Sherman DD	(8)		
4	Converted Sherman DD	(8)		
6	Brook FFG	(8)		
46	Knox FF	(8)		
11	Garcia FF	(8)		
2	Bronstein FF	(8)		

INTERMEDIATE-RANGE "THEATER" OFFENSIVE FORCES				
Intermediate-range ballistic missiles				
300	SS-20	3	150-kt. MIRV warhead	900
35	SS-5	1	(1,000)-kt. warhead	35
275	SS-4	1	(1,000)-kt. warhead	315
Ballistic missiles on conventionally powered submarines				
39	SS-N-5	1	(1,000)-kt. warhead	39
Medium-range bombers				
65	Tu-26 (*Backfire*)	1	(1,000)-kt. bomb	65
125	Tu-22 (*Blinder*)	1	(1,000)-kt. bomb or	
		1	(350)-kt. AS-4 *Kitchen*	125
250	Tu-16 (*Badger*)	1	(1,000)-kt. bomb	250
60	Tu-16 (*Badger*)	2	(350)-kt. AS-5 *Kelt*	120
Strike aircraft				
700	MiG-27 (*Flogger D/J*)	1	(1,000)-kt. bomb	700
650	Su-17/20 (*Fitter C/D/H*)	1	(1,000)-kt. bomb	650
400	Su-19/24 (*Fencer*)	1	(1,000)-kt. bomb	400
BATTLEFIELD WEAPONS				
few	203-mm. howitzers	1	(15)-kt. warhead	(20)
few	240-mm. mortars	1	(15)-kt. warhead	(20)
(480)	FROG (free rocket over ground)	1	(15)-kt. warhead	(480)
few	SS-21 SRBM	1	(15)-kt. warhead	(20)
(400)	SS-1 *Scud* SRBM	1	(15)-kt. warhead	(400)
65	SS-12 *Scaleboard* MRBM	1	(1,000)-kt. warhead	65
(5)	SS-22 MRBM	1	(1,000)-kt. warhead	(5)
ANTISHIP WEAPONS				
Land-based antiship aircraft				
35	Tu 26 (*Backfire*)	1	(1,000)-kt. bomb	35
35	Tu 26 (*Backfire*)	1	(350)-kt. AS-4 *Kitchen*	35
(40)	Tu 16 (*Badger*)	1	(200)-kt. AS-6 *Kingfish*	40
Surface ships				
2	Kiev CG	(16)	(350)-kt. SS-N-12	(32)
1	Kirov CG	20	(350)-kt. SS-N-19	(20)
4	*Kresta 1*	4	(350)-kt. SS-N-3b	(16)
4	*Kynda*	8	(350)-kt. SS-N-3b	(32)
21	Nanuchka	6	(200)-kt. SS-N-9	(126)
1	Sarancha	4	(200)-kt. SS-N-9	(4)
Submarines				
1	*Oscar*	24	(350)-kt. SS-N-12	(24)
1	*Papa*	10	(220)-kt. SS-N-7	10
16	*Charlie*	8	(200)-kt. SS-N-7	128
5	*Echo 2*	8	(350)-kt. SS-N-12	40
24	*Echo 2*	8	(350)-kt. SS-N-3a	192
16	*Juliet*	4	(350)-kt. SS-N-3a	64
4	*Whiskey-Long Bin*	3	(350)-kt. SS-N-3	12
2	*W-Twin Cylinder*	2	(350)-kt. SS-N-3	4

warheads. The aircraft, the howitzers and some of the ship-launched missiles have "dual capability": they can deliver either nuclear or conventional warheads. "Kt." stands for kiloton (a measure of explosive yield), "var. y." for variable yield, "diff. y." for different yields.

tored with high confidence from satellites; it would be no easier to replicate them secretly than it was to keep their construction secret the first time.

A long and well-worn production path precedes the deployment of nuclear-weapon systems. It begins with the production of fissionable material at specialized, highly visible plutonium-production reactors and uranium-enrichment plants. The fissionable materials go on to the factories that fabricate and assemble the components of missile warheads and free-fall bombs. The components are then transported to other factories where they are fitted in the nose cones of missiles or the casings of bombs. The nuclear missiles and bombs go on to deployment or to storage depots. All these activities proceed at plants and along transportation routes identified by the special equipment and procedures required for handling nuclear-weapon materials and for security. Possible new production facilities and transport routes can be kept under satellite scrutiny, as the old ones have been.

A variety of nonintrusive on-site verification measures can supplement satellite observation. They can take such forms as occasional, unannounced inspections or continuously monitored, sensor-equipped, secure "black boxes" installed in shut-down or controlled factories. The U.S.S.R., reluctant to agree to on-site verification in the past, has recently shown signs of greater flexibility on this point in the negotiation of a comprehensive nuclear test ban.

In the end there would be little to gain and much to lose in any clandestine attempt to violate an agreement banning production. In the view of most people the only value of nuclear weapons is as a deterrent to war. In order to play this role effectively nuclear arsenals must be known to exist and must be deployed in relatively usable form. Nuclear weapons made "in secret" and stored in warehouses or caves do not contribute to nuclear deterrence. Moreover, the number of weapons that could be produced clandestinely would be very small (some tens or hundreds) with respect to the size of the current arsenals (20,000 to 30,000 warheads, including those stockpiled but not deployed). Thus it is highly unlikely that either party would take the risk of trying to construct a nuclear-weapon production system in secret.

Most of these arguments support extending the bilateral freeze to intermediate-range and battlefield nuclear delivery systems. Like large strategic systems, smaller nuclear-weapon systems call for special security, handling and command-and-control procedures. These activities, signaling the presence of nuclear weapons, have made it relatively easy for each side to keep track of the other's arsenal of tactical nuclear weapons throughout the period since World War II.

More important, as long as new nuclear warheads continue to be manufactured for small delivery vehicles, the entire nuclear-weapon production chain will be operational. A cutoff of warhead production, which would be relatively easy to monitor if it were complete, would be difficult or impossible to verify if it were only partial. Stopping production completely, particularly the production of all nuclear warheads, would therefore make the verification of a freeze more reliable than would be the case if the freeze were limited to testing and deployment activities.

A strictly enforced freeze that includes production and testing as well as deployment could lead after some years to a decline in the reliability and readiness of existing nuclear armaments. Such incidental or inadvertent disarmament may be the only way the world will ever get rid of nuclear weapons, or so George B. Kistiakowsky, science adviser to President Eisenhower, has observed. A freeze should probably be designed and implemented, nonetheless, to avert an automatic decrease in nuclear-weapon stockpiles. Responsible officials will object to a situation in which the choice of what to reduce and when has been preempted by purely technical considerations that may not weigh equally on both parties to the freeze. What is more, even though reduced confidence in the nuclear arsenal may decrease the likelihood of nuclear war and make nuclear weapons seem less relevant to security, uncertainty in this regard is bound to make most people feel less secure rather than more so. Hence a freeze should be defined to allow the maintenance of existing nuclear forces until reductions can be agreed on with due deliberation.

Various factors in the aging of nuclear weapons must therefore be dealt with. For example, the tritium modules that initiate the fusion reaction in thermonuclear explosives must be replaced every few years. This implies that the freeze should allow the operation of tritium-component assembly facilities and the running of perhaps one military nuclear reactor to produce tritium. Special safeguards will be needed to ensure that the reactor does not produce plutonium for new warheads.

Among strategic delivery systems, submarines most clearly have a limited service life, generally estimated at 30 years. The "Call to Halt the Nuclear Arms Race" specifically excludes submarines from the freeze. It allows their replacement but requires the installation of existing missiles rather than new ones so that the quantitative and technical threat does not grow.

In principle aircraft and missiles have a shorter service life than submarines. In practice aircraft and missiles can be maintained indefinitely in good operating condition simply by the replacement of parts during regular maintenance and major overhauls. The B-52G's and B-52H's, the last of the B-52 series delivered to the U.S. Air Force in 1960–62, are expected to remain serviceable through the 1990's and even into the next century. With new engines and updated electronic gear installed and major structural elements replaced and reinforced, the aircraft are physically different entities from those originally delivered. The useful life of the planes is limited only by the availability of spare parts. Although some parts now being cannibalized from retired older-model B-52's may run out, new production lines could be opened.

Even missiles sitting in their silos deteriorate to some extent. The stored fuel can be corrosive and is subject to decomposition; the gyroscopes and electrical systems are in constant operation. By replacement of worn-out parts, however, missiles too can be maintained for long periods.

Tactical or battlefield nuclear weapons present much the same picture with respect to maintenance, except for supersonic fighters and attack aircraft subject to wear from high stress; they are replaced at the rate of about 10 percent of the inventory per year. For the administration of a nuclear freeze, tactical aircraft present a special problem because they are "dual capability" systems, intended to deliver conventional munitions as well as nuclear ones. The "Call to Halt the Nuclear Arms Race" would allow their continued production, but only with conventional capability. The verification of such a limitation might require on-site inspection. An alternative arrangement might allow the production of dual-capability systems to replace existing stocks on a one-for-one basis. The difficulty here is that there is no generally accepted accounting of such weapons today. A final possibility is to exclude these vehicles from the freeze and rely on the control of the nuclear warheads that can be carried by them. To be effective this would require not only a cutoff in the production of new nuclear warheads but also a complete accounting of existing warheads and of fissionable material in storage.

Some have argued that if offensive nuclear-weapon systems are frozen, a country's existing weapons will gradually become vulnerable to the improved defenses and countermeasures of its opponent. The U.S.-U.S.S.R. strategic competition, however, pits the offense not so much against the defense as against the opposing offense, keeping

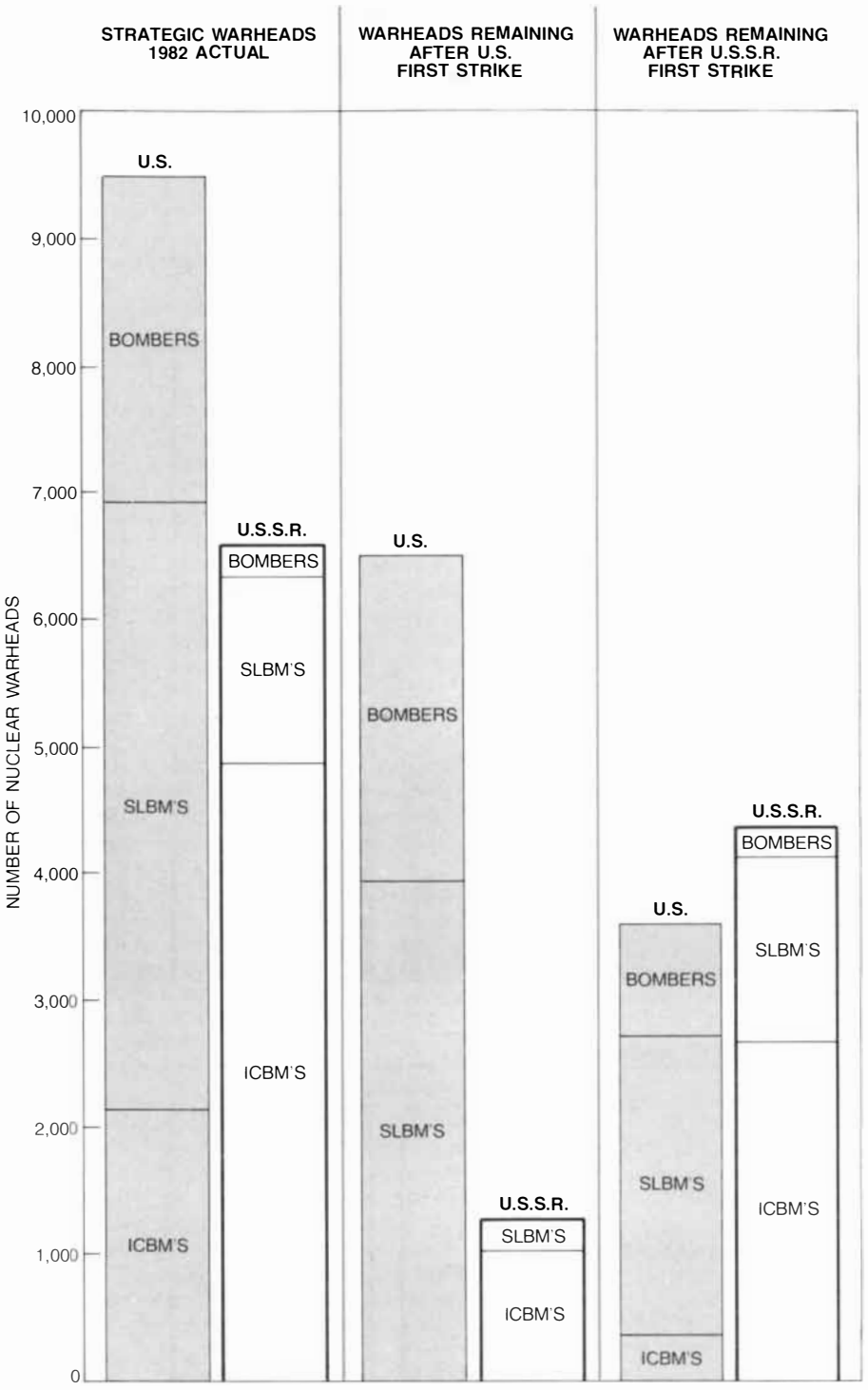
up, as it were, with the Joneses. In ICBM technology no technical improvements are needed to ensure the penetration of defenses as long as the treaty prohibiting anti-ballistic-missile (ABM) systems is kept in force. (Reagan Administration officials are, to be sure, considering the abrogation of the treaty in order to provide ABM defense of MX-missile sites.)

In the case of strategic submarines the U.S.S.R. has not yet initiated any programs that might threaten U.S. submarines in the way that U.S. antisubmarine forces currently threaten the strategic submarines of the U.S.S.R. Exploiting geographic advantages, the U.S. has spread vast underwater sonar arrays in friendly waters in the North Atlantic and North Pacific, and the U.S. fleet of 80 (expanding soon to 90) "hunter-killer" submarines, assisted by several hundred P-3C maritime patrol aircraft (with similar aircraft flown by Japan and Britain), keeps tabs on any strategic submarines that venture out of home waters. Apart from Cuba, the U.S.S.R. has no access to land near U.S. strategic submarine ports that it might rely on for comparable antisubmarine operations. In the event that the U.S.S.R. did begin to construct similar sonar arrays and expand its fleets of hunter-killer submarines and antisubmarine aircraft, the buildup would take 20 years and would be highly visible.

In the competing technologies of bomber aircraft and antiaircraft defenses there is relatively intense interaction between the offense and the defense. Relevant technical advances are likely to continue in conventional equipment even in the event of a nuclear freeze. Bombers, however, represent a nonessential supplement to strategic missile forces. They do introduce uncertainty and compel the opponent to plan and budget for defense, but for this purpose they do not need high penetration capability. The U.S. B-52's and the much less capable Russian Tu-95's and Mya-4's have always constituted an element of uncertainty in the strategic calculation and will continue to do so, regardless of improvements in air defenses.

The advances in the technology of anti-ballistic-missile systems, antisubmarine warfare and air defense that can be foreseen for the remainder of this century will do little to decrease the capacity for devastation that exists in the offensive strategic nuclear forces of the two sides today. In fact, most of the technical advances planned for the offensive forces are not intended to offset improvements in defenses. They seek increases in offensive power only—in yield, accuracy and numbers.

The new MX ICBM of the U.S. is a case in point. The missile is expected to have 10 warheads with a yield of



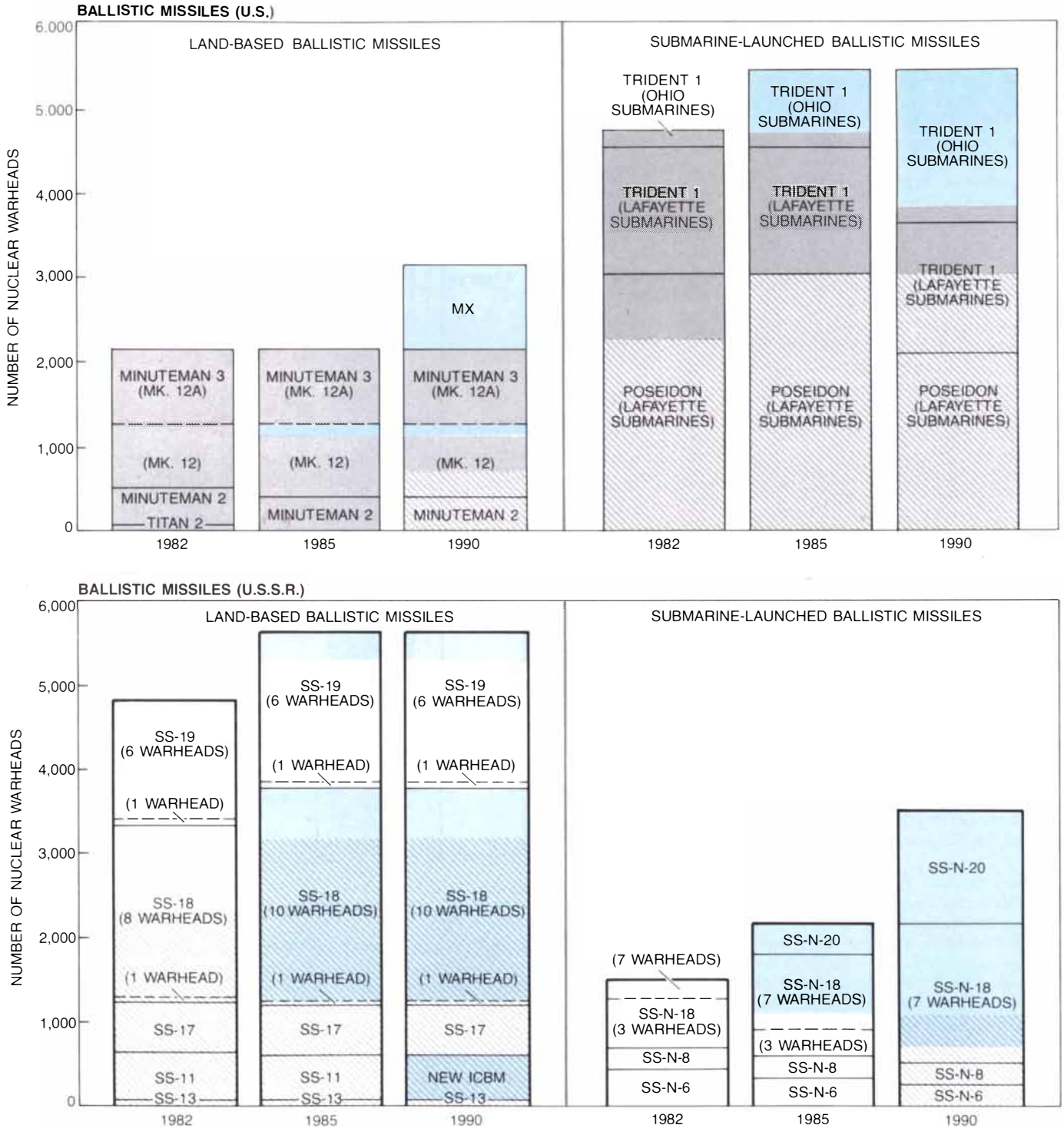
VULNERABILITY OF STRATEGIC NUCLEAR FORCES to a "first strike" is assessed. For many reasons the success of such an attack cannot be predicted reliably. In this chart it is assumed that bombers on the ground and submarines in port would be destroyed, along with most but not all intercontinental ballistic missiles (ICBM's) in blast-resistant underground silos. The bars at the left show the current force levels of both sides in terms of numbers of warheads. The bars in the middle show the result of a plausible first strike in which the U.S. launches all of its ICBM's and some of its submarine-launched ballistic missiles (SLBM's), sending two warheads toward each nuclear target in the U.S.S.R. The bars at the right show the result of a plausible first strike in which the U.S.S.R. launches some of its ICBM's to send two warheads toward each nuclear target in the U.S. Although the strategic forces of the U.S.S.R. are more vulnerable than those of the U.S., neither side is vulnerable to a disarming attack. Even after a preemptive strike each side could launch a counterattack that would cause millions of casualties. The chart does not take into account the possibility that the side being attacked might adopt a "launch on warning" strategy, firing its own missiles before the attacking force arrives.

600 kilotons each and an accuracy of 400 feet. (The accuracy refers to the radius within which half of the warheads would be expected to land.) Thus the warheads could be highly effective against hardened targets. The deployment of the MX would not reduce the vulnerability of U.S. ICBM forces to attack from the U.S.S.R.; it would simply raise the vulnerability of the ICBM's on the other side of the North Pole.

The way to reduce the vulnerability of land-based systems, of course, is not to give them a first-strike potential; that only increases their priority as targets. The wisest course would be to eliminate them altogether. This cheap measure, if taken by the U.S., would deprive the U.S.S.R. of its alleged advantage in counterforce capability and render militarily worthless its recent large investment in accurate, MIRVed ICBM's.

Although the U.S. and the U.S.S.R. both have many times over the power to destroy the population of the other, neither commands the capability to threaten a disarming counterforce attack. The proposed freeze would secure the parity to which their competition has brought them.

Under a freeze the U.S. would retain the preponderance that the evidence indicates it holds in short-range tactical

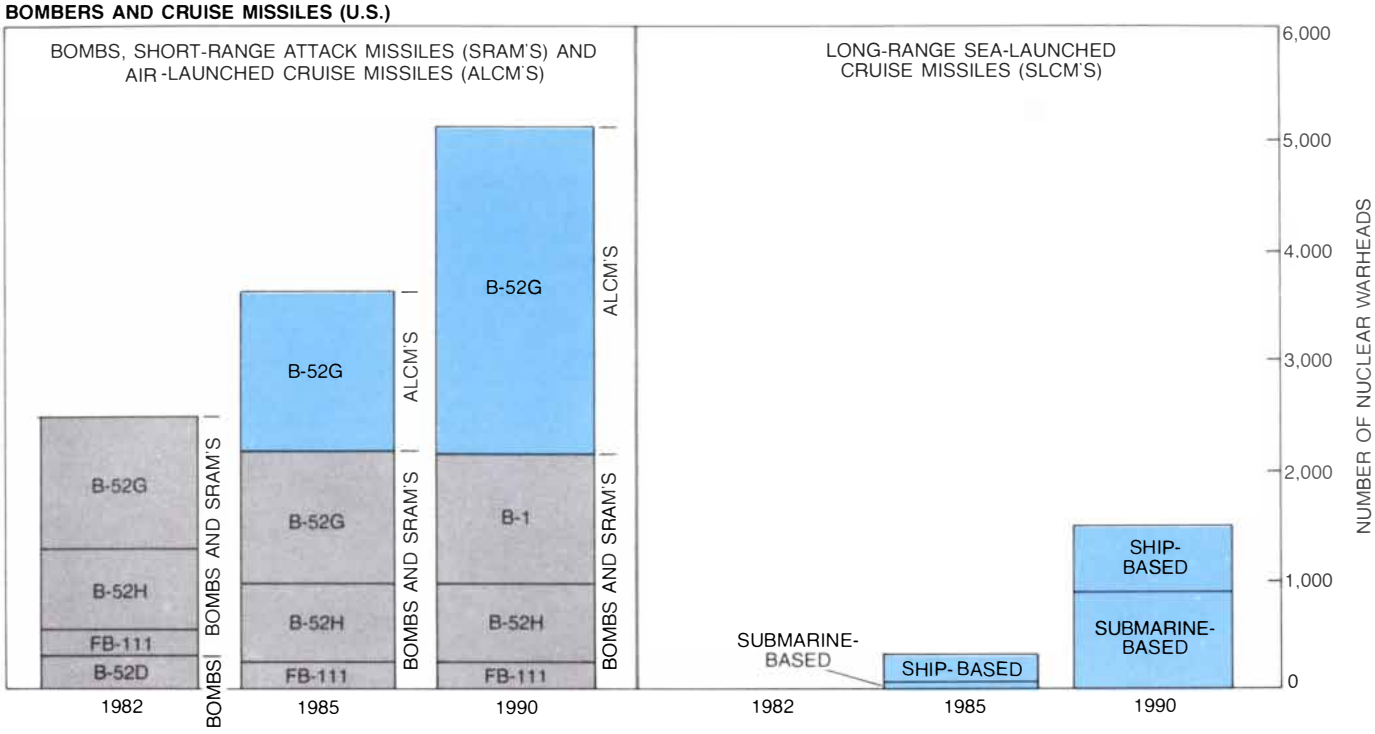


FURTHER DEPLOYMENT of strategic warheads is planned by the U.S. (*bars at the top*) and the U.S.S.R. (*bars at the bottom*) over the next decade. The U.S. is expected to deploy some thousands of strategic cruise missiles on aircraft, surface ships and submarines, to add 1,000 warheads on land-based MX missiles and to replace most remaining Poseidon submarine-launched missiles with new Trident 1 missiles. The U.S.S.R., which has not yet developed modern strategic cruise missiles, is expected to improve the accuracy of its land-

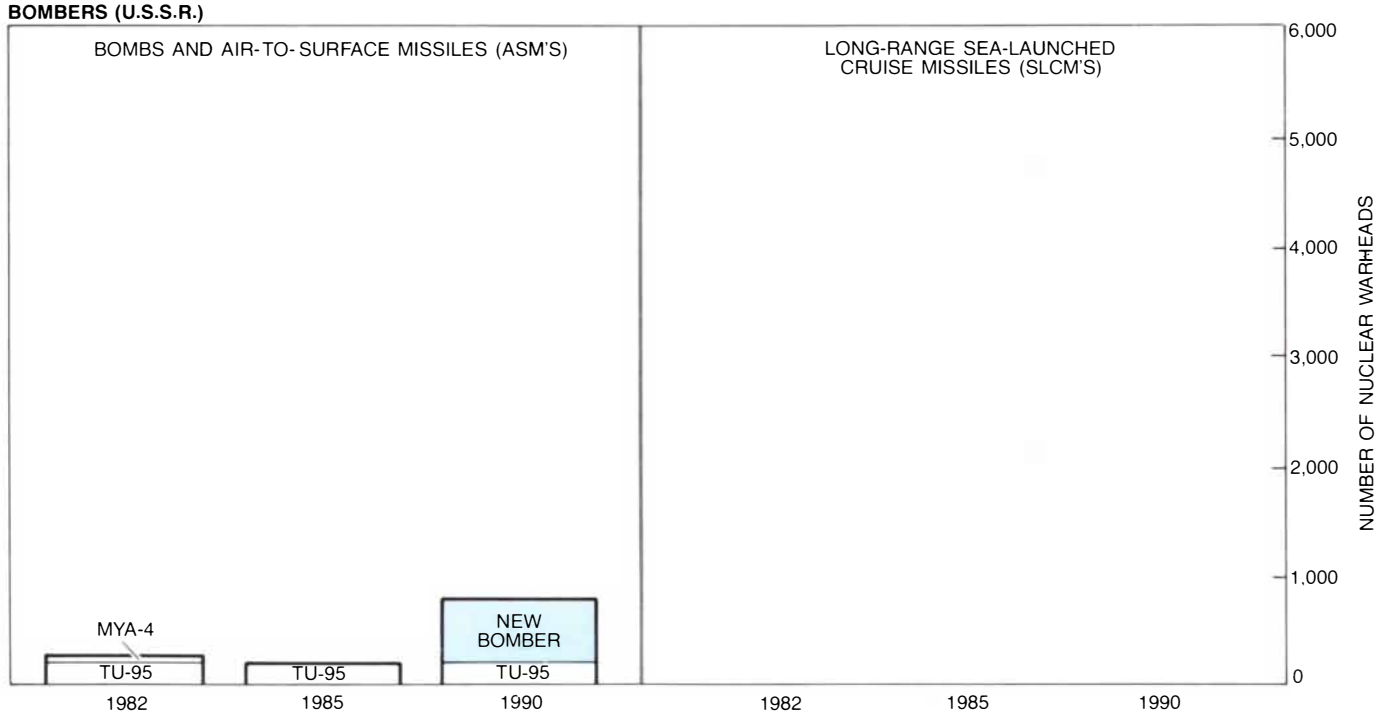
nuclear weapons. Because they do less injury to nearby civilian populations and friendly troops (in military jargon "collateral damage") the lower-yield tactical nuclear weapons fielded by the U.S. are said to increase the credibility of a threat of "controlled" escalation up from conventional war. This dubious "advantage" would not change if the U.S. were prevented from manufacturing new eight-inch and 155-millimeter rocket-assisted nuclear artillery shells, with a range of from 20 to 30 miles, and new warheads for an entire panoply of tactical weapons. Under a freeze the U.S.S.R. would also stop the manufacture of new SS-21, SS-22 and SS-23 battlefield weapons and artillery with a nuclear capability.

In intermediate-range weapons a freeze would prevent the U.S. from deploying in Europe the new Pershing 2 ballistic missiles (the first ballistic missiles with terminal guidance) and the first generation of ground-launched cruise missiles (GLCM's). The deployment of these new weapons has been justified as being necessary to offset the estimated 900 warheads on the U.S.S.R.'s new SS-20 intermediate-range missiles. The SS-20's are already offset, however, by a comparable number of missile warheads aimed at the

BOMBERS AND CRUISE MISSILES (U.S.)



BOMBERS (U.S.S.R.)



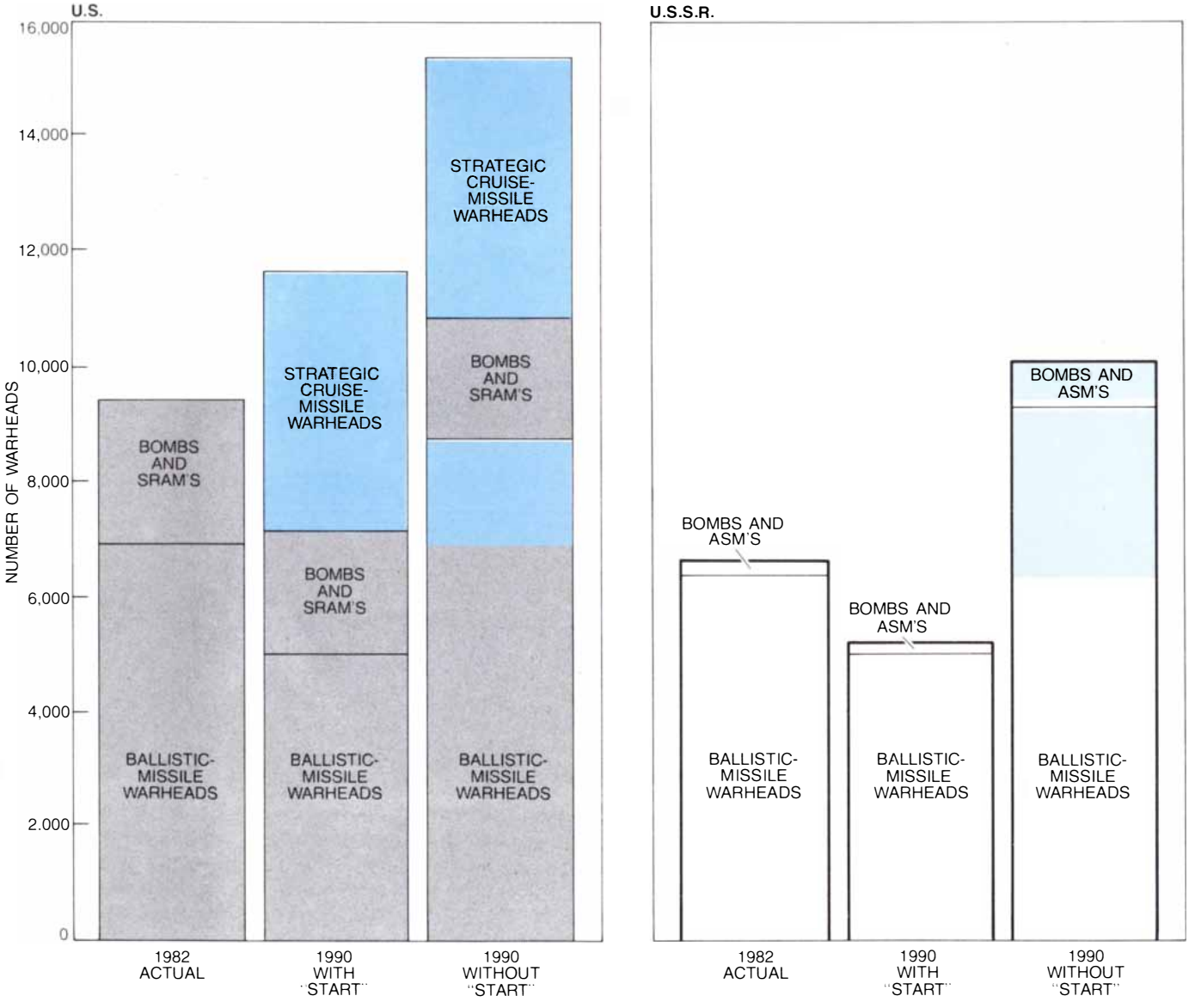
based SS-18 and SS-19 missiles, to replace the eight-warhead SS-18 missile with a 10-warhead version, to deploy a more accurate single-warhead ICBM in place of the SS-11 and to add seven-warhead SS-N-18's and new 10-warhead SS-N-20's on submarines. Under the Reagan Administration's START proposal all the planned U.S. strategic programs would be allowed. The U.S.S.R. would also be allowed some new programs, but more than half of the SS-18 and SS-19 missiles, which are now being upgraded, would have to be dismantled.

U.S.S.R.: 64 warheads on British submarines, 98 on French land- and submarine-launched missiles, 640 on four U.S. Poseidon strategic submarines assigned to the North Atlantic Treaty Organization (NATO) and 75 on Chinese land-based missiles.

The new SS-20's actually reduce the nuclear threat to Western Europe compared with the old SS-4's and SS-5's they are replacing. The older missiles carried bigger warheads, 1,000 kilotons compared with the 150 kilotons on the SS-20's. The SS-4's, which constituted 80 percent of the original force, are aboveground missiles with nonstorable liquid fuel; they were "sitting ducks" for a preemptive attack. The U.S.S.R. has thus replaced a destabilizing "first strike" force, which would have had to be used first if it were not to be destroyed, with a less vulnerable force that can be held back and launched on warning of attack. The greater accuracy of the SS-20's gives them a higher "kill probability" against the few hardened targets in Western Europe (nuclear storage depots and command-and-control centers). Their yield is not low enough, however, to present a credible threat of a "controlled" counterforce attack that would not kill millions in the densely populated Western European theater.

Concerning intercontinental strategic weapons, it is alleged that the U.S.S.R. now has ICBM's with an unparalleled first-strike counterforce capability against U.S. ICBM's. This claim applies particularly to a new 10-warhead version of the large SS-18 and an improved six-warhead version of the SS-19, both estimated to have 550-kiloton warheads, 800-to-900-foot accuracy and a kill probability against U.S. ICBM silos of slightly more than 60 percent. There is evidence, however, that the instrumentation providing high accuracy is not yet installed in most of the missiles but is being backfitted into 308 SS-18's in 1982 and 1983 and will be incorporated in 60 new SS-19's and 300 existing SS-19's in 1984 and 1985.

At the same time, the U.S. Mark 12A warhead, recently backfitted into the Minuteman 3's, has a comparable theoretical kill probability of about 60 percent against the hardest of the U.S.S.R.'s silos. The yield of the Mark 12A is 335 kilotons and the accuracy is 700 feet. On both sides the calculated kill probability depends on the estimated hardness, or blast resistance, of the opponent's ICBM silos. The hardness is not known precisely even for the U.S. silos, much less for those of the U.S.S.R., but it is assumed in these estimates that the silos can withstand a blast pressure of 2,000 pounds per square inch. Current plans call for 300 Minuteman 3's with 900 Mark 12A warheads to be deployed by the end of this year. This is enough



EFFECTS OF START PROPOSAL by the Reagan Administration on strategic warheads deployed by the U.S. (*left*) and the U.S.S.R. (*right*) are plotted. The proposal would limit both the U.S. and the U.S.S.R. to 5,000 warheads on ballistic missiles but would not limit warheads on bombers and cruise missiles. The nuclear-freeze proposal would hold the U.S. and U.S.S.R. to current nuclear force levels.

to send a single warhead against each of the 818 MIRV-capable silos in the U.S.S.R., or two warheads against the majority of the 658 silos estimated to contain MIRVed missiles. Since these 658 missiles carry nearly three-fourths of the U.S.S.R.'s strategic warheads, a hypothetical U.S. first strike conducted against them in late 1982 would be more devastating to them than a U.S.S.R. first strike against U.S. ICBM's.

Moreover, as many as 600 improved Minuteman 3's with 1,800 Mark 12A warheads (enough to put two of these warheads on each MIRV-capable silo) could be deployed by the mid-1980's, that is, by the time the U.S.S.R. is expected to have warheads with comparable counterforce potential deployed in significant numbers. There is no plan, however, to deploy all 600 improved Minuteman 3's—perhaps because these missiles would obviate the military requirement for the new MX ICBM, with its even more devastating countersilo capabilities. If the U.S. were to forgo the installation of the MX and the additional 300 improved Minuteman 3's under the terms of the freeze, it would still be secure in its large and invulnerable submarine-based forces. For its part the U.S.S.R. would have to halt the deployment of the 10-warhead version of the SS-18 and the more accurate six-warhead SS-19. It would also forgo production of a new single-warhead ICBM now under development.

Although the U.S.S.R. has 62 strategic submarines with 950 SLBM's (about twice as many as the U.S.), it keeps only nine or 10 submarines with about 225 warheads at sea in range of targets, leaving the other 52 submarines in just two ports, where they could be destroyed by a few nuclear bombs. Given the surveillance and trailing capabilities of the U.S. and its allies, the number of strategic submarines the U.S.S.R. keeps at sea and in port would allow constant surveillance, making most if not all of these vessels vulnerable to preemptive attack. In contrast, 16 of the 32 U.S. *Lafayette*- and *Ohio*-class submarines, with about 2,400 warheads, are kept at sea at all times. As far as is known, no U.S. strategic submarine in normal operating condition has ever been detected or trailed by the much more limited antisubmarine forces of the U.S.S.R.

Under the bilateral freeze the U.S. would retain its advantage in submarine-based weapons with their invulnerability to counterforce attack. It would, however, set aside plans to develop a submarine-based counterpart to the MX: the Trident 2. The U.S.S.R. would stop the rearming of its strategic submarines with the seven-MIRV SS-N-18 and stop production of the new 10-MIRV SS-N-20. In addition it would halt the deployment of the SS-N-19 cruise missile and stop the production of new submarine- and ship-based nuclear antisubmarine weapons.

To the extent that bombers carry weight in the nuclear balance, the U.S. clearly has the advantage. Its 330 B-52's and 60 FB-111's are superior in performance as well as numbers to the 154 antiquated bombers deployed by the U.S.S.R. In a U.S. first strike the Russian bomber force would be destroyed on the ground because it is not kept on quick-reaction alert. In contrast, a third of the U.S. bombers are kept on eight-minute alert at all times. Moreover, the entire force is about to be fitted with its fifth generation of electronic jamming and penetration equipment. The freeze would spare the U.S. the immense outlays planned for production of the B-1 bomber and the development of its Stealth successor. On the Russian side it would stop production and deployment of the Tu-26 "Backfire" intermediate-range bomber and the development of a new intercontinental bomber.

Even if U.S. land-based ICBM's are or become more vulnerable to preemptive attack than those of the U.S.S.R. (a disputable point), this would be offset by the invulnerability of U.S. bombers and submarines. On the U.S.S.R. side the high vulnerability of its strategic bomber and submarine forces is offset by the size of its ICBM force. Without a bilateral freeze this relatively stable balance will be eroded by the weapon programs planned for the next decade.

As an innovative approach to arms control, the freeze differs in crucial respects from the position of the Reagan Administration outlined in its proposals for the Strategic Arms Reduction Talks (START) and the negotiations on Intermediate-Range Nuclear Forces (INF). The Administration has inaccurately characterized its position as "reduce first, then freeze," to contrast it with the freeze proposal to "freeze first, then reduce." What the Administration proposes is a freeze in numbers only, not in technology or production. Its START proposal would limit U.S. and U.S.S.R. strategic warheads at a level about a third below their present number. Within this numerical constraint it would allow the replacement of existing missiles by new and more capable ones. Thus Trident 2 SLBM's could replace Poseidon and Trident 1 missiles on submarines, and new MX ICBM's could replace Minuteman 3 missiles on land, thereby raising the theoretical kill probability of U.S. missiles against land-based ICBM silos in the U.S.S.R.

The U.S. nuclear weapons to be built during the 1980's have been mistakenly characterized as "bargaining chips." This implies that there is some concession for which the weapons would be traded away. In the INF talks the Administration has in fact offered not to deploy the Pershing 2 ballistic missile and ground-launched cruise missiles in Europe if the U.S.S.R. will dismantle its SS-20's (including those aimed at China as well as those aimed at Europe). The Administration has not, however, put the MX, the Trident 2, the B-1 bomber, the air- and submarine-launched cruise missiles or the many thousands of new battlefield nuclear weapons on either the INF or the START agenda. The freeze proposal would ban the manufacture of all these new weapon systems and their counterparts in the U.S.S.R.

The Administration presents itself as advocating "not merely a freeze, but more: reductions." Even in the category of intercontinental strategic weapons, however, a comprehensive accounting shows the Administration proposing a net increase in the number of nuclear weapons, at least on the U.S. side. The START proposal would reduce ballistic-missile warheads on each side by about 2,500 but would place no limits on strategic cruise missiles. During the 1980's the U.S. plans to deploy about 3,000 air-launched cruise missiles on B-52G's (while putting the existing B-52G payload on new B-1's) and in addition more than 1,000 Tomahawk strategic cruise missiles on surface ships and submarines. The START proposal would therefore result in a net increase of at least 1,500 warheads in the U.S. strategic arsenal. Since the U.S.S.R. has not developed small, long-range cruise missiles that can be deployed in large numbers, the effect of the START proposal is to invite the U.S.S.R. to reduce its arsenal while the U.S. increases its own.

Under the Administration's proposals the technological arms race would continue indefinitely. The U.S. and the U.S.S.R. would operate a large nuclear-weapon industry, go on testing new warheads and missiles, and cultivate advances in the many old and new technologies associated with nuclear-weapon systems. Under the freeze proposal the nuclear part of the military industry would be closed down and there would be no future generations of nuclear weapons.

The freeze would not eliminate the existing capacity of the U.S. and the U.S.S.R. to bring about a global nuclear holocaust. As few as 100 nuclear weapons on each side, half of 1 percent of the current arsenals, could devastate the U.S. and the U.S.S.R. beyond any previous historical experience and perhaps beyond recovery as industrial societies. To end the danger of nuclear war the nations must not merely freeze nuclear weapons but abolish them. The freeze represents a modest but significant step toward abolition. It would terminate the technological arms race and shut down entirely this wasteful and dangerous form of human competition.

The Harvesting of Interacting Species in a Natural Ecosystem

The changing populations of whales and other animals that feed on the krill of the Southern Ocean are an example of the problem of utilizing a biological resource without extinguishing species

by John R. Beddington and Robert M. May

The depletion of whale populations by excessive harvesting over the years has given rise to the annual catch quotas set by the International Whaling Commission and to the commission's recent decision to forbid commercial whaling altogether, starting in 1986. Now several nations are beginning to harvest krill, which are the food supply of the overexploited baleen whales. This action raises a number of questions about the intricate relations among species in an ecosystem and about how the human population might best manage the world's fisheries to sustain a yield for human needs without exterminating species.

We discuss the subject here mainly in terms of the animals of the Southern Ocean: the vast seas surrounding the continent of Antarctica. One reason is that a commission established to put into effect the Convention for the Conservation of Antarctic Marine Living Resources, which was recently agreed to by the 10 nations of the European Economic Community and 14 others with an interest in the region, held its first meeting last spring in Australia. Second, the Antarctic ecosystem is relatively simple: whales, sea birds, fishes and squid feed on the shrimplike krill, which in turn feed on phytoplankton. Fairly good long-term records, compiled by the whaling industry or by scientific studies, are in hand for many of these populations. Third, the populations of krill-eating mammals change relatively slowly and are fairly closely related to the numbers of sexually mature adult animals. All of this contrasts with most other fisheries, where the interactions among species can be very complicated (for example, the adults of certain species eat the larvae of others); in addition the data are comparatively sparse and the processes of recruitment into the adult population by the successful raising of young are poorly understood, are only loosely linked to the number of adults, are highly variable and are likely to depend on the vagaries of the environment. Finally, the recent interest in harvesting krill is characteristic of trends in other fisheries in that the harvest is from a lower trophic level (consisting of organisms farther down in the food chain) than the one that is currently being exploited.

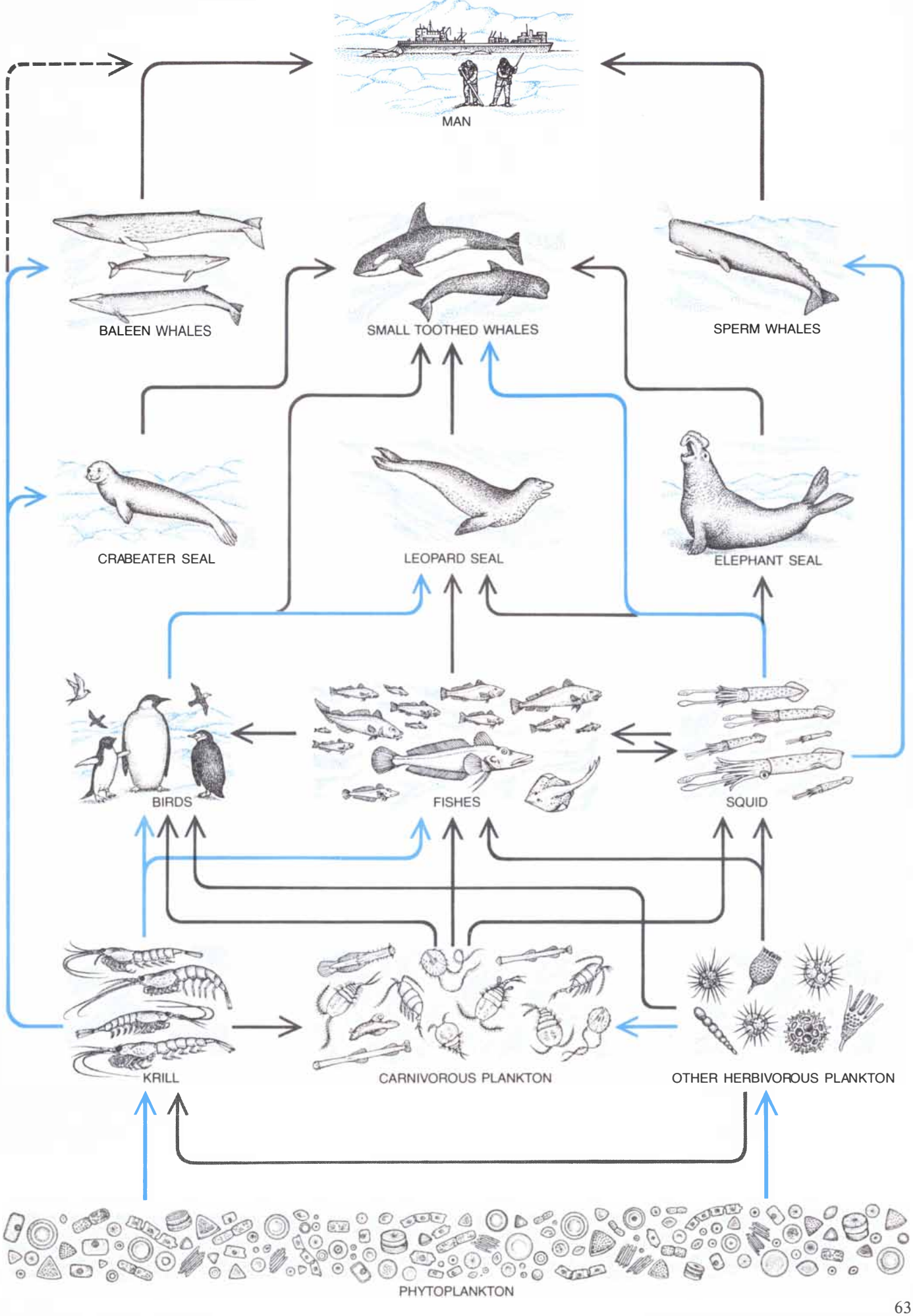
The modern era of whaling in the Antarctic began in about 1930 with the advent of the factory ship, a self-contained plant that could stay at sea for months steadily catching and processing whales. By 1935 fears that the whale stocks of the Antarctic would be depleted, as northern ones had been earlier, led to the formation of the International Convention for the Regulation of Whaling. (Another motive for regulation was that a surplus of whale products had depressed their market price.) Both whaling and regulation lapsed during World War II, but after the war the convention was reconstituted as the International Whaling Commission.

The stated aim of these regulatory bodies has been to manage whaling, in the Southern Ocean and elsewhere, for the optimal yield (later termed the maximum sustainable yield). Actually the commission has until recently tended to override the advice of its scientific committee, which from the earliest days has issued warnings that stocks were being exploited too heavily and has made pleas for stricter regulation.

Under pressure from various governments and from international organizations such as the International Union for the Conservation of Nature and Natural Resources, the commission adopted in 1974 a set of "new management procedures" that have since been followed as a basis for setting whaling quotas. Stripped of their technical details, these rules divide the world's oceans into several areas, in each of which individual whale stocks are classified into one of three categories. The classification is reviewed each year. If the stock is judged to be 10 percent below the level where its potential yield is at a maximum (the maximum sustainable yield), no harvesting is allowed; the whales are classified as "protection stock." If the stock is near the level of maximum sustainable yield, annual quotas are set with the intention of keeping the stock near that level; the whales are classified as "sustained management stock." If the estimated size of a stock is significantly above the level of the maximum sustainable yield, exploitation is allowed under quotas aimed at achieving a controlled reduction to that level; the whales are classified as "initial management stock." Under this formula blue, gray, humpback and right whales are protected in all the oceans and Bryde's, fin and sei whales are protected in most areas. (They are all baleen whales, that is, they strain their food through whalebone plates. Baleen whales are of the suborder Mysticeti and are to be distinguished from the toothed whales, suborder Odontoceti, of which the sperm whale is a member.)

In the Southern Ocean in particular

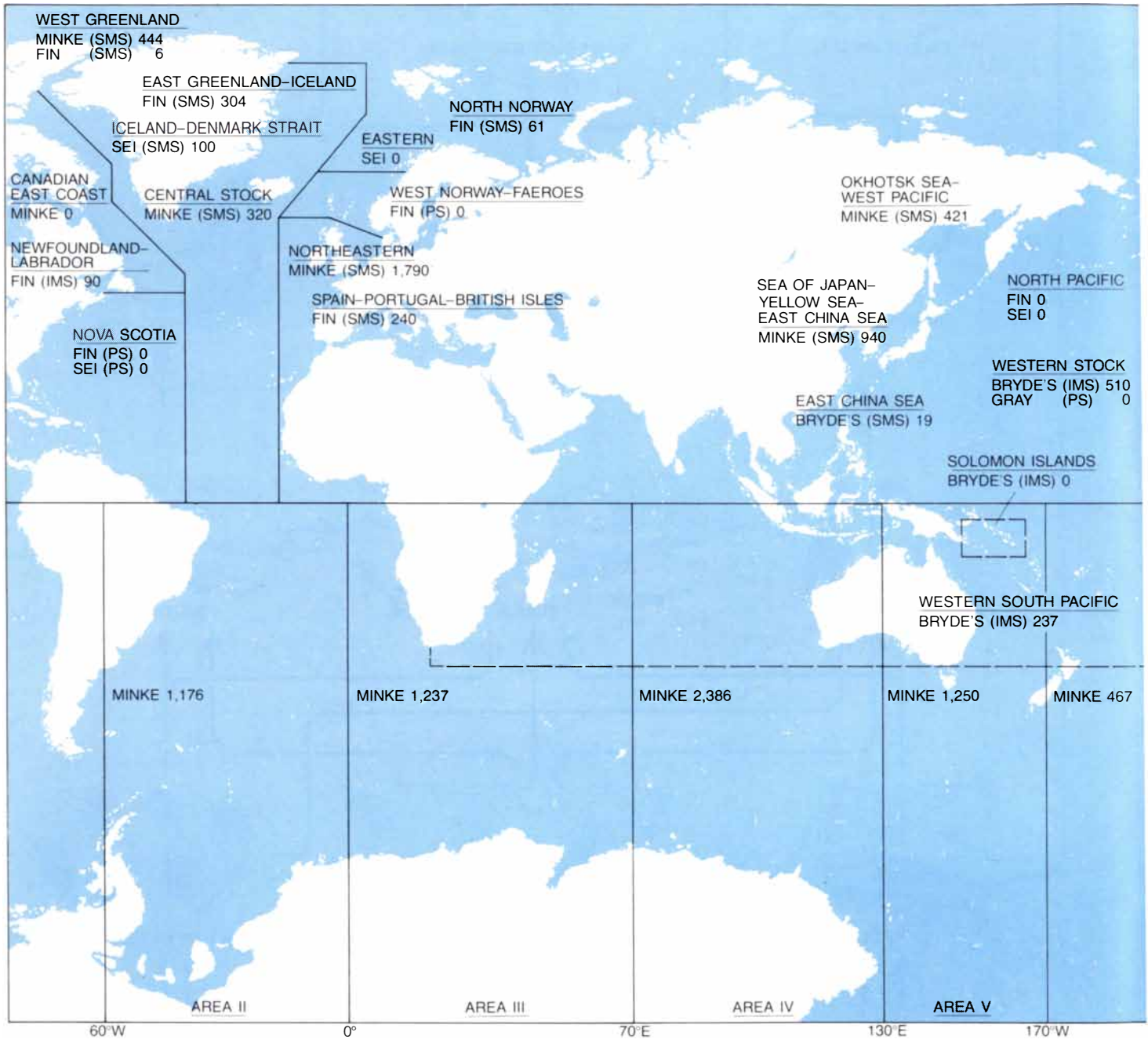
ECOSYSTEM OF THE SOUTHERN OCEAN, the seas surrounding the continent of Antarctica, is supported by phytoplankton (*bottom*), microscopic plants that subsist on inorganic matter and sunlight. One of the main links in the food chain extending from the phytoplankton to the great whales and man are the shrimplike krill, whose living mass is one of the greatest for any group of closely related animals on the planet. If the population of one of the animals that feed on the krill decreases (as has happened with the intensively harvested blue whale), the populations of other animals that feed on the krill may increase (as has happened with penguins, seals and some whales). Several countries are now moving toward harvesting the krill directly.



the successive targets of exploitation have been blue, fin, humpback, minke and sei whales. The result is a pattern of decline in stock after stock. In total the overexploitation of baleen whales in the Southern Ocean has reduced their net biomass to about a sixth of the estimated pristine value. All the species except the minke are now classified throughout the Southern Ocean as protected stock.

A variety of evidence suggests that significant changes are taking place in the baleen-whale populations as a result of the reduced competition within and among species. Shifts in the competitive balance are one effect; enhanced rates of population growth are another. Crude indications of the changes are evident in a graph of whale populations; the sei population shows an increase before the exploitation of the sei whales began in the mid-1960's, and the minke population is increasing even though the minke whales are being harvested.

To estimate the maximum harvest a particular stock is capable of yielding in a sustained way one needs information about survivorship (by age) and fecundity within the population. The data come mainly from whaling operations. In a pristine stock the birth rate and the death rate are assumed to be equal on the average, yielding an approximately steady level of population. Harvesting increases the mortality, which is offset somewhat by increased fecundity in the population. The task of the manager is to evaluate the way this enhanced per capita birth rate depends on population



WORLD IS DIVIDED INTO QUOTA REGIONS by the International Whaling Commission. The quotas are for the harvesting of eight species of baleen whale: blue, Bryde's, fin, gray, humpback, minke, right and sei. (The baleen whales are those that strain their food through whalebone plates.) If a whale stock is judged to be 10 percent below the level where its sustainable yield is at a maximum, no harvesting is allowed; it is designated "protection stock" (PS). The blue, humpback and right whales belong to this category in all oceans. If the stock is near the level of maximum sustainable yield, annual quotas are set with the intention of keeping the stock at about that level; the stock is designated "sustained management stock" (SMS). If the stock is well above the level of maximum sustainable yield, harvesting is allowed under quotas designed to yield a controlled reduction toward the level of maximum sustainable yield; the stock is "ini-

density and then to estimate the level of harvesting that will maximize the sustainable yield.

The observed increases in fecundity are the result of a combination of higher rates of pregnancy and the attainment of sexual maturity at younger ages. We have examined the changing pregnancy rates for blue, fin and sei whales in what the International Whaling Commission has designated as Area IV, which is typical of the Southern Ocean. These rates are essentially a measure of the probability that a sexually mature female whale will become pregnant in a given year. In recent years, because all three populations have been significantly depleted from their pristine levels, the rates have clustered around .5, meaning that most adult females produce a calf every other year.

From the data one can see that under the intensifying pressure of harvesting the pregnancy rates for blue and fin whales have increased significantly since harvesting began in the Southern Ocean in about 1930. The broad pattern is broken by the cessation of whaling during World War II; the pregnancy rates appear to have dropped during that period, perhaps partly because of the concurrent increase in the whale population. The pregnancy rate for sei whales shows no systematic increase over the relatively brief time they have been exploited. The rates for minke whales, which have only recently been significantly harvested, are high, reflecting their predominantly annual reproductive cycle.

Essentially all these data come from the harvesting of whales, and so there is no information for years in which a particular species was not being caught. Hence although the data can reveal a connection between population density and pregnancy rate in an exploited stock, they cannot show effects related to the depletion of other species, effects that sometimes appear even before the stock under study was exploited.

On the other hand, a recent technical advance makes it possible to reach back into the past in deducing the age at which baleen whales attain sexual maturity. A whale's ear has a horny plug formed of a compressed mass of skin cells; it is part of the auditory apparatus. The plug shows annual growth rings something like those in trees. When the animal reaches sexual maturity, the rings become much smaller. By this means it is possible to estimate the ages at which fin, minke and sei whales have reached sexual maturity over the past several decades. (The stocks of blue and humpback whales were so low as to be effectively unexploited by the time the significance of the earplugs was recognized, and so the counts for them are too sparse to be useful.)

For sei whales the data show a slight increase in the age at maturity during World War II and a slight decrease thereafter. In recent years the sei whales have altered their pattern of migration, arriving in the Antarctic earlier in the summer and penetrating farther south. This change could be due to reduced competition from blue, fin and humpback whales, but it could also reflect some slow environmental change.

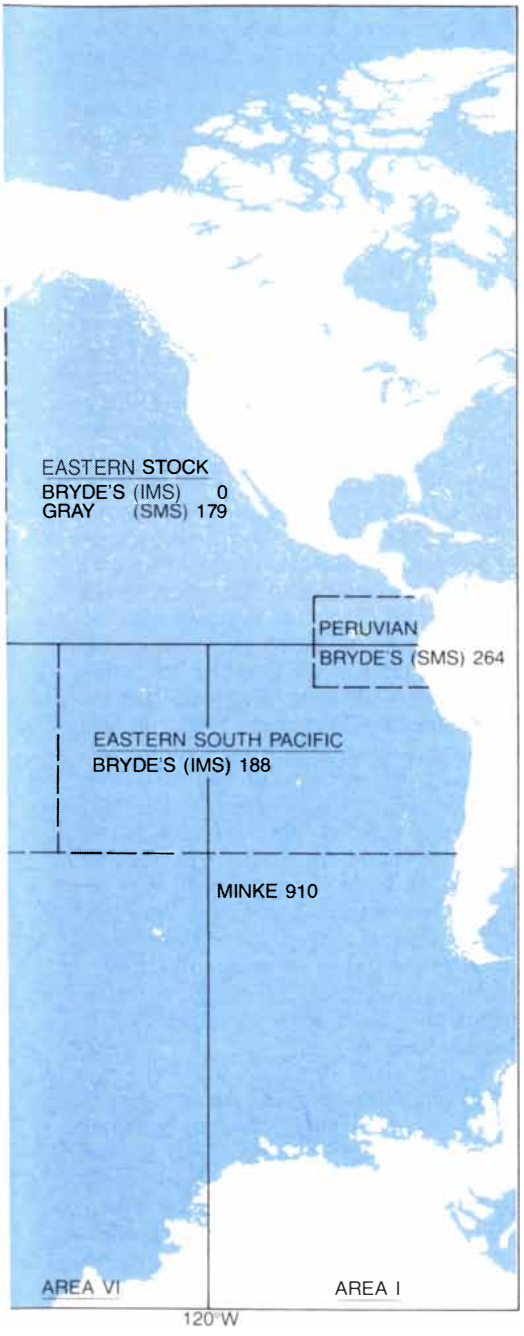
Fin whales show a pronounced decline in the age of sexual maturity in all areas of the Southern Ocean. In the pristine stocks of the 1920's the age of sexual maturity was 11 or 12 years; by the mid-1960's it was eight or nine years. It is particularly noteworthy that indications of this systematic downtrend appeared in some areas of the Southern Ocean before the fin stocks were heavily exploited.

The minke whales provide the most unambiguous evidence for changes associated with the depletion of other whale populations. The decline in their age of sexual maturity (from about 14 years to six or seven) was essentially complete before significant exploitation began. The most reasonable explanation seems to be that the minke populations are expanding into the ecological vacuum created by the removal of their competitors, particularly the blue whales. (Recent work by J. G. Cooke and William de la Mare of the Institute for Environment and Development in London indicates that the degree of the decline in the age at maturity may have been overestimated. This would imply a lower rate of population growth for the minke whales but does not alter the general conclusion.)

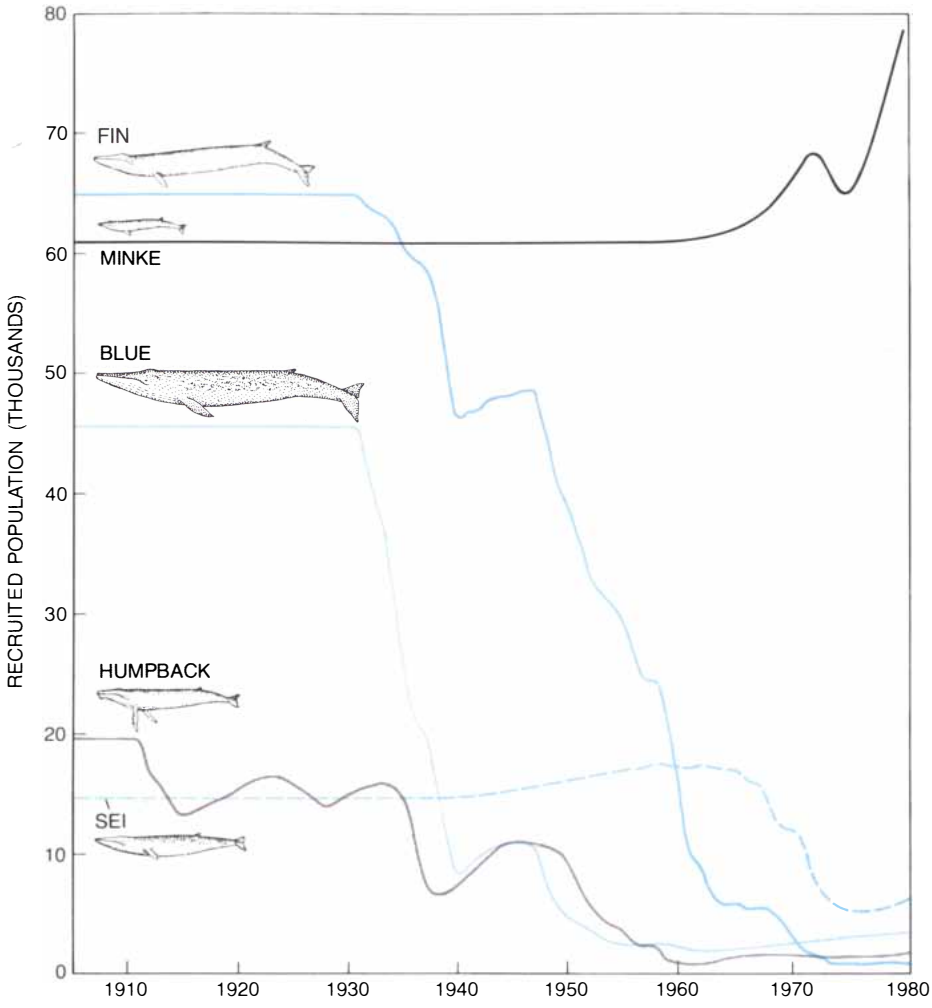
Other krill-eating animals in the Southern Ocean have in recent years shown population increases that may plausibly be attributed to the decline in baleen-whale populations. For example, the southern fur seal has had population increases that outpace any simple recovery from past overexploitation. The fastest increase for the seal has taken place in the Scotia Arc of Antarctica, where the seal overlaps the range of the baleen whales. Similar data have been gathered by Richard M. Laws, director of the British Antarctic Survey, for the abundant crabeater seal. (Notwithstanding its name, the crabeater seal eats mainly krill by foraging at the margins of the pack ice.) In the Antarctic Peninsula the seal's average age at sexual maturity was four years until the southern whaling zone known as the Sanctuary was reopened; since then the age has decreased steadily to 2.5 years.

Similarly, increases in the number of king penguins seem larger than can be explained simply as a recovery from the slaughter of the 19th century. Population increases have also been documented for Adélie, chinstrap and gentoo penguins and for some sea birds. It is significant that the best-documented increases in these populations of krill-eating penguins are in the South Atlantic, where the overlap between whales and penguins is greatest. In contrast, there is no indication of a population increase for the Adélie penguins on Ross Island over the past 50 years; their interaction with whales is small because whales do not generally go that far south.

It is thus apparent that the removal of most of the large baleen whales—fin,



tial management stock" (IMS). The numbers after the whales are the number that could be taken in the season 1980–81. Since the most recent meeting of the International Whaling Commission in July it has been decided that the number of whales that can be taken will be reduced to zero over the next three years.



PRECIPITOUS DECLINE IN THE STOCKS of blue, fin, humpback and sei whales since 1910 is plotted. The figures are for Area IV of the Southern Ocean (*see map on preceding two pages*). The increase in the number of minke whales is clearly apparent at the upper right.

humpback and, most important, blue—from the Southern Ocean has constituted a kind of vast, unplanned and poorly documented experiment in what ecologists call competitive release. Although much of the information is inferential and fragmentary, it seems perverse to interpret the observed facts as being anything other than evidence for competition among krill-eating species in the Southern Ocean. One practical implication is that baleen-whale quotas ultimately cannot be set stock by stock, as if each stock were a single, isolated population. The implication is particularly clear for the minke whale, whose population appears to have been growing (with the birth rate outrunning the death rate) before significant exploitation began. Such circumstances are forcing managers to take account of interactions among species.

Our discussion so far has focused on the krill-eating animals that broadly share the same trophic level as the baleen whales. What of the krill themselves? A simple estimate suggests that the depletion of baleen-whale stocks by harvesting has resulted in a "surplus" of krill in the Southern Ocean of some 150 million metric tons per year.

This naive estimate, however, takes no account of the likelihood that the Southern Ocean is moving toward some new equilibrium. Although the present understanding of the situation is not sufficient to specify the exact proportions, it is clear that the krill "surplus" is contributing not only to an increased standing crop of krill but also to increased rates of population growth among the remaining baleen whales (particularly the minke), the crabeater seal and other seals, penguins, sea birds, fishes and squid (whose populations are in turn increased by harvesting pressure on their chief predator, the sperm whale).

One of us (Beddington) and B. T. Grenfell of the Imperial College of Science and Technology of the University of London have studied the interactions between krill and baleen-whale populations in the Southern Ocean. The population dynamics of the whale species embodied in the study are based on estimates of the stock densities and on recruitment data; as we have noted, many of the effects of competitive release, within and between species, are implicit in the recruitment data. The study's description of the population dynamics of krill is based on the biology of their life cycle. Reasonable assumptions are made about the way predation depends on the population densities of whales and krill. The study thus arrives at estimates of the changes over time in the amounts of krill consumed by baleen whales in the main areas of the Southern Ocean [*see illustration on page 68*]. Although this analysis has shortcomings and makes no attempt to deal with changes in the consumption of krill by species other than baleen whales, it represents a useful first step.

One interesting prediction to emerge from the study is that time lags inherent in the interactions of prey and predator can, in this krill-whale system, lead to oscillations in the pregnancy rates of baleen whales at certain levels of harvesting. Such changes, slight but statistically significant, are indeed observed. Alternatively it is possible that the observed oscillations are associated with systematic environmental fluctuations, such as changes in the extent of pack ice from summer to summer. We mention these oscillations in order to give a hint of the technical subtleties that lurk under the broader patterns of population changes.

Partly stimulated by the notion of a krill surplus, several countries are moving toward harvesting krill from factory ships in the Southern Ocean. Presumably the intention is to convert the krill into animal feed, but it could also be that some of the catch will turn up on human menus in the guise of "prawns" and other delicacies. The total harvest was some 100,000 tons in 1979, but it is thought Russian ships may have harvested a million tons in the Southern Hemisphere in the summer of 1980–81. Although these numbers are still small compared with the annual production of krill, past experience suggests that the regulation of such harvesting activities is best started early, before the investment of capital in ships and other harvesting equipment generates an economic and political momentum that is hard to control.

What rules of management should govern commercial exploitation in a multispecies fishery such as the Southern Ocean is coming to be? Clearly the guiding principle cannot be maximum sustainable yield for each species (although this idea was advocated in the early discussions). The maximum sustainable yield of baleen whales is achieved by leaving their food (krill) entirely alone. For krill the maximum sustainable yield would be achieved by eliminating whales and other animals that compete with human beings for this food supply. To regulate harvesting by specifying maximum sustain-

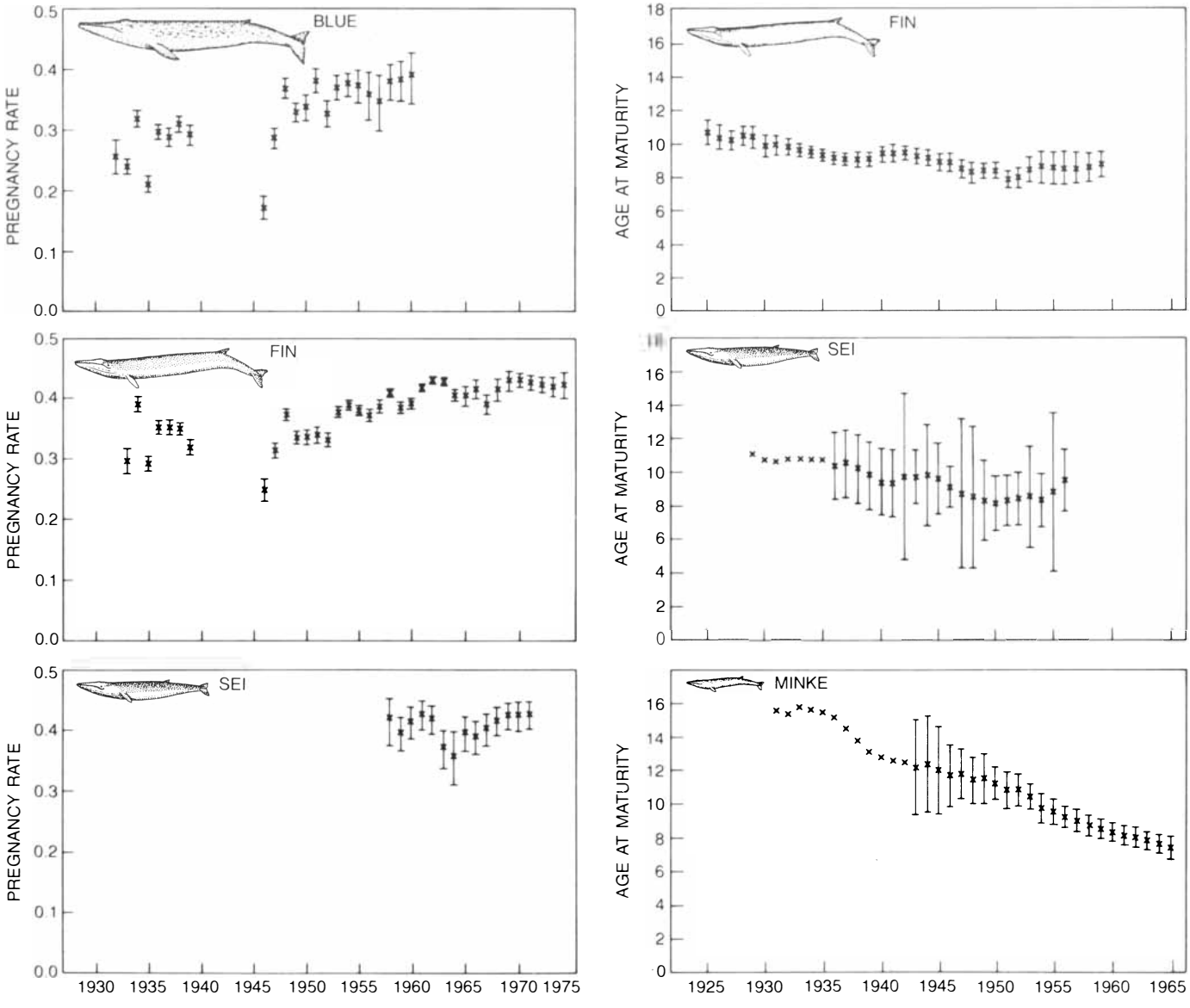
able yield for both prey and predator species would be to try to have one's cake and eat it too.

Nor is there any overarching biological criterion pointing to some optimal sustainable mixture of harvests. For example, although the maximum landed tonnage of protein might be realized by eliminating whales and exploiting only the remaining krill, this solution would do violence to various aesthetic and ethical constraints. Ultimately the rules must embrace political and social considerations along with biological ones.

Faced with these problems, the convention on marine resources of the Antarctic has specified that the harvesting of species in the Southern Ocean must be consistent with "maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations." This declaration answers some questions of principle, but it falls short of being an operational guide to management. Until the detailed relations among the constituent species of the Southern Ocean are much better understood a quantitative handbook setting quotas for harvesting in this multispecies ecosystem is infeasible. Certain qualitative guidelines can be laid down, however, and they are incorporated in the convention.

For populations at the top of the food web, which are not subjected to significant natural predation, the concept of maximum sustainable yield will often remain useful. The convention states such stocks "should not be allowed to fall below a level close to that which ensures the greatest net annual increment." For other populations the preservation of the ecosystem would seem to require that neither those stocks nor others dependent on them be severely depleted by harvesting. One concrete possibility, which is fairly clear in the relatively simple krill-and-baleen-whale system, is to forbid any exploitation that has the effect of depressing stocks at the top of the trophic structure below some specified fraction of their original levels.

Any effort to carry out such guidelines has to deal with the complication of changes in different populations taking place on many different time scales. A population of krill may adjust within a year or two to some harvesting regime,



PREGNANCY RATE AND AGE AT MATURITY are two measures of dynamic changes in populations of whales in Area III of the Southern Ocean. The graphs at the left show the increase in the pregnancy rate of blue, fin and sei whales. The rate is essentially the probability that a sexually mature female will become pregnant in any one year. The sequence of points is broken because data were not gathered during World War II. The increase suggests that these whale stocks are capable of slowly recovering to their original levels. The graphs at the right show the decrease in the age at maturity of fin, sei and minke whales. (Here "maturity" refers to the age of a female whale at the time of her first pregnancy.) More recent studies indicate that the decrease in the age of maturity of these whales may be somewhat less. The vertical bars above and below the points in the graphs indicate the statistical uncertainty in assessing pregnancy and maturity.

whereas the consequent effects may take a decade or more to be fully felt within the baleen-whale populations. The convention attempts to bring these considerations together by requiring the "prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades." Much research on multispecies systems in general and on the Southern Ocean in particular needs to be done to add specificity to these good intentions.

The world's fisheries provide a variety of other examples where major stocks have collapsed, with attendant effects on other species in the community. An example in the Tropics is the substantial fishing industry in the Gulf of Thailand, which in addition has been the subject of an unusually intensive research program. The program has included regular surveys by trawl that reflect the changes in the relative abundance of the various species.

The data show that the catches of some fishes—for example the Mullidae (red mullet), the Leiognathidae (slipmouths and pony fish), the Scolopsidae (monocle breams) and the sharks and rays—have fallen off much more markedly than others, such as the Priacanthidae (bigeyes), the Sauridae (lizard fish) and squid. The result is a decline of roughly tenfold in the catch of what the fishermen call "good fish" over a period when the catch of "trash fish" has remained roughly constant. Here two effects are felt: the species composition is changing toward smaller fish and the average size of the fish in particular species is declining. Thus the Leiognathidae, a major component of the good fish in the early years, are now regarded as trash fish because only small individuals are caught.

The fishing industry in the Gulf of Thailand represents a form of predation, and it is not surprising that the relative abundance of the prey species should change at the same time as their total abundance decreases. We have pointed out such effects in the Southern Ocean; they have been found also in other terrestrial, marine and laboratory ecosystems. In a deliberate oversimplification it can be argued that predation tends to drive the populations below the pristine levels at which competition for resources may have been important in regulating population densities; instead predation confers a relative advantage on the species that can produce offspring copiously and quickly. Therefore the firm-fleshed good fish give way to the coarser trash fish under heavy exploitation.

An intriguing feature of the Gulf of Thailand pattern is that some of the prey species initially most abundant (the Leiognathidae and the Mullidae) have declined at the fastest rates. One explanation of this phenomenon, suggested by Daniel Pauly of the International Center for Living Aquatic Resources Management in Manila, is that before the development of the commercial fishery the prey were being held by natural predation to a population density at about the level of maximum sustainable yield. After the additional mortality from fishing they would then decline at a rate determined by the fishing mortality. As usual, however, there are alternative explanations of this phenomenon; for example, it could be that these species, which inhabit shallow water, are more vulnerable to the fishery. Nevertheless, the data indicate the importance of making distinctions among species, and more particularly among the trophic levels of the community, in assessing the impact of harvesting.

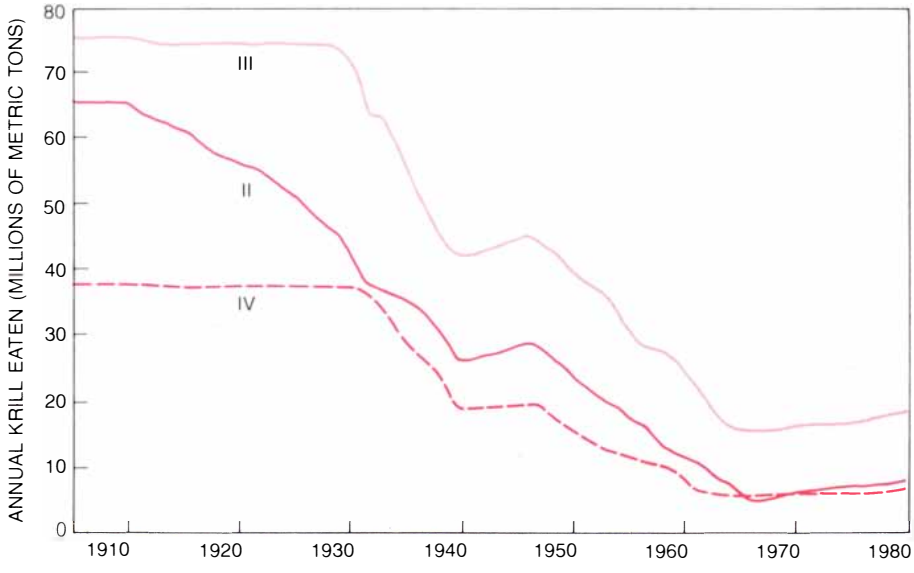
It is worth stressing that the patterns of change in the abundance of the various fish species in the Gulf of Thailand are notably different from the population changes recorded for whales. The changes in abundance for the whales are smooth, whereas for the fish there are substantial fluctuations around the basic trend.

The reasons for these differences are informative. For whale populations the absolute variation in recruitment is not large; although the pregnancy rates and ages at sexual maturity do show yearly changes, they are relatively small compared with the variations in recruitment typically observed for fish stocks. Moreover, because among whales the mortality rates are low and many age groups are present, new recruits are a small fraction of the population. In contrast the mortality rates in fish stocks are fairly high and the population has few age classes, so that recruits are a large fraction of the population.

These factors combine to make the management of fish populations more difficult than that of whale populations, even before multispecies effects are taken into account. The difficulties are even more pronounced for the fish stocks of the temperate zones, where reproduction takes place in a single season rather than being averaged out over the year as it is in the Tropics. An example is offered by the commercial fishery in the North Sea.

In the North Sea the total fish catch rose from about 1.5 million tons in 1960 to three million tons in 1967. Since then it has remained steady, with a pronounced decline in the stock and catch of the heavily exploited herring and mackerel being largely compensated for by increased yields of the large gadoids (cod, haddock, saithe and whiting) and other small fishes that some people would call trash fish (Norway pout, sand eel and sprat). It is not certain to what extent these changes are due to compensatory shifts in population densities, to changes in patterns of commercial exploitation or to coincidental environmental effects. It has been suggested, however, that the steady annual catch of three million tons has been drawn from a total stock that has remained nearly constant at about nine million tons while its composition has shifted from some six million tons of herring and mackerel and three million tons of other fishes in 1964 to about two million tons of herring and mackerel and seven million tons of other fishes in the late 1970's.

Complex mathematical models have



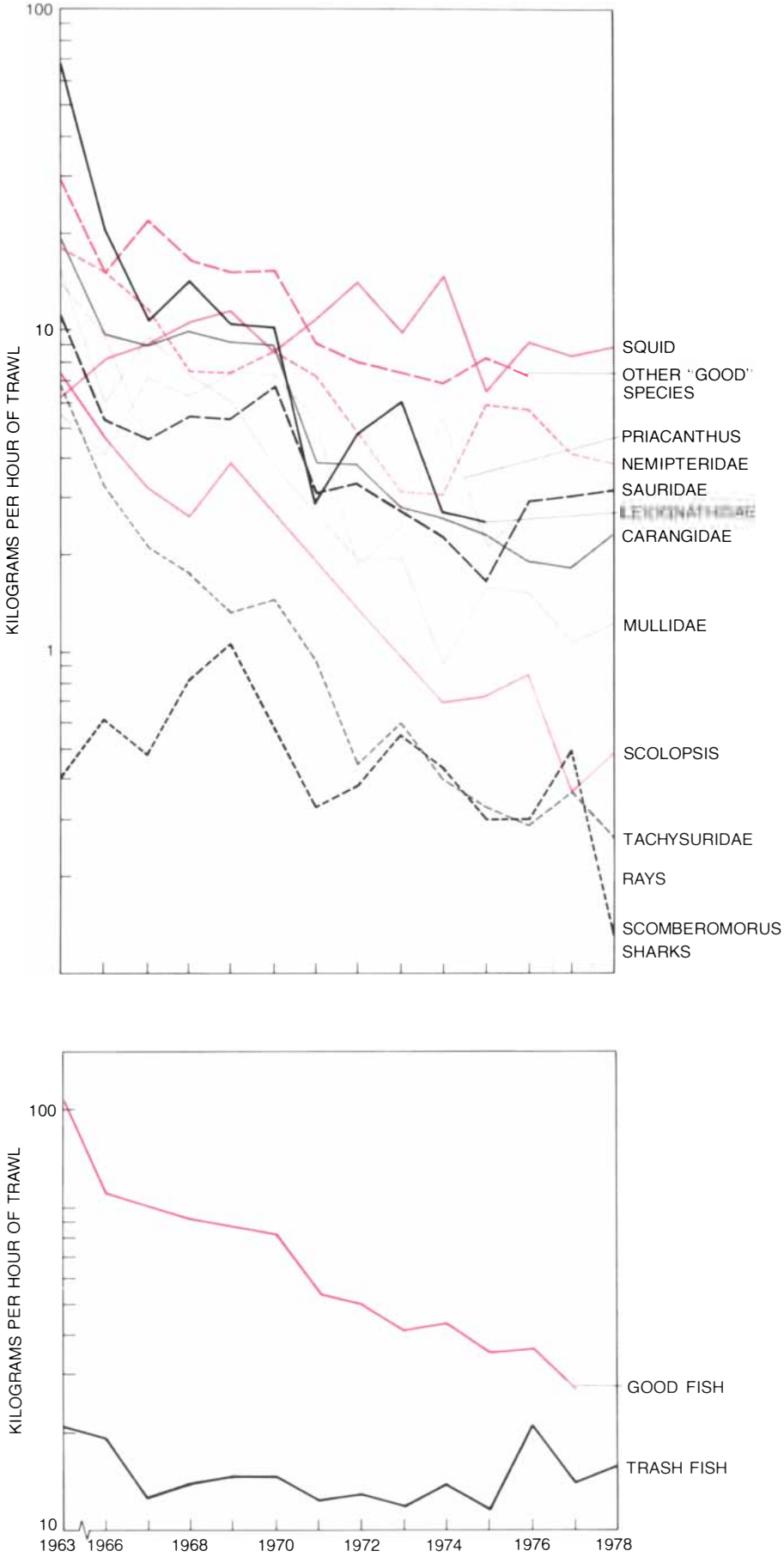
DECREASE IN AMOUNT OF KRILL EATEN by whales and other species is theoretically estimated for Areas II, III and IV of the Southern Ocean. The decrease is due to the decrease in the baleen-whale populations, and it presumably results in an increase in the amount of krill. It is this increase that has stimulated interest in the possibility of harvesting krill directly.

been constructed in the hope of arriving at a clearer understanding of the choice available to managers in this fishery, with its many interactions among species. One class of models, exemplified by the work of the Danish fisheries biologists K. P. Andersen and Erik Ursin, attributes the increase in the stocks of the larger gadoids and other smaller fishes to diminished predation on their larval and juvenile stages because the predatory herring and mackerel have been fished to low levels. It has been argued that the deliberate, systematic removal of other large predatory fishes (cod, haddock, saithe) could allow the taking of sustainable annual catches of up to five or six million tons. Such catches would come, however, mainly from the smaller trash fish that would eventually predominate in the North Sea. As we pointed out above, the eventual choice facing the managers of such fisheries is an economic and social one: should the harvesting emphasis be toward the larger fishes as human food or toward the smaller fishes as fish meal? As Andersen and Ursin put it, do we want the food resources of the North Sea to end up "on the dining table in the form of cod fed with living fish or in the form of chicken fed with fish meal"?

The population changes from year to year in Temperate Zone fisheries such as the North Sea and Georges Bank (off New England) tend to be even more variable and unpredictable than in, say, the Gulf of Thailand. The reasons presumably include the strongly seasonal behavioral pattern of the fishes and significant differences in climate and other environmental conditions from one season to the next. Such factors would make for a high variability in the relation between stock and recruitment.

As the human population increases, demands for food and other resources are exerting severe pressures on many natural ecosystems. In the seas such pressures have resulted in the collapse of several major stocks of fishes and whales, in the establishment of national and international zones for fishing and in a growing interest in harvesting new and "unconventional" species. Any possibility of harvesting these marine communities in a sustainable fashion depends on a greatly improved understanding of the way their constituent species interact with one another and with the environment.

The Southern Ocean provides a testing ground where one can begin to understand the effects of exploiting several species that occupy different levels in the food chain, but much more work is needed. The task of managing other multispecies fisheries, where the relations between stock and recruitment are intrinsically less predictable and where changes can take place faster, is correspondingly even more formidable.



SURVEY OF THE GULF OF THAILAND, one of the world's prime fishing areas, shows how the decline of the fish catch affects the character of the entire fishery. The curves in the graph at the top show declines in the fish catch over a 15-year period. Curves at the bottom average what fishermen classify as "good fish" and "trash fish." Trash fish are mostly too small.

The Growth of Western North America

Over the past 200 million years the continent has been extended westward by repeated collisions with smaller land masses, some of which appear to have come from thousands of kilometers away

by David L. Jones, Allan Cox, Peter Coney and Myrl Beck

According to the theory of plate tectonics, the earth's land masses are riding on great plates of the earth's crust that are in continuous motion with respect to one another. Since the theory became widely accepted less than two decades ago earth scientists have generally believed continents grow slowly and steadily, somewhat like trees, accumulating rings along their outer margins. Such growth rings consist of several different kinds of rock. Some are ocean-floor rocks scraped off against the edge of a continent where an approaching plate has plunged under the continental plate, the process known as subduction. Some of the rocks are derived from volcanic arcs, the chains of volcanic islands that form above subduction zones. Many of the rocks originate as sediments deposited on the continental shelf by rivers.

It now seems, however, that the growth of continents is not slow and steady. New evidence shows that it has been episodic, with the last major pulse in the growth of North America beginning no more than 200 million years ago. Virtually the entire Pacific Coast from Baja California in the south to the tip of Alaska in the north, and extending inland an average distance of some 500 kilometers, was grafted onto the preexisting continent by the piecemeal addition of large, prefabricated blocks of crust, most of which were carried thousands of kilometers east and north from their sites of origin in the Pacific basin. The horizontal dimensions of the individual blocks ranged from hundreds to thousands of kilometers.

Many of the blocks are of oceanic origin, consisting of oceanic crust, islands, plateaus, ridges or island arcs. A few blocks are clearly fragments of other continents. Some have traveled several thousand kilometers with remarkably little internal deformation. After they made contact with North America the blocks were usually sliced by shear faults and drawn out into thin strips parallel to the continental margin. During and after collision they were in many instances rotated. Thus western North America is a collage of accreted blocks that has been shaped to its present configuration over the past 200 million years by the impact of oceanic plates, each block carrying a burden of exotic rocks. The process by which the edge of a continent is modified by the transport, accretion and rotation of large crustal blocks is now often called microplate tectonics. The blocks themselves are called terranes.

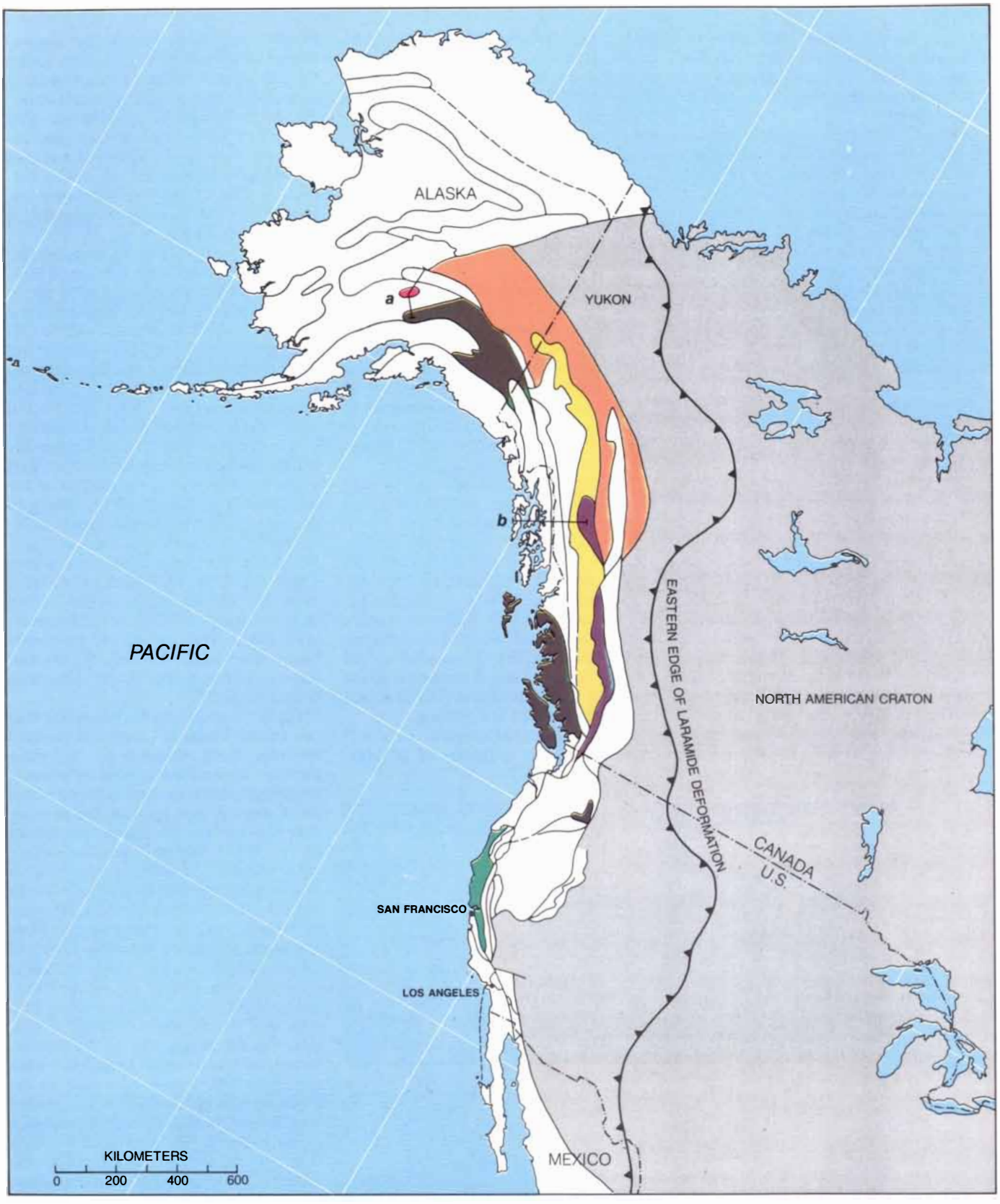
Microplate tectonics is a significant addition to that part of plate tectonics which describes the interactions of plates along continental margins that are called active. The basic theory of plate tectonics recognizes two ways continental margins can grow seaward. Where two plates such as the African plate and the South American plate are moving away from a mid-ocean rift that separates them, the continental margins on those plates are said to be passive, or rifted. Such continental margins grow slowly from the accumulation of river-borne sediments and of the carbonate skeletons of marine organisms, which are deposited as limestone. Suites—unbroken sequences—of such accretions, consisting of nearly flat strata, are called miogeoclinal deposits. Since most miogeoclinal deposits are undeformed and exhibit an unbroken history, it is evident that passive margins are generally not associated with mountain building.

Along active, or convergent, margins, such as those that ring most of the Pacific basin, continents tend to grow much faster. At an active margin an oceanic plate plunges under a continental plate, with the continental plate scraping off deep-ocean sediments and fragments of basaltic crust that then adhere to the continental margin. Simultaneously the plate plunging under the continental margin heats up and partially melts, triggering extensive volcanism and mountain building. A classic example is the Andes of the west coast of South America.

In the original plate-tectonic model western North America was described as being a passive margin through the late Paleozoic and early Mesozoic eras (roughly 350 to 210 million years ago), after which it became an active margin. It was assumed that the continent grew to a limited extent along this margin as sedimentary and igneous rocks of oceanic origin were accreted in a few places, as in the Coast Ranges of California. The model was successful in explaining such disparate features as the Franciscan rocks of the California Coast Ranges, formed by local subduction processes, and the granitic rocks of the Sierra Nevada, farther to the east, which clearly originated as the roots of volcanoes similar to those of the Andes.

The basic plate-tectonic reconstruction of the geologic history of western North America remains unchanged in the light of microplate tectonics, but the details are radically changed. It is now clear that much more crust was added to North America in the Mesozoic era (248 to 65 million years ago) than can be accounted for by volcanism along island arcs and by the simple accretion of sediments from the ocean floor. It has also become evident that some terranes lying side by side today are not genetically related, as would be expected from simple plate tectonics, but almost certainly have traveled great distances from entirely different parts of the world.

Here we shall address four major questions. How can one recognize the separate terranes that were accreted to form the tectonic collage of western North America? How can one establish where the terranes originated and how



ACCRETED TERRANES

NAME	TYPE
CHULITNA	OCEANIC BASIC
CACHE CREEK	OCEANIC BASIN–CARBONATE PLATEAU
FRANCISCAN	DISRUPTED OCEANIC BASIN
STIKINE	VOLCANIC ISLAND ARC
WRANGELLIA	VOLCANIC ARC–OCEANIC PLATEAU
YUKON-TANANA	METAMORPHIC

AREAS ADDED TO WESTERN NORTH AMERICA over the past 200 million years are shown in white and color. About 100 such "terranes" have been identified. Rocks in these areas differ sharply in geology, paleontology and paleomagnetic properties from rocks in the ancient North American craton: the primitive continent (*light gray*). Many of the terranes, including all of those in color (with the possible exception of Yukon-Tanana), are made up of rocks that originally formed on the ocean floor. Some of the terranes embody paleomagnetic evidence that they originated thousands of kilometers to the south of their present position. The barbed line near the western edge of the ancient continent marks the eastern limit of the Laramide orogeny, mountain building that began 150 million years ago and ended 50 million years ago. The sites *a* and *b* are shown in cross section in the upper illustration on pages 80 and 81.

far they have traveled? What are the structural relations between accreted terranes? How do the terranes become accreted to the growing edge of the continent?

Answers to these questions call for close collaboration among earth scientists from many subdisciplines. For example, geologists, geophysicists and paleontologists all have their own methods for recognizing pieces of the earth's crust that have been transported to their present location from distant locations. To take a simple but realistic example, Baja California and the narrow slice of California that lies west of the San Andreas fault are sliding northward at the rate of about five centimeters per year in relation to the rest of North America. Fifty million years from now, if the movement continues, the California rocks will have accreted along the continental margin of Alaska.

The discontinuity between the "native" Alaskan rocks and the "foreign" rocks of California would reveal itself in three principal ways. First, there would be abrupt discontinuities in rock sequences across major faults, implying very different geologic histories in terranes that had become adjacent. Second, there would be similar discontinuities in the fossils of plants and animals; tropical forms in the displaced rocks could readily be distinguished from the cool-temperate forms in the native Alaskan rocks. Third, the two kinds of rocks would exhibit markedly different magnetic characteristics. When molten rock cools, its intrinsic magnetism is aligned with the earth's local magnetic field. Thus rocks formed near the Equator, where the lines of force in the earth's magnetic field are nearly horizontal, would show a shallow paleomagnetic inclination. Native Alaskan rocks, which solidified at high latitudes where the lines of force in the earth's field plunge downward, would show a steep paleomagnetic inclination.

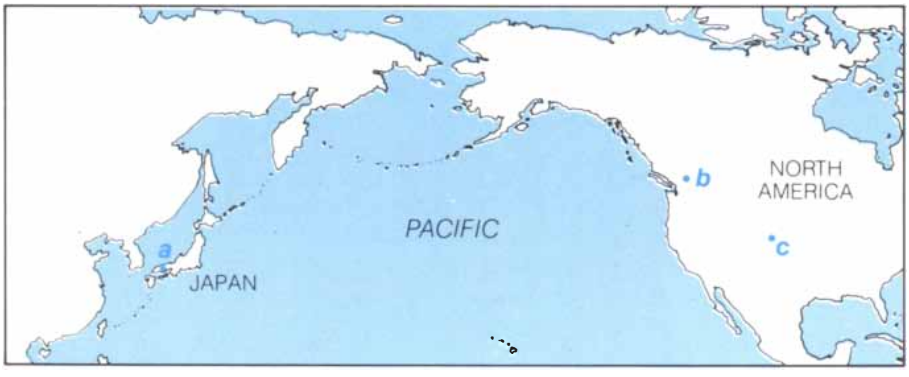
The original recognition of exotic terranes in western North America came about through observations of the first two kinds of anomalies: discontinuities in geology and in paleobiology. The explanation that these anomalies must be due to enormous displacements of large crustal blocks was advanced on the basis of striking differences in paleomagnetism.

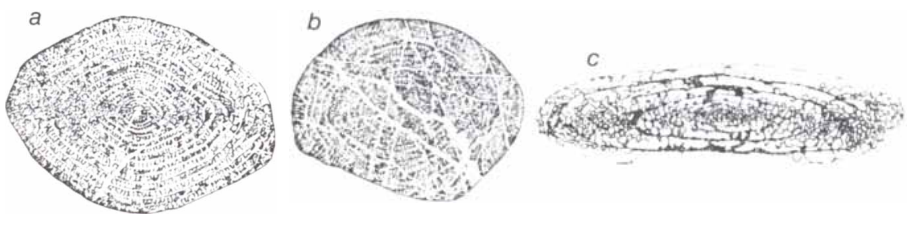
The illustration on the preceding page shows the distribution of major terranes in western North America. Many smaller terranes have been identified, but they cannot be shown at this scale. Each terrane represents a separate geologic entity characterized by a distinctive sequence of rocks that differs markedly from the sequence found in neighboring rocks. Each terrane is bounded on all sides by major faults; transitional strata or rocks that would serve to link one terrane to another are missing.

The defining characteristic of a terrane is a unique sequence of geologic events. The events include the deposition of volcanic and sedimentary rocks, the intrusion of granitic rocks and earth movements such as folding and faulting. The formation of ore deposits may also be part of the geologic history; one important result of the study of terranes has been an understanding of why certain mineralization processes stop abruptly at what are now recognized as terrane boundaries.

One of the first terranes to be identified is the Cache Creek terrane of British Columbia. As early as 1950 M. L. Thompson and Harry E. Wheeler of the University of Washington and W. K. Danner of Wooster College pointed out that certain distinctive marine microfossils known as fusulinids, dating back to the Permian period about 250 to 290 million years ago, are widely distributed in westernmost North America but are totally unlike species found farther east in the Rockies and in the middle of the continent. The western forms belong to species widely distributed through China, Japan, the East Indies and the Malay Peninsula. The Asian fusulinids help to define the Tethyan faunal province, a term that alludes to the ancient Tethys Ocean that lay southeast of the Eurasian land mass. The species of fusulinids found throughout Nevada, Texas and Kansas belong to the North American faunal realm.

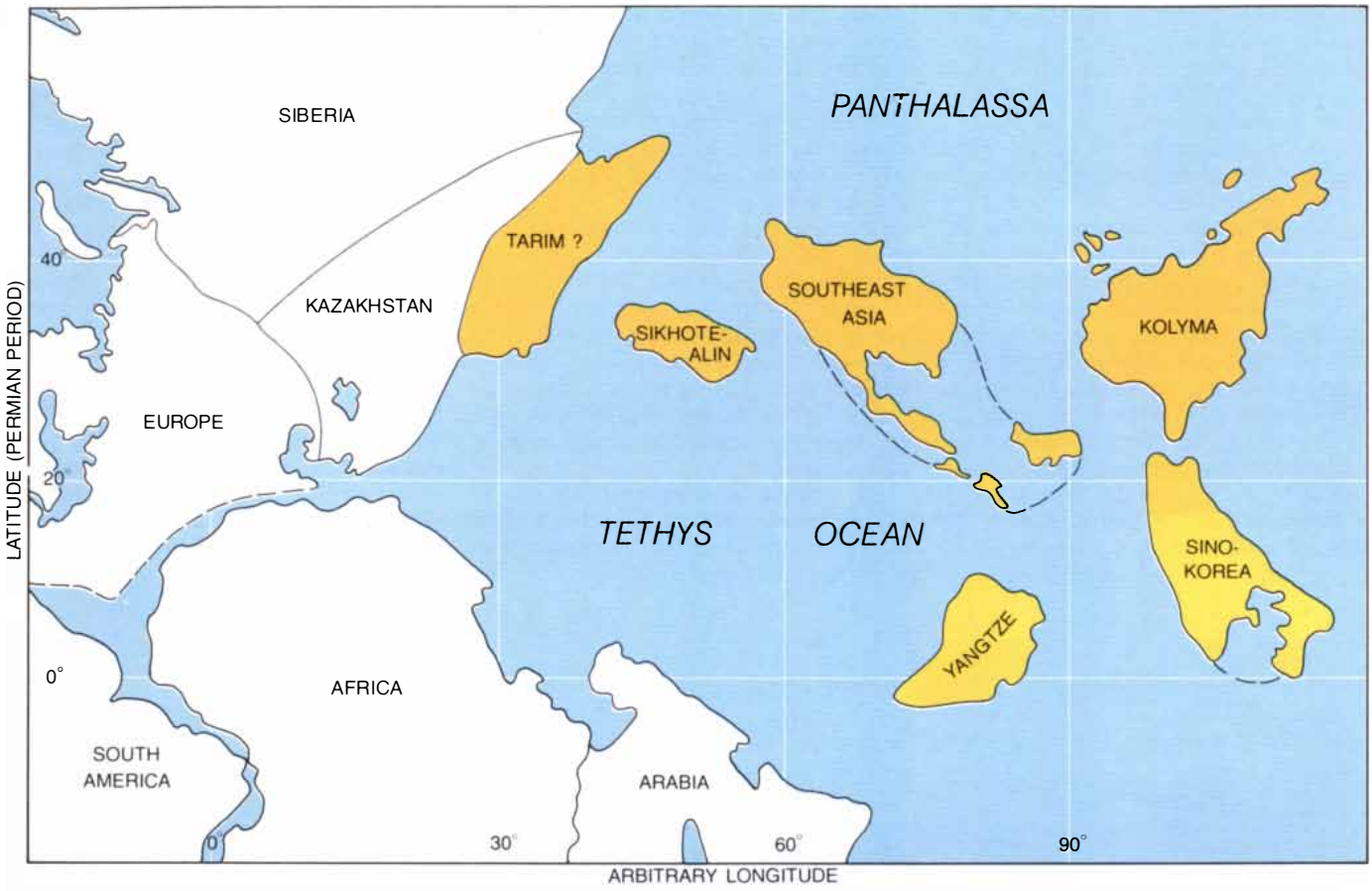
Early investigators hypothesized that the exotic Tethyan fusulinids reached western North America by migrating through a complex system of narrow "seaways" that somehow allowed travel from west to east but not the reverse. The seaways are the marine analogues of the "land bridges" invoked before plate tectonics to explain the similarly puzzling distribution of land animals. In 1968 J. Tuzo Wilson of the University of Toronto, an early proponent of plate tectonics, suggested that the presence of anomalous marine fossils in North America could be explained if the Pacific Ocean had once been closed, so that Asia and North America were in contact. On the reopening of the Pacific, scraps of Asia with Tethyan fossils would be left behind, plastered to the rifted margin of North America. Such a sequence of the closing and opening of a major ocean basin, now known as the Wilson cycle, is well documented for the Atlantic. There is little or no evidence, however, to support a complete closure of the Pacific basin, at least not over the past several hundred million years.



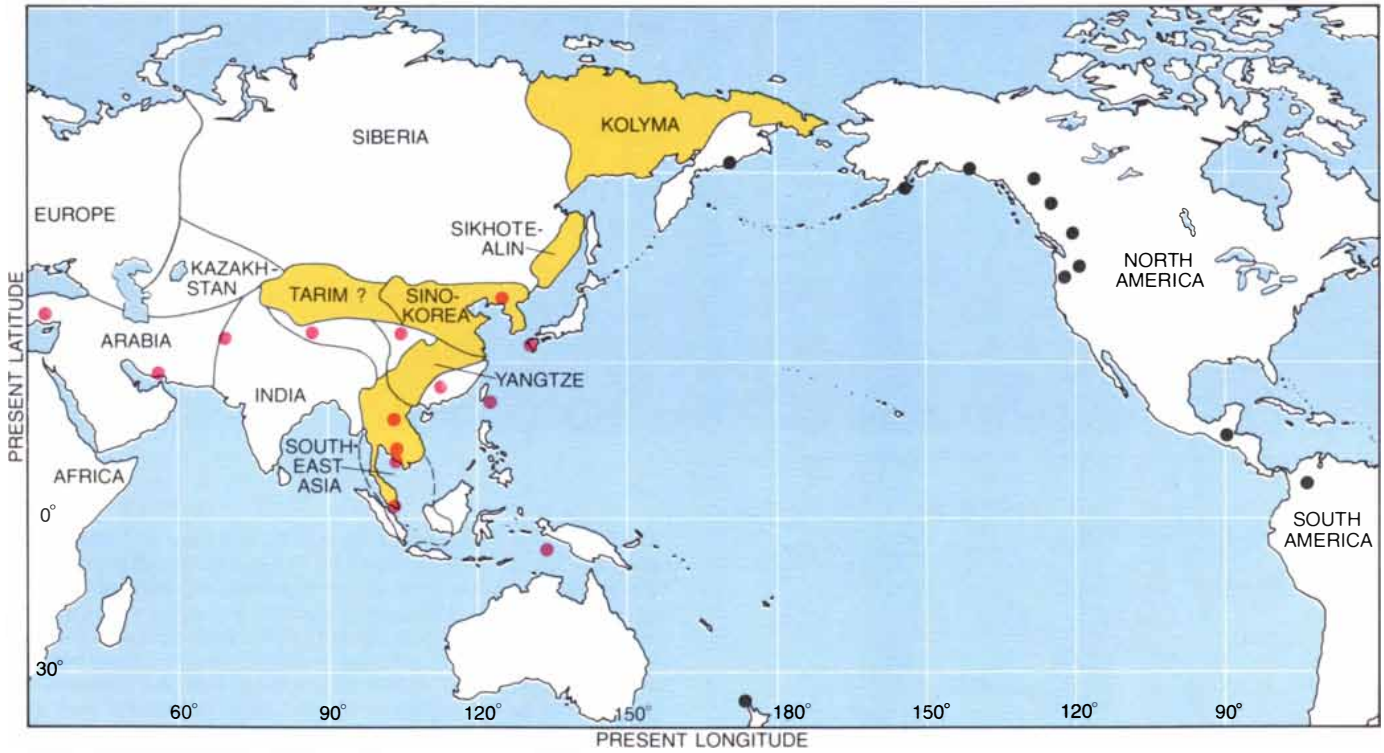


FOSSIL EVIDENCE FOR THE TRANSLOCATION OF TERRANES is supplied by differences in fusulinids, marine microfossils found in rocks from widely separated sites. The microfossils date back to the Permian period, 240 to 290 million years ago. The similar microfossils at sites *a* and *b* are described as Tethyan fusulinids because both presumably are from the ancient Tethys Ocean (*see top illustration on opposite page*). They can be distinguished from North American fusulinids (*c*) in external form and internal structure. Tethyan fusulinids in western North America were evidently carried on terranes that traveled thousands of kilometers.

In 1971 James W. H. Monger of the Canadian Geological Survey and Charles A. Ross of Western Washington University advanced the simple hypothesis that the Tethyan Permian fusulinids and the rocks in which they are found formed during the Permian period near



RECONSTRUCTION OF TETHYAN REGION at a time 250 million years ago in the Permian period shows the possible disposition of various blocks that were subsequently accreted to the Eurasian continent. The Tethyan region constituted a unique equatorial faunal province, for which the fusulinids are a key fossil index. The present location of the blocks is depicted below. The two maps are based on studies by M. W. McElhinny of Australian National University, B. J. J. Embleton of Australian Commonwealth Scientific and Industrial Research Organization Division of Mineral Physics and X. H. Ma and Z. K. Zhang of the Chinese Academy of Geological Sciences.



PRESENT DISTRIBUTION OF TETHYAN FUSULINIDS within their home territory is indicated by colored dots. Their presence in eastern Siberia, New Zealand and in the Western Hemisphere (*black dots*) provides strong evidence for large-scale tectonic dislocations of crustal blocks formerly in the Tethyan region. Tethyan blocks that joined Eurasia are shown in the locations proposed by McElhinny.

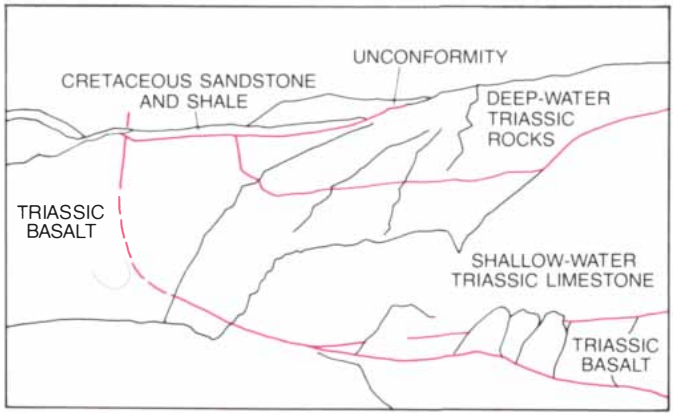
the Equator as part of the ocean floor. The rocks were later transported northward to Canada on an oceanic plate and eventually added to North America by accretion.

In order to establish the origin of the Cache Creek terrane of British Columbia it is important to know whether the equatorial marine organisms of the Tethyan fauna were confined to a single equatorial province or whether they were distributed along the entire Permian Equator. When the present distribution of Tethyan fusulinids is plotted, it seems quite clear that those found in a belt extending from the Mediterranean on the west to Borneo and possibly Japan on the east are indigenous. Their ancestral waters were the Tethys, which in Permian time lay between India, Tibet, Australia and Africa to the south and Europe and Asia to the north.

The Tethys embraced at least five substantial island masses that subsequently became accreted to the eastern margin of Asia at locations distributed from near the present Equator to the present Bering Sea. These accreted regions all have Tethyan fusulinids. Equally important is the observation that there are no Tethyan fusulinids in equatorial Permian rocks indigenous to the Western Hemisphere. The reason for the present dispersal of Tethyan fusulinids is clearly not a faunal migration during Permian time but rather a subsequent displacement of the Permian terranes that originally formed in the Tethys basin and on which the fusulinids were deposited and fossilized.

This simple explanation for the origin of the enigmatic fossils of the Cache Creek terrane carries an important implication. The exotic-fusulinid rocks are found 500 kilometers inland from the coast of North America. If the rocks are indeed of exotic origin, as Monger and Ross speculated, one must suspect that the rocks lying seaward of them to the west are exotic too. This suspicion is now being amply confirmed.

Many of the Paleozoic and Mesozoic rocks with ages between 590 and 65 million years found in parts of Alaska, British Columbia, Washington, Oregon, western Nevada, California and western Mexico lack obvious connections with the ancient craton, or core, of North America. The ancient western edge of North America at the last epoch when the continental margin was still a passive one can be delineated with reasonable accuracy on the basis of both lithological (rock type) and geochemical criteria. A major characteristic of such a margin is the presence of basement



CLIFF IN THE WRANGELL MOUNTAINS some 400 kilometers east of Anchorage, Alaska, displays a 100-million-year history of the Wrangellia terrane. The principal geologic features visible in the photograph are depicted in the map at the left. The oldest rocks, dating back to the Triassic period about 240 million years ago, were formed on an island arc somewhere in the ancient Pacific. The finely bedded limestone deposits, some 1,200 meters thick, hold the skeletons of shallow-water marine organisms that settled on the basaltic platform as it slowly subsided during the Triassic. The limestone was then covered by sediments composed mainly of deep-water organisms such as sponges and radiolarians. The ridge at the left, consisting of shallow-water sandstones and shales, was deposited in the Cretaceous some 120 million years ago. The authors propose that Triassic strata were folded and faulted when Wrangellia docked against North America.

rocks under thick Paleozoic sedimentary rocks derived from continental sources and deposited in deep water. In contrast to this sequence, the terranes found west of the ancient edge of North America consist of rocks characteristic of island arcs, oceanic crust and of sediments derived from them.

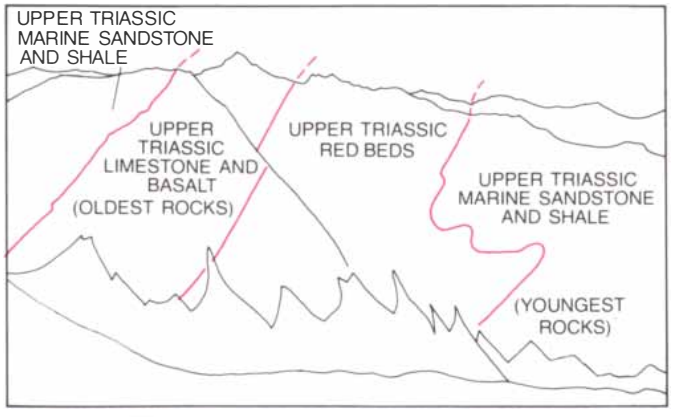
A key geochemical marker of the boundary between ancient continental crust and exotic rocks of oceanic affinity is a change in the ratio of two isotopes of strontium: strontium 87 and strontium 86. In ancient continental crust of Precambrian age (older than 590 million years) the ratio of strontium 87 to strontium 86 is high and in oceanic crust it is low. Such a distinctive change in isotope ratio provides a marker that coincides well with the lithological discontinuity.

The edge of the ancient continent defined by the two coincident markers lies from a few hundred to many hundreds of kilometers east of the present continental margin. This implies that all the rocks lying west of the ancient continental edge have been added by some accretionary process. Most of the accretion took place in a relatively brief period extending from about 200 million years ago to about 50 million years ago. We now believe that in this 150-million-year period exotic fragments derived from unknown sources in the Pacific were swept against and added to the western edge of North America. More than 100 highly diverse fragments have now been identified.

Terranes can be conveniently divided into four general categories: stratified, disrupted, metamorphic and composite. Stratified terranes are characterized by coherent stratigraphic sequences in which the order of deposition between successive lithologic units can be demonstrated. Basement rocks may or may not be preserved. Rock sequences within stratified terranes can be subdivided into three broad subcategories depending on whether the origin of the rocks is predominantly continental crust, oceanic crust or volcanic island arc. If the terranes have had a complex tectonic history, the strata will exhibit a succession of these crustal types.

Fragments of continents, the first subcategory, are characterized by the presence of a Precambrian basement with an overlying sequence of shallow-water sediments of Paleozoic and Mesozoic age. Included in this subcategory are sedimentary rocks of continental affinity that have become detached from their basement substratum.

Fragments of oceanic crust, the sec-



EXPOSED STRATA OF CHULITNA TERRANE lie about 60 kilometers to the northwest of the northern boundary of the Wrangellia terrane. The terrane exhibits a distinctive suite of rocks found nowhere else in Alaska or farther south in North America. The section in the photograph is folded and overturned so that the oldest rocks are the light- and dark-banded rocks at the left. These are of upper (late) Triassic age; the light strata are basalt, the dark strata limestone. They are overlain depositionally at the right by upper Triassic red beds (sandstone and conglomerate). The brown rocks still farther to the right are shallow-water sandstone and shale harboring an abundance of shallow-water marine fossils from the end of the Triassic. Strata were presumably overturned when Chulitna terrane reached Alaska 90 million years ago. Vertical relief is 600 meters. The photographs on these two pages were taken by one of the authors (Jones).

ond subcategory, are characterized by sequences of extruded molten rock typical of oceanic crust, usually overlain with layers of siliceous chert composed mainly of the skeletons of radiolarians (marine protozoans). Included in this subcategory are deep-sea deposits that have become detached from their basement substratum.

Fragments of volcanic arcs, the third subcategory, consist of stratified terranes composed chiefly of volcanic rocks or the plutonic (deep igneous) roots of volcanic island arcs, together with sedimentary debris originating from volcanoes. The rocks in this subcategory are similar in composition to those of currently active volcanic arcs such as the Aleutians.

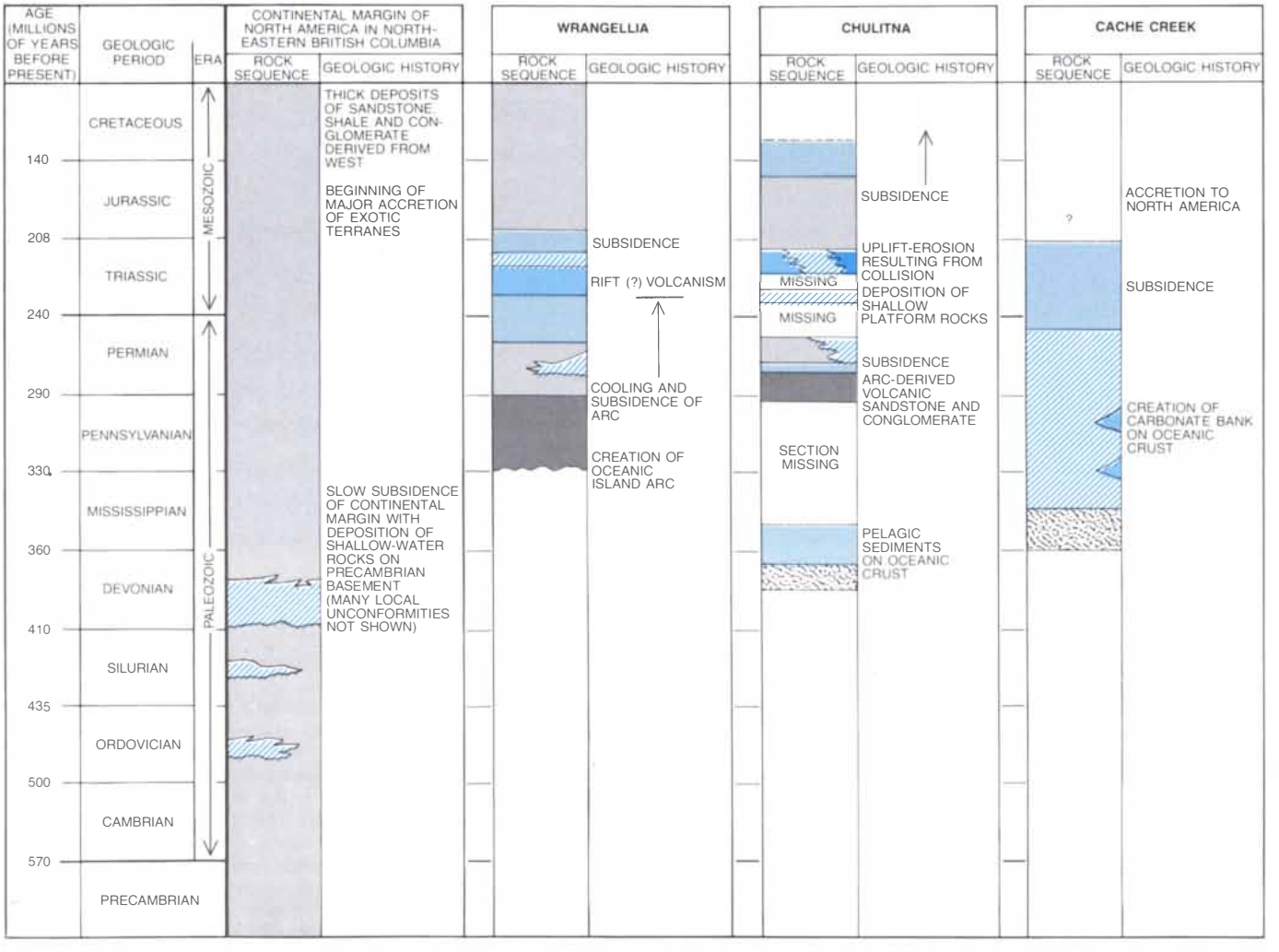
The second general category, disrupted terranes, is represented by blocks of heterogeneous lithology and age, usually set in a matrix of sheared shale or serpentinite (a rock poor in silica but rich in iron and magnesium). Most of these terranes harbor fragments of oceanic crust, blocks of shallow-water limestone, deep-water chert and packages of graywacke ("dirty sandstone") incorporating lenses of conglomerate. Many disrupted terranes also include blue schists (metamorphic rock formed under high pressure), which can be either indigenous or exotic.

Composite terranes, the third general category, are assembled from two or more distinct terranes that were amalgamated and then shared a common geologic history before their accretion to North America. The fourth category, metamorphic terranes, consists of rocks that have been subjected to terrane-wide geologic changes before or after being accreted to North America, including the development of metamorphic minerals to such a degree that the original stratigraphic features and relations are obscured.

Terranes vary enormously in size. Some cover tens of thousands of square kilometers, others only a few hundred. Many terranes that arrived in one piece were subsequently broken up and now consist of separate patches that can be correlated stratigraphically.

The remarkable fact that emerges from the analysis of the various terranes is that each terrane records a geologic history significantly different from its neighbors'. In most instances the differences are so pronounced that it would be inconceivable for the rocks of neighboring terranes to have formed in close proximity. Such differences emerge clearly when two terranes in southern Alaska—Wrangellia and Cache Creek—are compared with each other and with the stable western margin of North America [*see illustration below*]. The Cache Creek rocks consist of thick sequences of late Paleozoic shallow-water limestones deposited directly on oceanic crust. In contrast, the oldest rocks identified in Wrangellia are a thick sequence of late Paleozoic volcanic rocks characteristic of island arcs, capped by a thin sequence of shallow-water marine shale, sandstone and limestone. Fusulinids of Permian age in these limestones differ totally from the Tethyan forms of the same age in the nearby Cache Creek terrane, indicating that Wrangellia originated outside the Tethyan realm, presumably to the east of it in the Panthalassa Ocean, the predecessor of the Pacific.

The fossil-bearing late Paleozoic marine rocks in Wrangellia are overlain abruptly by a thick sequence of volcanic basalt. The first lava flows appear to have formed below sea level, but the volcanic pile soon rose above the sur-



rounding sea. It ultimately amounted to between 100,000 and 200,000 cubic kilometers of basalt. The source of this volcanic mass remains a mystery, but we speculate that it is related to the rifting of an ancient sea floor. The outpouring of basalt ended in late Triassic time and the entire plateau subsided below sea level. The earliest sedimentary rocks that cap the basalt resemble the shallow tidal carbonate deposits forming today in tropical waters such as the Persian Gulf. With progressive sinking the carbonate deposits were gradually overlain by deep-water deposits in which remains of deep-water fauna are abundant. There is no detritus of continental origin in these postvolcanic sediments. We suspect that at this time Wrangellia was isolated in mid-ocean, probably near the Equator. Its long northward drift had begun.

Close to both Wrangellia and Cache Creek in south-central Alaska but strikingly different from both of them is the tiny Chulitna terrane. Barely 50 kilometers long, Chulitna records a long and complex history of oceanic and continental sedimentation that is unique to North American geology. The oldest rocks of the terrane are basaltic lavas and altered plutonic rocks typical of oceanic crust, together with rocks formed from deep-sea sediments. Later Paleozoic rocks and the earliest Mesozoic rocks include conglomerates derived from an island arc, together with shallow-water carbonate rocks. Because there is no continental detritus in this sequence it must be part of a mid-ocean island. Conditions changed abruptly and dramatically in late Triassic time (243 to 213 million years ago) with the sudden influx of large amounts of coarse, quartz-rich detritus mixed with fragments from the terrane's own oceanic basement. These deposits record the docking of the Chulitna terrane against the edge of the North American continent.

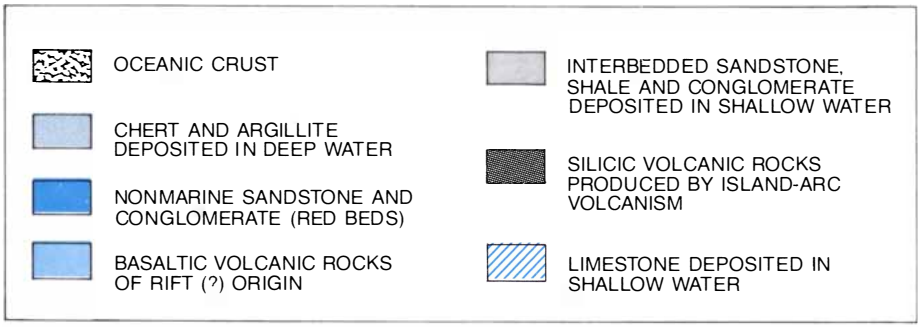
All this evidence shows that the Chulitna terrane underwent a profound change in Triassic time from having a strictly oceanic setting to being incorporated into a continental margin. Intense folding, faulting and uplift in the course of the collision led to the erosion of the oceanic basement of the terrane and to the mixing of the detritus with material from the adjacent continent. None of these dramatic events is recorded in the nearby rocks of Wrangellia. Although the two terranes are now next-door neighbors, they have completely different histories.

A major unsolved puzzle is where the Chulitna terrane was formed. In the stratigraphic and tectonic record it is totally unlike any other terrane known in North America. An origin far to the south is indicated by two independent lines of evidence. First, Chulitna has thick piles of reddish Triassic sediments ("red beds") whose only counterparts are found almost exclusively far to the south, below the U.S.-Canada border. Second, Triassic fossils in and below the Chulitna red beds are similar to forms known only from southern latitudes.

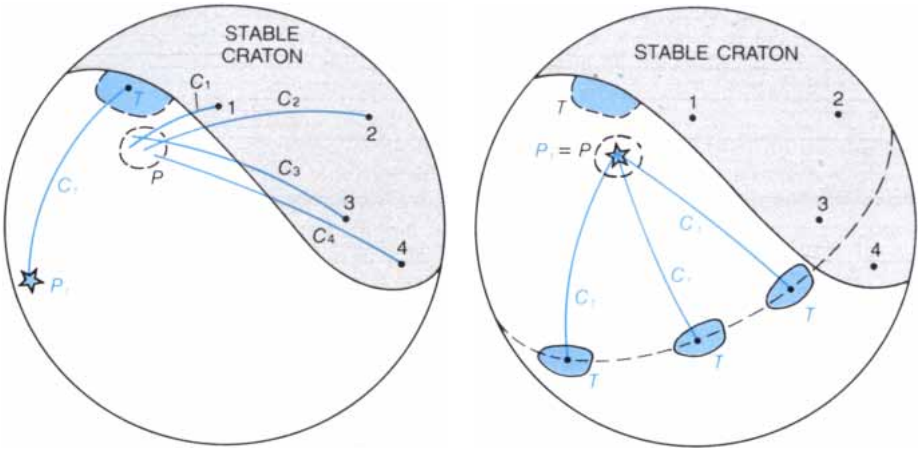
The remarkable geologic differences between neighboring Chulitna and Wrangellia are only two of many examples that could be cited. The essential point is that each terrane records a unique sequence of historical events that cannot be duplicated in detail anywhere else in North America. The discrimination of terranes is reasonably objective; it is based entirely on the preserved geologic data. The significance of the differences between the individual terranes and between the terranes and the ancient continent of North America, however, is the subject of continuing analysis and interpretation. The outstanding questions are: Where did the terranes originate? When and by what path did they move? In response to these questions paleomagnetic studies are now yielding significant new information.

The key to measuring the movement of terranes is close analysis of the magnetism frozen into basaltic and other igneous rocks at the time they solidified from the molten state. As we have indicated, the inclination of the magnetic vector locked into the rocks at the time of their formation is more or less horizontal near the Equator and gets steeper with distance north or south of the Equator. The orientation of the magnetic vector is also described by a second value: the declination, or the angle between the vector and true north.

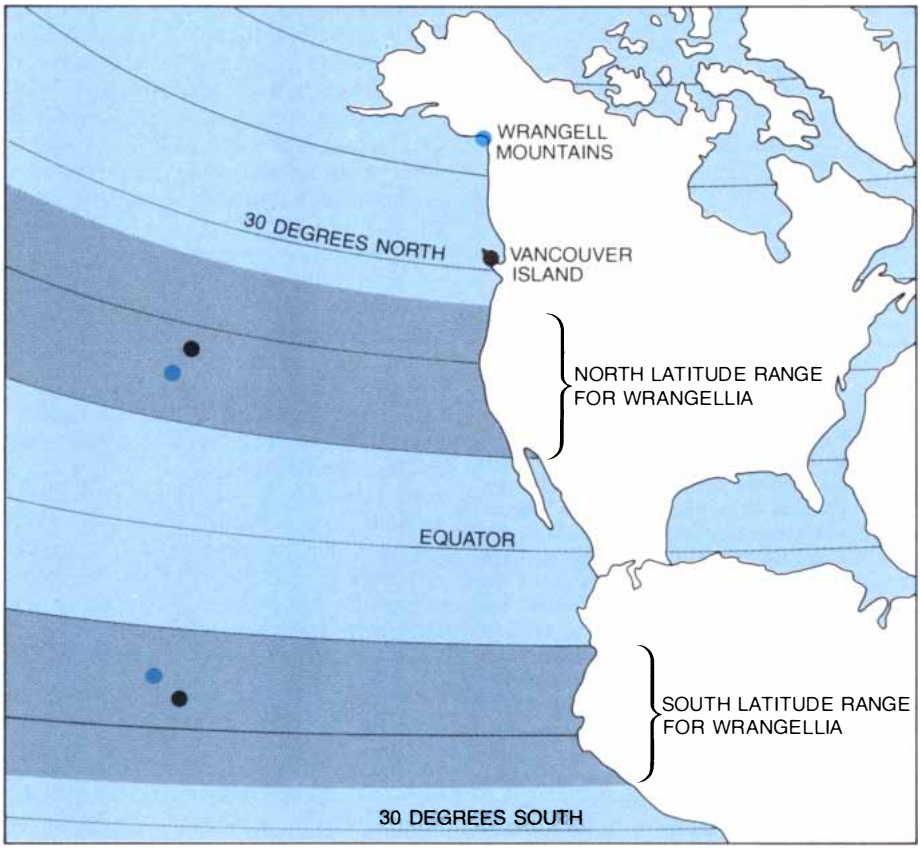
The paleomagnetic inclination reveals how far the rocks were from the geographic North Pole when they were formed. The distance is derived from a simple equation based on the assumption that the geomagnetic field can be represented by a magnetic dipole, or bar magnet, aligned with the earth's axis of rotation. At any one instant this is not exactly true because the geomagnetic field shows considerable variation. The dipole assumption is nonetheless valid if one gets an average inclination from rock strata whose ages span a time interval of at least several tens of thousands of years. Paleomagnetic data can then establish the latitude at which



GEOLOGIC HISTORIES OF THREE EXOTIC TERRANES, Wrangellia, Chulitna and Cache Creek, are distinctly different from one another and from the history of the ancient continental margin of North America. Beginning in each case with the oldest rocks, the geologic histories can be read as follows. The North American rocks laid down between 570 and about 200 million years ago are characteristic of passive continental margins, indicating that over the entire period the West Coast was slowly subsiding, as the East Coast is today. The margin then became active as Pacific oceanic plates began to be subducted under the western edge of the continent. The Wrangellia terrane originated about 300 million years ago as an island arc formed by volcanic action far from any continent. As the arc cooled and sank it was covered first by shallow-water sediments and then by deep-water sediments. About 220 million years ago the terrane rifted and was covered with thick deposits of basalt, establishing a volcanic platform and eventually a volcanic island. In time the island sank, collecting deposits of limestone and shale, both of marine origin. The earliest sediments of continental origin were deposited during the Cretaceous period as Wrangellia began to collide with North America. In the Chulitna terrane the geologic record begins much earlier in the Devonian period with the formation of oceanic crust and the subsequent deposition of pelagic, or deep-ocean, sediments. Coarse volcanic sediments derived from an island arc covered the pelagic deposits, to be overlain in turn by shallow-water limestones of Permian and early Triassic age. Somewhat later the terrane had an influx of coarse continental sediments, which formed the prominent red beds in the photograph on page 75. The sediments may record the original docking of Chulitna against North America at a low latitude. Later tectonic activity presumably lifted the terrane from its original point of collision. This was followed by a period of subsidence and then northward transport to the site of final accretion in Alaska. The history of the Cache Creek terrane began about 350 million years ago with the formation of oceanic crust and a basaltic platform on which several thousand meters of shallow-water limestone accumulated. These limestone sediments harbor Tethyan fusulinids of Permian age. In the Triassic the limestone platform subsided further and was overlain by deep-water deposits. In Jurassic time, 180 million years ago, Cache Creek completed its voyage from the western Pacific and docked in British Columbia.



PALEOMAGNETIC STUDIES yield evidence that some terranes such as Wrangellia have moved far from their origins. When rocks solidify, they become magnetized in a direction characterized by two components: declination and inclination. Declination points toward the location of the magnetic pole. Inclination is related to the dip of the lines of force in the earth's magnetic field, which are horizontal at the Equator and become increasingly vertical toward the poles. It reflects the distance, *C*, of the rock from the ancient pole. The paleomagnetic declination and inclination at several sampling sites (*1, 2, 3, 4*) on the stable craton establishes the direction and distance and hence the location of the mean cratonal pole, *P* (*left*). Rocks of the same age from the possible terrane, *T*, are analyzed to obtain a paleomagnetic pole P_T for the terrane (*star at left*). Since at a given time the earth has only one paleomagnetic north pole, at the time the rocks formed the location of P_T must have coincided with *P* (*right*). It is evident that the terrane must have originated at some location along the small circle of radius C_T.



ORIGIN OF THE WRANGELLIA TERRANE has been narrowed down on the basis of paleomagnetic evidence to one of two probable regions by Raymond W. Yole of Carleton University and Edward Irving of the Canadian Department of Energy, Mines and Resources. Two sites in Wrangellia were studied: one in the Wrangell Mountains of Alaska and the other on Vancouver Island in British Columbia. In the late Triassic the rocks of both sites were formed as part of an island in the proto-Pacific some 16 degrees either north or south of the Triassic Equator. Allowing for possible sources of error, the paleomagnetic data establish that Wrangellia was situated in one of the two shaded bands. Whether the origin of the terrane was north or south of the Equator depends on whether the magnetism of the Triassic rocks was "frozen" when the polarity of the earth's magnetic field was "normal" (what it is today) or when it was reversed. Indirect evidence favors the second possibility and the more southerly band.

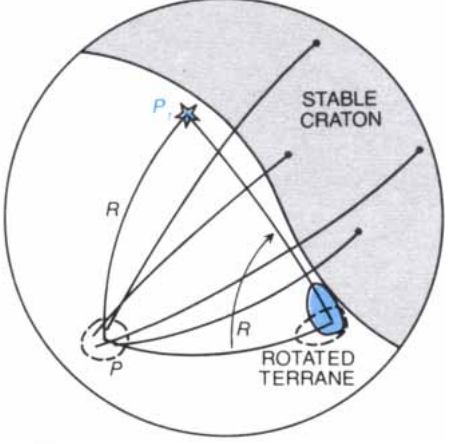
rocks first formed with an accuracy of about five degrees.

The second value, the paleomagnetic declination, establishes a paleonorth direction that points toward the ancient geographic and magnetic pole. As with inclination, meaningful values for declination call for the averaging of paleomagnetic directions in rocks spanning a substantial period of time. The accuracy of determining declination varies with the original latitude of formation, being greatest for rocks formed near the ancient Equator.

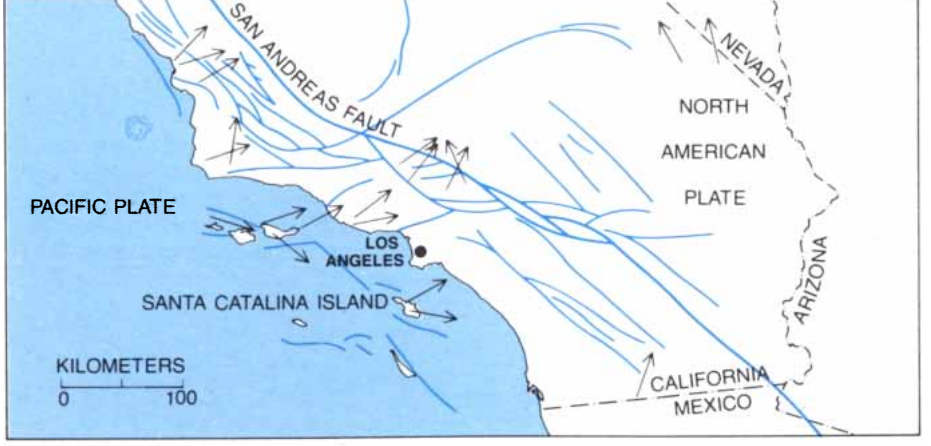
Having found the paleomagnetic inclination and declination at some site for rocks of a given age, finding the pole is a straightforward exercise in spherical geometry. The declination tells one that when the rocks were formed, the ancient pole lay along a great circle passing through the sampling site and deviating from the present true north direction by a certain number of degrees equal to the declination. The inclination tells one the distance to the ancient pole at the time the rocks solidified. One assumes that in the distant past the mean paleomagnetic pole and the ancient geographic pole coincided, just as they have in the more recent past. Because the North American plate has been moving in relation to the earth's axis of rotation the pole as seen from North America appears to have moved.

Here is an example of how paleomagnetism can reveal whether or not a terrane of, say, Triassic age is displaced with respect to a stable North America. One begins by determining the mean location of the Triassic paleomagnetic pole with rocks obtained from the stable part of the continent. One then determines the paleomagnetic inclination of Triassic rocks in the terrane of interest. This measurement establishes the terrane's paleolatitude, or distance from the pole, in the Triassic. The terrane therefore must have been somewhere on a circle of that paleolatitude centered on the mean Triassic paleopole for the stable continent. If the circle happens to pass through the present-day sampling site, the terrane is not displaced except for a possible movement along the circle.

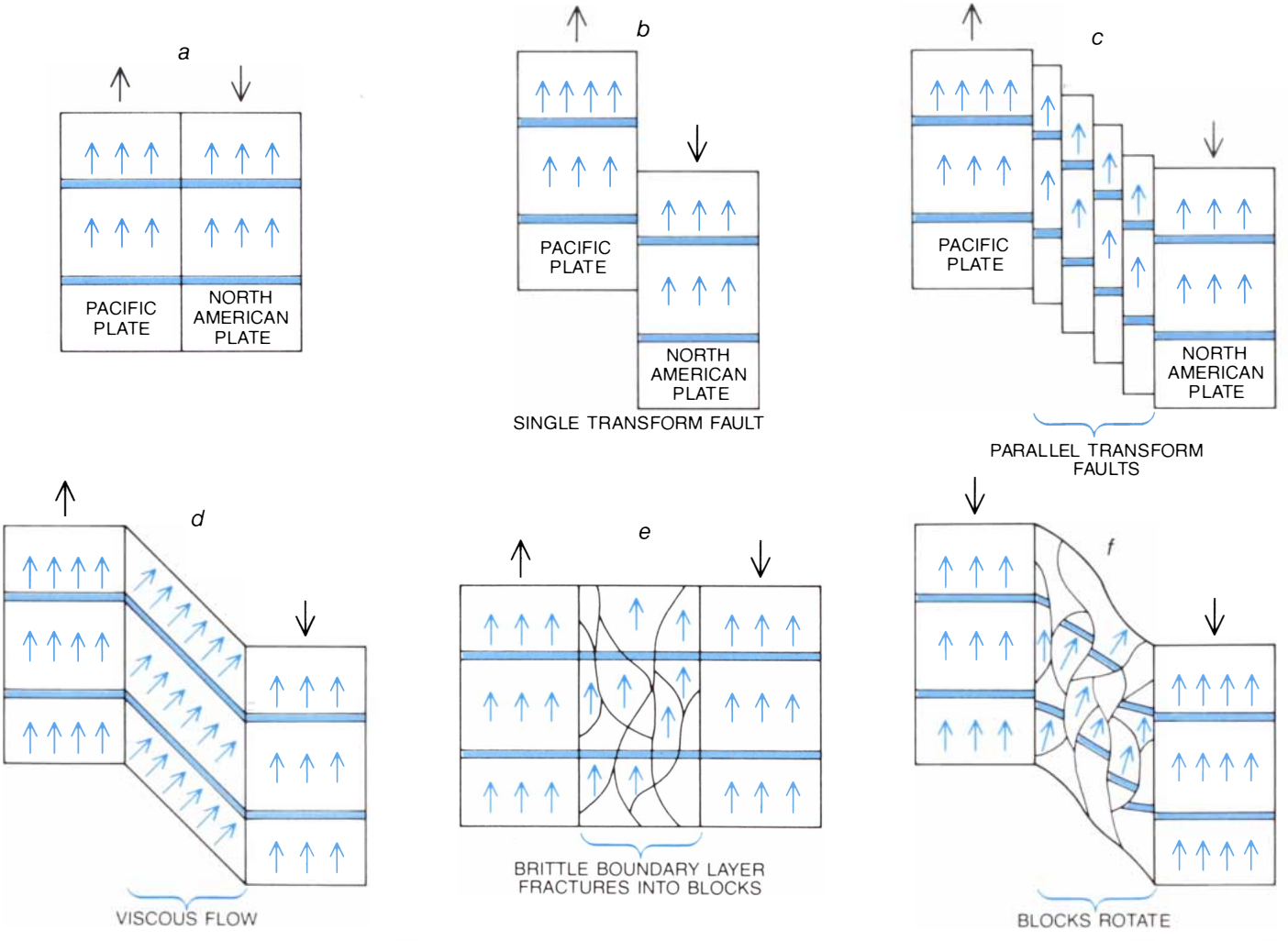
Studies of this type made in western Canada by Raymond W. Yole of Carleton University and Edward Irving of the Canadian Department of Energy, Mines and Resources, in Alaska by Duane R. Packer and David B. Stone of the University of Alaska and J. W. Hillhouse of the U.S. Geological Survey and in Washington, Oregon and California by one of us (Beck) have established that many of the terranes in western North America have traveled northward thousands of kilometers. The paleomagnetic results are particularly striking for Wrangellia. Rocks obtained from parts of the Wrangellia terrane on Vancouver Island in



WHEN A TERRANE ROTATES by some angle, *R*, at some time after the magnetism of its rocks was frozen, the apparent position deduced for the paleomagnetic pole is similarly rotated. On the basis of data from the stable craton the pole is known to have been at location *P*. The rotation of the terrane makes it appear that the pole was at P_T rather than *P*.



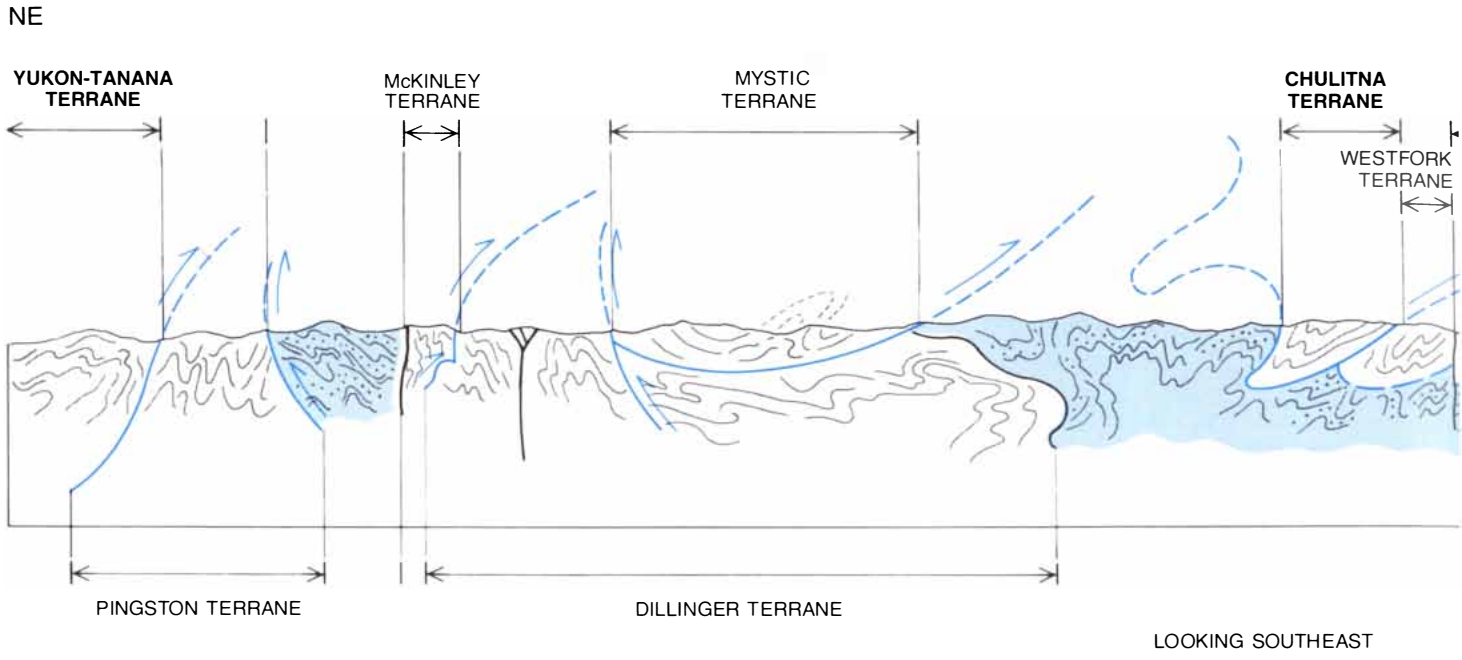
LARGE ROTATIONS ARE INFERRED for rocks in southern California on the basis of paleomagnetic declinations that deviate sharply from the craton declination, which is almost due north. The rocks range in age from 10 to 26 million years, a period in which the direction of the pole is known to have changed very little. The rotated rocks lie entirely to the west of the San Andreas fault on the Pacific plate, which is sliding northwestward parallel to the continental margin. Plate motion at a simple fault of this type, however, would not by itself be able to give rise to such large rotations, some of which amount to as much as five degrees per million years. These terranes must have been rotated by a more complex tectonic process.



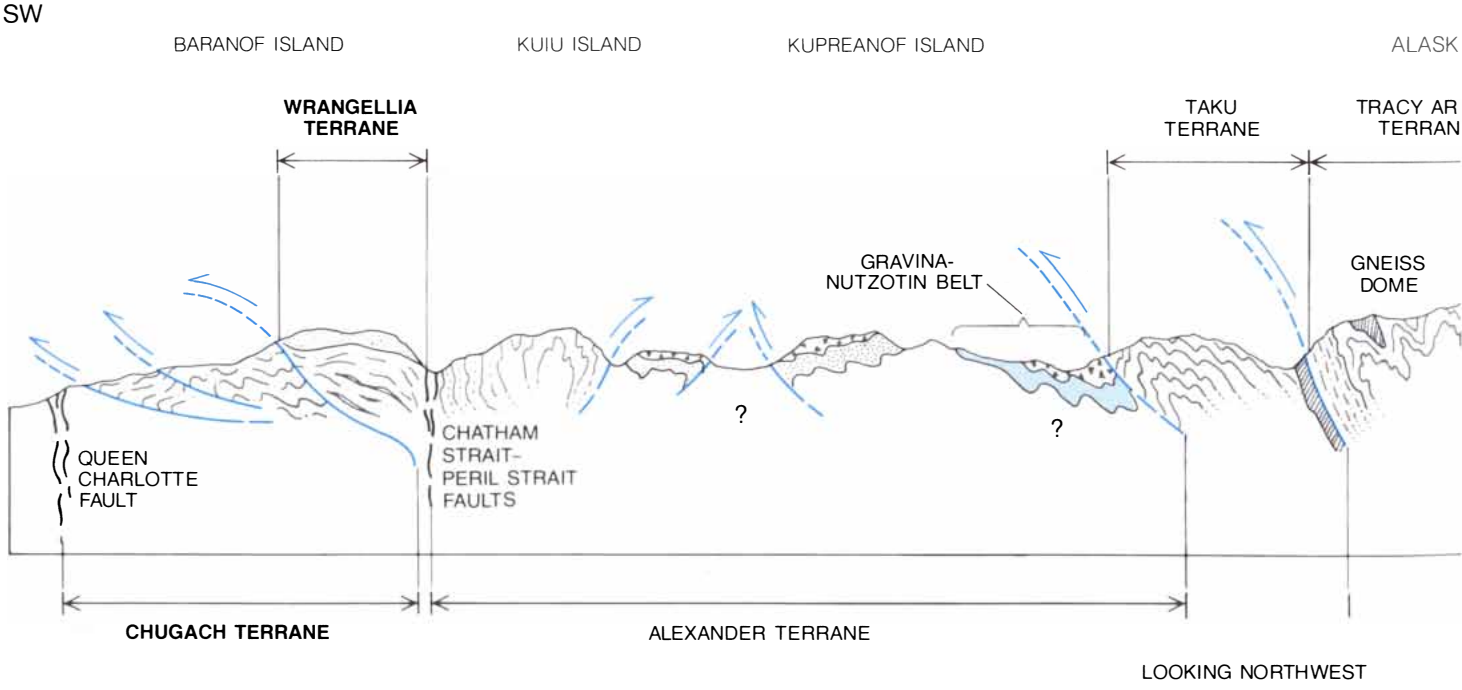
VARIETY OF DEFORMATIONS can result at a boundary where two plates slide past each other. The deformation can be followed by imagining two colored lines painted across the fault boundary before the plates began to move (*a*). Solid arrows show the orientation of paleomagnetic vectors embedded in the plates. Regardless of whether the relative motion of the two plates gives rise to a single fault (*b*) or to a series of faults parallel to the plate boundaries (*c*), the painted lines remain parallel and the magnetic vectors remain unrotated. If the plates are separated by a narrow crustal zone in which rocks behave like a viscous fluid (*d*), the magnetic particles in the viscous rock will be rotated. (Although this situation does not arise in the rigid upper part of the crust, it can arise in an underlying ductile zone.) If the crust between the two plates is brittle enough (*e*), it may crack in response to forces from the sides of the plates and from the bottom by flow in a ductile zone 15 kilometers down. Motion of the plates can then cause blocks to rotate, carrying their paleomagnetic vectors (*f*).

British Columbia and from the Wrangell Mountains in Alaska show that the rocks at both sampling sites, now 2,500 kilometers apart, originally formed near the Triassic Equator at essentially the same latitude. Their present separation is the result of strike-slip faulting during and after their accretion to North America, which appears to have strung Wrangellia out in a north-south direction.

Another surprising result of the paleomagnetic studies has come from the determination of paleomagnetic declinations. It has been discovered that many of the terranes in western North America have rotated, most of them in a clockwise sense and some in excess of 70 degrees. In some of these terranes the rotations call for a rethinking of the local geology. For example, in the Coast Range of Oregon marine sediments laid down in the Eocene epoch reveal the direction of currents on the ocean bottom. In the absence of paleomagnetic information it was believed the currents flowed in a northerly direction parallel to the present continental margins. Paleomagnetic studies by Robert W. Simpson of the U.S. Geological Survey and one of us (Cox) show, however, that the



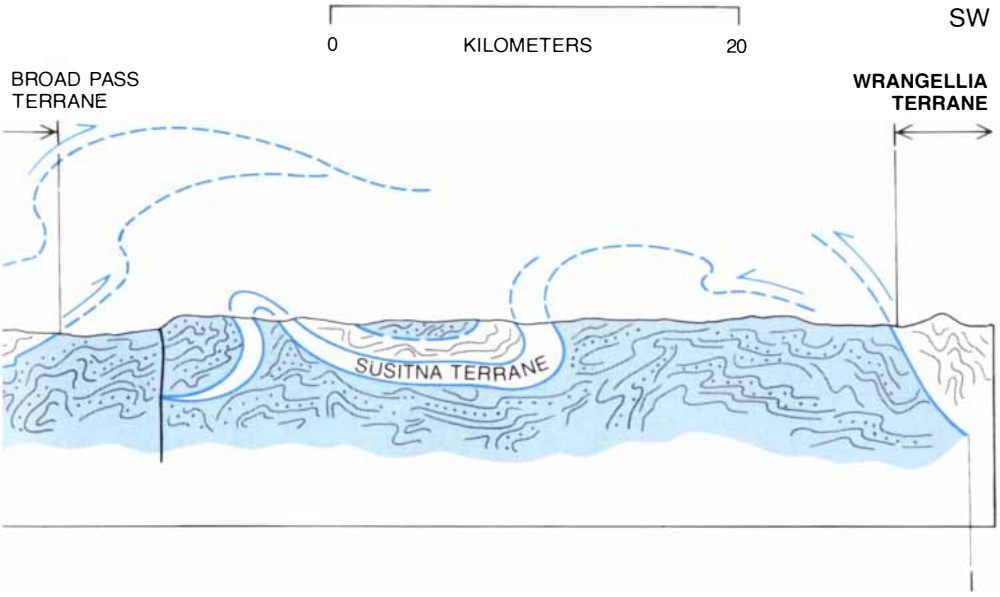
SECTION THROUGH CENTRAL ALASKA RANGE viewed toward the southeast cuts across 10 separate terranes, including the tiny Chulitna terrane (*see map on page 71*). The entire region is heavily deformed and most of the terranes are bounded by major thrust faults (*solid color*). Deformed Cretaceous sandstones and shales are shown in a light shade of color. The Yukon-Takana terrane to the



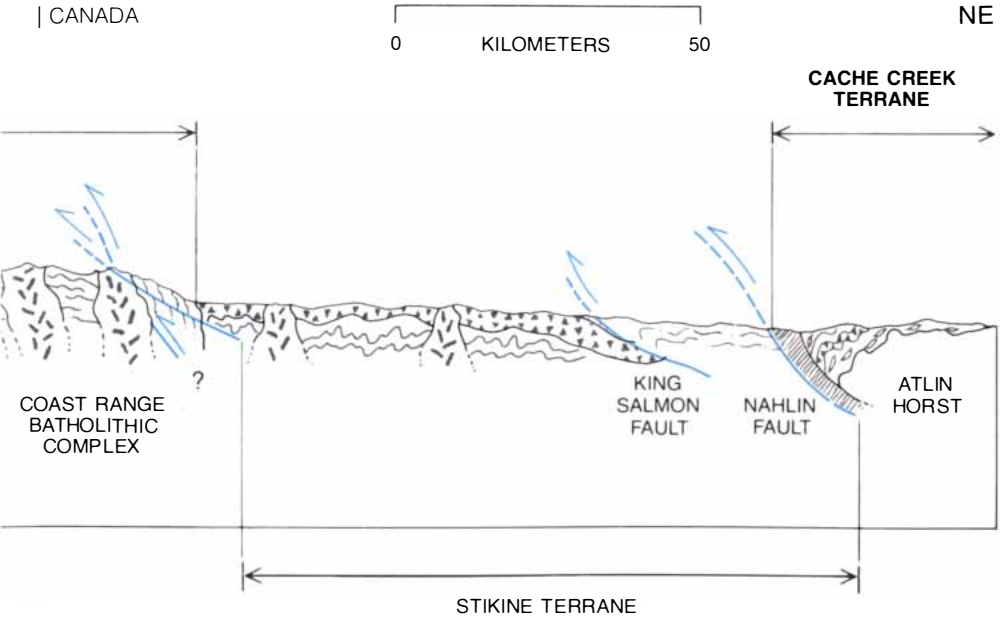
SECTION THROUGH SOUTHEASTERN ALASKA and British Columbia embraces the youngest accreted terrane, the Chugach terrane, on the left, and one of the first terranes to be recognized as exotic, the Cache Creek terrane, on the right. The Cache Creek terrane, some 500 kilometers inland, has Tethyan fusulinids that were native to regions of the Tethys Ocean that lay thousands of kilometers to the southwest in the Permian period. Carried on the eastward-moving plate of the Pacific basin, the Cache Creek terrane docked against

rocks that recorded the bottom currents have been rotated clockwise by more than 50 degrees since the time of their formation, so that the true direction of Eocene bottom currents was northwesterly, in a direction away from the coast.

In a terrane that has not been rotated the paleomagnetic declination will point toward the paleomagnetic pole as it is determined from rocks of the same age on the undisrupted part of the continent. If a terrane has been rotated, the declination of its rocks will not agree with the mean declination determined from the stable part of the continent. From studies in Washington, Oregon and California one of us (Beck) concluded in 1976 that many terranes have rotated in a clockwise direction.



north (*left*) was the first to be accreted against the margin of ancient North America, perhaps 180 to 200 million years ago. Wrangellia collided with the continental margin in the mid-Cretaceous time, about 90 million years ago. Intervening terranes arrived between those two dates.



North America 170 to 180 million years ago. On the west, Wrangellia has been thrust over the folded and faulted Cretaceous sandstones and shales of the still younger Chugach terrane. Between Chugach and Cache Creek lie four other terranes. Their rocks are mainly volcanic, mixed with igneous and metamorphic rocks, some created when terranes collided with the continent.

Rotations are found in terranes both with and without large latitudinal displacement. Rotations of the terranes that have been displaced can reasonably be attributed to changes in orientation in the course of the terrane's displacement and docking. The rotations of the terranes that have been only slightly displaced are less easily explained. We shall give two examples.

In southern California, Bruce P. Luyendyk and Marc J. Kamerling of the University of California at Santa Barbara have measured clockwise rotations of more than 60 degrees in rocks only 13 million years old. What tectonic forces could have produced rotations at the rate of nearly five degrees per million years? The ultimate cause must certainly be deformation produced by the northwesterly motion of the Pacific plate past North America. The sense of this motion is described as dextral, or right-handed, since an observer on either plate would see the other plate moving to the right. The challenge lies in discovering the precise mechanism by which dextral shear across the San Andreas fault creates the observed clockwise rotation.

In simple plate tectonics all displacement between two plates is assumed to occur along a single fault. Therefore if one were to paint a straight line across a boundary such as the San Andreas fault, after a million years the line would be offset by 50 kilometers or so, with the line segments on both plates remaining straight and parallel to each other. There would be no rotation. Similarly, if the plate motion were to be accomplished by a series of parallel faults, the painted line would simply be offset by a series of parallel steps, again with no rotation.

One suggestion is that the rotated crustal blocks in southern California should be regarded as microplates. Such plates can be defined as segments of lithosphere (the rigid upper part of the earth's crust) that have been displaced with respect to adjacent plates along a complete set of boundary faults penetrating all the way to the asthenosphere (the fluid region that begins about 100 kilometers below the lithosphere). One would expect the minimum length or width of a microplate to also be on the order of 100 kilometers. Inasmuch as many of the rotated blocks in southern California are much smaller than that, only 10 to 20 kilometers across, it appears that the faults that bound them are confined to the upper 15 kilometers of brittle upper crust and so do not penetrate the underlying ductile layer. Rotational domains that small are better described as intracrustal blocks than as true microplates. Fault patterns of great complexity seem to be related to the evolving geology of the lower San Andreas region, including the geology in-

volved in the origin and deformation of oil-bearing basins.

In western Oregon and Washington rotations ranging from 25 to 70 degrees have been found in rocks varying in age from 30 to 55 million years. The largest rotations are found in the oldest rocks, which include lava flows and sediments that were originally emplaced on the ocean floor and are now accreted to the western edge of the continent to form Oregon's Coast Range. The Cascade Range, which lies to the east of the Coast Range and is younger, has been rotated clockwise about 25 degrees.

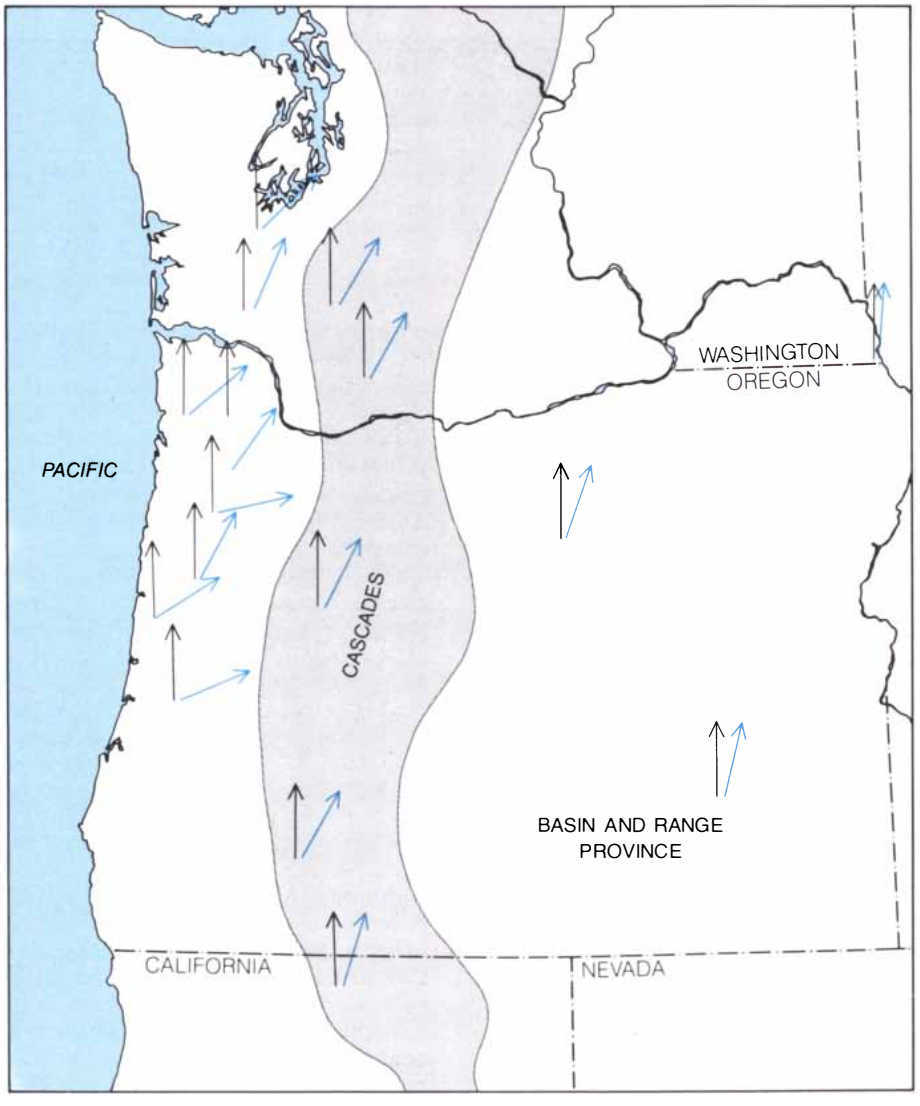
The tectonic environment in western Oregon is quite different from the one in southern California. There are fewer earthquakes and the geologic formations have been less disrupted by faulting. J. Magill of Stanford and one of us (Cox) believe the rotations in western Oregon were produced in two phases by separate tectonic processes. The first phase of rotation was between 55 and 40 million years ago, when oceanic crust, which is the oldest part of the Coast Range, was being accreted to the continent. The second phase began about 20 million years ago and accompanied the well-documented thinning and stretching of the crust in the course of the extension of the Basin and Range province in eastern Oregon and Nevada. Whether the rotated blocks in western Oregon and Washington are true microplates or are shallow blocks of crust detached from the underlying lithosphere is an open question. The great length of the rotational domains in Oregon suggests that microplates may be involved, whereas in Washington the rotational domains are smaller, suggesting some decoupling from the rest of the lithosphere.

In speculating how the displaced terranes became accreted to North America we can begin with several useful observations. The first is that the leading edge of an accreted terrane does not, as one might expect, take the form of sutures typical of subduction zones. In a subduction zone the edge of an oceanic plate plunges at a steep angle under the continental margin. The terrane edges take the form of simple thrust faults or strike-slip faults. In a thrust fault one block merely moves up and over another block along a shallowly dipping fault. In a strike-slip fault two blocks slide past each other horizontally along a steeply dipping fault.

The second observation is that most terranes have become highly elongated and stretched parallel to the edge of North America. This is particularly true of the older terranes of Alaska and British Columbia, which on a small-scale geologic map look like thin strips of veneer applied to the edge of the continent.

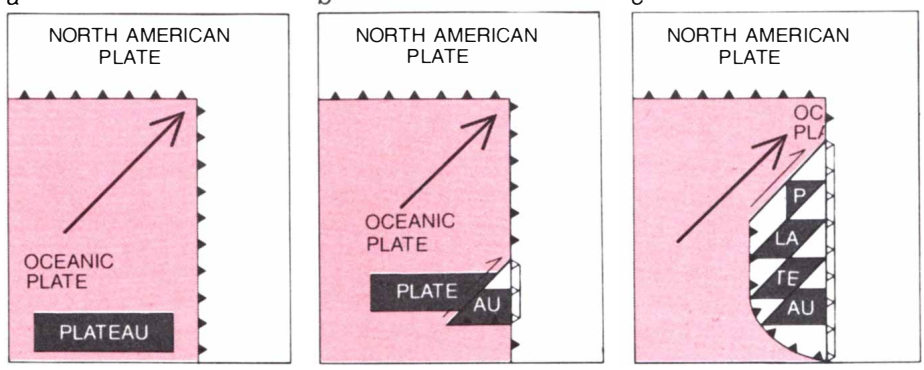
That many of these terranes were transported to North America on oceanic plates can scarcely be questioned on the basis of the fossil and paleomagnetic evidence. This being so, the oceanic plate must have been consumed at a subduction zone when the terrane arrived at the continental margin. It is clear the terranes themselves survived the subduction process. The puzzling scarcity of subduction-zone sutures along present terrane boundaries implies that the sutures have been altered or hidden by subsequent geologic processes. Thrust faulting and strike-slip faulting are ubiquitous processes that are both capable of hiding the sutures.

A second puzzling feature of terranes is that many of them have survived the accretion process with little internal deformation. Since accretion implies collision at a subduction zone, one would expect the terranes to be much deformed. On the contrary, one finds large islands of relatively undeformed terranes such as Wrangellia in close proximity to more deformed and smaller terranes such as Chulitna. The extent to which a terrane is deformed in the course of accretion evidently depends on several factors: the velocity of the converging plates, the angle at which the plates collide, the width of the collision zone, the length of time the exotic terrane stays in the accretion zone and the strength of the terrane's rocks. In addition if a subduction zone gets clogged by a buoyant terrane, the zone may jump to a new position seaward of the newly accreted and largely undeformed terrane.



ROTATION OF ROCKS LESS THAN 60 MILLION YEARS OLD is observed in the terranes that form the western edge of Washington and Oregon. The black arrows show the direction of the paleomagnetic pole based on samples from the stable North American craton. (The arrows are here rotated slightly to the north for the sake of simplicity.) The colored arrows show the average paleomagnetic direction observed at each sampling site. All the rotations are clockwise. Moreover, the greatest rotations are found in the oldest rocks, which formed offshore on the ocean bottom and are now accreted to the continent west of the Cascade Range.

A description of three areas within the exotic terranes of western North America may illuminate the complexity and variety of the structural features evolved in the accretion process. In southwestern Alaska and adjacent British Columbia a complex suture zone involving Wrangellia and several other accreted terranes is well exposed in fjords that form deep bays along the coast. Evidently in mid-Cretaceous time, some 100 million years ago, Wrangellia collided with terranes that are now to the east. The collision resulted in intense deformation and metamorphism, followed by a major uplifting of the terranes to the east. The comparative recency of the collision is attested by the presence of deep-water, fine-grained sedimentary and volcanic rocks from late Jurassic to mid-Cretaceous time that were deposited in a deep marine basin landward of Wrangellia. Plutonic granites that intruded into the uplifted eastern terranes in the early Tertiary are largely undeformed, indicating that by then the accretion of Wrangellia to North America had been completed.



ELONGATION OF TERRANES may result if the subducting oceanic plate strikes the continental margin obliquely (*a*). As the plate plunges under the margin a plateau riding on the plate resists subduction and is accreted to the continent. When the plateau collides with North America (*b*), it splits off along a fault and is wedged into position as the rest of the plateau continues moving northeast. Process is repeated (*c*) as subduction zone (*barbed line*) jumps west.

Farther north along the same boundary in southern Alaska an accretionary suture zone is beautifully preserved in the Alaska Range for several hundred kilometers east and west of Mount McKinley, but the geologic events recorded there are different from those in southwestern Alaska and British Columbia. In the Alaska Range, Jurassic and Cretaceous rocks that were deposited in a deep marine trough have been strongly deformed and telescoped to a small fraction of their original width and have been overridden by Wrangellia on the south along a major thrust fault. Scattered through the collapsed and disrupted basin are many fault-bounded small terranes, of which Chulitna is perhaps the most striking example. The origins and geologic histories of these small exotic terranes are totally unrelated to either Wrangellia or central Alaska, or for that matter to anything else known in North America. In the course of collision the small terranes were thrust over the younger strata of the deep marine trough, just as the Wrangellia terrane was. After the collision the entire region was further telescoped and deformed by dextral slip faulting, a process that continues to the present day.

The third area we shall describe lies in the Yukon Territory farther to the east, where work by our Canadian colleagues suggests that the Stikine terrane first made contact with North America in the mid-Jurassic. This enormous terrane, probably the largest yet recognized, arrived on a plate bearing the roots of a volcanic arc and what appear to be oceanic materials of the Cache Creek terrane, which borders the Stikine terrane on the east. The collision eventually carried the oceanic and arc material up and eastward over the continental margin in the form of vast thrust sheets. Subsequent accretions added Wrangellia and other younger terranes to Stikine's trailing edge. This pileup of thrusted sheets along the ancient western edge of North America created a belt of new continental crust as much as 600 kilometers wide. Later folding and thrust faulting that extended into late Cretaceous and even early Tertiary time was accompanied by extensive strike-slip faulting that shifted large parts of the Canadian Cordillera (the entire complex of mountain ranges on the western side of the continent) hundreds of kilometers northward with respect to North America as a whole.

Accreted terranes play a major role in one of the most dramatic processes of global tectonics, the creation of mountain chains along convergent continental margins. Collisions between continental masses had been invoked long before the advent of plate tectonics to explain certain mountain belts, such as the Himalayas, that are deeply embedded within two large converging land masses. The possibility that collisions may also play a role in forming mountain belts that directly face an open ocean, such as the Andes of South America and the Cordillera of North America, has only recently been suggested. Here the collision is between the continent and much smaller land areas, including seamounts (isolated mountains on the sea floor), island arcs, marine plateaus and microcontinental blocks. The massive telescoping of crust, thrust faulting and metamorphism, however, are essentially similar to the consequences of collisions between continental masses. If one accepts that similar effects imply similar causes, it follows that massive, complexly deformed mountain systems imply collisions between separate, converging thick crustal blocks.

The idea of a collision between continents has been highly successful in explaining the massive telescoping of rock strata in the Himalayas, where the crust appears to have been shortened by 800 kilometers or more. Evidently the continental crust of India, some 40 kilometers thick, was too buoyant to be subducted very deeply at the suture zone where it collided with the Asian plate. Instead the converging crusts of India and Asia telescoped along thrust faults until the crust was twice the thickness of normal continental crust, forming the Himalayas. In the 40 million years since the initial collision the Indian subcontinent has continued to move northward, shoving Asian crustal rocks toward the north and east and causing massive disruption far into China. The continuing convergence is responsible for most of the devastating earthquakes that have racked the region.

The Andes are less well understood. Presumably they were created by the subduction of oceanic crust under continental crust, yet there is abundant evidence of compression and shortening in broad belts well inland from the subduction zone. The compression was attributed by one of us (Coney), and later by Kevin C. Burke of the State University of New York at Albany and Wilson, to a rapid movement of the continent toward the oceanic trench immediately above the subduction zone, where the continent meets the descending oceanic plate, creating a compressive stress that is transmitted inland from the continental margin.

An alternative model for mountain building in which terranes play a key role has recently been advanced by Zvi Ben-Avraham and Amos M. Nur of Stanford and two of us (Jones and Cox). In this model mountain building of the Andean type is more closely related to

mountain building of the Himalayan collisional type than to simple subduction of oceanic crust. The model suggests that large oceanic plateaus, seamounts and volcanic ridges, some of which are comparable to continents in their thickness and density, may play the same role as the subcontinent of India in the creation of the Himalayas. Like India, these large masses of light rock are too buoyant to be subducted and so they serve to couple the forward motion of the lower subducting oceanic plate to the upper continental plate. On this view even the Andes may have been thrown up by the accretion of oceanic plateaus—perhaps exotic terranes not yet recognized—along the continental margin of South America. The difference in scale between the Andes and the Himalayas would reflect the difference between the width of the Indian subcontinent and the width of the plateaus responsible for the Andes.

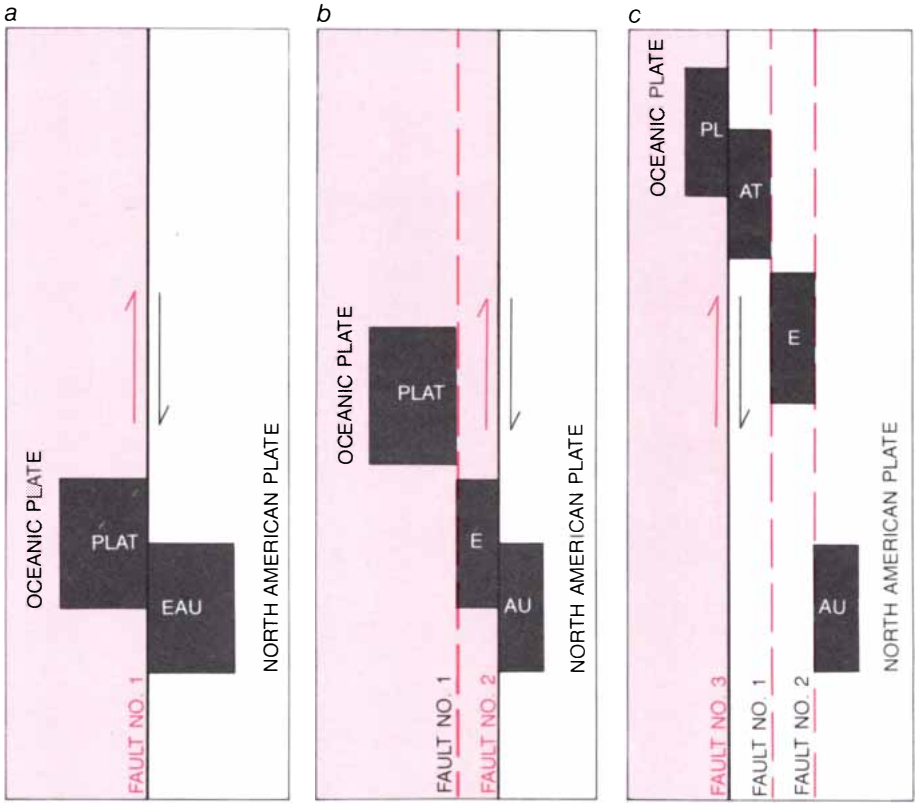
A testable prediction of this model is that the mountain building should coincide with the accretion of the exotic terranes. An ideal test case is provided by the Laramide orogeny: the last great deformation of the North American Cordillera. The Laramide orogeny was an intense and widespread deformation and building of mountains between 40 and 80 million years ago. It took in a broad zone extending from the Sierra Nevada to the Rockies. It is one of the best described and least understood of all mountain-building episodes. Extending as far east as Denver, the Laramide orogeny produced the giant uplifts of the Rockies and the Colorado Plateau, which together give the Cordillera its extraordinary width. Most of the deformation of the Canadian Rockies and of the Sierra Madre Oriental of eastern Mexico occurred at the same time. Throughout the period of deformation oceanic crust was being subducted along the west coast of North America. But how could subduction of ocean floor off California and Oregon be the cause of mountain building more than 1,200 kilometers to the east in Colorado?

Two alternative explanations based on plate-tectonic theory have been advanced by one of us (Coney). The first proposes that the angle at which the slab of oceanic lithosphere was subducted under North America was so shallow that even 1,500 kilometers from the coast the slab was still mechanically coupled to the overlying plate, thrusting it upward. The second explanation is that North America and the converging oceanic plate to the west were simply moving toward each other so fast that deformation took place at an unusually great distance from the subduction zone. Although there is some evidence supporting both explanations, many investigators have felt that even the two together are not adequate to account fully for such a wide and profound orogeny.

A third possibility is that the deformation was augmented by the arrival of terranes. Although most of the exotic terranes seem to have arrived before the Laramide orogeny, the event may represent the final phases of their collision with North America. The folding and faulting throughout the Cordillera would then represent the final "tightening up" of a poorly consolidated continental crust made up of newly accreted terranes. Interaction of the terranes with the adjoining ancient crust would presumably cause rotations, uplifts and overthrusts in a broad band encompassing both the North American craton and the terranes.

The driving force of such a process appears to have been the continuing subduction of the oceanic Pacific plates under North America rather than the successive arrival of new exotic terranes in the Cenozoic era. The collision of exotic terranes during the Laramide orogeny cannot, however, be totally ruled out. Recent paleomagnetic data obtained from central and southern California by David Howell, Jack Vedder and Dwayne Champion of the U.S. Geological Survey have led to the suggestion that in Eocene time, no more than 50 million years ago, a large continental fragment derived from the latitude of southern Mexico collided with the southwestern margin of California.

The recognition of many exotic terranes in western North America adds an important new chapter to the geologic history of our continent. We propose that western North America has grown by more than 25 percent through accretion since early Jurassic time, a period of barely 200 million years. The growth was provided mainly by the addition of terranes that are of oceanic rather than continental origin. This implies real continental growth, not just the recycling of old continental material. Although the process of collision, accretion and continental growth is complex and poorly understood, there must have been much telescoping and transport of mass. The end result is new crust thickened by thrusting to continental proportions and added to the old continent. The concept of terranes being accreted piecemeal in western North America has important implications for the origin and evolution of the world's great mountain chains, many of which may have had a similar history.



ANOTHER ELONGATION MECHANISM may involve the back-and-forth shifting of faults. After the plateau is lodged against the continental plate at the original docking line, Fault No. 1 develops to the west and begins carrying part of the plateau northward (*a*). In time Fault No. 1 becomes inactive and Fault No. 2 develops to the east of it (*b*), slicing through the area of the plateau that had been landlocked. Still later Fault No. 2 becomes inactive and is succeeded by Fault No. 3, which further slices the plateau, carrying fragments of it northward.

Sharpening light's pencil, to draw smaller chips.

Visible light is quite finite.

Its wavelength, while admittedly small, still has a specific minimum dimension of 0.4 micrometre. And that's too fat for tomorrow's electronics.

As the microelectronics industry continued its incredible shrinking act, it came ever closer to this very real barrier. In order to pack more and more functions into smaller and smaller chips, manufacturers must now be able to photographically expose and etch lines and spaces thinner than visible light.

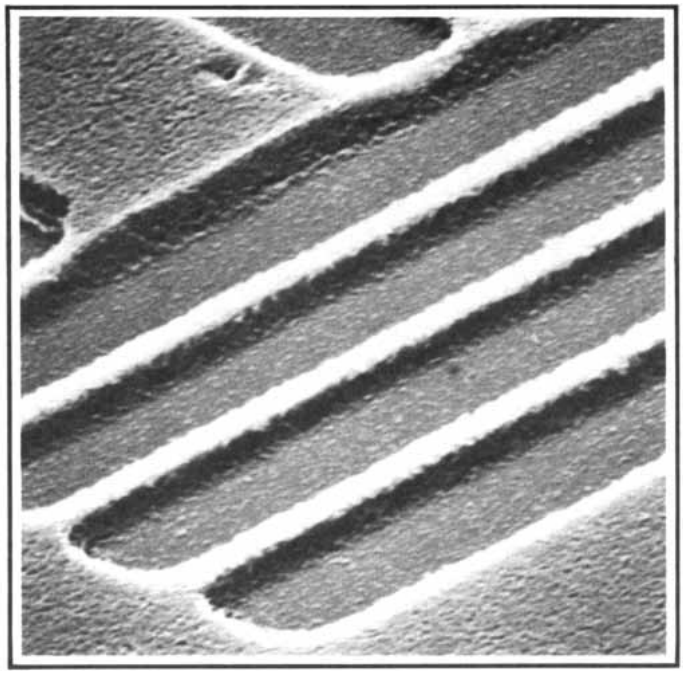
Kodak is ready. With a seeming contradiction.

We know how to "write" with a sharper pencil than visible light, using such short-wavelength sources as the electron beam and x-rays. But photo-resist compounds for use with e-beam/x-ray sources in the fabrication of VLSI devices (Very Large Scale Integrated Circuits) require properties that are, in theory, mutually exclusive. They demand both high radiation sensitivity and high-temperature, dry-etch resistance.

So much for theory.

Kodak research created a novel copolymer resist that provides high sensitivity, high thermal resistance, and submicron resolution. By structural manipulation of the polymer, it can be made to work equally well with either e-beams or soft x-rays.

This ability to further the technological advances (and spatial retreats) of the semiconductor industry stems from a blend of three factors that is unique to Kodak: 1. Kodak's ongoing efforts in applied research. 2. Our commitment of human and financial resources that permits us to meet such challenges, with no corners cut. 3. The peculiar depth of our experience as supplier to both the wafer-fabrication and masking ends of microelectronics.



SEM of IC traces produced with X-ray lithography, courtesy Perkin-Elmer. Lines measure 0.3μm.

To learn more about our contribution and commitment to the future of microelectronics, *please send for our brochure (B3-190), "...Resources to innovate, commitment to serve...."* Write: Eastman Kodak Company, Dept. SA-R-GB, 343 State Street, Rochester, NY 14650.

Kodak

Kodak. Where technology anticipates need.

SCIENCE AND THE CITIZEN

Arms in Orbit

A number of recent events suggest that military planners are taking increasing interest in outer space as a potential battlefield. Work is under way on antisatellite weapons and on hypothetical laser- and particle-beam weapons that would be placed in earth orbit. The first manned military mission in space was carried out earlier this year on board the space shuttle. The Jet Propulsion Laboratory of the California Institute of Technology, a pivotal institution in the scientific space program, has agreed for the first time to take on classified research; the new director of the laboratory, General Lew Allen, Jr., was formerly chief of staff of the Air Force. Meanwhile the Air Force itself has created an organizational niche for planners of space warfare: it has established a Space Command.

For at least two decades there have been military satellites for surveillance, communications and navigation. The systems now being designed and tested, however, are fundamentally different: they are actual weapons rather than adjuncts to terrestrial military operations. Their potential effectiveness has been seriously questioned; nevertheless, they raise the risk of extending the arms race to a new realm.

The impetus for the American space-weapons program is in part a Russian program with similar aims. The Department of Defense has stated that the U.S.S.R. can now maneuver a killer satellite to within about a kilometer of a target satellite and there explode a shrapnel-filled warhead. The Russians have tested killer satellites at least since 1968, although the results have been mixed. The antisatellite weapons can reach only those target satellites that are in a comparatively low orbit; thus certain weather and surveillance satellites might be vulnerable, but early-warning, navigational and communications satellites are not.

According to Kosta Tsipis of the Massachusetts Institute of Technology, the U.S. budget for fiscal year 1983 authorizes expenditures of more than $1.2 billion for the development of antisatellite weapons. One such device, called the miniature homing vehicle, is designed to be launched from an F-15 fighter aircraft and then boosted into space by a two-stage rocket, whereupon it is intended to intercept a low-orbit enemy satellite. The Air Force has designated $213.5 million in 1983 for the development of the vehicle; its first test was scheduled for last month.

Even if the miniature homing vehicle performs satisfactorily, it is by no means certain that the vehicle could provide a practical defense for U.S. satellites. D. L. Hafner of Boston College has noted that an effective defensive system would require a large number of widely dispersed and fast-reacting interceptors, constantly maintained in readiness at considerable expense. Furthermore, there are countermeasures available to the opposition, including decoys, backup satellites and defensive armament. Both sides might well conclude that the cost of protecting the delicate electronic circuitry needed to carry out passive satellite missions is too great. The stabilizing influence of the early-warning and surveillance satellites would then be lost and the prospects for arms control on the earth as well as in space would be dimmed.

The development of more exotic space weaponry such as laser- and particle-beam weapons has also been given continued support. Robert S. Cooper, director of the Defense Advanced Research Projects Agency (DARPA), argued before the House Armed Services Committee early this year that laser-weapons development should be shifted toward short-wavelength lasers and away from long-wavelength chemical lasers. In August a House-Senate conference committee approved funds nearly double those in fiscal year 1982 for short-wavelength laser weapons and restored funding for long-wavelength lasers, which the House had earlier eliminated. According to Tsipis, current funding requests for laser weapons, divided among the Army, Navy, Air Force and DARPA, amount to about $300 million for 1983, although it is unlikely the entire amount will actually be appropriated. Particle-beam weapons, a military application of the technology now employed to create new particles in accelerators, are beset by technical problems; about $32 million has been allocated next year to such weapons.

One reason the funds for laser satellite weapons will be decreased, Tsipis contends, is that Congress has recognized that the initial objective of the laser-weapons program is not technologically feasible. It had been proposed to station laser satellites in orbits from which Russian missiles could be destroyed as they were being launched. Atmospheric interference, however, would make such a system unworkable, even if the considerable problems of storing and generating enormous bursts of energy, aiming the weapon and verifying that the target had been hit could be overcome. The latter problems remain for other applications of laser weapons in space. Moreover, effective countermeasures against existing lasers are known, and it is likely they could be devised for future versions of the weapon.

The most effective countermeasure to laser satellites is also the most chilling form of space warfare, namely the detonation of a nuclear weapon in space. Such explosions are expressly prohibited by the 1963 Partial Test-Ban Treaty, but military analysts have nonetheless become anxious about the effects of nuclear explosions on satellite weapons systems.

Gamma rays and other forms of high-energy radiation from a nuclear explosion would expel electrons from the metal skin of a satellite and thereby generate an electric field inside the satellite; the potential could reach a million volts per meter. The electric field would disrupt or destroy the electronic circuitry of the satellite. The effects of a one-megaton explosion would extend throughout a spherical volume of space 50,000 kilometers in diameter. Any unprotected satellite in this range but not in the radiation shadow of the earth could be made useless by the explosion.

An Ill Wind

The contribution of cigarette smoking to diseases such as cancer of the lung and mouth, bronchitis and emphysema has been thoroughly documented since the mid-1960's. In response to the hazards of inhaling tobacco smoke the governments of many countries have adopted legislation intended to reduce smoking in their populations. The legislation has been enacted both in the economically advanced countries and in the developing ones; the most stringent legislation, however, has been passed in the developed countries of Europe and North America. According to a report by the World Health Organization (WHO), governmental action in the Third World has been far less decisive. As a result, in the developing countries advertising by cigarette manufacturers continues unabated, cigarettes containing substantial quantities of tar and nicotine are common and smoking retains the aura of glamour and sexual potency it is slowly losing in the more developed nations.

The WHO report was written by Ruth Roemer of the University of California at Los Angeles. She notes that laws prohibiting the sale of cigarettes to minors and proscribing smoking in theaters and certain other public places were enacted as early as the 1890's, although the primary intent of the latter regulations was fire prevention. The first legislation motivated by the effect of smoking on health was adopted in the 1960's, soon after reports by the U.S. Surgeon Gener-

How dare The Glenlivet be so expensive?

How dare we place such a premium on our 12-year-old Scotch? The same reason vintage wines and fine cognacs are so expensive. Superior taste. Just one sip and you'll know that The Glenlivet has a taste that's decidedly superior.

The Glenlivet is Scotland's first and finest single malt Scotch. Nothing but 100% Highland malt whisky, distilled from natural spring water and fine malt barley, aged in oaken casks, just as it always has been.

Only our time-honored methods can truly achieve The Glenlivet's unequaled taste. A taste that sets it apart. Its smoothness, body and bouquet are qualities found only in this unique Scotch.

Of course, you may elect to purchase a good Scotch that's less expensive. But for a truly superior taste, you have to pay the greater price.

The Glenlivet

12-year-old unblended Scotch.
About $20 the bottle.

al and others established without equivocation that there is a link between smoking and disease.

The early antismoking measures had relatively narrow aims, such as eliminating cigarette advertising on television and requiring that health warnings be printed on cigarette packages. According to Roemer, such statutes have only limited effectiveness. The U.S. has laws of both kinds; nevertheless, more than $400 million is spent each year in the U.S. on cigarette advertising. Moreover, several studies have shown that the printed health warning quickly loses its power to deter smoking. In an attempt to make the warnings more effective the government of Sweden has adopted 16 messages that describe specific medical consequences of smoking; some of the warnings are aimed at high-risk groups such as pregnant women. Cigarette importers and manufacturers in Sweden are required to use the 16 messages in turn, so that a smoker may get a different one with each pack of cigarettes.

In the mid-1970's the governments of some European countries introduced broader antismoking measures. The act adopted in Finland in 1976 is the most comprehensive. It was passed partly in reaction to the finding that the country's population had an extraordinarily high rate of death from diseases related to smoking. Under the act smoking is forbidden in all public places except where it is expressly allowed; in those places it is allowed only in designated areas. All advertising and promotion of cigarettes is banned, and the nicotine and tar content of cigarettes is strictly regulated. Of the funds collected in tobacco excise taxes .5 percent is applied to an educational campaign on the hazards of smoking. Health warnings are required on all cigarette packages. Sales of cigarettes to those under 16 are prohibited, and cigarette vending machines can be placed only where their operation can be supervised.

In part because of strenuous official action and in part because of a changing public attitude toward cigarette smoking, tobacco consumption decreased in the 1970's in the industrialized countries. In 1975 the average consumption of tobacco in the developed countries was 2.13 kilograms per person per year; by 1977 the consumption had decreased to 2.02 kilograms. In the developing countries, on the other hand, consumption increased from .79 kilogram to .81 kilogram in the same period; in Latin America the increase was from 1.04 kilograms to 1.18 kilograms.

Antismoking laws of some kind have now been enacted in 57 countries, about half of them in the Third World. In the developing countries, however, the legislation is much more limited in scope than it is in Europe. The largest cigarette manufacturers have been able to mount aggressive promotional campaigns in the developing countries without legal restraint. In Ghana, Kenya and Malaysia a tobacco company is either the largest or the second-largest advertiser. In Kenya, where Roemer reports that "smoking is considered a sign of sophistication and modernism," the market for tobacco products is growing at a rate of 8 percent per year.

Much of the tobacco consumed in the Third World comes from the U.S., which is the largest exporter of tobacco in the world. In 1976 two-thirds of American tobacco exports went to developing countries. The largest tobacco companies have substantial international distribution. For example, the R. J. Reynolds Tobacco Company sells 65 brands of cigarettes in 140 countries. Furthermore, exports to the developing countries are not subject to the standards of the home country, such as those regulating labeling or tar and nicotine content. Cigarettes shipped abroad are often considerably stronger than those for sale in their country of origin. According to Roemer, the tar yield of cigarettes sold in the Philippines is about twice that of the same brands sold in the U.S. and Britain.

The severity of the smoking problem in the developing countries is exacerbated by the fact that health care in those countries is generally inadequate. Roemer concludes that if action is not taken promptly to check the zeal of the cigarette manufacturers and to alter the public perception of smoking, the consumption of tobacco will spread rapidly in many Third World countries, "affecting their populations with the numerous smoking-related diseases before communicable diseases and malnutrition [have] been brought under control."

Polarized Fusion

The performance of an experimental thermonuclear fusion reactor is customarily described in terms of three physical quantities: the temperature, the density and the confinement time of the plasma, the hot gas of electrically charged particles in which the energy-releasing fusion reactions take place. It now seems that another attribute of the plasma may have a significant effect on the power output of at least one class of fusion reactors. Theorists at the Plasma Physics Laboratory of Princeton University, acting on a suggestion by Maurice Goldhaber of the Brookhaven National Laboratory, have investigated the idea of aligning the spin axes of the atomic nuclei with respect to the magnetic lines of force in a magnetically confined plasma. Their analysis indicates that such a polarized plasma would be surprisingly durable in the presence of various expected depolarizing processes. The new finding appears to open the way to the exploitation of several advantages of polarization.

Physicists have known for decades that fusion reactions depend in part on the spin angular momentum of the colliding nuclei. Indeed, the first theoretical study of the effect of nuclear spin on fusion was published by Goldhaber in 1934. Some nuclei are more likely to fuse if their spins are parallel, whereas in other cases the antiparallel or transverse arrangement is favored. Until recently, however, the possibility of polarizing the nuclear-spin axes in a bulk plasma was not seriously considered by most fusion-power workers, on the assumption that a polarized plasma (supposing one could be made) would become depolarized much too quickly in the extremely hot and electromagnetically complex environment of a fusion reactor to be of any practical value. Thus, for example, a 1963 proposal by Enrico Medi of the University of Rome to try the polarization approach was generally ignored.

Last winter Goldhaber raised the polarization question again in a cocktail-party conversation with Harold P. Furth, director of the Princeton fusion-research center. The inquiry led Furth and his colleagues Russell M. Kulsrud and Ernest J. Valeo to undertake the first detailed theoretical examination of the depolarization mechanisms likely to be encountered in a magnetically confined plasma. The study encompassed both toroidal magnetic-confinement devices, such as the large Tokamak Fusion Test Reactor, now nearing completion at the Princeton facility, and open-ended "mirror" machines, such as those currently under investigation at several other national fusion-research laboratories. To everyone's surprise the calculations showed that if a fusion reactor of either type were to be fueled with polarized nuclei, the plasma would remain highly polarized for about 100 seconds, much longer than the time needed for the fusion reactions to take place.

According to a report presented by Kulsrud at the biennial International Atomic Energy Agency conference on controlled fusion, held in Baltimore in September, "there are a number of practical advantages to be gained from the use of polarized plasma in a fusion reactor." One obvious advantage cited is the enhancement of fusion power. For a plasma composed of deuterium and tritium, the two heavy isotopes of hydrogen, it is estimated that the fusion reaction rate (and hence the power output) could be increased by 50 percent if the reacting nuclei were polarized parallel to the confining magnetic field. For a deuterium-deuterium plasma the picture is less clear, but it appears that the power enhancement might be even greater than 50 percent under certain conditions; one such approach calls for

80 years went into this Century.

1983 Buick Century.

That's how long Buick has been carrying on a love affair with the automobile. A devotion to bringing you comfortable, prestigious, quality cars. And that, of course, is exactly what Buicks have been down through the years.

Right down to today's state-of-the-art Buick Century. With its pleasing and efficient form. And its eminently luxurious passenger environment.

Among Century's impressive engineering credentials: front-wheel drive and a highly efficient 2.5 liter four-cylinder powerplant (see EPA mileage estimates below). Also available are V-6 gasoline and V-6 diesel engines.

EST. HWY.	EPA EST. MPG
39	24

The fact that 80 years went into this Century is surely reason enough to put yourself into one. You can do that at your Buick dealer's today. Oh, and before you turn the key, buckle up.

Use estimated MPG for comparison. Your mileage may differ depending on speed, distance, weather. Actual highway mileage lower. Some Buicks are equipped with engines produced by other GM divisions, subsidiaries, or affiliated companies worldwide. See your Buick dealer for details.

Official Car of the XXIIIrd Olympiad Los Angeles 1984

BUICK

Wouldn't you really rather have a Buick?

polarizing the reacting nuclei at right angles to the magnetic field.

The ability to reduce the rate of unwanted fusion reactions by unfavorably polarizing the reactor fuel might also be of practical importance, the report adds. If the nuclei of a fuel mixture consisting of deuterium and helium 3 were all polarized parallel to the magnetic field, the reaction rate for the fusion of deuterium with helium 3 would be enhanced (again by 50 percent), but the deuterium-deuterium reaction rate would actually be reduced. The main attraction of this scheme is in the nature of the energetic by-products of the two reactions: a neutron in the case of the deuterium-deuterium reaction and a proton in the case of the deuterium–helium-3 reaction. The polarization approach might therefore provide a shortcut to a "neutron-free" fusion reactor, thereby avoiding the problems of radioactivity and structural damage caused by neutron bombardment of the reactor walls. Moreover, because the proton carries an electric charge the energy released as a flux of protons could be converted directly into electric power; the energy of a neutron flux must pass through a much less efficient intermediate thermal stage.

Another advantage of the polarization approach is perhaps even more important from the point of view of the fusion-reactor designer. It arises from the fact that polarizing the reactor fuel would make it possible to control the angular distribution of the reaction products, simplifying not only the problem of confining the plasma but also that of capturing the output flux.

By a fortunate coincidence two new techniques for polarizing the nuclear spins of a bulk plasma, developed independently at Princeton and at the Massachusetts Institute of Technology, appear to be adaptable to the problem of fueling a fusion reactor with an adequate supply of polarized nuclei. The Princeton-based group concludes that the developments "could lead to fundamental improvements [in the] performance of nuclear fusion reactors."

Coat of Many Colors

The immune system of vertebrate animals combats infection by forming antibodies against a virtually unlimited range of potential antigens, or "nonself" molecules. An invading organism, such as a virus, a bacterium or a protozoan parasite, bears such molecules on its surface, and so the organism can be recognized and killed. It now seems that at least one parasite, the trypanosome, has evolved an ingenious way to evade destruction: it continually changes its display of antigens.

The remarkable diversity of antibodies is generated in the cells called *B* lymphocytes, where the genes encoding antibodies are shuffled and undergo mutation as the cells develop. As a result there are millions of lines of *B* lymphocytes, and the cells in each line are programmed to synthesize a different antibody, samples of which are displayed as receptors on the cells' outer membrane. When a *B* cell encounters the antigen for which it is specific, the cell proliferates and forms a clone of plasma cells; the latter cells in turn secrete millions of identical antibodies that do battle with the invader.

In the trypanosome the surface antigens are glycoproteins (protein-carbohydrate compounds). It is the protein component that triggers an immune response in the parasite's host, and in due course appropriate antibodies are secreted. Before all the parasites can be eliminated, however, some of them change their coat, that is, they display a different surface glycoprotein. Although the host can eventually make antibody to the new protein, the parasite population keeps one step ahead; the result is a serious chronic infection. Trypanosomes transmitted by the tsetse fly cause disease in human beings and in livestock in Africa; their antigenic variability makes the diseases particularly resistant to control by vaccination.

In the past several years some prog-

ress has been made in understanding the mechanisms whereby the trypanosome varies its antigenicity. It turns out that the trypanosome has more than 100 genes coding for the protein of the surface glycoprotein. Each gene has a "variable region" in which the sequence of nucleotides (the subunits of DNA) is slightly different; as a result the sequence of amino acids (the subunits of protein) specified by each gene is slightly different, and the protein's antigenicity varies accordingly. At any given time only one of these "basic copy" genes is expressed, or transcribed into RNA that is translated into protein. In most cases the mechanism by which a particular gene is selected for expression is apparently as follows. One of the basic-copy genes is duplicated. The duplicate (called an expression-linked copy, or *ELC*) is moved to a new chromosomal site, where it is adjacent to a promoter: a segment of DNA that stimulates the enzyme RNA polymerase to transcribe a gene into RNA. The *ELC* is thereupon transcribed and translated to yield a particular surface antigen.

In a typical population of parasites introduced into a host by the bite of a tsetse fly several *ELC*'s are expressed, so that there are several different surface glycoproteins. Eventually the host's immune system secretes the antibody appropriate to each antigen. Once in a while, however—in perhaps one parasite out of many millions in a generation—there is a switch of expression. A different basic-copy gene is duplicated and takes the place of the former *ELC,* which is eliminated. The new *ELC* directs the synthesis of a new surface protein. Enclosed in its new coat, the parasite proliferates to yield a new subpopulation that for a time cannot be dealt with by host antibodies.

The *ELC* mechanism is probably not the only method by which a succession of basic-copy genes can be activated. Phelix A. O. Majiwa and his colleagues at the International Laboratory for Research on Animal Diseases in Nairobi reported recently in *Nature* that several gene-shuffling mechanisms may be exploited by different surface-protein genes in closely related trypanosomes.

The antigenic diversity of trypanosomes has now been found to be multiplied by another and quite different mechanism: point mutation. John E. Donelson of the University of Iowa and his colleagues Allison C. Rice-Ficht and Kenneth K. Chen have compared the nucleotide sequence of an *ELC* with that of the corresponding basic-copy gene. Writing in *Nature,* they report finding a number of single-nucleotide differences, most of them in the variable region. In other words, not only are different basic-copy genes expressed at different times but also individual nucleotides in the gene are subject to mutation, so that the same basic-copy gene can give rise to many different *ELC*'s. Donelson suggests the mutations may represent errors made by the enzyme that duplicates a basic-copy gene to make an *ELC.* Sporadic point mutation, superimposed on variable gene expression, could conceivably enable the trypanosome to alter its antigenicity almost indefinitely.

Population III

What happened between the time when atoms became stable in the expanding, cooling universe and the time (perhaps a billion years later) when galaxies formed? Theoretical calculations suggest a surprising answer: giant stars condensed. Michael Rowan-Robinson of Queen Mary College in London notes that in the pregalactic universe a fluctuation in the distribution of matter whose mass was a million times the mass of the sun (but only a hundred-thousandth the mass of our galaxy) would have collapsed of its own gravitation in about a million years to form either supermassive black holes or extremely massive stars. Among the stars seen in galaxies today the young, bluish ones are said to make up Population I and the older, reddish ones Population II. The hypothetical pregalactic stars,

which presumably coalesced into galaxies, form Population III.

Rowan-Robinson and his colleagues point out that three fossils of the pregalactic stars might remain in the universe today. In the first place, it is presumed that a pregalactic star emitted a stellar wind and that the matter thereby freed from the stars must have contributed to a pregalactic medium of interstellar dust. The dust would have altered the spectrum of the electromagnetic radiation then pervading the universe. In particular the dust would have absorbed some of the radiation from the pregalactic stars and reemitted it at infrared wavelengths. The subsequent expansion of the universe, which includes an expansion in the wavelength of electromagnetic radiation, would by now have converted the infrared waves into microwave radiation. As it turns out, a "bump" in the spectrum of the background radiation has been reported at the predicted wavelength.

In the second place, it is presumed that thermonuclear fusion in the pregalactic stars reworked the mixture of atoms in the universe by fusing the nuclei of some primordial hydrogen atoms into the nuclei of more massive elements. On that presumption at least some of the helium thought to be primordial and some of the elements heavier than helium thought to have been made inside stars of Population II must be due instead to Population III. In the most extreme possibility that Rowan-Robinson and his colleagues have considered, the pregalactic stars make all the "primordial" helium in the universe and also account for all the background radiation in the universe today. The big bang is then a more tepid event than was thought. The stars of Population III could have emitted enough radiation to account for the background only if they were black holes millions of times more massive than the sun. The radiation would have been emitted by hot gas surrounding each black hole. In other models pregalactic stars make some of the heavy atoms and enhance the background radiation enough to create the spectral bump present today. Again, however, the pregalactic stars must have been supermassive black holes.

The third hypothetical fossil of the pregalactic stars consists of the stars themselves. It is hypothesized that a certain fraction of the mass of Population III survives as "dark matter" in the universe today. The dark matter is being sought as a result of studies showing that galaxies in clusters are moving faster with respect to one another than they would if visible stars constituted all their mass. The studies suggest the galaxies are moving under the gravitational influence of unseen mass in vast quantity. Physicists and astronomers have suggested many forms the mass might take; now supermassive black holes surviving from Population III can be considered a notable possibility.

How High Is the Sky?

Devotees of the harvest moon and the hunter's moon are acutely aware of an illusion best experienced when the full moon rises above the horizon at dusk: the moon appears to be from one and a third times to twice as large as it does when it is overhead a few hours later. Explanations of the moon illusion have ranged from the supposedly greater magnifying effect of the earth's atmosphere along a horizontal line of sight to the familiar perspective illusion, which makes a distant object seem larger than an identical object that is closer. Elaborating on the latter illusion, some psychologists have hypothesized that the sky is perceived as a flattened dome, nearer at the zenith than at the horizon, so that an observer is led to conclude that the moon near the horizon is farther away (and thus larger) than the moon overhead.

Pointing out that the flattened-dome hypothesis merely substitutes a sky illusion for the moon illusion without explaining either, two psychologists at Dartmouth College have reported their own experimental findings on observers' perception of the apparent distance from the earth to the sky. Writing in *Journal of Experimental Psychology,* John C. Baird and Mark Wagner give the results of an experiment in which 12 male and 12 female undergraduate volunteers were asked to estimate the height of the sky. Each volunteer was stationed on a clear, moonless night at a place on the campus offering an unobstructed view of the sky from the zenith to a point seven degrees above the true horizon, where a building stood some 300 yards away. A pointer directed the volunteer's attention to the sky at nine different angles. For half of the volunteers the first angle in the series was at the zenith; for the other half it was the horizon.

The volunteers, reminded that the distance to the sky is actually infinite in all directions, were told that the experiment concerned only perception of the apparent distance to the sky. Assigning an arbitrary value of 100 to the sky distance perceived in each volunteer's initial observation (either toward the zenith or toward the horizon), the experimenters asked the volunteer to report any perceived variations from that value at the other angles of observation. Each volunteer made the series of observations twice in a 20-minute period.

Of the 24 observations beginning with the apparent horizon, the conclusion in 18 cases was that the zenith sky is apparently more distant than the horizon sky. Of the 24 observations beginning with the zenith, the conclusion in 12 cases was that the zenith sky is apparently more distant, in 11 cases that it is less distant and in one case that both distances are the same. Baird and Wagner conclude that the results "disconfirm" the flattened-dome hypothesis. To the question "How high is the sky?" they suggest an appropriate retort would be "What a meaningless question!"

The Improvident Bee

The "Africanized bees" that for some 20 years have been advancing from South America toward North America have a reputation for being ferocious and therefore a danger to people who get near them. According to officials of the U.S. Department of Agriculture, however, the main reason for concern about the bees is that they pose a threat to agriculture. Compared with the European honeybee (*Apis mellifera*), which is now dominant in the U.S., the Africanized bees (*A. mellifera scutelata*) are considerably harder to manage and tend to produce less honey. The combination might cause many commercial beekeepers to go out of business. The pollination of many crops would then presumably be impaired, because much of it is furthered by beekeepers who transport their hives to the crop.

The Africanized bees originated in Brazil in 1957. Bees of an aggressive African strain had been brought there for experiments in breeding them with European bees in an effort to develop an improved strain. Some of the African bees escaped and interbred with the European bees in commercial hives and in the wild, giving rise to colonies of bees that are considerably more aggressive than *A. mellifera* and that tend to swarm more, that is, to set up more new colonies. Because of their frequent swarming the Africanized bees store less honey than European bees do. One reason for the difference in habits may be the origin of the ancestral African bees in the Tropics, where there is no need to store honey for the winter.

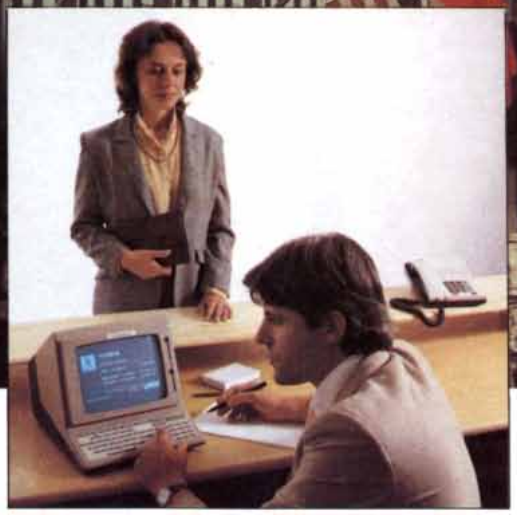
The bees have now reached Panama, and they may arrive in the southern U.S. by 1988. Some experts think their advance will stop at about the 34th parallel (the latitude of Columbia, S.C., and Los Angeles) because they will not be able to survive in places with fewer than 240 frost-free days per year. Even if the bees are stopped by such a climatic barrier, they could have a profound effect on U.S. agriculture because much of it is concentrated in the Southeast and California. Moreover, Thomas Rinderer of the Department of Agriculture's Bee Breeding and Stock Center Laboratory in Baton Rouge, La., points out that the inheritance of traits in bees is too poorly understood to support a prediction that the Africanized bees will not develop a capability to survive colder winters.

FRENCH TECHNOLOGY

PREPARING FOR THE 21 ST CENTURY

Advertisement

people to people with Telematique.



Today, more and more people are recognising the value of Telematique - the multi-product Program developed in France.

No other system offers simultaneously the rich diversity of Teletel Videotex, Electronic Directory and Smart Card yet retains complete compatibility. Low-cost terminals (Minitel), Teletel front-ends for existing "hosts", functionally designed "distributed gateways" and various software packages supporting all the popular index structures as well as electronic mail and other execution services, are available now.

Add to these Electronic Banking and Teleshopping facilities made secure with the Smart Card and the result is a versatile, cost-effective package available world-wide.

More detailed product information can be obtained from INTELMATIQUE - the promotional arm of the French Telecommunications Administration.

Intelmatique
FRANCE

THE ORGANIZATION FOR THE INTERNATIONAL PROMOTION OF TELEMATIQUE
98, rue de Sèvres 75007 PARIS. Tél. : (33) 1 306.16.36, Télex 203185 TELEMAT. F.

or call our representatives in U.S.A. : (203) 834.11.43; Australia : (61) 2. 27 21 81; New Zealand : (04) 844.870; West Germany : (49) 611.683271; Greece : (30) 1.9228.735.

FRENCH TECHNOLOGY
PREPARING FOR THE 21ST CENTURY

This special report analyzing the strengths and weaknesses of efforts by the French to upgrade their technology was compiled and written by Joel Stratte-McClure following visits to public and private research laboratories, universities, government ministries, financial institutions and industrial companies throughout France.

Document Alsthom-Atlantique

Renault

Aerospatiale

Contemporary French Technology—The French-designed and -manufactured high-speed train (TGV), which travels at a commercial speed of 260 kilometers per hour, Renault robots performing welding operations and an Aerospatiale Exocet missile launched from a French Navy vessel.

When France elected a Socialist government on May 10, 1981, its 54.2 million inhabitants embarked on an ambitious and controversial experiment. President François Mitterrand, ousting conservative forces that had run the Fifth Republic for 23 years, quickly introduced social reforms and simultaneously pledged to revitalize industry by updating production methods, introducing new technologies and dramatically augmenting research and development expenditures.

The Socialists felt a well-financed interventionist industrial policy with an emphasis on state-of-the-art technology would achieve a number of political, economic and social goals: increase investment and produce a national economic recovery, create employment and improve the labor force, inspire technological independence and promote innovative product development and boost transfers of technology and exports to other countries. Prime Minister Pierre Mauroy labeled 1982 the "year of investment," distributed social dividends to prompt consumption-led growth, boosted government spending on R&D by 29 percent and committed state expenditures to an expanded public industrial sector.

"Only a gigantic research effort will enable France to take its place among the rare nations capable of mastering their technology and maintaining independence," contended President Mitterrand, who also expressed concern "that technology not destroy jobs at a faster rate than it can create them."

The spirit of the laudable French effort was embodied by a national colloquium on science and technology last January, and a law pertaining to research and development passed in July. The French formed a Ministry of Research and Industry to oversee technological and industrial strategy and nationalized a number of financial and industrial groups. The government also formulated national mobilizing programs and sectoral plans to determine the major technical engagements for the future.

"The colloquium was the necessary brainstorming session to establish long-term goals, while the ministerial restructuring provides a coordinated approach to the innovation and industrialization of our technology," says presidential adviser Jacques Attali, noting that the Socialists will be in power at least until 1988. "The law pertaining to R&D makes France one of the few countries with a commitment to develop state-of-the-art technology."

Although the previous government had begun to increase R&D expenditures, the Socialist effort represents the first serious French attempt to return to prominence in technology since General de Gaulle boosted science spending from 1.15 percent of the gross national product (G.N.P.) in 1959 to 2.13 percent in 1966, increasing the number of researchers in the country from 9,000 to 21,000. During the 1970's funds allocated to public R&D decreased, largely because national efforts concentrated on industrialization, and by 1980 the percentage of the G.N.P. devoted to R&D had fallen to 1.8 percent. Although the Socialist approach is different from that of General de Gaulle, the concept of national technological independence—which has produced a technical, industrial and commercial infrastructure in aerospace, defense, nuclear energy, parapetroleum, telecommunications and transport—and control of the domestic marketplace are two recurring themes.

"The 1958 programs moved France from an agricultural to an industrial society and were tied largely to defense, while today there is a much more coordinated approach," says Claude Fréjacques, president of the National Center of Scientific Research (CNRS). "More sectors will benefit because of the intended cross-fertilization between laboratories, universities and different industrial sectors."

The most tangible aspect of the government's effort is a law similar to one traditionally employed by the Ministry of Defense to protect management of the military budget. Effective from 1982–85, it fixes a 17.8 percent annual increase in the government civil R&D budget with the objective of government R&D spending attaining 2.5 percent of the G.N.P. by 1985. It calls for an annual budget increase of 13 percent in fundamental research and requires that public and private companies increase their R&D expenditures by 10 percent and 6 percent respectively. Funds will be allocated to specific mobilizing programs, fundamental research, final research and programs to develop and commercialize technology. The law stipulates that the number of researchers will be increased by 4.5 percent a year and supports continued efforts in nuclear, space, aeronautics and oceanography development programs. State-controlled research organizations will have four tasks: ensure that research is pursued in every domain, commercialize results, disseminate scientific knowledge and train personnel "through research."

The current mobilizing programs, which involve combined efforts in the public and private sectors, include electronics, biotechnology, the rational utilization and diversification of energy, scientific research and technological development in less-

At the time of writing 1 US dollar equals approximately 7 French francs.

developed countries, research pertaining to employment and working conditions, promotion of French culture and French as a scientific language and industrial development.

"The current program is very commendable if the financial aspirations can be maintained," says Pierre Aigrain, former Minister of Research and Technology and now scientific adviser to the president of the Thomson Group, France's largest electronics company. "But will industry actually be able to obtain adequate funds for research and development? Can the educational system respond to increased demand for researchers? Will there be enough researchers for industry or will they all pursue public research? Will the mobilizing programs be commercially realistic? Will maintaining employment be more important than the profit motive?"

It is too early to answer these questions, but scientists, businessmen and politicians throughout France are asking them.

"The French have always had the analytical capabilities required for long-term planning," explains Bernard de Passemar, senior vice-president for development and marketing technology at Vallourec, France's leading steel tube manufacturer. "But we must see whether the government is as capable a manager as a planner."

"Much of the future of France will depend on whether the government is realistic," adds Jean Babaud, vice-president of Schlumberger's measurement, control and components division.

To support its blanket approach to technology, the government has created integrated product areas—known as *filières*—to cover vertical chains of production from raw materials to finished products in sectors including energy, biotechnology and electronics. The government will attempt to coordinate the overall technical direction of the *filières* by inspiring joint research activities linking industry with large research organizations and universities. There will be an attempt to avoid duplication and concentrate on technological advances and development of products that can be commercially successful in domestic and foreign markets.

The *filières* are all-encompassing and extremely ambitious in breadth. The electronics *filière,* requiring global expenditures of 140,000 million francs between 1982 and 1986, will integrate communications, data processing, microelectronics, medical electronics, telematics, and other areas. The energy *filière* theoretically includes every laboratory and company interested in reducing energy costs or exploring alternative energy techniques. The biotechnology *filière,* which involves a 2,500 million franc investment by the government and industry in 1982-83, cross-fertilizes sectors including chemistry, energy, agriculture, biotechnology, pharmaceuticals and medicine, as discussed in this assessment:

Throughout this report French public research organizations are identified by their acronyms. The following chart provides an explanation:

ADI Agence de l'Informatique
(The Data Processing Agency)
Collaborates with research laboratories, users and industry to determine new data processing applications, processes and systems.

AFME Agence Française pour la Maîtrise de l'Energie
(The French Agency for the Management of Energy)
Coordinates and provides technical direction for energy conservation and new energy applications.

ANVAR Agence Nationale de Valorisation de la Recherche
(The National Agency to Valorize Research)
Finances research and its commercialization.

CNES Centre National d'Etudes Spatiales
(The National Center of Space Studies)
Created in 1961, the French space agency has 700 researchers

CNET Centre National d'Etudes des Télécommunications
(The French National Telecommunications Research Center)
Founded in 1944, the CNET conducts research, exploratory development and technical assistance in telecommunications.

CNEXO Centre National d'Exploitation des Océans
(The National Center for Ocean Exploitation)
Created in 1967, CNEXO coordinates French oceanography activities.

CNRS Centre National de la Recherche Scientifique
(The National Center of Scientific Research)
Created in 1939, France's largest fundamental research organization also includes the National Institute for Astronomy and Geophysics and the National Institute for Nuclear and Particle Physics.

CEA Commissariat a l'Energie Atomique
(The Atomic Energy Commission)
Created in 1945, the CEA is geared toward research in atomic energy for science, industry and defense.

GERDAT Groupement d'Etudes et de Recherches pour la Développement de l'Agronomie Tropicale
(The Study and Research Group for the Development of Tropical Agronomy)
Created in 1970, the GERDAT coordinates activities for agricultural research in forty tropical and subtropical countries.

INRA Institut National de la Recherche Agronomique
(The National Institute for Agronomic Research)
Created in 1946, INRA conducts agricultural research in areas such as soil management, crop and animal production and new farming methods.

INRIA Institut National de la Recherche en Informatique et en Automatique
(The National Institute for Computer Sciences and Automation Research)
Restructured in 1980, INRIA executes research in data processing and automation.

INSERM Institute National de la Santé et de la Recherche Médicale
(The National Institute of Health and Medical Research)
Created in 1964, INSERM conducts biomedical research and is concerned with advances in the area of public health

ORSTOM Office de la Recherche Scientifique et Technique Outre-Mer
(Overseas Scientific and Technical Research Agency)
Created in 1943, ORSTOM coordinates research and training in France's overseas territories.

THE FUTURE OF BIOTECHNOLOGY IN FRANCE

by Joël de Rosnay
Director of Research Applications
at the Institut Pasteur

The basis of the French biotechnology program is a report submitted to the government by Professor Pierre Douzou's biotechnology mission, which was prepared by 23 professionals from academia, private industry and government agencies. Its conclusion: France should attain a 10 percent share of world markets for biotechnology products by 1990.

Why this significant program? Traditionally French training has been oriented toward fundamental research in the hard sciences and mechanical and electronic engineering. Life sciences were largely forgotten and biology was considered a subdiscipline of medicine.

A study pertaining to biology and its future developments was requested in 1979, and three well-known scientists—François Gros, François Jacob and Pierre Royer—prepared an assessment. Entitled "Sciences de la Vie et Société" with an annex "Biotechnologies et Bio-Industries" by myself, this study led to the creation of four biotechnology centers. Enzyme research would be conducted at the University of Compiègne, genetic engineering at the Institut Pasteur, fermentation at the University of Toulouse and soil microbiology at the Institut National Agronomique laboratories. A second report in 1981 provided the framework for structures to promote the development of the field and proposed the creation of a flexible body to catalyze and coordinate new biotechnology projects.

The current program provides special support to seven disciplines that can be commercially exploited, including genetic engineering, microbiology, enzymology and immunology. The plan involves fundamental research by most public research organizations and the creation of groups to coordinate the relation between research institutions and industrial companies. For example, France will set up special R&D firms to protect itself against the cost of importing most of the kits, vaccines and bioreactants used in clinical diagnosis and immunization.

But it is the lack of qualified scientists and technicians—as well as a lack of coordination and follow-through among universities, research organizations and the public and private sectors—that could slow down French R&D efforts in biotechnology.

How will France solve these problems? The quality of research in molecular biology is high, but France is weak in bioengineering, the kinetics of growth and pro-

duction, the techniques of culture of microorganisms and cells, in enzymology, in reactor design, in extraction and purification and in analytical control and equipment. In addition, the budding biotechnology establishment involves an intricate network of governmental bodies, nationalized industries, private enterprise, educational institutions and special purpose subsidiaries.

In order to understand how this area can be developed in a country suffering from excessive compartmentalization and specialization of disciplines, biotechnology must be regarded not as a scientific or technical discipline but as a technological system in the making. This system is composed of advanced technologies (like genetic engineering or cloning techniques), traditional processes (e.g., fermentation), equipment (e.g., cell sorters), apparatus, instrumentation and kits for bioassays. Because of its complex nature, massive financing in one or two given areas will not necessarily solve problems requiring an intricate mode of action.

To develop the "system" as a whole requires a catalytical mode of action based on a policy mix. There must be a choice to finance small projects as well as large interdisciplinary programs, training programs and industrial developments. Where traditional techniques exist, such as in fermentation or process control, they should be employed. At the same time, proper logistics should be provided in areas where France is lagging behind: fermenters, biodigesters and purification and analytical equipment.

Incentives should come from industry and not always through government-financed programs. There could be a better coordination between universities and nationalized industries, but these heavy structures might inhibit new high-risk projects. The scientific entrepreneur is seldom encountered in France and scientists prefer to be advisers or consultants. It is probably through such consulting/engineering agreements that new biotechnology projects will evolve in France.

There is also a tendency, in a country that relies on Cartesian logic, to approach technological systems in a unidirectional way and look for narrow market niches to obtain a quick investment return. Looking for short-term profits in biotechnology might sterilize the entire field, and a massive flow of government money could create an "industrial addiction" to this type of financing. Any timing error might damage the development of biotechnology in France.

Consequently, the French hope to approach biotechnology as a "body of knowledge"—a *filière*—which has a time dimension and cuts vertically across several disciplines. This is quite the opposite of a market niche, which has a space dimension and probably led France to miss the microelectronics revolution.

Biotechnology is a highly interdisciplinary field because biology involves many subdisciplines. The key to the future is hybridization between fields, long-term markets, catalytical action, flexible coordination and proper training. A new area in biotechnology is resulting from the hybridization of data processing, electronic control engineering, semiconductor technology and molecular biology. This new field, which I call "biotics," involves the application of large computer data banks to molecular biology and genetics and the production of machines to write the code of life. The financing and development of this field will be a test of how France can cope with advances in biotechnology. Cartesian logic has its merit, but so has the Anglo-Saxon system approach involving trial and error and risk taking. A French *filière* must attempt to combine the two.

Technology and marketing studies, similar to those in biotechnology, have been made in robotics, mechanics, materials, fine chemistry, scientific instrumentation, medication, engineering, wood, transport, machine tools, chemicals, housing and other areas to determine specific technical and industrial directions. The government has made it clear that, unlike the Japanese, they will not abandon any sectors. This expensive decision was made primarily to protect jobs.

"There are no condemned sectors," Prime Minister Mauroy has said. "There is simply underinvestment, technologies to be modernized, products to be improved and equipment to update."

Steel, chemicals, textiles and other depressed areas are not being neglected or made redundant by the government. For example, the government decided to continue making heavy investments in steel over the next four years to increase production capacity and create an internationally competitive industry. Promises have been made to numerous sectors, such as shipbuilding, that no jobs will be lost. Unfortunately, these guarantees to outmoded industries draw scarce capital away from emerging sectors and the French, by avoiding a stern selection process, may produce a handful of exceptional industries stymied by a number of inefficient ones.

Many critics of the French program do not believe there is enough financing to go around. The attempt to reinflate the economy—which raised salaries, reduced the work week by an hour, induced early retirement, increased rent subsidies and unemployment insurance and extended vacations with pay from four to five weeks a year—was a very costly failure. The government was forced to reverse its stimulative policies and, in the wake of its second devaluation, introduce wage and price controls. Today industrial production is stagnant; investment in 1982 dropped 6 percent, unemployment and trade deficits have increased and expenditure in R&D and new technology will be competing with other priorities as the government attempts to limit the budget deficit to 3 percent of the G.N.P. There is justified skepticism that financing will be found for all of the mobilizing programs, sectoral plans and *filières*.

INNOVATION THROUGH NATIONALIZATION?

In addition to the social expenditures the government has financed a costly nationalization program. The French nationalized the banks and increased state ownership of credit-granting institutions from 70 percent to 85 percent. They took control of nine industrial groups, which employ 750,000 persons—Compagnie Générale d'Électricité (CGE), Pechiney Ugine Kuhlman (PUK), Saint-Gobain, Thomson, Rhone-Poulenc, Matra, Avions Marcel Dassault-Breguet Aviation and the steel companies Usinor and Sacilor—and three foreign-controlled groups (ITT-France, Cii Honeywell Bull and Roussel Uclaf). The purpose was to theoretically steer the country to investment-led growth, promote job creation and spark an economic recovery. The government also controls previously nationalized companies, including automaker Renault, oil company Elf Aquitaine, aircraft manufacturer Aerospatiale, Air France, the tobacco monopoly, the railways (SNCF), Paris transport, the electricity monopoly Électricité de France (EDF) and others. 32 percent of all industry in France is now under state control, including 60 percent of the market in electronics and information processing, 54 percent in basic chemicals, 75 percent in armament, 75 percent in synthetic fibers and 80 percent in iron and steel.

Previous French governments tended to control industry covertly, but the latest nationalization empowers the Socialists to direct the economy openly, create employment, modernize industry through the control of capital and technology and provide state-owned companies with long-term provisions for research. Nationalized companies are expected to devote more funds to R&D than private industry does—they are to be the strike force, the technological commandos, to rebuild France and stimulate the economy—and take a longer-term view than the business manager of a private concern. Theoretically, industrial decisions will not be based on political strategy but determined by realistic market conditions.

If you like the biggest and the

Alsthom-Atlantique's track record. Our T.G.V. set a world record rail speed of 380 km/h in February 1981. We built four supertankers of 550,000 deadweight tons each, "the largest in the world". We built the world's first 800 kV metalclad substation. We build the most comprehensive nuclear turbine manufacturing program. In 1981 our total sales reached $ 2,500 million.

From Africa's tropics to the icy shores of James Bay, Canada, Alsthom-Atlantique's 42,000 people and 40 industrial units are busy today installing machines and developing techniques around the world that keep France in its leading role going into the 21st century.

ALSTHOM ATLANTIQUE

Alsthom-Atlantique is a subsidiary of Compagnie Générale d'Electricité.

best, we'll get along very well.

CIT-Alcatel. The pace-setter in telecommunications. The E10 is now the world's best-selling digital telephone exchange. Nine million lines are in service, or on order, in 28 countries. We are proud to be the world leader in digital technology, including an optical fiber communications system now in operation in the heart of Manhattan.

In Europe, the Alcatel Group is the leader in electronic mail systems and is ranked amongst the top companies for business telecommunications, automated office equipment, computer-related peripherals, highspeed telecopiers. CIT-Alcatel, the people who started digital switching are, today, at work on the communication networks of the 21st century.

CIT Alcatel

CIT-Alcatel is a subsidiary of Compagnie Générale d'Electricité.

"The decision-making autonomy of nationalized groups will be complete," President Mitterrand has said on numerous occasions, "and they will contribute to our economy by creating employment, augmenting investment, and increasing research facilities while providing France with an international stature."

"There has never been economic progress in France without a dynamic public sector," explains Jacques Delors, the Minister of Finance. Adds a government official, "The French state has been the researcher's best friend since Colbert founded the Academy of Sciences in 1666. The state has directed the economy, performed entrepreneurial functions and been industry's patron."

The Socialists point to past efforts—such as in telecommunications—when the government has provided well-planned and quickly-implemented national programs, nationwide product specifications and innovative products—as well as the infusion of capital and protection for domestic manufacturers.

"There is a relationship between the state and industry in France that doesn't exist anywhere else," says Jacques Stern, head of computer manufacturer Cii Honeywell Bull.

The industrial reaction to the nationalization program is varied. While nationalized companies are forced to accept their new majority shareholder, there are positive and negative sentiments:

"What's important are sales and I do not think that nationalization can help sales," says Charles Guinard, director of marketing at newly-nationalized PUK's aluminum branch. Adds Bernard Delapalme, director of research, development and innovation at Elf, "Companies, public or private, must continue to take the technological initiative because nationalization is not a panacea."

"Renault pioneered R&D after the war in the area of front wheel drive, ergonomics and accidentology," says Renault deputy director Pierre Tiberghien. "Many of our developments were due to the fact that we played a social as well as economic role because we were nationalized." Adds Bruno Revellin-Falcoz, technical director general at Dassault, "The idea of having a continual long-term policy of national independence in defense equipment obviously pleases us and as a nationalized company we hope to play an important role."

The government considers private small- and medium-sized companies extremely important. They are expected to benefit from nationalization because investment plans will create orders for suppliers. Nationalized industries are also expected to give smaller companies access to their specialized services, including overseas sales networks, while nationalized banks are urged to finance start-up companies and provide loans to private firms. The government also hopes to stimulate creation of new companies, increase aid to fund research in the private sector and bring new technical developments into production. But rising social costs have already reduced the R&D expenditures in the private sector and have forced many industrialists to think short-term to survive. Many companies have submitted plans to the government regarding new research approaches and expanded facilities but complain they have not received responses or financial assistance. As the private sector awaits the industrial and commercial benefits resulting from nationalization, there is a mixed reaction to the government effort:

"If nationalization leads to increased productivity we will benefit as a private company," says Philippe Gazeau, president of components company Sfernice. Adds Marcel Leroy, president of connector manufacturer Souriau, "We hope the government can now provide us with financing for new projects on a par with the amount our international competitors receive from their governments." But "I cannot increase my R&D budget by 6 percent unless the government provides funds or financial incentives," explains Michel Kennel, technical director of rubber product manufacturer Hutchinson, "and they haven't done that yet."

"The government has a lot of ideas, but a severe selection process is required based on marketplace reality," says Alain Monié, commercial director at Sogitec, which designs computer software and systems. "I fear they will favor large nationalized groups and not young entrepreneurs because they can't afford to finance competition."

"We'll see whether the government's orders tend to favor nationalized firms," says Michel Coiron, technical director at telecommunications company TRT.

"The government's ambitions concerning R&D will necessarily imply substantial human and financial resources, but the crucial question is whether financing is available," contends Michel Staib, director of strategy at Schneider, France's largest private company. "In view of the financial situation, strategic choices must be made coordinating private companies, nationalized firms and the different research organizations."

"We operate in a specialized technical area and to date the government has concentrated primarily on nationalized companies and the *filières*," concludes Jean Massoubre, research and development coordinator of tiremaker Michelin. "We do not exclude participation, but we can't wait for any help or encouragement from government."

CHANGING THE RESEARCHER'S ATTITUDE

As intriguing as the debate on nationalization are efforts by the government to alter French consciousness regarding technology, the importance of applied research and the necessity of a healthy industrial and commercial sector. France's Socialists were brought into power by discontented voters not particularly impressed by technocratic planning and management, high technology and international competition. The Socialists are trying to dignify these capitalist tendencies by introducing a humanist, decentralized, voluntarist and democratic process to the scientific field. French researchers have traditionally scorned industry's profit motive and rarely concentrated on applied results of their work. But the government contends that a Socialist approach will alter this tendency and encourage more transfer of technology between public laboratories and industry.

"The colloquium gave science an honorable name again," explains Bernard Descomps, director of research in the Ministry of Education. "There is a sense that universities, which often shunned national economic efforts, are now ready to participate."

"Researchers want to have a social and economic function but the capitalist persuasion of previous governments prohibited them from doing so," Descomps adds. "With added responsibility in the decision-making process, they can perform an important role in the production process." But, says Paul Peraud, of Alsthom-Atlantique, "Getting stubborn French scientists to respect industry, even with a Socialist government, will not be easy."

The decentralization and democratization of decision-making in a traditionally centralized country ideally permits local autonomy. It involves more collective bargaining in companies and factories and better dialogue with national planners in Paris. These efforts theoretically make crucial economic decisions—investment, organization of production, regional economic directions—subject to a democratic process with the researchers and factory workers assuming a more meaningful role in the economic structure.

"Good ideas need collective discussion," says one government official.

"Centralization has been a fundamental obstacle to development in France," contends Jacques Delors, French Minister of Finance. "Decentralization will put the responsibility, capacity and initiative at the local level," says Minister of Planning Michel Rocard.

But again there are contrary views.

"Too much discussion and an anti-elitist attitude toward science is ludicrous," says

FRENCH TECHNOLOGY:
CREATING AN ELECTRONIC COUNTRY

The computerization of any society is a complex technical and sociological undertaking that ultimately involves every facet of the data processing industry as computer usage rapidly penetrates an increasing number of economic sectors. The French are attempting to efficiently introduce the widespread use of computers through the efforts of a unique public nonregulatory organization. The Agence de l'Informatique, established in 1980 with a 1982 budget of 350 million francs, is a multidisciplinary group of professionals in contact with consumers and manufacturers to promote the orderly growth of computer and communications technologies. Charlie Garrigues, who became president of the Agence in July, discusses its activities.

Question: What role does the government play in the computerization of France?
Answer: Data processing products and services have traditionally been imposed on users by manufacturers, with only large clients having any significant influence over product and system designs and capabilities. As the market developed it became apparent that mass distribution and market forces alone would not bring to the smaller user all the benefits that data processing has to offer.

As a French government agency we take the user's perspective and assume a technological, conceptual and cultural role in accelerating the introduction of information processing while managing the social impact—without affecting actual market forces. We do not promote products, compete with service companies or set industrial policy. Instead we encourage the efficient use of computer and communications technology by determining the requirements of small businesses, manufacturers, farmers, students, community clubs, training organizations and other groups through a cost-effective collective approach. We help different professions communicate with each other and provide methodological guidance and financial support for user specification and development. Naturally we maintain close contact with hardware, software and service manufacturers to monitor developing technologies.

The computerization of France has not proceeded as quickly as in the United States or Japan because the average businessman is traditionally more cautious than his American counterpart and does not necessarily have the same technical background as his homolog in Japan. But today business and other sectors, such as agriculture and medicine, are increasingly open to new ideas and there is no psychological opposition to computerization. Traditionally the French prefer tailored systems—they are not overly fond of time sharing, for instance—rather than buying off the shelf. We encourage these users first to define their software requirements, in cooperation with others with similar interests, before selecting a particular hardware. The use of software packages is also encouraged if they satisfy the functional requirements or can be used as building blocks for the development of a tailor-made system. The two approaches are complementary. There's no question that computerization is international and that French advances are part of that trend. The purchases of computers in France grew 23% last year, computer shops are flourishing and French equipment is internationally competitive.

The problems we face in the future are similar to those in other countries. How do we best utilize human resources to introduce computers, obtain the maximum benefits from new technology and overcome social inertia?

Question: What are you doing to achieve the computerization of France?
Answer: Our budget is devoted primarily to application development and dissemination, training, research and experimentation. But we are a window on the full spectrum of activities in the data processing arena. For example, we conduct economic, social and legal studies to measure the impact of computerization, predict social consequences and anticipate legal implications. Our teams, representing government and industry, are currently in contact with 600 organized sets of users and provide financial and logistical support to make computerization a reality at all levels. It is important to develop education and computer literacy in schools and communities. To accomplish this we work in conjunction with various government ministries and public organizations. The Ministry of Education, as a result of our joint programs, has produced a supplementary annual flow of 600 engineers and introduced data processing and computer education into numerous schools for teacher training and computer-aided instruction.

Much of our future will involve the cross-fertilization of disciplines and the expanding introduction of computers in every industrial sector. The integration of mechanics, robotics and electronics, creating a new discipline we call *productique*, will result in computers, microprocessors and integrated circuits playing a greater role in the design, production and operation of machinery. We are closely monitoring these crossroads and work in conjunction with individuals and companies to integrate their activities with advances in robotics, industrial computers, systems engineering, and computer aided design and manufacturing systems. We are helping prepare the country for new industries and job categories that will result from *productique* activity.

We also feel it is important to transfer our knowhow to developing countries, and we keep abreast of technological advances in other industrial nations. We have just published an intriguing study of computerization in Japan. There must be increased exchanges between countries because the impact of computers is international—it is a world market—and there is no room for isolationism.

Question: What are some notable French projects that might have applications in other countries?
Answer: Although we don't conduct research ourselves, we orient and finance it to create new tools, services or applications. We have fundamental and applied research activities with both public and private laboratories. Our pilot projects, each four to five years in duration, are geared toward transferring knowhow from research to industry as defined by user requirements. Our current pilot projects include activity in office automation (Kayak), software portability (Sol), distributed processing (Sirius), heterogeneous networks (Rhin) and use of satellites for data processing applications (Nadir). Our long-term research includes new computer architecture, languages and programming, man/machine interface, design aids, automation and robotics, security, computer assisted training, translation, and the use of flexible work shops.

French strengths have traditionally been in software—ADA and Prolog are French-developed computer languages—and we have sixty ongoing software projects. It's encouraging that today there are an increasing number of mathematicians entering the software field and applying highly theoretical concepts to the data processing discipline, especially in the area of artificial intelligence and creative computers. Large and small French companies are progressing in hardware innovation and developing their own range of mini- and personal computers for the domestic and international markets. The French *télématique* program, a tremendous educational experience for France, will spread the use of terminals and increase public interest in computers during the next decade. It will not be long before we have a computerized nation, an electronic country.

Professor Michel Jouvet, chairman of the department of experimental medicine at Claude Bernard University in Lyon and a specialist in the mechanics of sleep and dreams. "I'm disturbed by the fact that decision-making will be done by a group. Unions cannot control innovation."

Adds the director of a laboratory in Paris, "The result will be more bureaucratic controls, more reflection and less action, more union demands for increased social benefits and an inability by anybody to make a decision."

The government is also attempting to introduce a voluntarist attitude.

"We are not changing our technical thrust into digital telecommunication," says Jacques Dondoux, the Director General of Telecommunications, "but we are Socialists and our approach is to show more respect for users, take into account their needs, and discuss the future with them. The rule for development must be freedom of choice and voluntary participation."

The government's mobilizing programs also call for a new approach to less-developed countries. Socialist principles will be applied in formulating a code of conduct requiring nationalized companies and government research laboratories to form technical and scientific agreements "that take into account the requirements of the developing country."

The government will also attempt to promote the use of French as a scientific language. They are already known for creating their own terminology, especially in the electronics industry. The word for data processing, *informatique,* was coined in the 1960's and accepted by the French Academy. Since then the French have spawned a mini-dictionary of their own. *Bureautique, productique, robotique,* and *télématique* are some examples. "We have a culture that we must protect by expanding our scientific language," said a government spokesman. In the future, French scientists will be asked to publish in French and the government will finance new scientific publications.

THE FRENCH

The French are an aesthetic race and, whatever the government, tend to look at the world through a largely literary tradition. Their extreme logic and Cartesian approach has led to numerous innovations in pure mathematics and theoretical sciences but has hindered cross-fertilization, mobility and risk taking. They are as analytical as the Japanese are practical and have the logical sustained thought process required for creativity but less of the dynamism required for successful product development and marketing. In the past this produced a penchant for high tech grandeur, embodied by the technically successful but commercially disastrous Concorde, and a profusion of talents in arts, fashion and gastronomy. But French companies have a conservative attitude toward investment in plant and equipment and are restrained by high social, health and welfare costs. Efforts to increase research will be worth little if products are not brought to the marketplace. The government is attempting to alter attitudes and fiscal regulations to permit more risk taking.

The government has boosted the role of public organizations and is putting a great emphasis on converting research into tangible products. For example, ANVAR finances R&D projects with commercial applications in electronics, biotechnology, energy, food and agricultural industries, optics, plastics, fish breeding, metallurgy, energy, pollution fighting, measurement control, medicine and other areas.

"Our Latin character turns us more toward ideas than practicality," says François Juillet, who represents the Rhône-Alpes region at numerous national conferences. "But we must commercialize our innovation if the government efforts in R&D are to succeed."

"People do not company hop or take chances in France," says Claude Jablon, advanced technology planning director at missile and electronics manufacturer Matra. "Mobility and cross-fertilization, which are necessary for a dynamic industry, are rare, and a government law won't change this ingrained mentality."

"Failure is not acceptable in France, and you rarely get a second chance," says Vallourec's de Passemar. "The objective of French youth is still to be a government civil servant with job protection, security and retirement."

France has high-quality civil servants and a patriotic bureaucracy drafted from elite schools. There is pride, power and self-interest in serving with the government—much more than in other countries—and many engineering graduates choose to go into government service rather than research or industry. The government hopes to increase science graduates by 50 percent to 55,000 per year, but what is required is an overhaul in education that will make it less abstract.

"The resistance to pursuing a career in science begins at a young age in France," says Guy Aubert, director of the Service National des Champs Intenses in Grenoble. "To rectify this requires changing the instructors at the lowest level and dignifying the role of both fundamental and applied research."

"While the *grandes écoles* in France are oriented to applied research, the universities have had little contact with reality," says Auguste Moiroux, director of the École Centrale de Lyon.

THE REVERSE BRAIN DRAIN

While French researchers are waiting to see whether their budgets will be increased, government efforts have already created a noticeable influx of foreign scientists. The new World Center for Computer Sciences and Human Resources is directed by Nicholas Negroponte, a professor on two-year leave from the Massachusetts Institute of Technology, with a number of participants from American institutions, including Seymour Papert of M.I.T., Alan Kay of Atari Inc. and D. Raj Reddy of Carnegie-Mellon University. In fact, the Center stirred charges that the French were buying American scientific talent in a "reverse brain drain" and one United States senator said the Center was a "stalking horse for the French electronics industry." Foreign scientists have recently been employed at other companies, particularly in the area of biotechnology, and there are numerous foreign researchers at the CNRS and other organizations.

"While the French computer industry has its weak points," says Negroponte, "there's no question that the French are making a much greater innovative effort than other countries in this field." Adds the Center's president, author Jean-Jacques Servan-Schreiber, "The people here today will encourage France's risk takers of tomorrow and are participating in the dramatic social and psychological change in the attitude towards science in this country."

Although the French government is not conducting a scientific headhunt, it does not discourage foreign scientists from coming to France.

"We are not actively looking for foreign scientists, but the fact that they are coming indicates the exciting atmosphere in our laboratories and a confidence in our programs," says Attali.

EXPORTING FRENCH TECHNOLOGY

French technology, of course, predates the Socialists, and France is challenging Japan as the number three exporter after the United States and West Germany. Because the French market is comparatively small, French industrialists have literally been forced into world competition. Ten French companies are in the top 50 on the Fortune 500 list of the largest industrial corporations outside the United States—Compagnie Française des Pétroles (Total), Renault, Elf Aquitaine, Peugeot, CGE, Saint-Gobain, PUK, Thomson, Michelin and Schneider—and the French have established international reputations and product specifications in numerous areas—armament, telecommunications networks, subway systems, parapetroleum

products, power equipment, heavy electrical and industrial installations.

Foreign companies have been watching the situation in France, and investment is continuing because of attractive incentives for new types of industry in crisis-stricken regions. High-technology firms and corporations planning employment-producing ventures are particularly welcome. Today there are 1,900 foreign companies representing 13.5 percent of industrial activity and last year 60 firms invested in France. Foreign direct investment in 1982 will be over 10,000 million francs led by companies from the United States, West Germany, Britain and Switzerland.

France naturally has things to offer: exceptional contacts with the Third World, a stable environment and a strong industrial base; but interested parties are carefully analyzing terms of foreign participation, tax propositions, fiscal reforms, plans to overhaul the social security system and the impact of labor relations. Government officials contend they are "positive and open toward foreign investment" but have made it clear they frown upon "simple commercial networks in France that do not assist domestic development."

The government contends, however, that it will not increase protectionist regulations to enable French companies to boost their domestic market share.

"You don't see 'Buy French' written on our boutiques," said a government official. "All protectionism will do is destroy competition and slow industrial growth." But presidential adviser Attali feels, "We have a lot to learn about protectionism from other countries."

PART II
FRENCH TECHNOLOGY: THE STRUCTURE OF PUBLIC R&D

Although fundamental research knows no politics, French science has traditionally been effectively controlled and managed by the government hierarchy in Paris. Most fundamental research in France is conducted by public research organizations and universities, although the government is encouraging them to conduct more applied R&D, have a closer relationship with industry and commercialize their efforts. The allocation of R&D budget boosts will vary according to different sectors and organizations but there will be general efforts to increase manpower and integrate R&D with national programs.

"The country's economic and technological requirements must reach researchers everywhere," says a government official. "There must be a consensus between what the state wants and what the worker wants."

Total research expenditures in France in 1982 are estimated at 74,000 million francs with the state financing 59.7 percent and industry 40.3 percent (nationalized industries spent 14,600 million francs on R&D in 1982, while private industry spent 15,200 million francs). In the public sector the Ministry of Defense spent 17,600 million francs, while the Ministry of Research and Industry and other government ministries spent 26,600 million francs. The execution of the research is being carried out by the administration and public organizations (35.7 percent), nationalized companies (33.3 percent), the private sector (25 percent) and the military (6 percent)—who contract most of their R&D activity to industry.

"Observers outside France could attribute the capabilities of French technology solely to the government effort," says Philippe de Montgolfier, head of the Association National de la Recherche Technique (ANRT). "But in 1966, industry executed 51.4 percent of R&D projects and financed 28.2 percent. Today industry executes 58.2 percent of the R&D and finances 43 percent. This participation has kept increasing despite the financial problems and recession that have hit companies around the world."

There has always been a link between politics and research in France, and the reaction to the current government effort varies from laboratory to laboratory, company to company. There is virtually no opposition to the government's overall intentions, but there is skepticism about whether all that has been promised will be delivered. Many researchers contend that they were inspired during the colloquium but are now disappointed because they have not yet seen an increase in budgets, manpower or material. In addition, some remain disenchanted with the proposed industrial application of their laboratory efforts. Industrial observers often mention that many government-inspired innovations are too theoretical and will not have any commercial applications. They contend that applied R&D is better left to industry. The government counters that industrial R&D expenditures will not increase unless given a boost by taxpayer-provided funds and contends that a common effort is required if France is to attain its lofty technological and social objectives.

"The big problem in France is not financing research but financing industrial development, and our base in fundamental R&D is admirable," says CNRS president Claude Fréjacques. "We want to put our people into industry and will have a committee to commercialize R&D. Although only 15 percent of our current activity is applied R&D, I would like to see that figure at 30 percent by 1987."

The 1982 CNRS budget of 5,950 million francs (23.6 percent of the public civil research budget) was up 25 percent on the previous year and created new posts for 348 researchers and 193 engineers, technicians and administrators, giving the CNRS a total of 23,820 employees with 1,200 laboratories and research teams operated directly (350) or in cooperation with universities and other organizations (850). The 1982 budget breakdown was as follows: life sciences, 25.5 percent; chemistry, 15.7 percent; nuclear and particle physics, 12.9 percent; earth, atmospheric, ocean and space sciences, 11.8 percent; mathematics and basic physics, 11.7 percent; social sciences, 8 percent; physical sciences for the engineer, 7.9 percent; humanities, 5.5 percent and interdisciplinary programs, 1 percent. Future budget increases are meant to create internationally competitive laboratories, purchase larger machines, create new support programs and give younger researchers a chance to create their own groups.

The CNRS has scientific accords with 30 countries. For example, an agreement with the National Science Foundation in 1982 provided for an exchange of 20 researchers, 11 seminars and 75 joint research projects. There are also specific agreements with the National Institute of Health, Harvard Medical School, M.I.T., the American Geological Institute, NASA and the University of Chicago. In Canada the CNRS cooperates with the country's National Research Council (CNRC) and in Japan it has an agreement with the Japanese Society for the Promotion of Science.

French industrialists have mixed attitudes toward the CNRS.

"The CNRS does not want us to propose practical R&D programs," says Roger Dumon, director of research and development for Creusot-Loire. "They always want to take the initiative and lack the ability to communicate with industry."

But "our contacts with government laboratories could improve if the message spreads from the government to the researcher," says Bernard Julien at Rhône-Poulenc's R&D division.

Other companies contend that you must know how to use the large, diversified organization.

"You do not go to the CNRS to solve applied problems; instead you look for fundamental R&D that is parallel to your own efforts," says Erich Spitz, director of Thomson-CSF's central research laboratory. Adds Schlumberger's Babaud, "The CNRS works well on defined subjects."

The commercialization of research is extremely important for the success of the government's technical scenario, and the CEA, the second largest public research institute, with a 1982 budget of 5,260 million francs has industrialized many of its

FRENCH TECHNOLOGY:
AN ONGOING COMMITMENT TO NUCLEAR POWER

Creys-Malville—The world's first commercial scale sodium-cooled fast breeder reactor (fbr), the 1,200 MW Super Phenix, is scheduled to come on line here in 1984—another tangible indication of France's commitment to the continual development of nuclear power, which supplied 37.4 percent of the country's electricity and 12 percent of its total energy demand in 1981. The French nuclear program, which has been supported by governments of different political persuasions for almost three decades, mobilizes technical ambitions toward national energy goals employing a close-knit, centralized industrial approach.

Energy produced by this one billion dollar commercial prototype fbr unit, located on the Rhone river 60 km from Lyon, will be more expensive than power from the twenty-four 900 MW pressurized water reactors (pwr) currently operating in France. Although its commercial value cannot be realistically appraised until operations are under way, French engineers are confident Super Phenix will be a technical success and current development objectives are to reduce breeder and related fuel cycle expenses so electricity costs will compare favorably with equivalent-capacity light water reactors. A critical examination of an operational Super Phenix, coupled with developmental work on 1,500 MW reactors and new equipment technology, will enable the French to select an advanced reactor type for the 1990's.

France, one of the few countries with a concerted approach to nuclear energy, may also require a fast breeder reactor program to meet future uranium requirements. An fbr becomes less expensive per kilowatt hour than a pwr at higher uranium prices, and its breeding capacity provides a better use of natural uranium. French nominal capacity of uranium production will peak at 3,900 tons per year (tpy) in the mid-1980's but the pwr program will require 9,700 tpy by 1990, according to the French Atomic Energy Commission (CEA). Although a report by the General Accounting Office in the United States contends "the continuing deterioration in the nuclear power industry and current information indicating that commercial breeder reactors are unlikely to be deployed for the next 40 to 50 years make it difficult to argue that developing the breeder reactor is an urgent task in the United States," Super Phenix—which includes German and Italian partners and additional scientific agreements with Belgium and the Netherlands—is an indication the French believe otherwise.

Like the entire French nuclear program, Super Phenix is the result of a long-term political, technical, industrial and commercial cooperation that envelops the full cycle of nuclear requirements—from fundamental research to large-series manufacturing to installation of turnkey plants throughout the world. The country's nuclear program is geared to a coherent contract schedule covering a series of essentially identical 900 MW and 1,300 MW plant units—a repetitive process that facilitates design, construction and quality control operations.

The principal constructors of the nuclear facilities are Framatome for pwr nuclear steam supply systems and Novatome for fbr extended nuclear steam supply systems, while Alsthom-Atlantique is responsible for turbine generators and the turbine hall. The monopoly electricity supplier Electricité de France (EDF) is the industrial architect, engineer and operator of nuclear power plants—as well as controller of the construction, production, transmission and distribution of all other forms of electricity in France. Operations in the fuel cycle, from mining to fuel reprocessing and vitrification, are carried out primarily by CEA affiliate Cogema while Eurodif, a European joint venture in which Cogema is a major shareholder, represents twenty-five percent of the western world's fuel enrichment capacity. Pwr nuclear fuel is designed and sold by Fragema, a Framatome-Cogema subsidiary with industrial affiliates, and Novatome has ordered the first core and the first two fuel reloads for Super Phenix from Cogema. Cogema has run industrial-scale reprocessing plants since 1958, and at mid-1982 Cogema had treated 510 metric tons of pwr spent fuel. Cogema is expanding its La Hague fuel reprocessing facility to an annual capacity of 1,600 metric tons which will permit reprocessing of 6,000 metric tons contracted by foreign utilities.

Other organizations underline the vast, comprehensive nature of the French industrial infrastructure. The Société Générale pour les Techniques Nouvelles (SGN) is active in nuclear fuel cycle engineering; the Agence National pour la Gestion des Déchets Radioactifs (ANDRA) handles radioactive waste management; and the Protection and Nuclear Safety Institute (IPSN) maintains a continuing research and development effort pertaining to the full spectrum of safety requirements. Both ANDRA and IPSN are CEA affiliates.

The result is a complete and coherent research, industrial, engineering, and commercial structure that has developed product standardization, series manufacturing of equipment, fixed price conditions, speedy replacement time for spare parts, feedback of knowhow, quick construction time (66 months from order of execution of the nuclear boiler to commercial operation of a 900 MW unit) and a smooth industrial approach.

Of course, an important objective of the French nuclear industry is to penetrate export markets. Framatome competes for nuclear power projects worldwide, offering its technical capabilities and wide-ranging maintenance services; Fragema is exporting an increasing amount of nuclear fuel and SOFRATOME provides technical assistance to foreign utilities for production and use of nuclear energy. Two 900 MW plants in Belgium, constructed by a Franco-Belgian consortium led by Framatome, are nearing completion, and in South Korea two identical 900 MW units are being constructed by Framatome and Alsthom-Atlantique. Fuel for the plants will be supplied by Fragema. A consortium led by Framateg—a Framatome and Alsthom-Atlantique affiliate—is completing two 900 MW plant units at Koeberg, South Africa with the aid of Sofinel, a technical coordination company owned by EDF and Framateg. A similar contract was signed with Iran, then cancelled by the current government.

A COHERENT EVOLUTION

The French nuclear effort began in the early 1950's when France produced its first nuclear kilowatt hours with graphite-moderated reactors and constructed nine units using this technology. In 1969, the French decided production capacity per kilogram of uranium was limited with gas graphite technology and opted for light water methodology. In 1970, the EDF ordered twin pwr 900 MW units with a steam supply system for Framatome. At the same time EDF, the CEA and the design team that later formed Novatome constructed Phenix, a prototype 233 MW fbr, which began operation in 1973.

Between 1970-82 the nuclear program resulted in orders for thirty-three 900 MW units and thirteen 1,300 MW units. Construction on sixteen 900 MW reactors began in 1974-76, construction on a second group of twelve began in 1977-81 and the first four 1,300 MW units will come on line in 1983. There will be a slowdown from nine to six new reactor starts in 1982-83, but the EDF is now looking for sites for five 1,300 MW units and one 900 MW reactor.

There is ongoing fundamental and applied research and development activity at every level of the nuclear effort, ranging from further attempts to understand internal organization of atomic nuclei to measuring performance of newly-developed nuclear equipment or improving existing

Framatome

The world's first commercial-scale fast breeder reactor, Super Phenix, will come on line in early 1984. At right is Framatome's Chalon facility where steam generators and pressure vessels are manufactured for the French nuclear program.

plants. In 1981, a licensing agreement between Framatome and Westinghouse was replaced by a technological partnership, and a continuing four-party research accord includes Westinghouse, EDF, the CEA and Framatome for research and development in the area of pwrs. Some 57 R&D programs are under way. Research and development efforts are also conducted within the framework of an agreement between Framatome, EDF and the CEA—a tripartite group, that defines joint objectives and shares financing. The CEA has R&D installations in Grenoble, Cadarache and Saclay, while the EDF devotes twenty-three percent of its R&D budget to programs in the nuclear sector. Framatome's research centers include the Creusot-Loire Unieux Center for metallurgical research, the Creusot-Loire and Framatome Applied Welding Techniques Centers and the Framatome Non-Destructive Testing Research Center. The industrial partners also use EDF and CEA experimental facilities by special agreement in addition to their own laboratories.

R&D orientations are all-encompassing. For example, CEA teams are analyzing behavior of reactors under high thermal stress, while the EDF has installed a test circuit for sodium-heated steam generators with a thermal capacity of 50MW to demonstrate reliability of an fbr under operating conditions. Corrosion resistance and fatigue sensitivity is continually improved for valves, taps, generator tube material and stainless steels for condenser tubes. There is a permanent exchange of information between scientists in the CEA reprocessing research division and the engineers at Cogema's two reprocessing plants.

Research teams are studying a wide range of environmental problems including architectural design of buildings for better integration into various landscapes; analysis of cooling tower plumes in hydraulic basins to assess dispersion and the impact on the climate; measurement of noise and acoustics engineering; and the dispersion of waste water and detection of changes in the aquatic environment as a result of thermal affluents. The EDF has already built plants on cliffs, on the banks of an unpredictable river, on sandy soil and on a site requiring a long dike extending into the sea.

The nuclear program has also created R&D efforts with applications in related fields. There is development in research reactors and in marine propulsion spearheaded by Technicatome as well as potential for medium power generation and district heating. New technology is being developed for uranium exploration, mining and enrichment plants—employing gaseous diffusion, chemical processes and laser enrichment methods. An entire range of testing equipment has evolved including new techniques for acoustic water leak detection, camera and projector systems for inspection purposes, and a sensitive range of valve tests for high temperature behavior of materials. In the area of operations, studies include the architecture of automatic control systems, modern closed-loop controls and advances in data processing applications. Because France now has an abundance of low-cost nuclear-base electric power, research is well advanced in the use of electricity for water electrolysis and hydrogen production.

Safety and training are important aspects of the French effort. Regular product controls include microscopic examination at the manufacturing stage, ultrasound tests on site and welding quality controls by sweating techniques and radiography. The overall surveillance system is based on a diagnosis of the mechanical condition of the equipment, an endoscopic auscultation of steam generators and continual examination of watertightness and vibrating behavior of internal reactor parts. A particular development in the area of safety is the Kali loop, a special tool that verifies the integrity of safety-related components under accident temperature and pressure conditions through predetermined variation of environmental conditions. The French seriously evaluated the Three Mile Island incident and have incorporated findings, particularly regarding operation and intervention procedures, into their extensive simulator training programs for 900 MW and 1,300 MW units.

French nuclear plants meet quality assurance criteria defined by the International Atomic Energy Agency and are shut down for servicing every 2-3 years. To date, the French nuclear industry has not had any major technical bottlenecks or disasters and the primary technical problem is overall valve performance. Although the Marcoule process for the vitrification of highly active wastes has been sold abroad, the French do not yet have a long-term waste disposal site.

The French goal is to have seventy percent of electricity requirements and 26.7 percent of total French energy demand supplied by nuclear sources (56 nuclear plants and a total installed net capacity of 56 GW) in 1990. The French are understandably critical of countries that have abandoned domestic nuclear programs and concur with the 1981 activity report of the Organization for Economic Cooperation and Development's Nuclear Energy Agency, which cautioned that unless governments make a firm commitment to develop nuclear power over the next decade, the resources of the nuclear construction and uranium mining industries will rapidly disperse—making it more difficult to meet projected energy targets.

innovations. The CEA is a vast group that includes a Fundamental Research Institute with operating units conducting basic research in physics, controlled fusion research, biology, metallurgy, nuclear astrophysics, radiation chemistry and numerous other nuclear-related areas.

The CEA transfers knowhow to industry either as a licensee or by becoming a full industrial partner and sharing development risk with a private company. It has a special subsidiary that facilitates the financial and industrial launching of new, high-risk technologies and industrial applications in areas such as ionizing radiation, biomedical engineering, electronics and data processing, energy and material resources, agriculture and food processing and software. Other research organizations in France are being officially encouraged to follow the CEA's lead in commercializing R&D.

TELECOMMUNICATIONS

The strides made in French telecommunications are largely due to the CNET, which has 3,700 employees and six laboratories conducting both fundamental and applied research. The CNET influences industrial development of telecommunications products by preparing specifications, participating in consultations, monitoring market studies and standardizing new equipment. General network studies, optoelectronics and intercontinental links are studied in two Paris laboratories. One laboratory in Lannion, in Brittany, concentrates on R&D in local network, switching and enhanced services, while a second concentrates on reliability, components and digital transmission. New services and terminals are studied in Rennes at the CCETT (Common Center for Television and Telecommunications Research) and microelectronics R&D is centered in Grenoble.

Breakthroughs by CNET include developments in solid state physics, signal processing (speech synthesis and recognition), knowledge of atmospheric behavior and radio communications, data processing, optoelectronics, microelectronics, satellite communications, network design, systems architecture and software. R&D is conducted both internally and in common with other laboratories and industry.

"Our work stops at the demonstration of feasibility when industry takes over," says CNET director Jean-Pierre Pointvin. "We have been extremely successful in commercializing our findings on a global basis and our main effort today is to create lower-priced products and digitalize the network to the subscriber level."

France does not have a central laboratory for microelectronics, but in February the Grenoble-based Laboratoires d'Électronique et de Technologie de l'Informatique (LETI), a CEA affiliate, and the CNET's Norbert Segard Microelectronics Center formally joined forces. LETI will increase its technical personnel from 500 this year to 650 in 1986, while the CNET will ultimately have 250 engineers.

Says LETI vice-president Jacques Lacour, "We will continue our applied research in conjunction with industry and hope to have more commercial spinoffs."

SPACE

CNES, the French space agency, had a 1982 budget of 3,013 million francs with 31.7 percent destined for multilateral cooperation, 28.6 percent for program support, 20.9 percent for national programs, 15.7 percent for bilateral cooperation and 3.15 percent for R&D. Multilateral projects include numerous European Space Agency (ESA) programs such as the Ariane launcher, Spacelab, the ECS telecommunications satellites, earth and marine navigation satellites and numerous scientific programs.

The bilateral programs include cooperation with NASA on Jupiter 3, an astronomical experiment on an American balloon for static spectroscopy and gamma source imagery; high-resolution imagery of the sun coupled with simultaneous study of the magnetic and velocity fields; the Winters Upper Atmosphere Research satellite, aimed at measurement of wind and temperature between an altitude of 85–250 kilometers; the Lidar U2 Aircraft, which will measure vertical profiles of ozone; a study of induced solidification of alloys in weightless conduction and experiments in Spacelab. The CNES also contributes to the Franco-American-Canadian SARSAT program for the location, identification and rapid rescue of ships and aircraft in distress.

The CNES conducts a number of scientific programs in conjunction with the U.S.S.R., which include high-energy gamma radiation studies; construction of an ultraviolet spectrometer for investigation of the ultraviolet spectrum of stars; a study of the interplanetary environment and the launch of a satellite to orbit Venus and study, among other things, the atmosphere and chemical composition of the soil.

CNES experiments in the Soviet Salyut 7 spacecraft, which carried a French cosmonaut last July, included infrared photography of the atmosphere and night sky, study of galactic and extragalactic X rays, study of the effect of heavy ions and cosmic rays on biological objects, an assessment of the influence of space environment on bacterial sensitivity and an ecographic study of man's cardiovascular system under weightlessness.

AGRONOMY AND ENERGY

INRA, the National Institute for Agronomic Research, with a 1982 budget of 1,800 million francs, is a centralized scientific organization with researchers and laboratories throughout France. Agriculture is considered extremely important to France and conveniently intersects with the mobilizing program—energy, electronics and biotechnology. INRA's R&D ranges from cartography and teledetection to vegetal production, animal production, biotechnology, biomass, product quality and the social sciences. The president of INRA, Jacques Poly, is also president of GERDAT, and intends to increase ties between France and the Third World.

"38 percent of the French population was involved in agriculture prior to 1940, while today that figure has decreased to only 9 percent," says Jacques Poly. "But agricultural and livestock production has increased, largely because INRA has a practical approach to R&D and concentrates on *implementing* its programs. Naturally we must intensify our work with agribusiness and will try to mobilize the CNRS to concern itself more with agriculture.

"We are very centralized, which permits a national effort avoiding duplication," Poly continues. "While increased collaboration with less-developed countries is extremely important, we must also intensify our work with the United States and other industrialized countries. The United States has excellent R&D projects in agriculture, and although our problems are a bit different we should collaborate and formulate a practical approach toward agriculture in developing countries."

The AFME is responsible for national energy coordination and its objectives for 1990 are threefold: reduce the role of imported oil in France from 50 percent to 30 percent of energy requirements, economize energy and triple alternative energy sources. Energy is consumed in France by industry and agriculture (34 percent), the residential and business sector (35 percent), transport (19 percent) and energy production (12 percent). The AFME will provide technical direction and financial assistance in these areas, and R&D is aimed at better price/performance ratios, industrialization of new energy-saving ideas, standardization of products and development of coherent systems for the final user.

"We want to be the inspiration and financial support behind national energy-saving and management efforts," says Philippe Chartier, scientific director of the AFME. "We hope to work with all the public research centers in France and other countries."

A MULTIDISCIPLINARY APPROACH TO AGRICULTURE

Studies conducted by the National Institute for Agronomic Research (INRA) have well-defined objectives that take into account the scientific, technical, social and economic requirements of the agricultural and agribusiness community. Although some research is of a long-term fundamental nature, the full scope of INRA's R&D activities—involving 8,000 researchers and technicians at 300 facilities associated within 21 research centers throughout France—is applying a multidisciplinary approach that results in comprehensive, realistic agronomic solutions available to a wide range of users in France and abroad. INRA's policy is to manage the entire knowledge channel in developing new agronomic concepts liable to supply alternative solutions to cope with various changes in the overall economic situation.

While INRA's activities are extremely varied, the following progress report provides a very restricted sampling of its scientific trends.

• **Poultry** is the fifth most important facet of French agricultural production—after cereal, cattle, fruit and vegetables, and wine—and INRA is investigating the complete chain of production activities, from selection to all management problems, such as feeding and health. INRA's dwarf breeder hen ("Vedette") is currently the spearhead of the French poultry industry for broiler production and the latest varieties result in a twenty-two percent reduction of food consumption. The "Vedette" products currently comprise forty-five percent of the French market and is quickly penetrating the American market.

The French have also taken a global lead in guinea fowl, Barbary duck and rabbit production as a result of well-integrated studies conducted by INRA.

• INRA has bred new varieties of **rapeseed** and considerably improved cultivation techniques and yields. INRA solved the problem of erucic acid possible toxicity in rapeseed oil by producing an acid-free variety of winter rapeseed called "Primor." INRA has reduced the antithyroid sulfur substances in rapeseed oil cake, which improves rapeseed oil cake quality for animal nutrition. Recent studies indicate that new hybrid varieties and progress in fighting parasites will lead to an improvement in productivity.

• Techniques in agronomy, soil preparation, fertilizer, weed killers and fungicides have considerably increased **wheat** productivity per acre since World War II. But economic or ecological factors sometimes limit use of industrial production. INRA expects to maintain the present productivity level with lower production costs and a better seed quality while increasing productivity by using new breeding methods. INRA's **wheat** "Roazon" has shown there is less need for fungicides when genetic resistant varieties are developed and this variety is resistant to parasites—a useful quality for developing countries. INRA is also studying the hereditary transmission of seed proteins and their influence on flour quality. Results indicate it will soon be possible to control production of suitable varieties in a fast and reliable manner.

• Significant advances have been made by INRA scientists in the understanding of the reproductive mechanisms in domestic animals including cattle, sheep, goats, pigs and poultry. This had led to a faster and better extension of genetic progress in areas such as artificial insemination in all species and semen deep-freezing. It has also resulted in a better control of reproduction in livestock through estrus induction, synchronization and other methods. The problem of **embryo transfer** has been extensively studied by INRA researchers in areas including nonsurgical ova collection, freezing and transplantation into recipient cows.

This technique requires a foundation in the basic mechanisms of reproduction and first steps in embryo development. INRA researchers are currently working in the field of embryo sex-determination techniques, which will permit the choice of an animal's sex, and gene transfer, which will determine an animal's genetic makeup. Another area of research involves increasing the efficiency of embryo producing techniques. Numerous solutions are being investigated and include in vitro maturing ova or the micromanipulation of embryos using each cell of an egg at the first step of segmentation to obtain a separate embryo. Other work in this area involves means of preserving embryos, which will permit transport to developing nations to improve herd production.

• Membrane technology and knowledge of milk proteins coagulated by rennet in cheese production has led INRA research to produce cheese by milk **ultrafiltration.** A liquid with the same composition as the cheese is prepared and then treated with rennet at various stages of evolution. This process avoids drainage of whey and permits the recovery of nutritional quality proteins. It improves cheese yield by fifteen percent, provides a higher-quality product without lowering organoleptic properties of the cheese and saves seventy percent of rennet. The process is well-established for fresh cheese and Feta and is currently being investigated for soft cheese. INRA is studying this process under farm conditions allowing use of the ultrafiltrate in cattle feeding while simultaneously providing the dairy industry with a concentrate product instead of milk.

• And the last example in developing countries: Tomatoes are difficult to grow in tropical countries because of the inordinate amount of heat and rain. INRA researchers in the French West Indies have created a **new tomato** variety, "Caraibe," which is resistant to blight bacteria *(Pseudomonas solanacearum),* pathogenic fungi *(Fusarium* and *Stemphylium solani)* and adapted to growth during the hot and humid season. The "Caraibe" is round, somewhat flat and of average size with a production potential of fifty tons per hectare. Although it is particularly suited to the Caribbean zone, INRA is currently determining whether it is adaptable to other tropical regions. In France, INRA researchers in Montfavet are conducting a wide range of research on the tomato for various purposes.

FRENCH TECHNOLOGY:
A COHERENT APPROACH TO THE ENERGY CRISIS

Although the French have initiated an ambitious nuclear program, they have simultaneously pursued other avenues to creatively and efficiently meet future energy requirements. As part of a concerted government effort in the field of energy, a public agency with 300 persons and a 3,200 million franc annual budget, was formed in May 1982 to formulate a coherent energy program utilizing the full scope of the French research and industrial infrastructure. The objective: to develop a wide range of energy conservation methods, promote the use of alternative energy, and commercialize cost-effective products and systems. Philippe Chartier, scientific director of the Agence Française pour la Maîtrise de l'Énergie (AFME), discusses the problems and progress.

Question: How can somewhat disparate sectors—electricity producers, petroleum companies, nuclear equipment manufacturers, and industrial companies—realistically combine research and commercial efforts in the area of energy?

Answer: There are contradictions but we formed thirty working groups with 650 experts from different research and industrial sectors to discuss the vast range of energy-related problems. Companies and laboratories defend their own interests, but there is general agreement that France must reduce the consumption of primary energy through energy substitution and price-competitive alternative energy systems. We must have a rational industrial policy and an aggressive technical structure.

The AFME, which is principally a public service agency, takes a leading role in defining strategies and evaluating technical innovations while industry tackles the manufacturing and marketing aspects. We would like to inspire a venture capital approach by financing numerous innovative ideas and creating a variety of technologies. Unfortunately energy is not a priority for many industrial sectors and won't be until we provide concrete financial assistance and practical projects.

Question: What current programs will have the greatest influence?

Answer: Reducing the cost of petroleum-dependent industrial and home heating represents one third of our efforts, and we are investigating new methods of ventilation, automation, generators, and other equipment for existing and new buildings. We are looking ahead to the 1990's because a long-term offensive position is essential to define the range of geothermal and other heat sources, develop new storage methods and expand applications for high and medium temperature solar heat.

Transport is a priority and research is well-advanced because of a traditional collaboration between industry and public laboratories in energy-economic automobiles, combustion techniques, alternative fuels, new motors and industrial diesel engines.

French agriculture is an important sector for biomass techniques, greenhouse design, methanization and other energy programs that will provide an important commercial boost if accompanied by a concrete industrial process.

To date, alternative energy sources still have not made a substantial commercial impact, but our orientations include solar, wind, hydraulic and photovoltaic energy. Ultimately alternative energies will have a considerable impact, but prices must decrease and a sensible philosophy regarding the rational utilization of energy must be more widely accepted.

Our Horizon 2000 program concentrates on fundamental research, and we have made significant progress in thermodynamics, fluid mechanics, industrial storage processes, photochemistry, biotechnology, and other fields. We have contracts with research organizations and universities that involve computer aided design, meteorology, wind energy, greenhouse structures, photovoltaic conversion techniques, pumping methods, energy storage, wood-fuel mixtures, methanization, biomass, and carburants—to name just a few priorities. Recently we developed a solar biotechnology research center concentrating on photosynthesis and enzymology with the French Atomic Energy Commission and industrial partners, a venture with the French Petroleum Institute to construct a pilot unit for biocarburants, and new laboratories for wind research and methanization of waste from agribusiness industries. But more pilot plants are required across the board.

AFME

A silicon ribbon puller used to produce silicon for photovoltaic cells has been developed at the Compagnie Générale d'Électricité laboratories at Marcoussis.

Question: Isn't one of your mandates to increase collaborative research efforts with other countries?

Answer: A major international effort is required to efficiently design the rational future of energy and we actively disseminate information and attend international conferences. We have technical agreements with Canada, the United Kingdom, the Soviet Union and Spain as well as developing countries like Mexico, Brazil, Egypt and India. More importantly, we have tangible contacts with less-developed countries, especially in Africa, and have recently established a delegation in Bangkok to coordinate activities in Southeast Asia. Last year fifty operations were launched in forty countries.

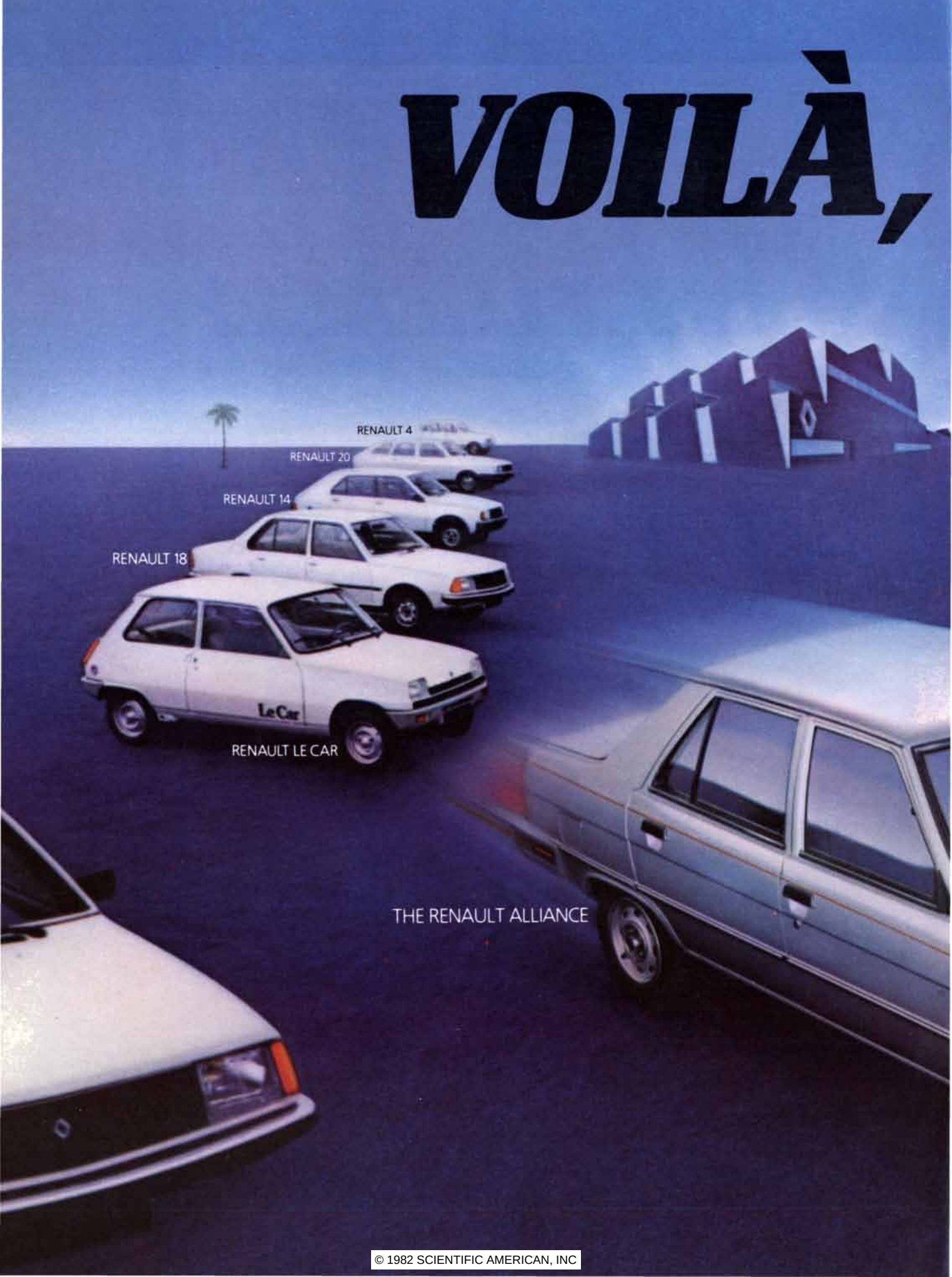
We collaborate with the European Economic Community, the Organization for Economic Cooperation and Development and the United Nations and have established pilot projects in many areas: gasification, biomass, bioconversion of algae, solar energy in housing, thermodynamic and photovoltaic conversion and wind energy. We have joint research activities with numerous universities and laboratories throughout the world. Although Japan has made a firm financial commitment to the area of energy we are somewhat dismayed that the United States is tending to reduce the amount of funds destined for alternative energy activities. France is eager to transfer its knowledge and technology to other countries in areas including scientific cooperation, project studies, training and the installation of new energy-saving systems.

AGENCE FRANÇAISE POUR LA MAÎTRISE DE L'ÉNERGIE

27 rue Louis Vicat, 75015 Paris Telephone: 645-4471 Telex: 203351

QUICK. WHO JUST WON EUROPE'S MOST COVETED PRIZE FOR AUTOMOTIVE EXCELLENCE?

FOR THE ANSWER, TURN THE PAGE.



When 32 journalists from 16 countries were asked to choose the best new car on the roads of Europe, they spent weeks testing entries from Volkswagen, Datsun, Toyota, GM—even a $23,000 BMW. And then they named the Renault 9 Europe's Car of the Year for 1982.

RENAULT

Now you can drive the Renault Alliance, the U.S. version of the car that's breaking sales records across the Continent. Built in the States by American Motors, the Alliance has been carefully tailored to meet the needs of the American driver. Including the need to be affordable. Get behind the wheel and understand what Europe's automotive experts mean when they smile and say, "Voilà, Renault."

For more information, please write: Renault Marketing Dept., American Motors Corp., 27777 Franklin Road, Southfield, Michigan 48034.

MEDICINE AND OCEANOGRAPHY

INSERM, with 1,500 researchers and a 1982 budget of 1,040 million francs, has laboratories conducting R&D in immunology, genetics, biochemistry, molecular biology, microbiology, pathology, pharmacology, neurosciences, nutrition and public health.

"We have four missions: R&D, valorization of this research, information dissemination and training," says INSERM director Philippe Lazar. "We are developing contractual relations with industry and need more laboratories in nutrition, microbiology and clinical research."

Numerous researchers from the CNRS and INSERM work in collaboration with private institutes, like the Institut Pasteur, which has 400 research scientists and 62 research units. It has research application projects under way in bacteriology, virology, parasitology, molecular pharmacology, diagnostic tests and equipment, services and industrial microbiology.

CNEXO, which had a 1982 budget of 400 million francs, conducts experimental projects in aquaculture, tropical thermal energy, deep sea mining, manned diving, unmanned vehicles, pollution control, drilling platforms, submarine instruments and tools, remote marine detection and spatial oceanography.

DATA PROCESSING

Substantial budget allocations will be distributed to electronics and data processing R&D organizations. INRIA conducts basic and applied R&D, creates experimental systems and organizes international scientific exchanges. Its R&D projects include linear automatic control, automation of complex technical systems and automation of large-scale interconnected systems. The ADI works more closely with users and issues proposals for specific themes requiring research financing. It also provides public and private research laboratories with pilot projects selected to provide a framework for development activity and to bring together researchers, manufacturers and the user community. The World Center for Computers and Human Resources is conducting research in areas including man/machine interface, new languages, personal computers, microcomputer architectures, interactive and personalized media (optical videodisc research), programming and natural language, speech recognition, interactive graphics and low-cost image processing, computer systems for agriculture and medicine. It is also planning social experiments in France employing personal computers at a community level.

"We are doing things here that are simply not being done elsewhere," says Seymour Papert, "and that are particularly interesting because they involve community interaction."

The following report assesses French R&D in data processing from the viewpoint of a multinational company:

RESEARCH AND DEVELOPMENT IN THE FRENCH ENVIRONMENT

By
Hervé Caron
Assistant General Manager,
IBM France

One of IBM's prime R&D objectives has been to reconcile two factors: the creation of a single, integrated worldwide R&D effort preserving homogeneity in the design and development of a common product line and the desire to distribute R&D missions among various countries to contribute to constant progress in the development of information processing technology.

There are certain prerequisites for a particular country to make such contributions. These include a comprehensive high-level education system; an active research environment; a positive government attitude toward public and private R&D; and an easy flow of information and ideas within the country.

IBM France's R&D investment began in 1935 with the creation of a Paris laboratory. In 1962 IBM established a laboratory at La Gaude, near Nice, with a worldwide mission for telecommunications R&D. At the same time, the company set up a scientific center in Paris and formed another laboratory in 1971 to specialize in advanced microelectronics.

These R&D investments were made because France met the preconditions outlined above. The university system in the fields of science and technology provided a high level of education. While this education system annually supplies very competent graduate recruits for IBM, it has numerous other advantages. The differences between the American and French academic processes often result in original approaches that stimulate competition and progress within IBM's international organization. An example is in telecommunications, where French technical schools have successfully integrated electronics and traditional communications engineering for many years. As a result, a special competence in two important areas, voice/data integration and telematics, was developed earlier in France than in most other countries.

IBM France has made the deliberate decision to be an intricate part of the French business, educational and R&D environment. There is a history of joint studies and cooperation with the CNET, CNRS, CNES and other national institutes. Reciprocally, IBM France has welcomed university students, and IBM staff hold memberships on the boards of numerous scientific associations.

These valuable connections can be improved in two areas:

*Industry/university relations have been far from efficient, and cross-fertilizations between university and the private business sector has not achieved its potential.

*Foreign-owned companies have not always been readily associated with national R&D in leading edge technologies. The government recently stated that major electronics projects were to be developed as a nucleus for future industrial progress in key areas and all French-based companies, whatever their ownership, would be involved. This will improve chances of better international cooperation as opposed to a narrow nationalistic approach.

The following are four examples of current or completed developments at IBM France's scientific center that are consistent with government-sponsored projects:

- Speech training for deaf children and automatic voice recognition.
- Teledetection by satellite.
- 3-D graphics research.
- Expert systems.

The fact that IBM France's R&D activity is both national and international in nature has been beneficial to the company and the local environment. The merging of different cultures and approaches has allowed for diversification and innovation. It is required in France and other countries for future technological progress in information processing.

MINISTERIAL R&D

French ministries also have internal technology-related activities. CODETEC, at the Ministry of Research and Industry, studies technologies pertaining to coal, while the Bureau de Recherches Geologique et Minières (Office of Geological and Mining Research) exploits mineral resources. The National Applied Chemical Research Institute's R&D covers chemistry, polymers, plastics and biochemistry. The Ministry of Transport conducts socioeconomic research at its Transport Research Institute, and the Ministry of Agriculture has a center that studies agricultural machinery and water-related problems. The Ministry of Foreign Affairs establishes scientific relations with other countries, signing formal bilateral agreements, exchanging researchers and sponsoring conferences. The Ministry of Culture has R&D activities in archaeology, archives, music and the arts and will construct a new science museum in Paris. The Ministry of Environment supervises the French Scientific and Technical Center for buildings.

The Ministry of Defense is traditionally

aerospatiale

this is who we are:

one of the world's largest aerospace manufacturers

Not the first in the world, but already the first in Europe in terms of turnover (above 16,5 billion french francs in 1981) and diversity of products. We were incorporated in 1970 under the name of Société Nationale Industrielle Aérospatiale, as a result of the merger of Nord-Aviation, Sud-Aviation and Sereb. Some have been inclined to shorten our name, retaining only the initials S.N.I.A.S. ; with the same object in mind we prefer to be called commonly **aerospatiale**. It is our signature.

top manpower

Men whose imagination and creativity have made our achievements possible. Close to 40,000 employees, specialists, engineers, chosen for their skill in particular fields.

ways and means

The most modern research, development and production facilities, where data processing plays a leading part: Computer Aided Design (CAD), Computer Aided Manufacturing (CAM). Behind these means, a policy: to come up with the best product at minimum cost.

products

The most diversified range of aerospace products: airplanes, helicopters, tactical missiles, space and ballistic systems, combining top performance and low cost of operation in order to satisfy market requirements.

We are the largest manufacturer of helicopters and tactical missiles in Europe, and the French Nuclear Defence Forces are equipped with our strategic ballistic missiles.

Finally, in the framework of multinational industrial programs, we are responsible for the success of a number of famous products that are not signed only with our name: AIRBUS A 300/A 310 - ARIANE - CONCORDE - HOT - MILAN - ROLAND - INTELSAT V - METEOSAT...

1/1693/I de M 81 Publicité **aerospatiale**

exports

We are exporting 80 % of our helicopter production, 70 % of our missiles, 90 % of our airplanes, as a mark of quality of our products - tailored to market requirements, and of our competitive sales policy.

aerospatiale

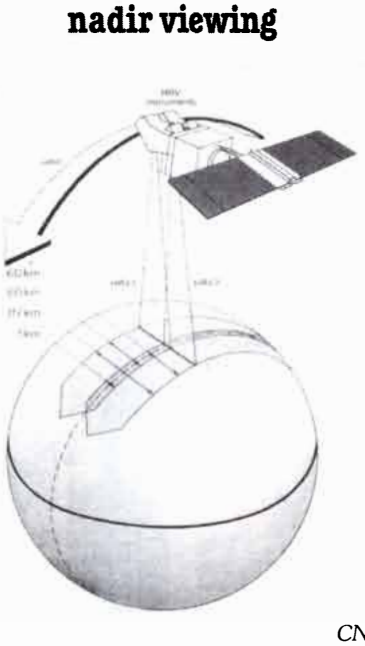
37, bd de Montmorency 75781 Paris Cedex 16, France

FRENCH TECHNOLOGY:
THE SPOT PROGRAM

by Gerard Brachet,
Chairman of SPOT IMAGE

The launch of the LANDSAT-4 spacecraft by the National Aeronautics and Space Administration (NASA) last July marked the beginning of the second generation of land remote sensing satellites. With the launch of SPOT-1 scheduled for October 1984, France will join the United States as an operator of satellites providing high-resolution images and observation data for land use studies, assessment of renewable resources, mineral and oil exploration and cartographic work.

The SPOT program, which consists essentially of an earth observation satellite and earth stations for data reception, was initiated by the French government in February 1978 and is a key element of the country's space activities. It is managed by the French Centre National d'Etudes Spatiales (CNES) and includes Belgian and Swedish participation with industrial contracts awarded according to the financial stake.



CNES

SPOT's two high-resolution visible (HRV) instruments can be positioned to cover adjacent fields. In this configuration the total swath width is 117 kilometers with the two fields overlapping by three kilometers. Since the distance between adjacent ground tracks at the equator is approximately 108 kilometers, complete earth coverage can be obtained with this fixed setting of instrument fields.

The SPOT system has been designed with an emphasis on providing an operational service for numerous users of collected data and images. Observation instrument and orbit parameters create optimum observation conditions, and the use of on-board recorders will provide access to the most remote regions of the world—including those outside the circle of direct reception stations.

The CNES is associated with a number of foreign reception stations and has worked in close collaboration with NASA to formulate compatible transmission and reception standards between LANDSAT-4 and SPOT. To develop a global network of correspondents, the company SPOT IMAGE is responsible for marketing SPOT products.

Technical Specifications

To achieve optimum observation conditions, the following observation instrument characteristics and orbit parameters have been selected:

- observation in the visible and near infrared bands for adaptation to data interpretation methods developed during the past ten years.
- fine selection of spectral bands to provide maximum discrimination of vegetation cover.
- sunsynchronous, near polar orbit, passing over the equator at 10:30 A.M. local time providing favorable lighting conditions that remain relatively constant throughout the year.
- a ground sampling interval of twenty meters in the multispectral mode (color images) and ten meters in the panchromatic mode (black and white images). These values have been selected to take advantage of the global and synthesized nature of data gathered by observation satellites at an effective scale of between 1/25,000 to 1/50,000—values compatible with the typical landscape encountered in numerous capacities.

An oblique viewing capacity offers the following advantages:

- reduced minimum time between two observations of a given area. While a satellite will pass vertically over a particular area at 26 day intervals, vertical and oblique viewing combined reduce this to a mean value of 2.5 days at a latitude of 45 degrees.
- composition of stereoscopic image pairs for a given area, using oblique observations made on two separate passes of the satellite in visible range of the area concerned.
- programming of image acquisition on request, inside a 950 kilometer band centered on the orbit path, providing a dedicated service adapted to user requirements.

The payload carried by the SPOT satellites will include two identical observation instruments in the high-resolution visible band (HRV) which can be independently telecommanded for different viewing directions or operation in the multispectral or panchromatic modes. Each instrument, depending on viewing direction, will observe zones with a width of 60–80 kilometers. On reception observation segments will be subdivided into images with a length of 60 kilometers. Data will be transmitted in digital form with coding at eight bits in the multispectral mode and six bits, after on-board data compression, in the panchromatic mode. Two on-board recorders, designed for off-line data transmission, will store several hundred images per day and transmit them during the night.

SPOT images will be collected via a network of ground stations. The two main stations in Toulouse, France, and Kiruna, Sweden will receive data stored on on-board recorders in addition to real time data over the area within the range of the station. Real time data will also be transmitted to direct receiving stations located in other countries and operated by agencies who have signed agreements with CNES.

Images will be distributed to users by the operator of a direct receiving station or by SPOT IMAGE, which will market the SPOT data on a worldwide basis. The pricing policy for SPOT images calls for a complete recovery of costs including operating expenses and amortization of capital for the satellites. R&D costs associated with the first satellite are not included. Given the estimated size of the market a price of $1,000 per image on computer-compatible tape is expected. This can be compared with $650 for a LANDSAT multispectral scanner scene.

At this stage, the substantial interest shown by the user community based on simulated data from airborne operations confirms a large market potential. It is expected the market will develop further with availability of new thematic mapper data from Landsat-4 that prepares the transition to fully operational remote sensing satellite systems such as SPOT. SPOT satellites have a design lifetime of two years and a second SPOT satellite is scheduled to be launched in 1986. There will be subsequent satellite launches to provide service continuity over a ten-year period.

the most independent research arm in the government. Its General Delegation for Armament (DGA) is responsible for maintaining an up-to-date armament industry and, among its numerous activities, the DGA supervises public and nationalized firms involved in armament research, studies and production. Its cabinet includes a functional Directorate for Research, Studies and Techniques (DRET) and a directorate that defines and implements a coherent industrial policy for production of electronic equipment. In addition, four technical directorates conduct studies and coordination for land weapons, shipbuilding, aircraft manufacturing and missiles.

The DRET finances fundamental research through contracts with industry (60 percent), public laboratories (25 percent) and universities (15 percent). It evaluates the evolution of science and technology on armament, performs design work for future weapon systems and ensures the coordination of research and study programs. DRET research groups include computer science and systems control, telecommunications and detection, general physics and environment, quantum electronics and electromagnetism, semiconductors and components, fluid dynamics and physics, chemistry, energy, propulsion, materials, biology and human sciences.

The DRET also supervises the Central Technical Establishment for Armament (ETCA) and the National Office of Aerospace Research and Studies (ONERA). ONERA's research is conducted in six main scientific departments—aerodynamics, propulsion, structure, materials, physics and systems.

INDUSTRIAL R&D

There are also research laboratories for various industrial sectors that work in conjunction with industry, ministries and the public research organizations.

Cerchar was created in 1947, one year after the nationalization of the coal industry, and its coal-oriented research activities concern liquification, ex and in situ gasification, combustion in fluidized beds and fuel-coal mixtures. The interministerial Comité d'Études Pétrolières Marines (CEPM), the French offshore oil survey committee, creates and develops techniques for exploring and producing from offshore hydrocarbon fields. Research in the petroleum and parapetroleum sector is conducted by the French Petroleum Institute (IFP) in areas including exploration, refining and energy management.

French private industrial sectors have their own technical centers, which undertake basic research, standardization, preparatory work leading to product labeling, technical assistance and personnel training.

Another innovation in French R&D is Sophia Antipolis, a research "city" near Nice, which is, according to founder Pierre Lafitte, a "multidisciplinary, international research development" financed by 60 participating companies.

Some companies, like Thomson-CSF at Corbeville and CGE at Marcoussis, have central research laboratories. Although the Thomson laboratory conducts only 5 percent of the group's research, it has produced one-sixth of their patents. Fifty engineers transfer from the lab to company affiliates each year and there is a continual interaction with universities and CNRS laboratories. Thomson's R&D orientations include work in crystal liquid flat screens, integrated optics, optical communications, ultrarapid transistors, real time holographic measurements, optical numerical disks, microlithography and III-V semiconductor material.

The CGE laboratory is involved in projects in the area of materials, equipment and systems for the group's numerous affiliates. Its activities range from heavy electrical engineering and shipbuilding to telecommunications, electronics, data processing and automation. Marcoussis researchers are studying new techniques to produce silicon for photovoltaic cells, designing laser-equipped flexible manufacturing facilities, developing optoelectronic devices for single-mode fiber optic links and evaluating high-power cryoalternators. One affiliate is studying lasers for range finding, target illumination, alignment, measurement and welding.

"The central lab conducts 8 percent of the group's total R&D with about 40 percent financed by government," says laboratory director Laurent Citti. "We are concentrating on artificial intelligence, software, fiber optics, lasers and cryogenerators."

EDF has five main testing and inspection laboratories to analyze equipment supplied by manufacturers and R&D is pursued in fields like cryoelectricity, production of hydrogen, and quality-control assistance.

Most French companies are not altering their general approach to R&D as a result of the government program, but technical and research directors hope to feel the financial repercussions of the national programs.

"We expect that the administration will substantially contribute to our development in a wide variety of fields, including power semiconductors, ferrite components, piezoelectric components, capacitors and interconnection products," says Bernard Lévi, director of R&D for Thomson-CSF's Components and Electron Tube Group.

"France lacks engineers in data processing and software," adds Erich Spitz, director of Thomson-CSF's central laboratory, "and we hope the government efforts will attract people into these fields."

The major problem, however, will be commercializing future research.

"In California, part of the enjoyment of R&D is bringing the new product to the market, and we must somehow capture that spirit," says a government official. "We must concentrate on introducing a risk-taking philosophy and a venture-capital structure."

Suggests Marc Lassus, head of Matra-Harris Semiconducteurs, "The government should encourage real cooperation with U.S. companies in the area of R&D programs and reward those companies that are most successful in the international marketplace. Actual competition in the real world is the acid test."

Perhaps the most interesting R&D in France will be conducted at research centers being created to study the economic and social changes resulting from measures introduced by the Socialists.

"The social and economic reforms and the resulting dynamics of social change have transformed this entire country into one huge laboratory," says Angers-based sociologist François de Singly.

PART III
FRENCH TECHNOLOGY: AN INDUSTRIAL PANORAMA

While it would be difficult to fully describe the vast nature of present and future industrial developments and programs in France, the following panorama provides an overview of activity and innovations in selected sectors.

AEROSPACE

This sector combines research, development, production and commercial capabilities that have made French industry a leader in airborne and ground-based navigation aids, combat and executive jets, wide-bodied aircraft, helicopters, missiles, engines, satellite launchers, satellites, sophisticated electronics, simulators and other areas. The aerospace industry had sales of 43,700 million francs in 1981, up 24.5 percent on the previous year, with over half the turnover due to exports.

Aerospatiale, Europe's leading aerospace company and the world's second-largest manufacturer of commercial aircraft, participates in such pan-European projects as Airbus, Euromissile, Eurosatellite and numerous space programs. R&D parallels the company's five industrial divisions: aircraft, tactical missiles, helicopters, space and ballistic systems.

"We have abandoned our supersonic transport activities but are developing the next aircraft for the Airbus family with our

industrial partners," says Aerospatiale technical director Jacques Balazard. "Each division handles its own R&D, but three themes are constant: increased use of composites, computer-aided design and manufacturing (cad/cam) and intelligent systems."

The French have a fully integrated space sector, equipped to produce a wide range of satellites. Aerospatiale, along with West German and British firms, has received a contract from the ESA to study future European launcher systems. Thomson-CSF has taken an integrated approach to satellite communications and supplies turnkey systems for telecommunications, television, research, observation and navigational satellites. The company is providing the payload for France's direct broadcasting satellite and supplying onboard hardware for processing and transmitting photographs on SPOT, the ground resources observation satellite. R&D is mainly in five areas: satellite payloads, earth stations, tubes, components and data processing.

Space activities account for 10 percent of Matra's turnover and the company is the chief contractor for technical subsystems on the Ariane launcher and the prime contractor for Télécom 1. Matra furnishes electronics systems for Spacelab and constructs multipurpose observation satellites, including the high resolution visible instruments for SPOT. SPOT, like the Ariane space launcher, which is sold through Arianespace, is being marketed by a private organization, SPOT IMAGE.

Dassault, which exports over three-quarters of its turnover, has developed 167 prototypes and pre-series aircraft representing 35 different types of planes since 1947. It is Europe's leading manufacturer of military aircraft and top ranking builder of business jets with 4,000 military and civil aircraft in service in 56 countries. Dassault is run by engineers, and one-fourth of the workforce is involved in R&D, which absorbs about 14 percent of the company turnover.

"Our R&D continues until the realization of the prototype," says Bruno Revellin-Falcoz, technical director general at Dassault. "We are currently working on seven military and four civil programs and have a horizontal approach to R&D. Each section is responsible for all developments in particular areas—structure, materials, aerodynamics, equipment, avionics and armament, acoustics and flight quality. We feel we lead in areas like operational imagery, fly-by-wire and integration of avionics and armament."

Aerospatiale, Dassault and Matra have developed cad/cam systems for the conception and manipulation of three-dimensional forms. Dassault Systemes' Catia is being marketed by IBM and tested in industries outside the aerospace arena.

"We are trying to determine the full range of industrial applications for three-dimensional design," says Dassault Systemes' technical director Francis Bernard.

AUTOMOTIVE

The two leading automotive companies in France, Peugeot and Renault, both lost money last year, but the French automobile industry, which employs 254,000 people, remains the fourth largest in the world. There is a move to standardize parts, introduce more cost-effective production and promote European cooperation.

"We're not as large as U.S. companies and require collaboration with other firms for fundamental research," says Jean Lagasse, head of Renault's Direction des Affaires Scientifiques et Techniques. "We hope to participate in the electronics and energy *filières* and maintain the French lead in automobile economy, accidentology and safety. Our R&D effort, which accounts for 2.69 percent of our turnover, is devoted to energy saving, increased productivity, quality control and reliability, and comfort and safety improvement."

Renault is a leader in international robotics and a body assembly plant in Douai employs robotics and information processing control to increase tool flexibility for welding, paintwork and final assembly.

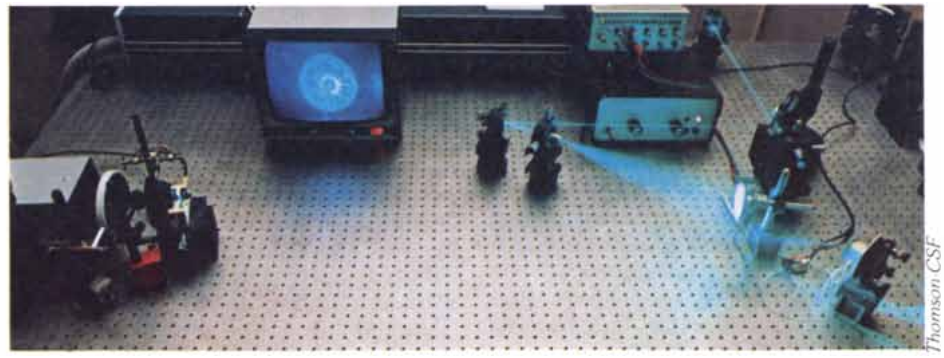
"We progressed fairly quickly in robotics because we combined our machine tool and assembly line background," asserts Freddy Ballé, president of Renault's industrial equipment and technical division. "We can ultimately use robotics at every level and transfer our knowhow to other industries—which corresponds with government efforts to cross-fertilize the *filières*. The industry will see a joint evolution of hardware and software—programmable controllers, numerical command and a general combination of machinery."

In the area of energy conservation, Peugeot is developing the VERA (Economical Applied Research Vehicle) and Renault the EVE (Eléments pour une Voiture Econome) to study all aspects of fuel saving. Researchers are attempting to reduce air and rolling resistance, increase the use of electronics, lower weight by using composite materials and improve motor/transmission performance. The objective at both companies is to reduce fuel consumption by 30 percent. Both Renault and Peugeot are also working on vehicles that will consume three liters of gasoline per 100 kilometers.

"The automotive industry is undervalued by the government when compared to other sectors," says Noël Bureau, technical and scientific secretary in the Direction of Research and Scientific Affairs at Peugeot. "But we expect to have fruitful relations with the AFME in the energy area and hope to 'Europeanize' our basic research."

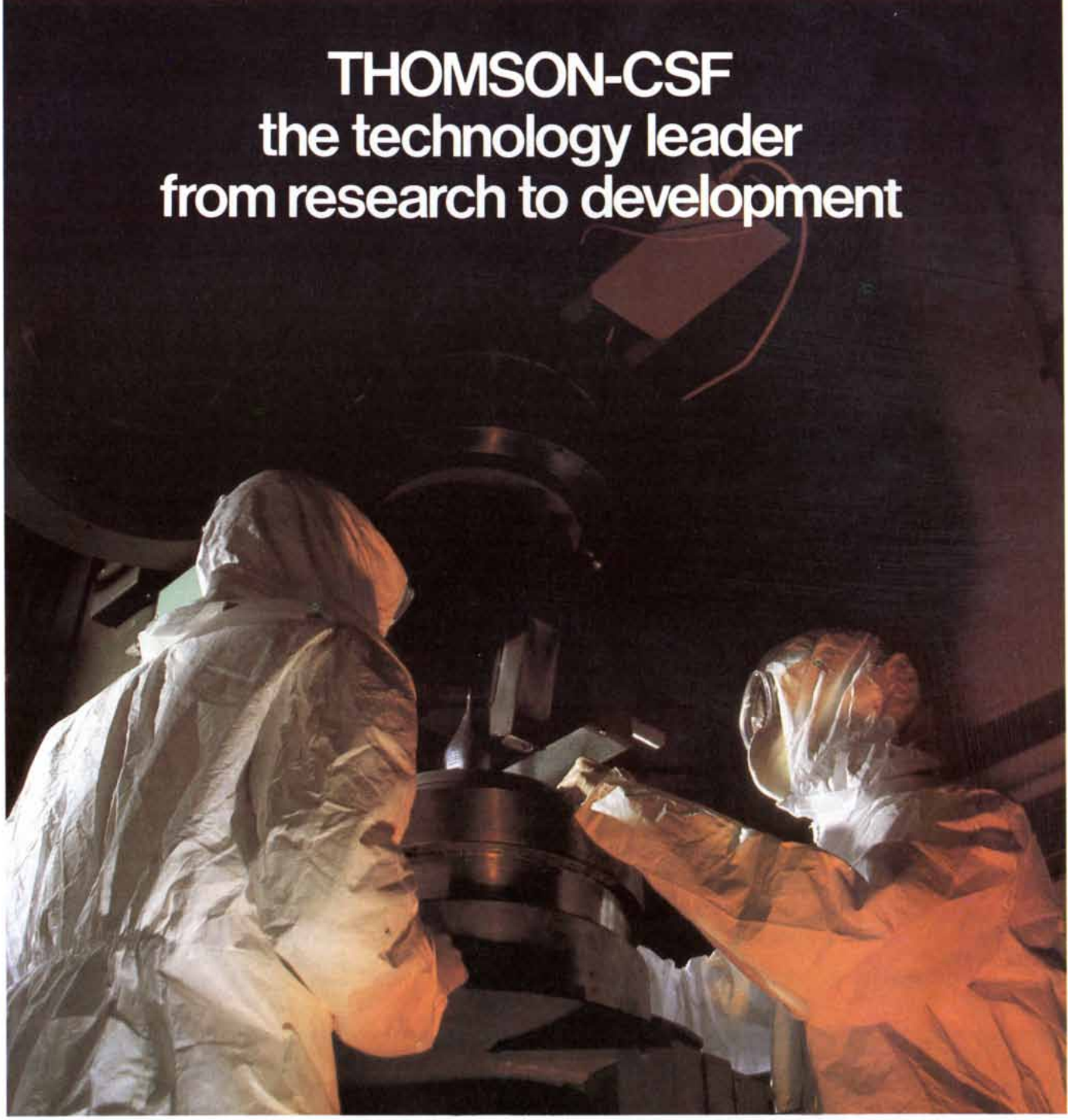
BIOTECHNOLOGY

Forty companies are involved in 15 biotechnology projects and the government plans to double the number of researchers and increase R&D collaboration with the United Kingdom, Canada and Japan. The main weaknesses in biotechnology are a lack of microbiologists, poor background in the area of antibiotics, insufficient training of genetic engineers and poor links between research and industry. French strengths include excellent teams in molec-



Contemporary French Technology—Engineers at CGE's central laboratory at Marcoussis are working on military and industrial laser applications, while engineers are studying real time holography at the Thomson-CSF laboratory in Corbeville.

THOMSON-CSF
the technology leader
from research to development



Production of gallium arsenide monocrystals, 75 millimeters in diameter, which are used for key components required for the Thomson group's electronics products.

Thomson is the leading French company in research and development expenditure. France's largest electronics group spent 4,500 million francs, equivalent to 13% of its turnover, on R&D in 1981.
75% of its R&D activity is self-financed and the group applied for 600 patents in 1981 – 10% of the total for all French industry – following innovations at its Central Research Laboratory and decentralized R&D divisions.
Thomson-CSF, a successful international competitor in a number of high technology sectors, considers R&D an essential part of its preparation for the future. Today the company's 17,000 professional scientists are continuing to make breakthroughs in areas including components and electron tubes, avionics, radars, radiocommunications, transmission and broadcasting, space communications, fiber optics, public telephone switching, private telephony, data processing and medical electronics..

The emphasis on R&D at Thomson-CSF has enabled the company to become a French export leader of state-of-the art technology for a variety of electronics-related products. This international presence has also allowed the group to keep abreast of technological advances in other countries and to pioneer exciting innovations with global ramifications.

Thomson-CSF does not just talk about R&D. It sets the pace.

Thomson-CSF - 23, Rue de Courcelles
B.P. 96-08 / 75362 Paris Cedex 08 / France
Tel. : (1) 563 12.12

Thomson-CSF, Inc. - 2 Gannett Drive
White Plains
New York, N.Y. 10604 / USA
Tel. : (914) 694-4450

4899

THOMSON-CSF

FRENCH TECHNOLOGY:
TESTING A HIGHLY SECURE AND PORTABLE DATA BANK

The smart card, a French industrial development that is influencing the overall design of electronic banking, combines large-scale integrated circuit technology with the packaging of a chip on thin film. The intelligent plastic credit card contains an imbedded integrated circuit capable of storing information and conducting numerous transactions without costly interfaces or communication with a central computer.

The smart card may be employed as an electronic checkbook for point of sale purchases, a telepayment card to conduct financial services over a videotex system, a high security authorization and access card, a portable file card, a prepaid card for pay telephones or a billing method for computer time sharing, pay television programs and other automated services.

Unlike other contemporary payment methods, the monolithic self-programmable microcomputer chip in the smart card combines memory and logic capabilities, which protect against fraud, reduce clerical handling costs, minimize errors and facilitate personalized banking and retail transactions. The smart card permits remote user identification, paperless transaction capabilities, access control to databases and encryption.

This autumn the French are launching large-scale field trials with 120,000 cards and 650 point of sale terminals in three cities—Lyon, Blois and Caen—as part of a 10 million dollar test financed by a syndicate of French banks. The cards provide retailers with speedier customer processing, guaranteed payment, more-efficient accounting systems and a reduced possibility of crime. Banks eliminate the costly processing of classical checks and can control user expenditure by limiting purchasing power of the card over a specific period. The ultimate goal is a nationwide electronic funds transfer system, and an American bank is already testing the smart card as a vehicle for electronic payment in the United States.

In addition, the French telecommunication authorities are promoting use of the card in the Télétel 3V videotex experiment near Paris with 300 volunteer users employing the smart card for teleidentification and telepayment over the system. Six commercial organizations, including two banks, the national railway system and two large mail order firms, have been equipped to accept payment for goods and services by smart cards.

The home user places the card into an add-on card reader/processor linked to a videotex terminal or standard television set and, after typing a personal identification number, the memory written into the card by the issuing authority identifies the user, indicates the money value or banking power of the card and automatically dates and records information within the circuit.

The varied uses of the card over the videotex system include home banking, which permits statements, recent transactions and other information to appear directly on the terminal screen. Teleshopping lets the user request information concerning a specific product, choose the merchandise from displayed information and insert a smart card into the terminal to activate a cash transfer to the merchant's account. The user can also pay utility and other bills using the videotex system.

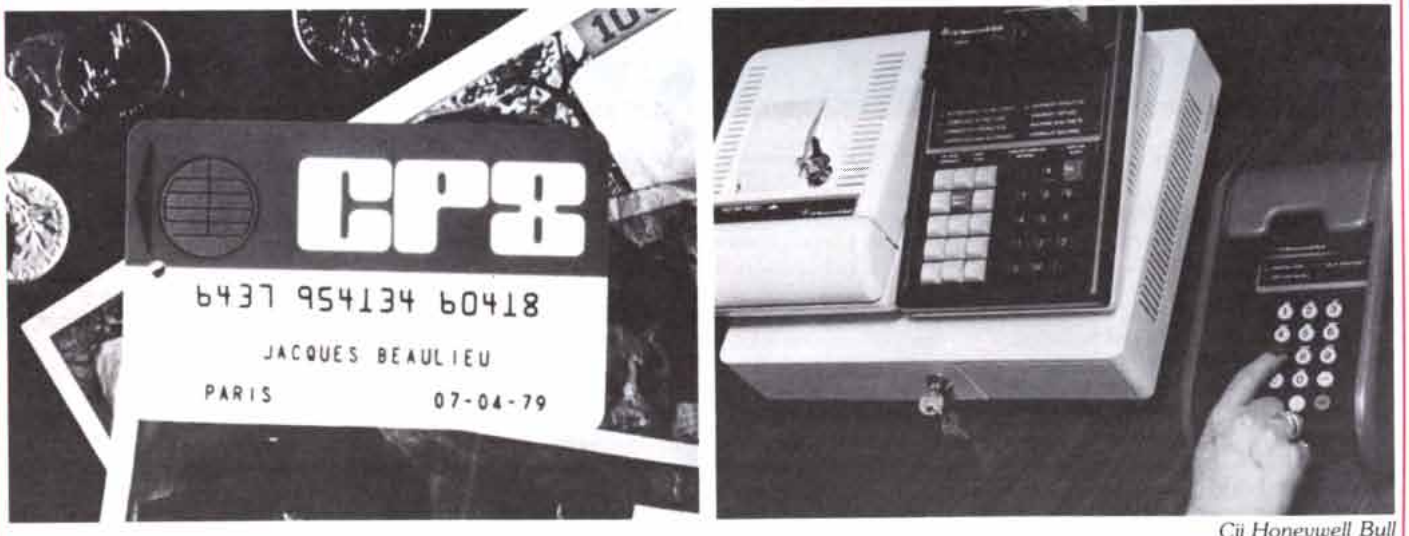
It is also possible to access confidential data bases and debit the smart card for the service. For this and other applications the card contains internal algorithms inaccessible to the card holder with nested nonerasable memory, which stores information including application-related parameters, holder identification, card issuer identification, and service-related information and access data.

An average smart card transaction, which dramatically simplifies man-machine dialogue procedures, takes about half a minute and the built-in security measures guarantee privacy of transactions and secure data integrity—providing mutual protection to the user and the account manager.

Three French companies—Cii Honeywell Bull, Flonic Schlumberger and Philips Data Systems—are developing the card in collaboration with in-house or external software firms. Although each firm has a different technical approach, the cards conform to ISO standards and the Association Française de Normalisation is working with manufacturers to define a common card reader interface. In addition, an international association (INTAMIC) has been formed to monitor common standards for the smart card.

According to manufacturers, the smart card is tamper-proof and quickly immobilized if stolen because it is protected by both the user's code and a bank code. If false codes are entered the electronics of the card will lock out. The card memory is, for security reasons, nonerasable and the current version offers 8 Kbits capacity.

Research and development today is geared toward increasing memory capacity, improving the electronic components, reducing the cost (which will depend to a large degree on volume orders), making the card more durable and determining different applications. Meanwhile, a number of U.S. organizations, including the Department of Defense and Department of Agriculture, are actively planning user trials.



Cii Honeywell Bull

The smart card looks like a regular credit card but contains an imbedded integrated circuit. The card is being used for point of sales purchases in conjunction with terminals during field trials now underway in France and has a variety of other applications.

ular biology and new laboratories will open in public research organizations and private institutions. A joint fundamental R&D agreement between Sanofi, Roussel Uclaf and Rhône-Poulenc is likely.

"France is strong in basic research in immunology and molecular biology, but we're three years behind in industrial microbiology," explains Dr. Paul-Henry Schmelck, manager for the development of biotechnology at Sanofi Research.

Elf is active in biotechnology through its subsidiary Bioelf and its share in Sanofi, which has acquired a majority interest in Institut Pasteur Production. Elf and Sanofi are constructing a laboratory for biotechnology research in Toulouse. INRA, INSERM, CNRS and Institut Pasteur have formed the Groupement Genie Genetique for genetic engineering production of interferon, polio vaccine and hepatitis B vaccine. Rhône-Poulenc has created Genetica for molecular genetic research and a number of new companies—such as Transgene, Immunotech and GERME—have been created.

"We want to conduct applied research in immunology while maintaining our links with national laboratories," says Immunotech's scientific director Michel Delaage, whose company is located on a university campus near Marseille in proximity to CNRS and INSERM laboratories.

The spinoff from universities into industrial biotechnology is best illustrated by the creation of GERME—an industrial microbiology, scientific instruments and quality-control equipment company—which was created in Marseille by four professors still teaching at the University of Provence.

DEFENSE

The Socialists will slightly decrease overall defense spending in 1983, but still hope to maintain the French position as the world's third armament exporter and support an aggressive marketing program with few regulations to prevent sales. Budget cutbacks are not expected to affect R&D programs such as development of an ocean-going strategic force, a new air-to-ground missile, a program of mobile missiles and a neutron weapon. France argues that it provides Third World customers with alternatives to superpower suppliers and that nations purchasing French equipment maintain their independence.

A variety of companies conduct R&D in aerodynamics, flight mechanics, propulsion, materials and motors, and notable technical achievements have been made in rotor blades for helicopters, fiber optics, ducted rockets, navigation and guidance instruments and deep ocean diving.

Current R&D concentrates on increasing performance and effectiveness through increased use of electronics.

"Our new generation of missiles will be smarter and better integrated," says Aerospatiale's Balazard.

"We are not building planes but complete arms systems that require extreme coordination and integration," says Dassault's Revellin-Falcoz. "We have simulated techniques to study 90 different types of aircraft, which makes design speedier and more efficient."

ENERGY AND PUBLIC SERVICES

Energy independence has been a long-time aspiration in France, a country with no domestic oil reserves and a steadfast conviction that there is a permanent energy crisis. A major turning point was the oil price leap in 1973–74 when the increase in energy costs necessitated a total remodeling of energy orientations. The most tangible result is a powerful nuclear industry and a long-term energy plan that will continue to reduce dependence on imported oil through diversification of energy sources and intense conservation methods.

The AFME will attempt to coordinate the industrial effort for French energy sav-

ing and the creation of alternative energy sources in areas including heating for homes, industry and new buildings (heat pumps, insulation materials, storage processes, solar techniques), agriculture (biomass), transport, combustion techniques, alternative fuels and new energy technologies (wind, hydraulic, geothermal).

"One of our current priorities is the restructuring of our approach to company R&D as an investment and one of the common themes is energy," says Michel Staib, director of strategy at Schneider. "It's a coherent link that affects all of the group interests—hydraulic energy, nuclear energy, coal gasification, energy-saving techniques and the search for alternative energy sources."

"Our R&D and production goal is to employ energy-saving techniques in offshore work, airports, refineries, petrochemical and industrial plants," agrees Pierre Cros, director of research and development at electromechanical and civil engineering concern Spie Batignolles.

ELECTRONICS/DATA PROCESSING

The electronics industry, with 1,700 companies and a workforce of 490,000, is the keystone of the French industrial program. Investments in traditionally strong areas such as telecommunications and military electronics will remain at recent levels, but increases will be made in spatial electronics, computers, components, consumer electronics, software, medical electronics, robotics, scientific instrumentation and office equipment. France lags behind in consumer electronics and is traditionally strong in professional electronics, but this all-encompassing *filière* will cover the gamut of activities from chips to computers.

"We're in a highly competitive export market with fast-moving technology requiring new product lines every 3–7 years," said Pierre Aigrain of the Thomson group. "Without an aggressive R&D policy we cannot have technological independence and a substantial market share. In the future Thomson, and France, must make the right technical choices early enough, open new market areas, train more scientists and maintain a competitive industrial base."

The Thomson-CSF "RDM" multirole radar being fitted on a Dassault Mirage-2000.

The French are launching national projects, which include: central processing units for mini- and microcomputers; consumer electronic systems; display systems; local communication networks; cable television networks; design and fabrication of very-large-scale integrated circuits; and computer-aided translation, instruction, design and fabrication. Critics contend that the vast plan is too comprehensive and must be realistically curtailed.

French companies have licensed chip-making technology and basic chip design from abroad, creating joint ventures and technology cross-licensing agreements with American firms. Following an expensive five-year integrated-circuit plan, which has created an overcrowded industry, France is currently reorganizing its components industry around industrial poles.

There is a large trade deficit in measuring equipment and instrumentation due to what one government official calls "the need to buy American." The only large French group that could serve as an industrial pivot is Schlumberger, which has numerous measurement and control affiliates in France.

"The French must realize instrumentation is international and not ignore multinational companies based in France," says Schlumberger's Jean Babaud. "Technological independence in this area makes no sense and we should work instead on developing market niches. It would be a mistake to concentrate all activities on a single company."

The French have been attempting to create a solid computer industry since their first *plan calcul* in the 1960's and have consistently failed to field an internationally classed industry.

However, Jacques Stern, president of Cii Honeywell Bull contends that "we have not performed well in the past because there hasn't been a coherent long-term plan. We now have that plan, we will implement it and it will succeed."

Stern encourages the French government, which controls his company, to "buy French because the American administration uses 100 percent American material, the Japanese 99 percent Japanese and the French only 40 percent French. All high technology in the U.S. is financed by the government and the only difference in France today is that we have a more direct contact with our government."

The French have been traditionally strong in software and are consolidating their position.

"France is effectively stressing the importance of computer development, which will encourage more software advances," says Michel Jalabert, vice-president of corporate development at software company Cap Gemini Sogeti. "We expect to progress more rapidly as a result of the electronics *filière*. France will remain internationally strong in software because the French have the mathematical background and mental skills that inspire that type of lonely work."

MATERIALS

It is likely that the government will officially create another mobilizing program for materials because the use of aluminum, composites, ceramics, fibers, glass and other materials is common to all industries. Leading the way will be the nationalized companies CGE, PUK and Saint-Gobain.

"A national program in the area of materials is required because no company in any industry is capable alone of financing the voluminous R&D required for development of materials," explains Jean-Pierre Causse, research director at Saint-Gobain. "Housing, automotive, aerospace, telecommunications and other industries simply must get together."

"Half of the R&D in Creusot-Loire's metallurgy laboratories is directed to fatigue, corrosion and other studies of materials for the nuclear industry," adds Michel Colombié, deputy director of R&D at Creusot-Loire. "And the advances in nuclear have applications in other areas."

PARAPETROLEUM

France's parapetroleum industry is the country's largest exporting sector and has 8 percent of the world market. And while the oil companies diversify into petrochemical and energy activities, they remain leaders in offshore technology. Although highly competitive with their own R&D units, Total and Elf Aquitaine participate in an IFP program to study and develop techniques and equipment for drilling and producing oil and gas in deep water.

"The government has tightened financing terms for fundamental R&D," says André Brun, Total's director of production. "More audacious projects will be limited, but we're still working toward finding the 70 percent of existing oil resources that are not recoverable by current methods. In five years we believe we can improve by 50 percent."

"We maintain an aggressive posture in R&D and regularly use universities and the CNRS for long-term studies," says Ber-

FRENCH TECHNOLOGY:
CONTINUING BREAKTHROUGHS IN TELECOMMUNICATIONS

by
Rio Howard
Consultant for New Technologies

The French approach to telecommunications has been characterized by particularly astute long-term planning based on an early commitment to digital switching and transmission techniques. The country's telecommunications authorities were among the first to recognize the importance of digital technology for the proliferation of wideband services and distribution systems utilizing fiber optic cables—features that create an integrated services digital network (isdn) capable of speedily processing and transmitting the high volume of data required for image transmission and other forms of written and oral information. More importantly, these technical capabilities form the foundation of an adaptable system readied for evolutionary developments in wideband data transmission techniques for future communications networks.

To address the immediate importance of the business sector in the telecommunications market, the French are developing an effective network of business communications systems—a preliminary step in the creation of a multiservice communications system for the entire country. One of the key facets of the present program is the first French domestic satellite.

Télécom 1 is scheduled for launch in the second half of 1983 and will provide the French with a spatial telecommunications network for the private and public sectors. The satellite will primarily guarantee efficient internal communications networks for French and European business traffic, will be used for videocommunication services, and will operate in conjunction with the French military communications network. The French PTT, which administers the satellite program, has signed an agreement with the West German Bundespost and Eutelsat to provide access to Télécom 1 for all European commercial customers. The system, expected to have approximately 3,000 business users, will utilize some 300 earth stations in Europe, with 150–200 located in France.

The Télécom 1 satellite system has been developed by the Direction Générale des Télécommunications (DGT). Three satellites, two in orbit and one in reserve, are being constructed by prime contractor Matra and numerous other French firms including Thomson-CSF, which is developing the payload. The satellites will be operational by 1984 in geostationary orbit above the Gulf of Guinea in the Atlantic Ocean with the terrestrial reference station located at Mulhouse, France.

An interesting feature of the Télécom 1 system is that it can be installed independent of existing infrastructure. A small antenna placed on the user's premises is all that is required for participation in the network. The time division multiplex access method (tdma) of communication will permit substantial system flexibility, allowing users access to the satellite only when required. The wide range of data capacities, from 2400 bits/s to 2 Mbits/s, permits numerous forms of transmission and processing of a wide variety and intensity of traffic demands.

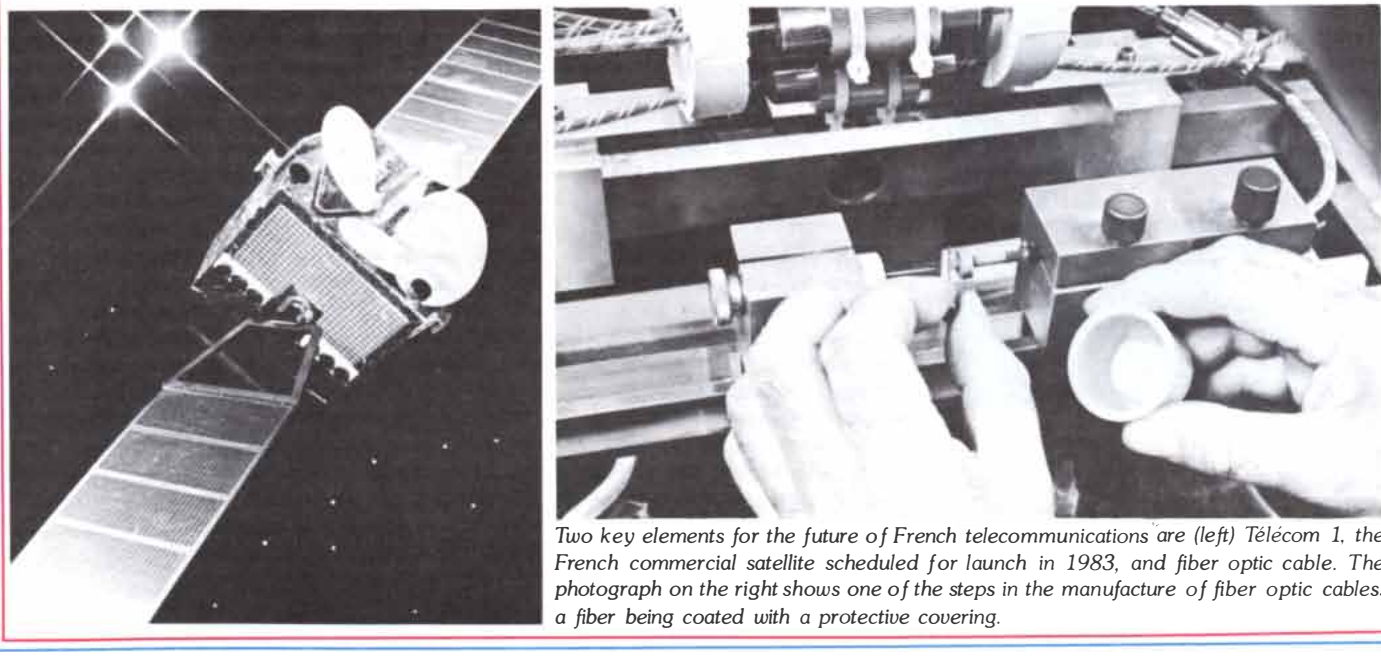
Fiber Optic Systems

For the extension of telecommunications services in France, the installation of fiber optic cable systems will be employed to transmit satellite information to individual private users and to distribute terrestrial point-to-point programs and services.

Fiber optic systems have been installed in the United States to make existing services more efficient and less expensive. However, the French are world leaders in the exploitation of fiber optic technology, which will make wide-band services and interactive videotex available on a national scale. French developments have placed great emphasis on perfecting cost-competitive manufacturing techniques for all elements in the system—glass fibers, connectors, lasers and detectors—and French industry will soon manufacture fiber optics systems that are in the same price range as their coaxial cable counterparts. Fiber optics will ultimately be employed for interurban links, large-band links to subscribers, submarine cable, video telephone and video teleconference.

In addition to experiments with fiber optic networks in Biarritz and other metropolitan areas, the French are installing fiber optic cables in the Mediterranean. These tests will culminate with the installation of a submarine fiber optic link of 200–300 kilometers between Corsica and the French mainland in 1985. Cables have been installed for the experiment in Biarritz that provide television, telephone, data bank and videophone services to 1,500 subscribers throughout the city. It is considered an important test due to the novelty of the technology, the multiple services available to the user and the large size of the user sample.

These direct experiences with satellite communication and fiber optic links are only two examples of the determination of the French to continue their aggressive advances in telecommunications technology. As a result, French manufacturers are well placed to install new systems and services for any business and consumer requirements, national or private, throughout the world.



Two key elements for the future of French telecommunications are (left) Télécom 1, the French commercial satellite scheduled for launch in 1983, and fiber optic cable. The photograph on the right shows one of the steps in the manufacture of fiber optic cables: a fiber being coated with a protective covering.

nard Delapalme, Elf's director of research, development and innovation. "We will continue to participate in French energy programs—particularly those regarding new motors, storage facilities and better uses of petroleum products."

Comex, the Marseille-based company, is working on new equipment and procedures to repair pipelines at depths of 400 meters. Their approach combines divers and remote controlled work vehicles.

"We are investigating the intermediate steps between man and robot underwater," says Jean-Pierre Icard, method and development manager at Comex Services. "We do not expect robots to be universal and anticipate that in 30 years they will handle 30 percent of underwater activity."

TELECOMMUNICATIONS

The French came from behind in the 1970's to modernize their telephone network and will increase the number of subscriber lines from 6.2 million in 1974 to 28 million in 1987—while the *télématique* program integrates numerous compatible products and services using improved digital switching and transmission techniques. *Télématique* developments include an electronic directory for telephone users and a videotex experiment in Velizy near Paris. By the end of 1982, France will have a national videotex network that uses simple packet assembler/disassemblers to patch users into Transpac, the public packet–switched data network.

"We have a variety of product and services that are capable of penetrating international markets," says France's Director General of Telecommunications, Jacques Dondoux. "Because of the rapid developments, R&D investments will stabilize during the next few years. The challenge now is to create easy languages and lower-priced products."

"French companies are now working on integrating complete systems," explains Roy Bright, head of the government's promotional organization Intelmatique. "There is a merging at the level of terminals, concentrators and data bases and the creation of new network architectures."

"The French lead in digital switching, public packet networks and new services where they have defined standards and protocols," says Etienne Gorog, director of telecommunications systems at IBM's La Gaude laboratory. "But they are not as advanced in telefax or teletex."

CIT Alcatel and Thomson-CSF are France's two major telecommunications firms, and both have made substantial inroads in digital switching and transmission systems, private telephones and low-cost terminals. Both firms are expanding into the area of data processing, office equipment and local automatic office networks. In addition, there are numerous other companies with international reputations including Jeumont-Schneider, Matra, TRT, SAT, SAGEM and SESA.

"We spend 20 percent of our turnover on R&D, with 35 percent coming from government agencies, because R&D is the bread and butter of tomorrow," says TRT technical director Michel Coiron. "We are diversifying into new areas—mobile radios, fiber optics, terminals, rural telephones—and are investing in cad/cam and software to create the atmosphere required for original developments."

CONCLUSION

Much of what is occurring in France today is preparation for tomorrow. Ultimately the French will be judged not by their present technical ambitions but by the future health of their society and economy. However, the actions of the French government discussed in this report invite a number of questions:

Can the Socialists successfully attend to social change and still improve industrial efficiency and competition? Can they accomplish a cultural and social transformation as well as material amelioration?

Can François Mitterrand's team efficiently manage knowledge acquisition and application by selecting the right technologies, overseeing the evolution from one technology to another and preparing for technological change?

Can France achieve technological independence and control of its domestic markets without isolating itself from international competition?

Is there a contradiction between nationalization and efforts to decentralize, between nationalization and the desire to have a healthy private corporate sector, between nationalization and technical innovation?

Will there be serious political problems if the current programs fail, or will the Socialist technological strategy and structure continue into the 1990's—which is when some of the current ambitions will finally pay off?

It is too early to fully answer these questions. But the French government—by protecting employment, nationalizing industry and refusing to jettison outmoded industrial sectors—has chosen an expensive road to technological independence and international competition.

The educational and sociological reforms may take a number of years, but there has been a waiting game, indeed increasing impatience, in the industrial sector during the 17 months of government planning: of colloquiums, missions, mobilizing programs and sectoral plans. This period is almost completed, and 1983 should provide indications of whether the government and its nationalized industrial sector can be creative, productive and meet objectives.

France certainly cannot attain its ambitions without the restoration of activity in the private sector and the government still has not provided the required psychological and economic impulse. When the head of Rhône-Poulenc resigned in July, claiming his nationalized company could not play a locomotive role, he was replaced by a government functionary. It makes a businessman wonder: Is the role of industry to produce or provide employment?

Whatever the final outcome, the government-sponsored efforts to boost technology in France contrast with the situation in other countries where research is on the wane. Despite the obvious teething problems of the Socialist government, the French program is replete with noble intentions. Whether it succeeds depends on political, psychological and economic factors—many of them beyond the control of François Mitterrand or anyone else.

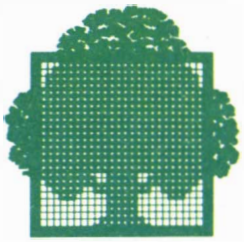
"The Americans used to laugh at Japan," concludes a government official.

FRONT COVER DESIGN: L'AGENCE PUBLIC AFFAIRS CONSULTANT: MAURICE BOOD

50 YEARS OF COMPUTER EXPERIENCE ON YOUR SIDE.

Satisfying the precise computer requirements of each customer has been our underlying vocation for 50 years. We have been among the fore-runners in new technologies. Today we span the five continents.

Together we can use this capability and experience to confront today's business challenges and those of the future.



Cii Honeywell Bull

Feldman, Calleux & Associés

Africa's biggest dam, Cabora bassa in Mozambique.

The largest supertanker afloat, the 555,000 T. Pierre Guillaumat.

The most powerful electrical networks, 800,000 Volts switchgear in the United States.

The world's most comprehensive nuclear turbine manufacturing program.

If you like the biggest and the best, we'll get along very well.

We' re big. And we never stop trying to be the best in everything we do. In energy, construction, engineering, transportation, telecommunications, data processing, defense. C.G.E. is active in all these areas throughout the world, with added benefits for clients in each area thanks to cross-fertilization between all these different fields. C.G.E.'s know-how makes it possible to combine these resources efficiently in conceiving, designing, and financing large-scale projects anywhere in the world - completing and delivering them "key in hand". All this is no accident, but the fruit of careful planning going back to C.G.E.'s beginning in 1898. Quietly, but very dynamically C.G.E. has developed into one of the world's leading industrial groups.

With annual sales of 10 billion dollars, and a workforce 180,000 strong C.G.E. keeps pace with the fast developing technologies of the 1980's and 1990's while maintaining a rigorous research program that prepares C.G.E. for the next century.

C.G.E. A unique combination of technological, industrial, and financial strengths.

Compagnie Générale d'Electricité. U.S. Subsidiary: Cogenel. Inc. - 45 Rockefeller Plaza - New York - N.Y. 10.111. Tel. (212) 541.58.12.

Compagnie Générale d'Electricité

Nous parlons le langage de ceux qui font le futur.

POUR LA SCIENCE is read by 41,321* decision-making professionals throughout France.

The fortunes of major corporations increasingly depend on technically sophisticated people. POUR LA SCIENCE attracts a young audience (average age: 38) of well-paid professionals who are in positions of prominence because of their technical expertise. More than half of them hold top-management job titles.

We speak the language of more than 3,000,000 world shakers in 140 countries each month. We reach the people who make the future happen in French, Spanish, Italian, German, Japanese, Chinese and English.

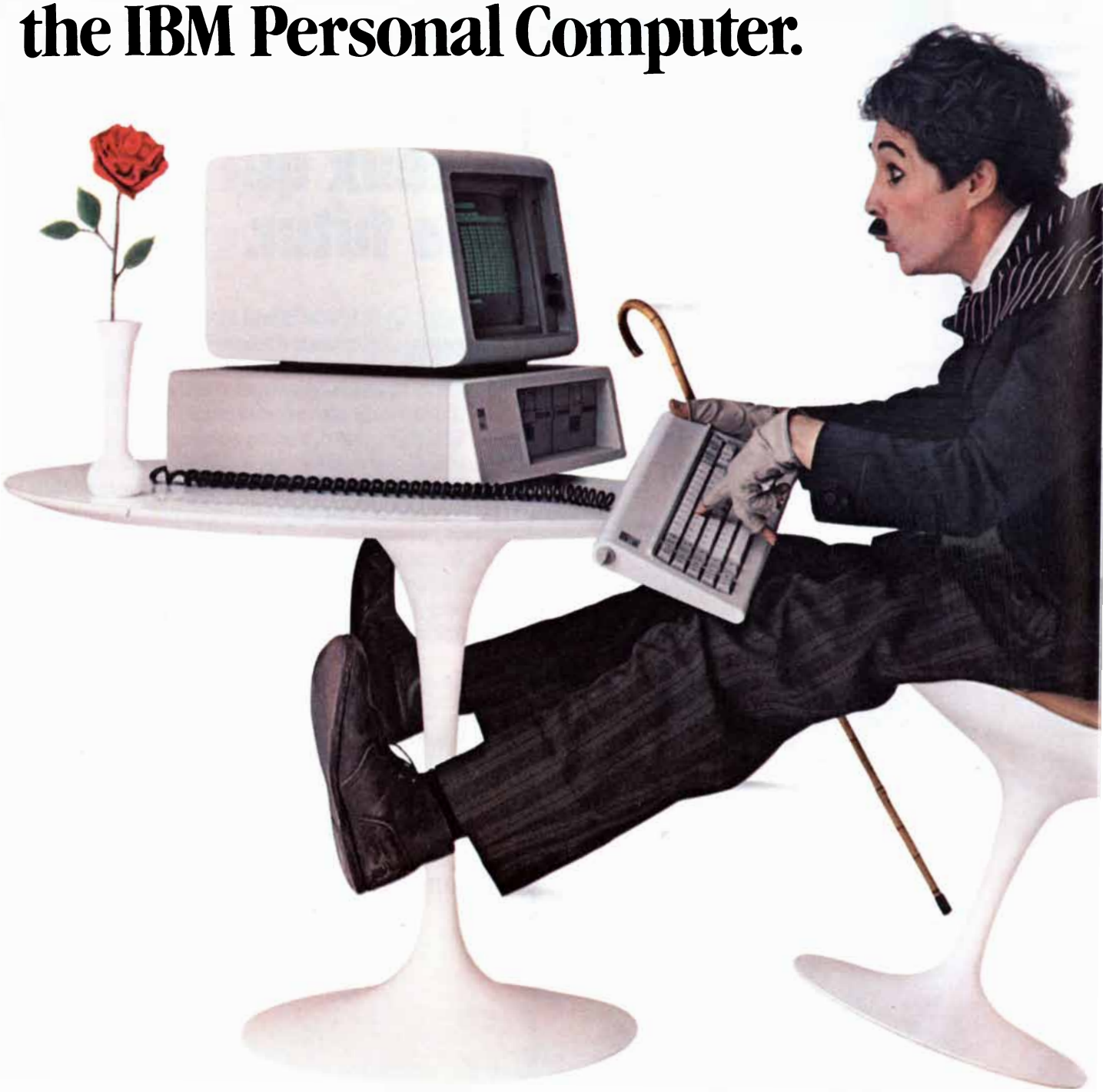
For more information on the French-language edition of SCIENTIFIC AMERICAN contact:

Miguel Tejedor
POUR LA SCIENCE
8, rue Férou
75006 Paris, France
Telephone (011-331) 325-1501

*OJD audited

SCIENTIFIC AMERICAN
We reach the people who make the future happen.

How to test drive the IBM Personal Computer.

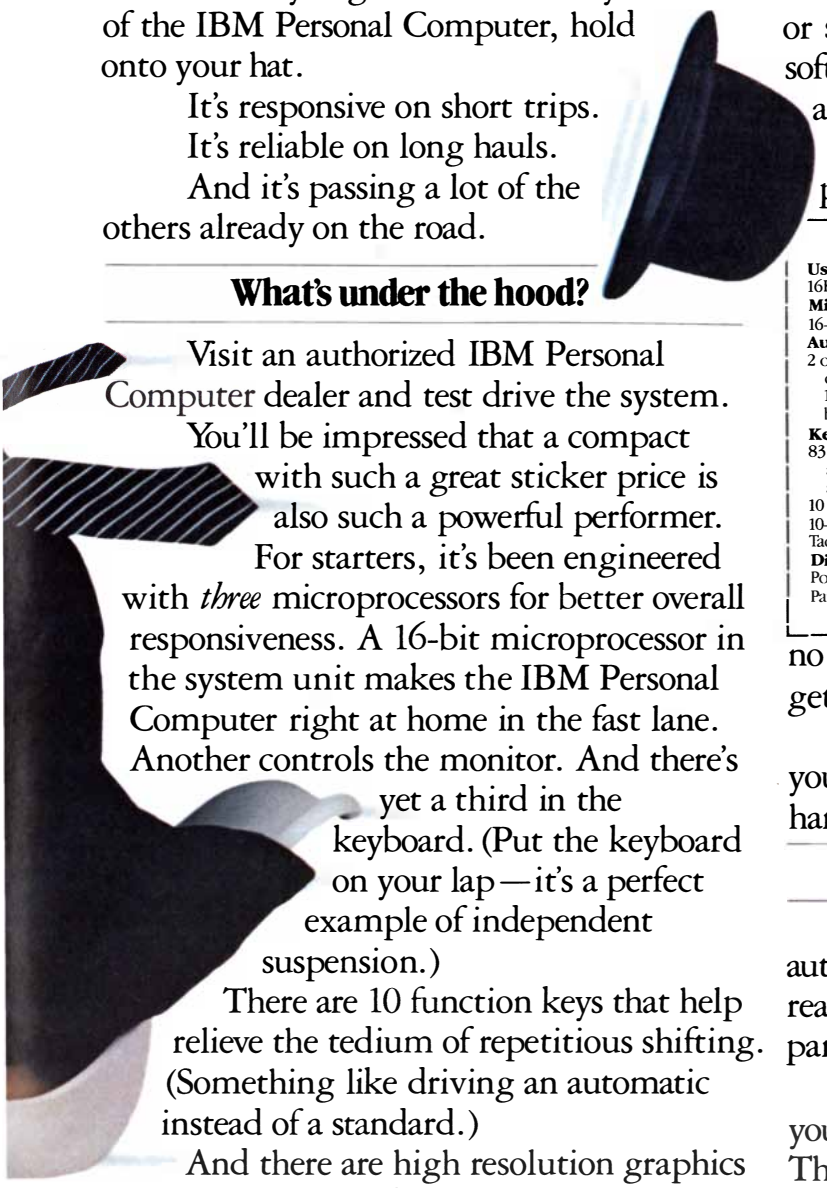


When you get behind the keyboard of the IBM Personal Computer, hold onto your hat.

It's responsive on short trips.

It's reliable on long hauls.

And it's passing a lot of the others already on the road.



What's under the hood?

Visit an authorized IBM Personal Computer dealer and test drive the system.

You'll be impressed that a compact with such a great sticker price is also such a powerful performer.

For starters, it's been engineered with *three* microprocessors for better overall responsiveness. A 16-bit microprocessor in the system unit makes the IBM Personal Computer right at home in the fast lane. Another controls the monitor. And there's yet a third in the keyboard. (Put the keyboard on your lap—it's a perfect example of independent suspension.)

There are 10 function keys that help relieve the tedium of repetitious shifting. (Something like driving an automatic instead of a standard.)

And there are high resolution graphics that could come in first—were there a Grand Prix of personal computers. Get a demonstration of the text and graphics mix. And be sure to see it all in living color. (For more specifics, check out the box at right.)

Easy acceleration.

Whether you plan on using the IBM Personal Computer to manage a department, run a business, teach a course, learn a lesson or simply go on a pleasure drive—there's software to head you in the right direction and to help you stay ahead.

While you're at the store, try a few programs—first hand. Even if you've had no computer experience, you can quickly get into gear.

The driver's manual IBM wrote for you will help simplify matters. And the hardware's been designed to do the same.

IBM PERSONAL COMPUTER SPECIFICATIONS

User Memory
16K-512K bytes*
Microprocessor
16-bit, 8088*
Auxiliary Memory
2 optional internal diskette drives, 5¼", 160K bytes or 320K bytes per diskette
Keyboard
83 keys, 6 ft. cord attaches to system unit*
10 function keys*
10-key numeric pad
Tactile feedback*
Diagnostics
Power-on selftesting*
Parity checking*

Display Screen
High-resolution*
80 characters x 25 lines
Upper and lower case
Green phosphor screen*
Operating Systems
DOS, UCSD p-System, CP/M-86†
Languages
BASIC, Pascal, FORTRAN, MACRO Assembler, COBOL
Printer
Bidirectional*
80 characters/second
12 character styles, up to 132 characters/line*
9 x 9 character matrix*

Permanent Memory
(ROM) 40K bytes*
Color/Graphics
Text mode:
16 colors*
256 characters and symbols in ROM*
Graphics mode:
4-color resolution: 320h x 200v*
Black & white resolution: 640h x 200v*
Simultaneous graphics & text capability*
Communications
RS-232-C interface
Asynchronous (start/stop) protocol
Up to 9600 bits per second

*ADVANCED FEATURES FOR PERSONAL COMPUTERS

They won't steer you wrong.

The trained salespeople at your authorized IBM Personal Computer dealer realize that you may never have been in this particular driver's seat before.

They want you to relax. They want you to ask any question you want to ask. They're ready and willing to provide you with all the answers—and to help pick the system and the software right for you.

For more information on where to buy the IBM Personal Computer, call 800-447-4700. In Illinois, 800-322-4400. In Alaska or Hawaii, 800-447-0890.

You'll see why the IBM Personal Computer doesn't take a back seat to any other system.

IBM®

The IBM Personal Computer
A tool for modern times

†UCSD p-System is a trademark of the Regents of the University of California. CP/M-86 is a trademark of Digital Research, Inc.

A Genetic Switch in a Bacterial Virus

Two regulatory proteins interact with a region of viral DNA to turn one set of genes off and another on in response to an environmental change. The switch is described in terms of its molecular structure

by Mark Ptashne, Alexander D. Johnson and Carl O. Pabo

Certain strains of the bacterium *Escherichia coli* harbor a dormant virus called lambda. If a population of such bacteria is exposed briefly to ultraviolet radiation, viral genes that were previously inactive are suddenly switched on. The viruses proliferate and some 45 minutes after irradiation the bacteria burst, yielding a crop of new virus particles. If the bacteria are not irradiated, on the other hand, they grow normally generation after generation; only rarely does a bacterial cell give rise to viruses spontaneously.

In every organism, from viruses and bacteria to human beings, inherited instructions for growth and development are encoded in genes. The genes are regulated, or turned on and off, as the organism develops and as it adapts to varying conditions. The induction of a bacterial virus as the result of a transient change in the environment is a dramatic example of gene regulation. It was first described soon after World War II by André Lwoff and his colleagues at the Pasteur Institute in Paris [see "The Life Cycle of a Virus," by André Lwoff; SCIENTIFIC AMERICAN, March, 1954]. Gene regulation is easier to study in bacteria than in the more complex cells of higher organisms, and the mechanisms that regulate viral genes in bacteria have been studied in increasing detail ever since Lwoff's original observation.

Now, some 35 years later, the sensitive and efficient molecular mechanism that switches lambda's genes on and off is understood in considerable detail. The switching is done by regulatory proteins that interact with specific segments of viral DNA. In our laboratory at Harvard University the goal has been to describe the interactions in terms of molecular structure. In the first part of this article we shall discuss the essential features of the switch and tell how it works. Our account is based on the results of a long series of biochemical and genetic experiments (which we shall not attempt to describe) that have defined the location and the approximate size and shape of the molecular components of the switch. In the second part we shall report on recent findings concerning the precise three-dimensional structure of some of the regulatory molecules.

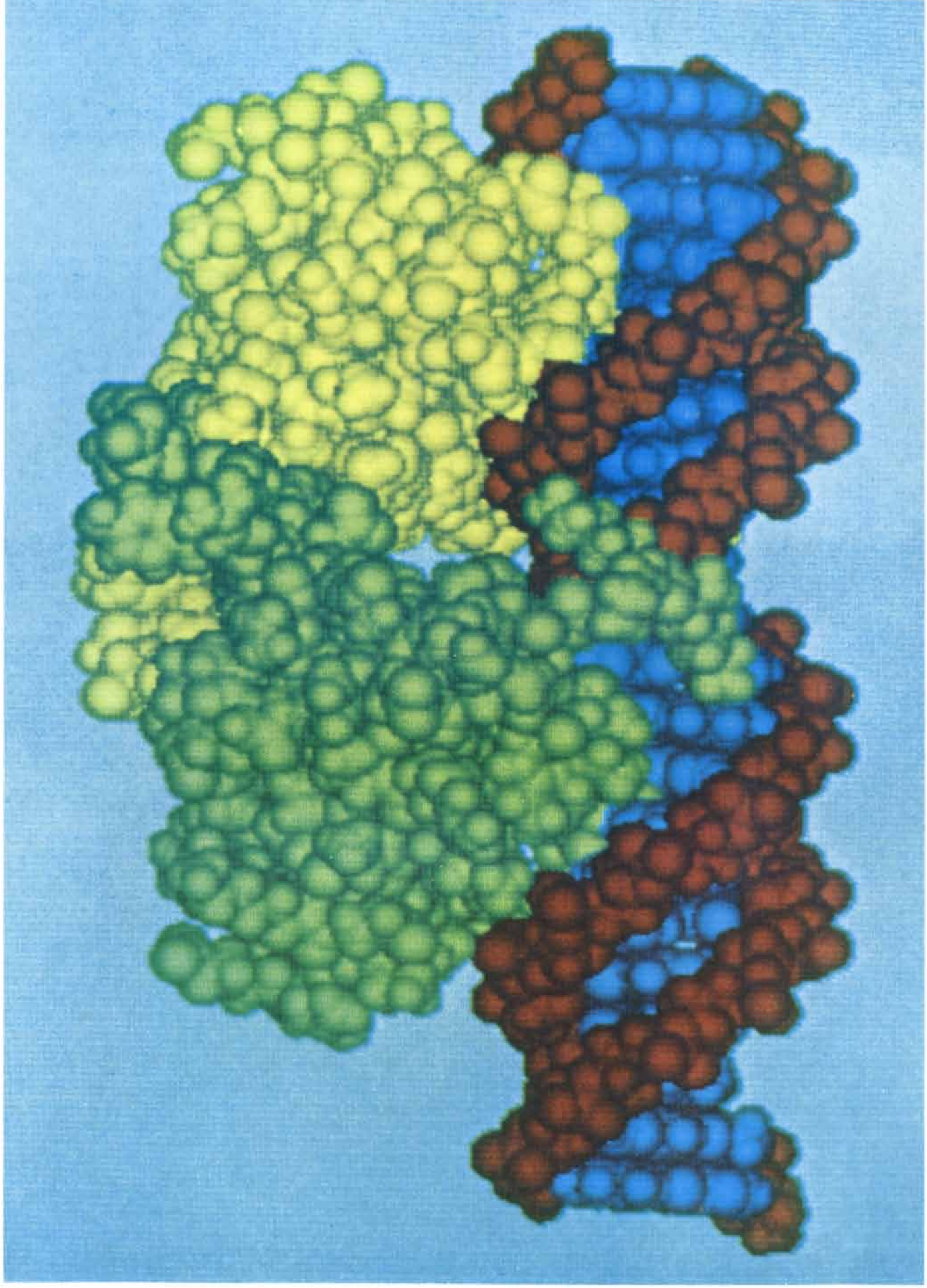
The Lambda Switch

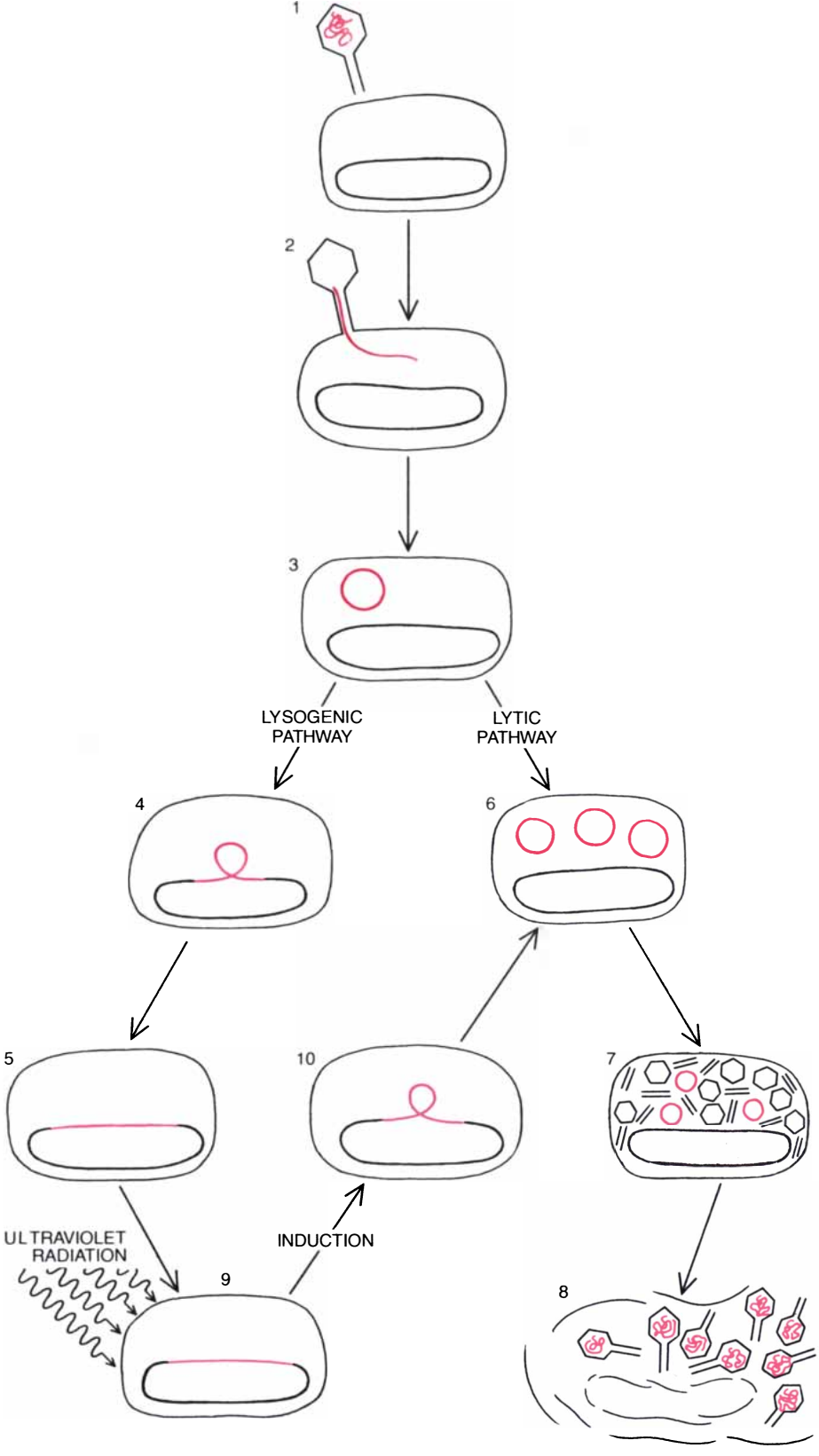
A particle of the lambda virus (or bacteriophage lambda) consists of a long molecule of DNA enclosed in a protective coat of protein. The DNA carries some 35 or 40 genes, each of which codes for a different protein. The virus infects *E. coli* by attaching itself to the bacterial cell and injecting its DNA through the cell wall, leaving the protein coat outside. From this point infection can follow either of two pathways. The viral DNA can direct the synthesis of proteins that replicate it and of other proteins that form a coat to package the newly made DNA. In each cell about 100 new virus particles are assembled in this way. The bacterial cell then lyses, or bursts, releasing the progeny viruses. This sequence of events takes about 45 minutes and is called lytic growth.

Lambda is a "temperate" virus, and so there is another possible outcome of lambda infection. Instead of multiplying in the host cell and thereby destroying it, the virus can switch off its genes and insert its DNA into the host cell's chromosome. Thereafter the viral DNA is replicated passively as a component of the bacterial chromosome and is passed on to the bacterium's own progeny. Such a dormant molecule of viral DNA is called a prophage and the bacterium carrying it is called a lysogen. A prophage can be induced, or activated to begin lytic growth, by many agents in addition to the aforementioned ultraviolet radiation. What all inducing agents have in common is that they damage DNA and thus threaten the viability of the host cell; induction is in effect an escape mechanism for the virus. Most carcinogens damage DNA, and so the induction of prophage in a lysogen provides a sensitive test for carcinogens.

In the two modes of growth of the lambda virus different sets of viral genes are expressed, or translated into proteins. In the prophage state only one prophage gene, designated *c*I, is expressed. It directs the synthesis of one protein: the lambda repressor. The repressor turns off all the other viral genes, including those whose expression leads to lytic growth. The existence of the repressor was predicted in 1961 by François Jacob and Jacques Monod, two of Lwoff's colleagues. Seven years passed

BINDING OF LAMBDA REPRESSOR TO DNA is depicted, on the basis of X-ray-diffraction findings by one of the authors (Pabo) and Mitchell Lewis, in a computer-generated model made by Richard J. Feldmann of the National Institutes of Health. The repressor is a protein encoded by one of the genes of the bacterial virus called phage lambda; it acts with other proteins to control the expression of its own gene and of other viral genes. Each sphere in the model represents an atom. The backbones of the DNA double helix, consisting of alternating sugar and phosphate groups, are in brown; the DNA bases, which form pairs to link the two backbone strands, are in blue. The repressor has two subunits: an amino-terminal domain and a carboxyl-terminal domain. It is the amino-terminal domain that binds to DNA. The repressor binds as a dimer, or double molecule. The model shows the two amino-terminal domains of a dimer, one domain in yellow and the other in green. As is most clearly seen in the case of the upper domain, a part of the domain (designated helix 3) protrudes into the "major groove" of the DNA, where it comes in contact with pairs of bases and thus recognizes a specific site on DNA.





INFECTION OF THE BACTERIUM *Escherichia coli* by the lambda virus begins when a virus particle attaches itself to the bacterial cell (*1*) and injects its DNA into the cell (*2, 3*). Infection can take either of two courses depending on which of two sets of viral genes is turned on (*see illustration on page 132*). In the lysogenic pathway the viral DNA becomes integrated into the bacterial chromosome (*4, 5*), where it replicates passively as the bacterial cell divides. The dormant virus is called a prophage and the cell that harbors it is called a lysogen. In the alternative lytic mode of infection the viral DNA replicates itself (*6*) and directs the synthesis of viral proteins (*7*). About 100 new virus particles are formed. The proliferating viruses lyse, or burst, the cell (*8*). A prophage can be 'induced' by an agent such as ultraviolet radiation (*9*). The inducing agent throws a switch, so that a different set of genes is turned on. Viral DNA loops out of the chromosome (*10*) and replicates; the virus proceeds along the lytic pathway.

before repressors, including the lambda repressor, were first detected biochemically and shown to be proteins by two groups at Harvard, headed by one of us (Ptashne) and by Walter Gilbert; the groups went on to show that each repressor turns particular genes off by binding to specific sites on DNA [see "Genetic Repressors," by Mark Ptashne and Walter Gilbert; SCIENTIFIC AMERICAN, June, 1970]. Since then it has been found that the lambda repressor has an additional important role, which makes its name somewhat inappropriate. Although repressor turns off most viral genes, it stimulates the expression of one gene, namely *c*I, the gene that codes for the repressor itself. The repressor, then, is a positive as well as a negative regulator of gene expression.

In lytic growth a different negative regulator is expressed, and it turns the repressor gene off. The regulatory protein is called cro and the gene that encodes it is designated *cro*. (The origin of the name is now obscure, but it was probably chosen to stand for "control of repressor and other things.") Whereas repressor turns off *cro* along with other genes in a lysogen, cro turns off *c*I during lytic growth. Induction switches repressor synthesis off and cro synthesis on. Remarkably, both repressor and cro work by binding to the same region of the lambda DNA, a region called the right operator (O_R). How can the two control proteins bind to the same region of DNA and yet have opposite effects on gene expression? The first step toward answering this question is to describe the organization of the O_R control region. Before doing that it is necessary to review the structure of viral DNA.

The Right Operator

The lambda DNA molecule consists of two strands of nucleotides wound around a common axis to form a right-handed double helix. Each nucleotide consists of a sugar group, a phosphate group and a base. The backbone of each strand is composed of alternating phosphate and sugar groups; from each sugar a chemical group called a base extends toward the interior of the helix and is linked to a base on the opposite strand by hydrogen bonds. There are four kinds of base: adenine (*A*), guanine (*G*), thymine (*T*) and cytosine (*C*). The sequence of bases along the two chains is complementary. An *A* on one strand is always paired with a *T* on the other, and a *G* is always paired with a *C*. The information content of the DNA is specified by the sequence of bases on either strand. The DNA of the lambda virus has about 45,000 base pairs; a typical gene in lambda is made up of about 1,000 base pairs.

The two strands of nucleotides in a

Audi It is rather puzzling why some carmakers are still building low-performance luxury cars.

Here in Bavaria, Audi engineers find it inconceivable that a true luxury car can't maneuver through the mountain roads of Oberbayern without stumbling, or rocket down the Munich-Salzburg Autobahn without maintaining directional control.

We have never sacrificed mindful performance for mindless luxury.

Granted, we do appreciate thick carpets, sumptuous seats and the like. So, a luxury Audi comes replete with the *de rigueur* amenities that the modern world expects in a car. But it also comes replete with something else: legendary engineering finesse.

Searching constantly for new innovations, such as our front-wheel drive, high-efficiency five-cylinder engines, negative steering roll radius, and torsion crank rear axles is what makes Audi engineering unique.

It makes every Audi we build a driver's car. A performance car.

Indeed, it's not surprising that Audi offers perhaps the greatest variety of performance oriented German automobiles sold in America, including the 5000, the 5000 Turbo and Turbo Diesel, Quattro, Coupe, and the 4000 Gas and Diesel.

After all, who takes performance more seriously than Audi?

For your nearest Porsche Audi dealer or details on the Audi Delivery In Europe Program, call toll free (800) 447-4700. In Illinois, (800) 322-4400.

PORSCHE+AUDI

Audi: the art of engineering.

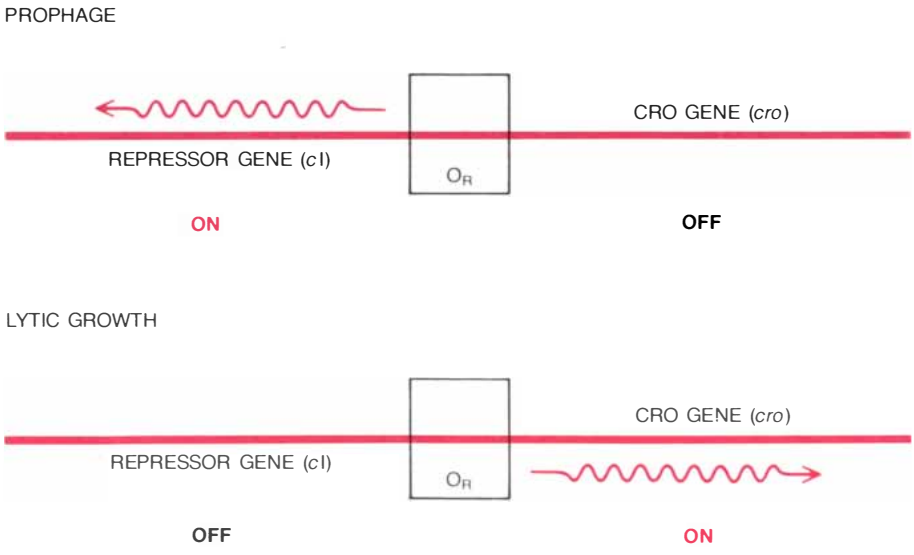
DNA molecule are wound in such a way that two grooves run the length of the molecule in a helical path, like the groove between the threads of a screw. One groove is wider and is called the major groove; the other is the minor groove. The pairs of bases are in the center of the molecule between the sugar-phosphate chains, but the bases are partially exposed in the two grooves.

There are two ways of gaining access to the information content of DNA. One decoding process is employed when a gene directs the synthesis of a protein. The enzyme RNA polymerase partially unwinds the DNA strands and transcribes the base sequence of one strand into a molecule of messenger RNA, which is similar to DNA in structure but which remains single-stranded. The actual translation of the information into protein is done by complex molecular machinery that assembles a chain of amino acids, the subunits of proteins. Each amino acid is specified by a three-base "codon" in the RNA. The chain of amino acids folds spontaneously into a characteristic three-dimensional form determined by the sequence of amino acids and hence ultimately by the sequence of bases in the gene.

A different DNA-recognition system is exploited by regulatory proteins such as the lambda repressor and cro. These proteins must find a particular region on the DNA molecule (in this case O_R) and attach themselves to it, but they do not unwind the double helix. Instead they (figuratively) examine the major groove in double-strand DNA and bind to the appropriate sequence of bases.

The right operator is a region of the lambda DNA 80 base pairs long. Immediately to its right (as lambda DNA is conventionally diagrammed) is the cro gene and immediately to its left is the repressor gene. The operator DNA, which is not translated into protein, includes three discrete recognition sites, designated O_R1, O_R2 and O_R3. Each site is 17 base pairs long, and the base sequences of the three sites are similar but not identical [see "A DNA Operator-Repressor System," by Tom Maniatis and Mark Ptashne; SCIENTIFIC AMERICAN, January, 1976]. Significantly, either repressor or cro can bind to any of the sites.

In addition to the three recognition sites the region between the cro and the repressor genes also includes two sequences that are called promoters. A promoter is a sequence of bases that directs RNA polymerase to bind to it in a specified orientation and to begin transcribing the adjacent genes in a specified direction. One of the promoters directs the RNA polymerase to proceed in the rightward direction, transcribing *cro* and some other genes farther downstream whose products have a role in the early stage of lytic growth. The other promoter is oppositely oriented, and it directs the polymerase to read leftward, so that the repressor gene is transcribed. The two divergent promoters overlap the operator sites to which repressor and cro bind. This spatial arrangement of the promoters and the operator sites is crucial to the mechanism of the lambda switch. A regulatory molecule bound to its recognition site (or sites) in the operator region necessarily keeps polymerase from binding to one promoter or the other, thereby blocking transcription either to the right or to the left.



MOLECULAR SWITCH determines which of two sets of genes is turned on and thereby commits the virus either to the prophage state or to lytic growth. The switch is in a region of the viral DNA called the right operator (O_R), which is flanked by genes encoding two regulatory proteins. Gene *c*I encodes the lambda repressor and gene *cro* encodes cro, another regulatory protein. In the prophage state *c*I is turned on, that is, it is transcribed into RNA (*wavy line*), which is translated to make repressor; *cro* is turned off. In the early stages of lytic growth *c*I is switched off; *cro* is turned on and transcribed into RNA, which is translated to make cro protein.

The Two Proteins

The lambda repressor gene (*c*I) directs the synthesis of a protein chain composed of 236 amino acids. The chain folds into two globular domains, or substructures, connected by a short link. The two domains have different functions. The domain that includes the amino (NH_2) terminus of the chain binds to the operator DNA. The other domain, which includes the carboxyl (COOH) end of the chain, has no direct role in DNA binding. Rather, it has sites that make single repressor molecules (monomers) tend to associate to form double molecules (dimers). The link connecting the amino and the carboxyl domains is particularly sensitive to cleavage by proteases, the enzymes that cut proteins, and so the two domains can easily be separated and studied individually.

A dimer of repressor molecules binds to the DNA much more tightly than a monomer does. Binding reactions are on-and-off affairs; a molecule that is said to bind tightly is simply one that is more often bound than unbound. A repressor dimer binds tightly because when one monomer momentarily lets go of the DNA, the other monomer is likely still to be holding. It is therefore the dimers that bind to O_R and control gene expression. In addition to the dimers bound to the operator there are some 200 other repressor chains in the cell. Most of them form dimers, but many of them remain in the form of free monomers. The tendency of the dimers to dissociate into monomers turns out to have important implications for the sensitivity of the switch mechanism.

Cro is much smaller than repressor and its chain of 66 amino acids folds into a single domain. Like repressor, it binds to the sites in O_R as a dimer. Cro's single domain must therefore have a site that mediates dimerization as well as one that binds to DNA.

To understand the essential elements of the genetic switch one can picture a repressor dimer as a pair of dumbbells and a cro dimer as a pair of spheres. At each of the three 17-base-pair sites in O_R a dimer of either repressor or cro can attach itself. A key feature of the switch mechanism is that repressor and cro differ in their affinity for the three sites. Indeed, their order of preference is opposite. It is largely because the two regulatory molecules tend to bind to different sites that they have opposite effects on transcription.

Gene Control in a Lysogen

In a lysogen, where the viral DNA has been inserted into the bacterial chromo-

"THE COMMODORE 64 COULD BE THE MICROCOMPUTER INDUSTRY'S OUTSTANDING NEW PRODUCT INTRODUCTION SINCE THE BIRTH OF THIS INDUSTRY."

–SHEARSON/AMERICAN EXPRESS

The Commodore 64,™ to judge from the above comment, is generating as much excitement among the people who invest in companies as it is among the people who run them.

The reason for this is that, for the first time, high-level computer power is limited only by the inclination to have it, rather than the means.

HALF THE COST = TWICE THE PRODUCTIVITY.

This simple equation reflects the Commodore 64's most basic—and outstanding—qualifications.

Its standard memory is 64K. Which is unusual enough in a micro at any price.

At $595, it is astonishing.

Compared, for example, with the Apple II+,® the Commodore 64 offers 33% more power at considerably less than 50% of the price.

Compared with anything else, it's even more impressive.

And if you're a businessman, it can effectively double your computer-equipped work force.

PILE ON THE PERIPHERALS.

Because the basic cost of the Commodore 64 is so low, you can afford more peripherals for it. Like disk drives, printers and a telephone modem.

For about the price of an Apple II+ computer alone, you could equip your company with a Commodore 64, disk drive, printer and modem.

HARD FACTS ABOUT SOFTWARE.

The Commodore 64 will be able to run virtually any program important to business and industry.

Commodore software will include an electronic spreadsheet; business graphics (including printout); a user-definable diary/calendar; word processing; mailing lists; an electronic mail program; and much more.

Even programs that can teach operators how to program.

It is programmable in BASIC.

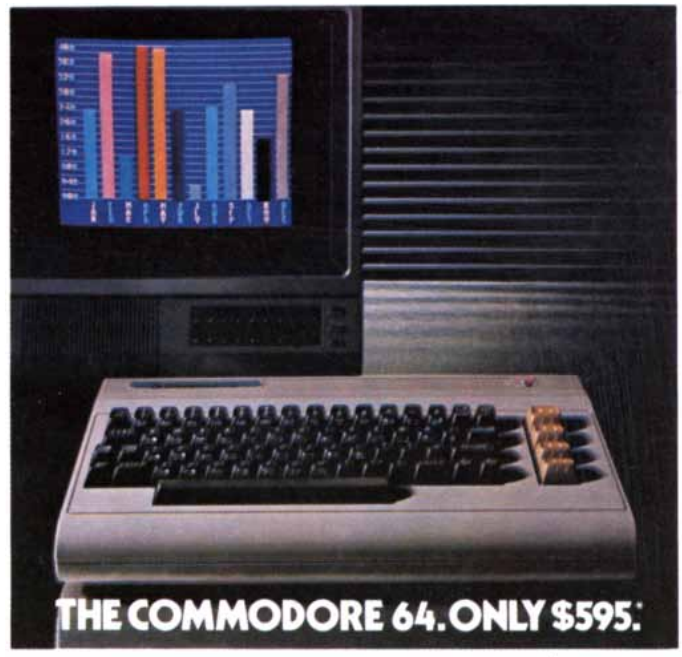
With the added CP/M® option, you can have access to hundreds of existing software packages.

In short, its applications are virtually limitless.

THE FUN SIDE OF POWER.

The Commodore 64 can become very playful at a moment's notice.

You can use it with Commodore's game cartridges or invent your own diversions. All will be enhanced by brilliant video quality and high resolution graphics (320 x 200 pixels, 16 available colors, 3D Sprite graphics), plus its own unique music synthesizer.



NOW'S YOUR CHANCE.

If you've been waiting for the "computer revolution," consider it as having arrived.

Through its 25 years of existence, Commodore has been committed to delivering better products at lower prices.

Today, the company's vertical integration has resulted in the Commodore 64's price performance breakthrough heralded by Shearson/American Express.

So if you run a company, you couldn't make a more cost-efficient capital investment.

For more information, contact your local Commodore dealer, or send in this coupon.

Commodore Business Machines/Personal Systems Division
P.O. Box 500, Conshohocken, Pennsylvania 19428

Please send me more information on the Commodore 64.™

Name_____

Title_____ Company_____

Address_____

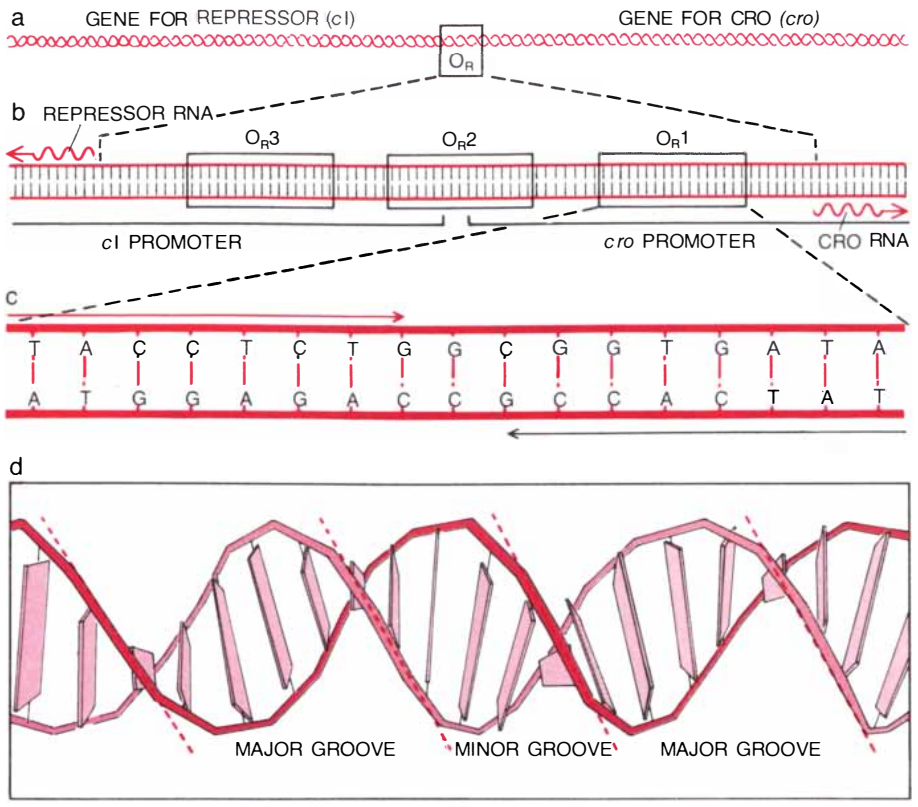
City_____ State_____

Zip_____ Telephone_____

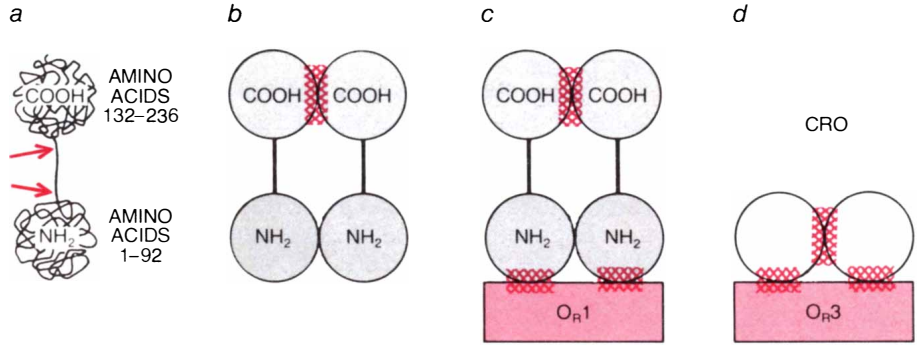
commodore COMPUTER

SA-11

CP/M® is a registered trademark of Digital Research, Inc. *Manufacturer's suggested retail price: July 1, 1982. Disk drives, printers and monitors are not included in price. The 64's price may change without notice.



RIGHT OPERATOR (O_R) is shown in increasing detail in this series of drawings. The operator is a region of the viral DNA some 80 base pairs long (*a*). To its left lies the gene (*cI*) encoding lambda repressor, to its right the gene (*cro*) encoding the regulatory protein cro. When the operator region is enlarged (*b*), with the DNA's sugar-phosphate backbone in color and the base pairs in black, it is seen to include three subregions, each 17 base pairs long: O_R1, O_R2 and O_R3. They are recognition sites to which repressor and cro can bind. The recognition sites overlap two promoters: sequences of bases to which the enzyme RNA polymerase binds in order to transcribe a gene into RNA (*wavy lines*), which is translated into protein. Site O_R1 is enlarged (*c*) to show its base sequence. The four bases are adenine (*A*), guanine (*G*), thymine (*T*) and cytosine (*C*). The bases are complementary, *A* pairing with *T* and *G* pairing with *C*. The O_R1 site has partial twofold rotational symmetry: the sequence of bases read on opposing strands from opposite ends toward the middle (*black and colored arrows*) is quite similar. Such palindromic symmetry is characteristic of many protein-binding sites in DNA. The spatial arrangement of the two backbone strands and the base pairs connecting them (*d*) is such that the double helix has major and minor grooves; portions of the base pairs are exposed in the grooves.



LAMBDA-REPRESSOR PROTEIN is a chain of 236 amino acids. The chain folds itself into a dumbbell shape with two substructures: an amino-terminal (NH_2) domain and a carboxyl-terminal (COOH) domain. The two domains are linked by a region of the chain that is susceptible to cleavage by proteases, or enzymes that cut protein chains; the enzyme papain cleaves the link at the sites indicated by the colored arrows (*a*). Single repressor molecules (monomers) tend to associate to form dimers (*b*); a dimer can dissociate to form monomers again. A dimer is held together mainly by contact between the carboxyl-terminal domains (*hatching*). Repressor dimers bind to (and can fall off) the recognition sites in the operator region; their greatest affinity is for site O_R1 (*c*). It is the amino-terminal domain of the repressor molecule that makes contact with the DNA (*hatching*). Cro (*d*) has a single domain with sites that promote dimerization and other sites that promote binding of dimers to operator, preferentially to O_R3.

some and is dormant, repressor dimers occupy O_R1 and O_R2 but leave O_R3 vacant. The events that lead to this state of affairs are as follows. Repressor is attracted most strongly to site O_R1, and it binds there first. Once a repressor dimer is bound to O_R1, site O_R2 becomes much more attractive to another repressor dimer and O_R2 is filled immediately. Without this help O_R2 would not be occupied unless the concentration of repressor dimers were higher than it usually is in a lysogenic cell. The helping effect—the stimulation by an event at O_R1 of a similar event at O_R2—is an example of the phenomenon called cooperativity.

Whereas repressor dimers bind cooperatively to sites O_R1 and O_R2, the repressor bound at O_R2 does not ordinarily aid the binding of another repressor to O_R3, and so the third site remains free of repressor. Only if the concentration of repressor were to increase greatly above that found in a lysogen would O_R3 be filled.

What is the mechanism of the cooperative binding of repressor dimers? It is likely that the carboxyl-terminal domain of the dimer bound at O_R1 makes contact with the carboxyl-terminal domain of another dimer and thereby helps the second dimer to bind at O_R2. We suggest this mechanism because experiments show that removal of the carboxyl-terminal domain abolishes the cooperativity of repressor. If a dimer at O_R1 helps to bring another dimer to O_R2, however, why is it that the second dimer does not assist a third in binding to O_R3? The section of the repressor chain that links the domains is flexible enough for the dimer at O_R2 to "lean" either to the left or to the right to contact an adjacent DNA-bound repressor, but the dimer cannot simultaneously come in contact with both neighbors. We imagine that a repressor dimer bound to O_R2, brought there by contact with the dimer to its right (at O_R1), is not free to lean to the left and interact with another repressor at O_R3. This explanation is supported by the finding that in a mutant virus whose DNA lacks O_R1 we do detect an interaction between repressors bound at O_R2 and O_R3.

The configuration of repressors at O_R in a lysogen (O_R1 and O_R2 filled, O_R3 vacant) has opposite effects on the expression of the adjacent cro and repressor genes. First, the repressors bound at sites O_R1 and O_R2 mask DNA sequences within the rightward promoter and thereby keep RNA polymerase from binding to that promoter. This prevents rightward transcription and so turns off *cro* and other lytic genes. Second, the bound repressors actually stimulate the synthesis of more repressor. When repressor dimers are bound at O_R1 and O_R2, polymerase binds to the

promoter of the repressor gene and begins leftward transcription about 10 times more frequently than it does in the absence of repressor. (This stimulatory effect was unknown when repressor was named.)

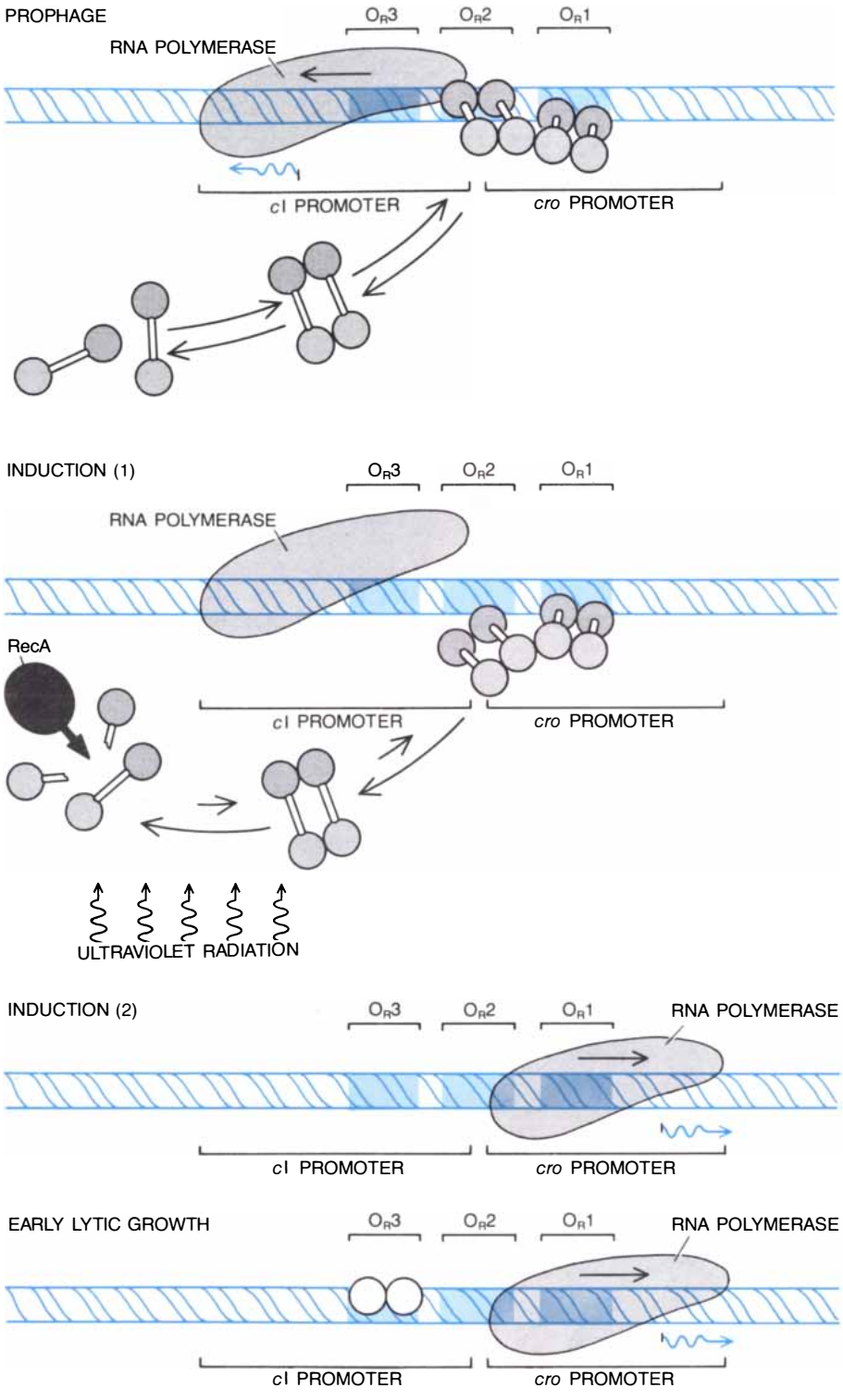
How does repressor activate transcription of the repressor gene? We think repressor bound at O_R2 touches polymerase, helping it to bind to the promoter and begin transcription. The interaction of repressor and polymerase is somewhat similar to the cooperative interaction of two repressor dimers. Whereas the carboxyl-terminal domains are responsible for the cooperative binding of dimers at O_R1 and O_R2, however, it is the amino-terminal domain of repressor at O_R2 that influences the binding of RNA polymerase. Repressor bound only at O_R1 does not stimulate polymerase binding to the repressor-gene promoter. O_R1 must nonetheless be intact if the gene is to be transcribed because a repressor dimer must bind there to ensure that another dimer will be bound to O_R2.

The Switch

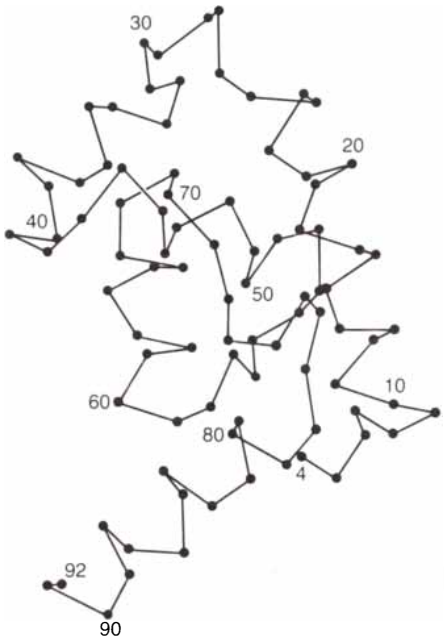
When an *E. coli* lysogen harboring a lambda prophage is exposed to an inducing signal, that is, a DNA-damaging agent such as ultraviolet radiation, the lambda repressor is inactivated. The mechanism of this effect was worked out largely by Jeffrey W. Roberts of Cornell University with colleagues at Cornell and Harvard. They have shown that DNA damage causes a cellular protein called RecA to function as a protease. Ordinarily RecA catalyzes the recombination of DNA molecules. Remarkably, some factor produced as a result of DNA damage (perhaps short single strands of DNA) binds to the protein and causes it to change its activity and become a protease.

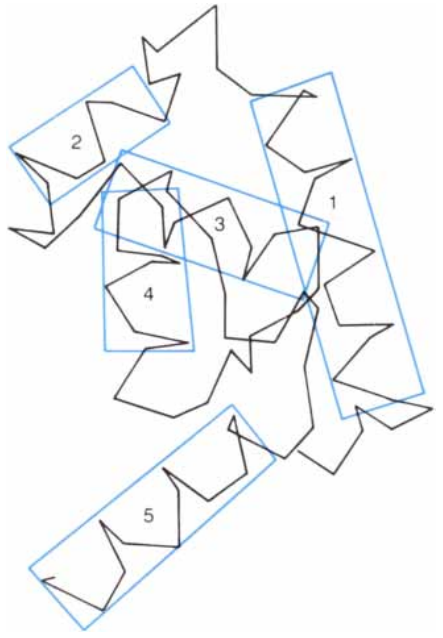
The protease cleaves lambda-repressor monomers at a site between the two domains, thereby separating the carboxyl-terminal domain from the amino-terminal one. The amino-terminal fragments do not dimerize efficiently and therefore do not bind efficiently to the operator. As a consequence the equilibrium favoring the binding of repressor to DNA is reversed. Bound dimers that fall off the DNA dissociate and the resulting monomers are cleaved. The cell's concentration of repressor dimers falls and soon both O_R1 and O_R2 are vacated.

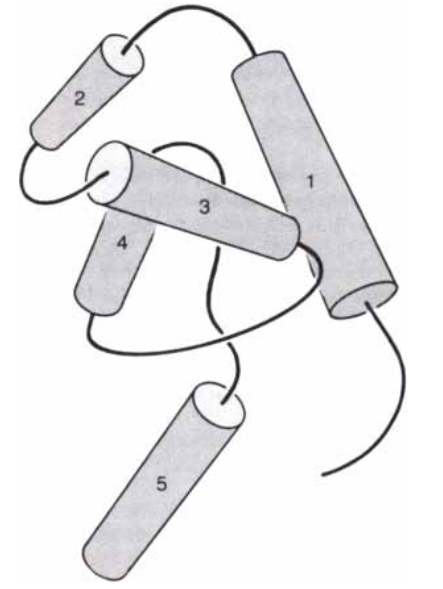
This has two important consequences. First, the rate of new repressor synthesis drops because there is no repressor bound at O_R2 to stimulate the transcription of the repressor gene. Second, the rightward promoter is freed from repression. Now RNA polymerase can get to the rightward promoter and be-



CONFIGURATION OF THE SWITCH is shown at four stages of lambda's life cycle. The lysogenic path (in which the virus remains dormant as a prophage) is selected when a repressor dimer binds to O_R1, thereby making it likely that O_R2 will be filled immediately by another dimer. In the prophage (*top*) the repressor dimers bound at O_R1 and O_R2 prevent RNA polymerase from binding to the rightward promoter and so block the synthesis of cro (negative control). The repressors also encourage the binding of polymerase to the leftward promoter (positive control), with the result that the gene *c*I is transcribed into RNA (*wavy line*) and more repressor is synthesized, maintaining the lysogenic state. The prophage is induced when ultraviolet radiation activates the protease RecA, which cleaves repressor monomers. The equilibrium of free monomers, free dimers and bound dimers is thereby shifted, and dimers leave the operator sites. Polymerase is no longer encouraged to bind to the leftward promoter, so that repressor is no longer synthesized. As induction proceeds all the operator sites become vacant, and so polymerase can bind to the rightward promoter and cro is synthesized. During early lytic growth a single cro dimer binds to O_R3, the site for which it has the highest affinity. Now polymerase cannot bind to the leftward promoter, but the rightward promoter remains accessible. Polymerase continues to bind there, transcribing *cro* and other early lytic genes. Lytic growth ensues.







gin transcribing *cro* and other genes required for lytic growth.

We mentioned above that cro binds to the same three sites in O_R as repressor, but that cro binds with a site preference opposite to that of repressor. This difference underlies the switching mechanism and explains the opposite physiological effects of repressor and cro. Cro binds most tightly to O_R3; only at high concentrations does it occupy O_R1 and O_R2. Unlike repressor dimers, cro dimers do not bind cooperatively to adjacent sites on the DNA, and cro does not facilitate the binding of RNA polymerase to the promoter.

As soon as the operator is vacated by repressor the synthesis of cro begins. The first newly synthesized molecules of cro bind to O_R3. In this position a cro dimer covers part of the repressor gene's promoter, preventing transcription of the repressor gene and so abolishing the synthesis of repressor. On the other hand, cro at O_R3 does not interfere with the binding of polymerase to the rightward promoter; rightward transcription of *cro* and a number of other early lytic genes proceeds unimpeded. The genetic switch has been thrown; the dormant virus is committed to grow lytically. As lytic growth continues, the concentration of cro increases until it fills O_R1 and O_R2 as well as O_R3. This turns off the transcription of all the early lytic genes, including *cro*. The delayed repression of rightward transcription, which halts the synthesis of products needed for the early stages of viral growth, is apparently necessary if the later stages are to proceed on schedule.

Sensitivity of the Switch

The genetic switch we have described is ordinarily very stable, and yet it is readily flipped in response to certain environmental signals. Whereas the prophage in a lysogen is induced spontaneously only about once in every million cell divisions, transient treatment with an inducing agent triggers full induction in virtually every cell in the bacterial culture.

We think several features of the switch's design contribute to its sensitivity: repressor dimerization, the cooperative nature of repressor's binding to DNA and repressor's activation of its own synthesis. A detailed quantitative discussion is beyond the scope of this article, but the following description gives the essential ideas. As RecA cleaves lambda repressor monomers, the concentration of unbound repressor dimers in the cell falls rapidly. (The concentration of dimers varies with the square of the monomer concentration.) When a repressor dimer bound cooperatively to the operator falls off the DNA, it tends to dissociate to monomers, which are cleaved before they can rebind. As the operator is vacated the rate of new repressor synthesis drops because continued transcription of the repressor gene depends on activation by DNA-bound repressors.

The three special features of the switch combine to amplify the effect of the initial destabilizing event: the cleavage of repressor monomers by RecA. The inactivation of repressor quickly leads to the synthesis of cro, which in turn, as we have described, abolishes further repressor synthesis and commits the phage to pursue lytic growth. The lambda switch poises the system so that a moderate change in the intracellular concentration of repressor—less than tenfold—has a drastic effect on gene expression.

We have studied comparable switches in two other temperate viruses of bacteria: phage 434, which also infects *E. coli,* and phage P22, which infects a different bacterium, *Salmonella.* Like lambda, these viruses can become prophages that are efficiently induced by ultraviolet radiation. We have found that 434 and P22 have switches similar to lambda's; indeed, the correspondences are remarkable. The repressor, cro and operator of 434 and P22 differ in detail from those of lambda, but in each case we find these features: a tripartite operator, a repressor and a cro that bind with the opposite site preferences, stimulation by repressor of its own synthesis, cooperative repressor binding to the sites O_R1 and O_R2 and repressor dimers that readily fall apart into monomers that are sensitive to cleavage by RecA protease. The fact that these features are widespread supports our view that they are important components of the switch's operation.

The analysis of the switch we have presented above leaves several important questions unanswered. How do repressor and cro bind selectively to the operator sites and not to other regions of the DNA? Is a common strategy exploit-

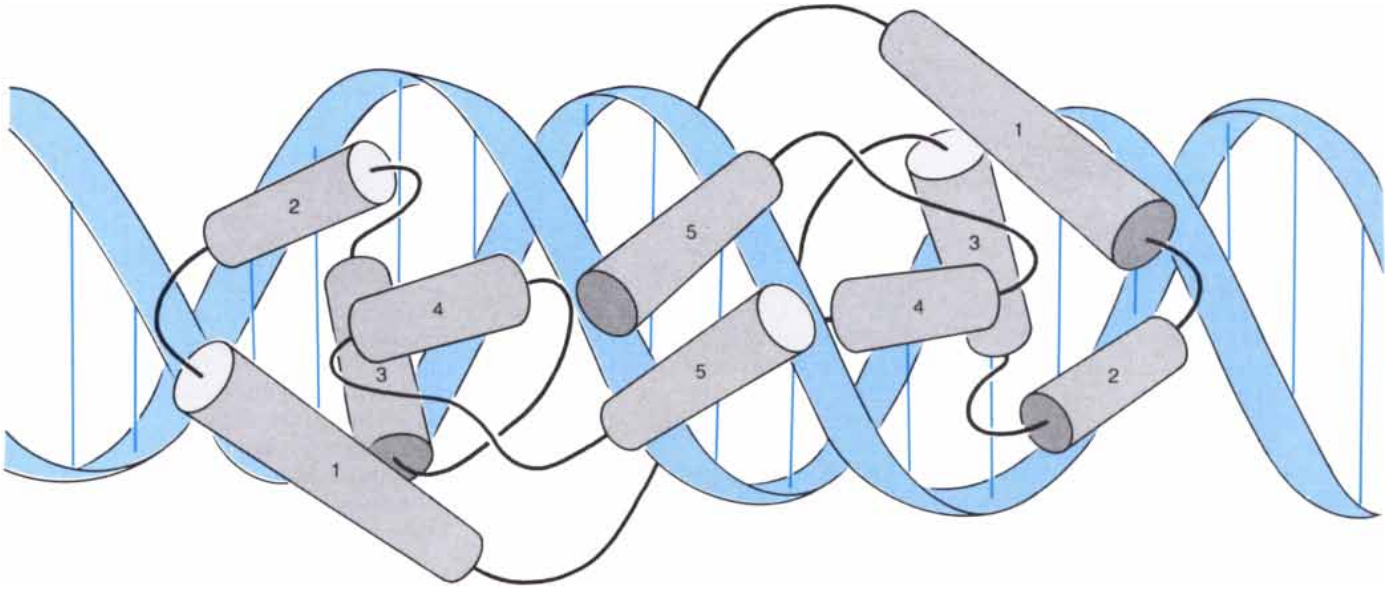
STRUCTURE of amino-terminal domain of the lambda repressor was determined by X-ray crystallography. The drawing at the top shows the folding of the protein chain (flattened into two dimensions). Each dot represents an amino acid, or more specifically the central carbon atom of an amino acid. (The first three amino acids of the chain are not shown; the beginning of the chain is so flexible that their position varies in different molecules of a crystal.) Five regions of the chain are in the form of an alpha helix; those regions are outlined by rectangles in the middle drawing. In the schematic model of the domain at the bottom the five helixes are represented as cylinders, which are connected by lines representing the nonhelical regions of the domain. Helix 3 protrudes from the surface, in this view extending upward. A flexible arm extends from the amino end of helix 1.

ed by all regulatory proteins for recognizing specific base sequences? How valid is the notion that repressor stimulates transcription of its own gene by coming in contact with RNA polymerase? To begin answering these questions we must consider the three-dimensional structure of repressor and cro.

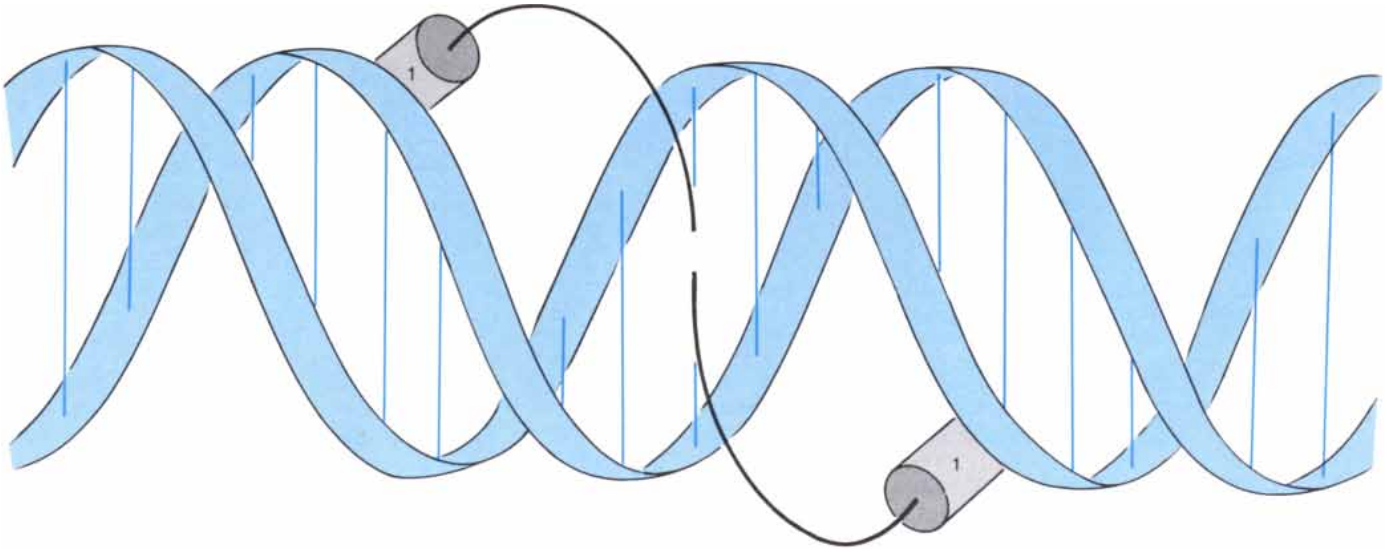
Protein Structure and Function

Together with Mitchell Lewis, one of us (Pabo) has determined the precise three-dimensional structure of the lambda repressor's amino-terminal domain, the part of the molecule that binds to DNA. After an unsuccessful attempt to crystallize the intact repressor molecule for analysis by X-ray crystallography, the amino-terminal domain was separated from the carboxyl-terminal domain by treatment with the enzyme papain. Then the amino-terminal domain was purified and crystallized and the crystals were analyzed by X-ray diffraction. The method yields a map of electron densities that can be interpreted to reveal the position of each atom in the protein. The amino-terminal domain was found to have five regions where the protein chain forms an alpha helix, a particularly stable configuration seen in many proteins. The five alpha helixes are connected by four nonhelical regions. At the amino terminus itself a long, flexible arm extends from the body of the domain.

Knowing the three-dimensional structure of the repressor's DNA-binding domain enabled Pabo and Lewis to propose a plausible model for how repressor binds to an operator site. According to the model, the two amino-terminal domains of a dimer fit against a single repressor binding site in the operator. One alpha helix (helix 3) protrudes from the surface of each domain and fits neatly into the major groove on the surface of the DNA double helix. An adjacent alpha helix (helix 2) is also close to the DNA, although it does not protrude into either groove; part of helix 2 may be in contact with the DNA backbone. In addition the flexible arm that extends from each repressor molecule encircles the DNA near the middle of the operator site. We think several weak but specific



TWO AMINO-TERMINAL DOMAINS of a dimer are thought to bind to DNA in the way shown here. The two domains, positioned symmetrically, just cover a single operator site. (Here the domains have been rotated so that helix 3 is closest to the DNA.) The helix 3 of each domain protrudes into the DNA's major groove, where it presumably makes contact with specific bases. Helix 2 may come in contact with the DNA's backbone. The helix-5 regions of the two domains may interact with each other to help stabilize bound complex.



FLEXIBLE ARMS at the amino end of helix 1 on each domain extend around the "back" of the DNA and make additional contacts with the major groove. The arms are thought to wrap around the DNA after the body of the dimer has bound to the "front" of the DNA.

chemical bonds are formed between the amino acids in alpha helix 3 and portions of the base pairs exposed in the major groove of the DNA. The flexible arm also makes specific contacts on the "back" of the helix, again in the major groove. We are now trying to learn exactly which amino acids interact with which bases and thus how the various contacts determine specificity.

A comparison of the structure of the amino-terminal domain of the lambda repressor with the structure of lambda's cro suggests that a number of fundamental principles underlie the mechanism of various specific protein-DNA interactions. The structure of cro was reported last year by Brian W. Matthews of the University of Oregon and his colleagues. In some ways the two proteins are quite different. Cro lacks the amino-terminal arm that repressor wraps around the DNA; unlike repressor, cro has regions in which the protein chain is folded into a structure called a beta pleated sheet. Yet some parts of the two molecules are remarkably similar. Cro has three alpha helixes, and the third helix protrudes from each monomer and fits into the major groove of DNA, as does repressor's helix 3. The second helix of cro, like helix 2 of repressor, is positioned close to the DNA and may make contact with the DNA's sugar-phosphate backbone. Although the arrangement in space of helixes 2 and 3 is the same in repressor and cro, the sequence of amino acids in the helixes is not the same. That is what one would expect. We think it is precisely the differences in sequence (particularly in helix 3) that enable repressor and cro to make different specific contacts in the major groove and thereby to discriminate among the three similar (but subtly different) binding sites in the operator.

The spatial arrangement of helixes 2 and 3 in repressor and cro may be characteristic of many other DNA-binding proteins as well. Thomas A. Steitz of Yale University and his colleagues have determined the structure of the CAP protein, a regulatory protein of *E. coli*. It too has two alpha helixes in a region that can come in contact with DNA. The Matthews and Steitz groups, comparing their findings, noticed that the spatial arrangement of the two alpha helixes in CAP is virtually identical with the arrangement of cro's helixes, which we now know is also the same as that of repressor's helix 2 and helix 3.

Matthews' group and another headed by Robert T. Sauer of the Massachusetts Institute of Technology have noted further that the amino acid sequences of a large number of proteins that bind to specific sites on DNA correspond in a limited but striking way. The similarities suggest that in each case pairs of helixes arranged like the helixes 2 and 3 of lambda repressor bind to DNA. We imagine that in each case one helix, analogous to helix 2 of lambda repressor and lambda cro, contacts the DNA backbone. The other helix, analogous to helix 3, would fit into the DNA major groove. The particular amino acids along the latter helix would then interact with a particular sequence of bases in the DNA and thereby enable the protein to find its operator site.

Positive Control

Our model of repressor structure provides support for our proposal, originally based on biochemical and genetic experiments, of a mechanism by which repressor stimulates the transcription of its own gene. As the reader will recall, we proposed that an amino-terminal domain of repressor bound at O_R2 contacts RNA polymerase and helps it bind to the promoter. Knowledge of repressor structure made it possible to specify the exact orientation of repressor when it is bound to O_R2. Although little is known about the structure of RNA polymerase, we were able to delineate the region of DNA that would be covered by an RNA-polymerase molecule bound to the promoter, and so we could predict what part of the surface of an adjacent DNA-bound repressor would touch the polymerase. Our model suggested that polymerase contacts repressor in the region of repressor's helix 2 and at the bend between helix 2 and helix 3. Presumably the particular sequence of amino acids along this surface of repressor promotes a fruitful interaction with polymerase. If the sequence were changed, repressor would presumably no longer be able to stimulate the binding of polymerase.

To test our hypothesis workers in our laboratory isolated a class of mutant lambda viruses whose repressors bind DNA normally (or nearly so) but have lost the ability to stimulate the binding of polymerase; the DNA-binding site is intact in the mutant repressors, but the site that contacts polymerase has been damaged. When the amino acid sequence of the three mutant repressors was determined, each protein turned out to bear a single amino acid substitution either in helix 2 or in the bend connecting helix 2 to helix 3. Each of the changes lies along the surface of the protein we predicted must contact polymerase. Moreover, each of the substitutions increases the positive charge of that surface. Whether the increase in positive charge has a role in reducing the influence of the repressor on polymerase cannot be established until we know more about the structure of polymerase.

Our analysis indicates that in the case of lambda repressor the requirements

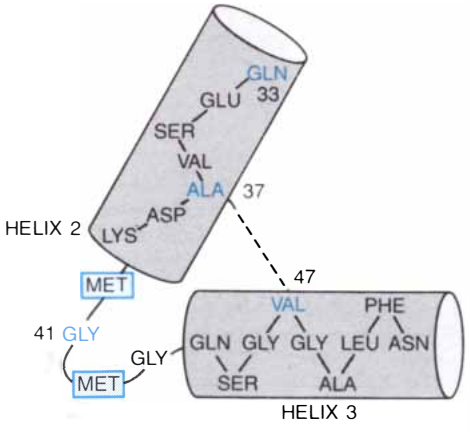
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
LAMBDA REPRESSOR	GLN	GLU	SER	VAL	ALA	ASP	LYS	MET	GLY	MET	GLY	GLN	SER	GLY	VAL	GLY	ALA	LEU	PHE	ASN
LAMBDA CRO	GLN	THR	LYS	THR	ALA	LYS	ASP	LEU	GLY	VAL	TYR	GLN	SER	ALA	ILE	ASN	LYS	ALA	ILE	HIS
434 REPRESSOR	GLN	ALA	GLU	LEU	ALA	GLN	LYS	VAL	GLY	THR	THR	GLN	GLN	SER	ILE	GLU	GLN	LEU	GLU	ASN
434 CRO	GLN	THR	GLU	LEU	ALA	THR	LYS	ALA	GLY	VAL	LYS	GLN	GLN	SER	ILE	GLN	LEU	ILE	GLU	ALA
P22 REPRESSOR	GLN	ALA	ALA	LEU	GLY	LYS	MET	VAL	GLY	VAL	SER	ASN	VAL	ALA	ILE	SER	GLN	TRP	GLN	ARG
P22 CRO	GLN	ARG	ALA	VAL	ALA	LYS	ALA	LEU	GLY	ILE	SER	ASP	ALA	ALA	VAL	SER	GLN	TRP	LYS	GLU
lac REPRESSOR OF *E. COLI*	LEU	TYR	ASP	VAL	ALA	GLU	TYR	ALA	GLY	VAL	SER	TYR	GLN	THR	VAL	SER	ARG	VAL	VAL	ASN

HELIX 2 — TURN — HELIX 3

AMINO ACID SEQUENCES of seven regulatory proteins in three viruses and in *E. coli* are compared. The region of comparison spans the so-called helix-turn-helix region (helix 2, helix 3 and the link between them) defined by X-ray crystallography of lambda's repressor and cro (*drawing at right*). The amino acids at four positions are conserved with notable consistency: those corresponding to lambda repressor's amino acid 33 (almost always glutamine), 37 (almost always alanine), 41 (always glycine) and 47 (always either valine or isoleucine, which are functionally equivalent). In addition the amino acids on both sides of the glycine at position 41 are invariably hydrophobic, or water-repellent. The drawing shows the positions of these conserved amino acids in the helix-turn-helix region. Glycine is of-

for positive control of transcription (gene activation) are subtler than the requirements for negative control (repression). To act as a repressor the protein need only bind tightly to DNA and cover a region of the DNA that would otherwise be covered by RNA polymerase bound at a promoter. In contrast, to act as a positive regulator the repressor not only must bind to DNA very near the promoter but also must present, on the appropriate surface, the proper amino acids for contact with polymerase.

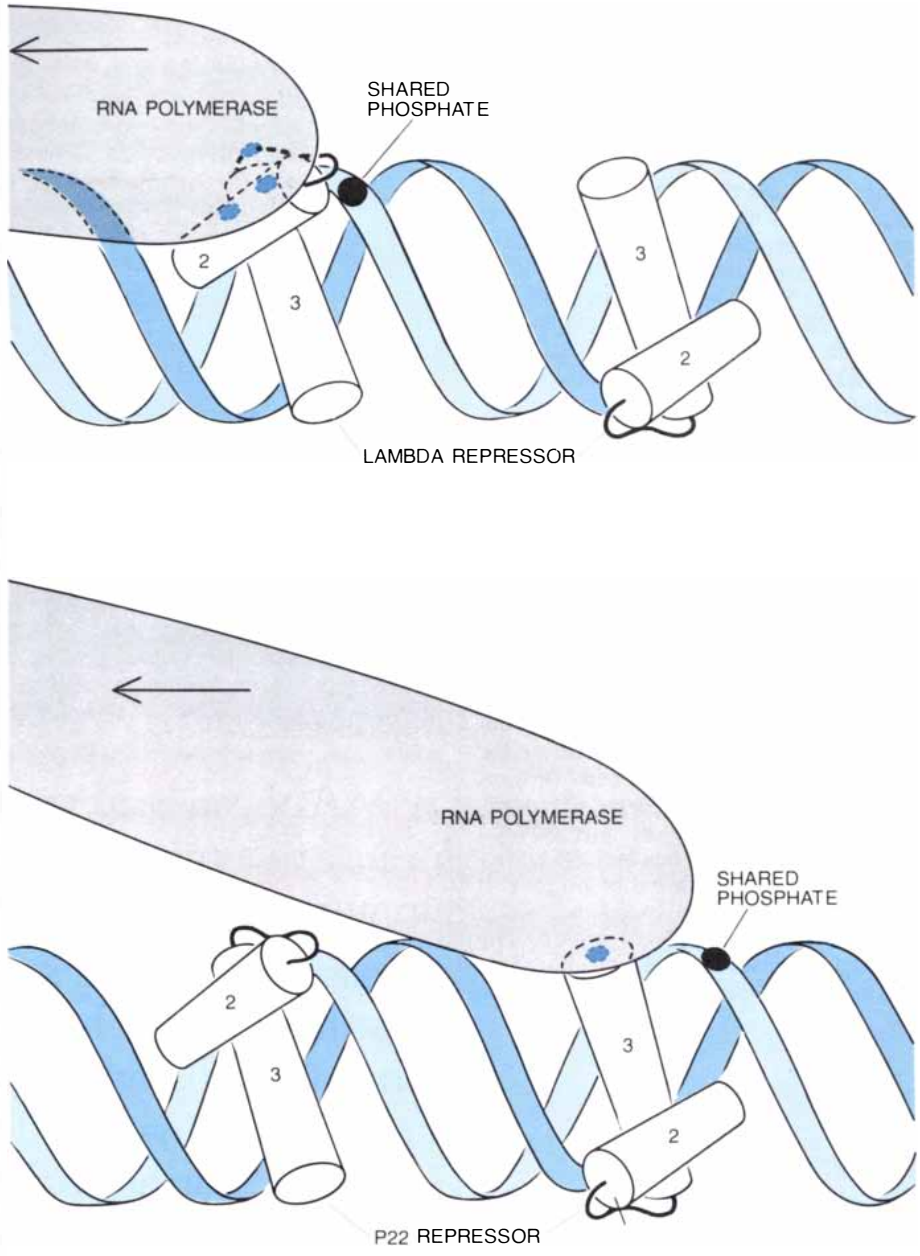
Two of our ideas—that many repressors bind to DNA by means of two alpha helixes with the same spatial arrangement and that they act as positive regulators by making contact with polymerase—suggested a prediction that has been strikingly confirmed by a recent experiment. We made the prediction for virus P22's repressor, whose structure has not yet been solved. We assumed that it recognizes DNA by means of two alpha helixes arranged like lambda repressor's helixes 2 and 3 and that, when it is bound to its O_R2, it stimulates the transcription of its own gene by making contact with RNA polymerase. We knew of one interesting difference between the P22 and the lambda repressor in this respect: the spatial relation between polymerase at the promoter and repressor at O_R2 is different in the two viruses. Our models predicted that, in contrast to the lambda case, the surface of the P22 repressor that comes in contact with polymerase would lie at the carboxyl end of helix 3, the end farthest from helix 2 [*see illustration on next page*]. A mutant P22 repressor was isolated that binds DNA but has lost the ability to stimulate transcription of its gene. It turned out to have a changed amino acid in precisely the predicted region. The change increases the positive charge on the surface of the protein, as in the case



ten present at a particular kind of sharp turn in a protein chain. Contact between the side chains of the alanine at position 37 and the valine at position 47 controls the distance between them (*broken line*) and helps to establish the angle between helix 2 and helix 3.

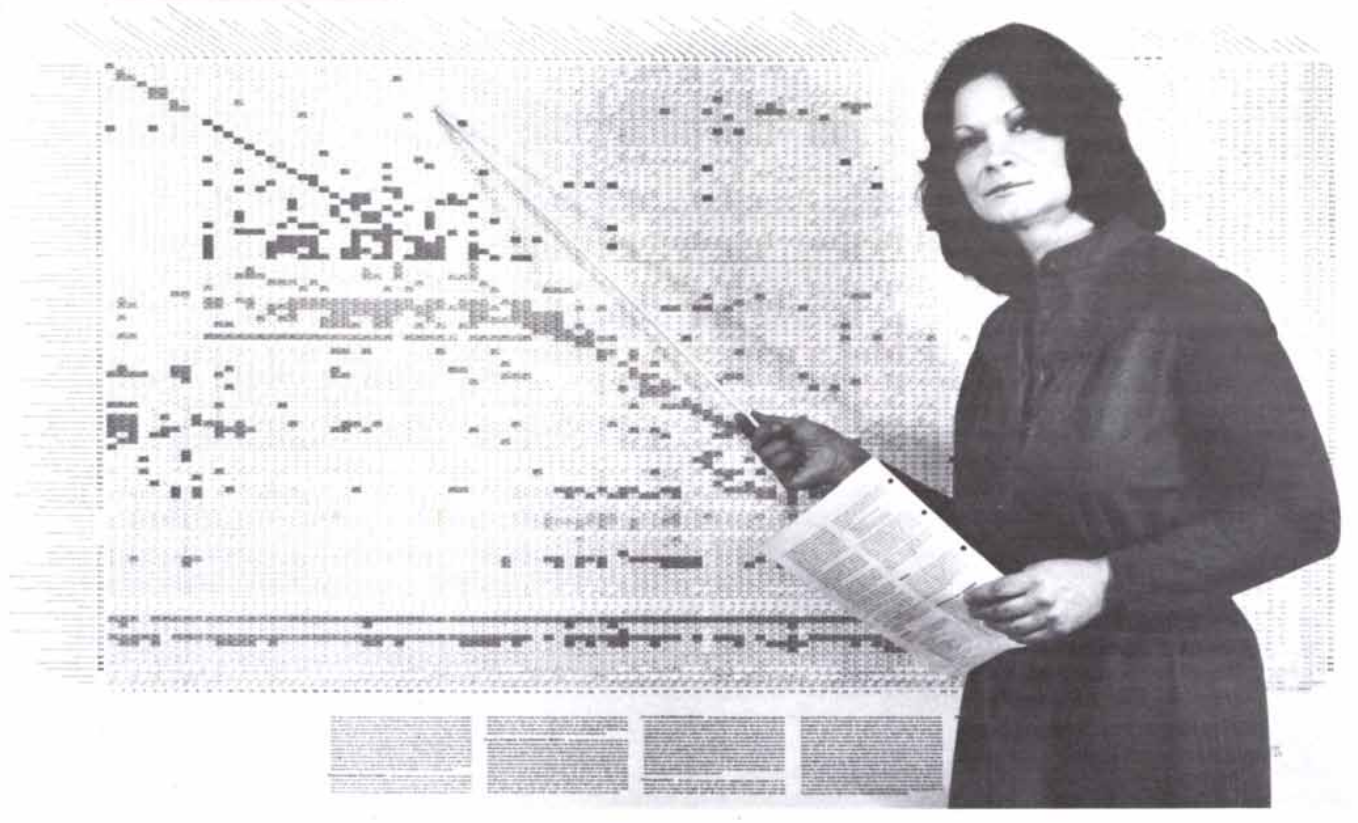
of the corresponding lambda mutants.

The results suggest that both the lambda repressor and the P22 repressor act as positive regulators of transcription by coming in contact with the same region of RNA polymerase, but that in each case a different repressor surface makes the contact with polymerase. Moreover, these results increase our confidence that the common arrangement of two alpha helixes plays a crucial role in many protein-DNA interactions. Whether this theme recurs throughout nature remains to be seen.



POSITIVE-CONTROL HYPOTHESIS, which holds that repressors activate their own synthesis by making contact with RNA polymerase and helping it to bind to the promoter, is supported by experiments with mutant repressors. The top drawing shows helixes 2 and 3 of two lambda amino-terminal domains bound to O_R2 and a polymerase molecule bound to the *c*I promoter. (The rest of the repressor domain is omitted for clarity.) The relative positions of the repressor and the polymerase are known because a particular phosphate group (*black dot*) in the DNA backbone is known to be in contact with both a repressor dimer at O_R2 and a polymerase molecule bound to the promoter. In three mutant repressors that are unable to activate polymerase the amino acid substitution responsible for that inability is either in helix 2 or in the bend between helix 2 and helix 3 (*colored dots*). Each of these sites is on the repressor surface most closely approaching polymerase, suggesting that repressor-polymerase contact is indeed a requirement for activation of the polymerase. A similar experiment was done with the repressor of virus P22. Its structure is not known, but the pattern of conserved amino acids suggests it has the same arrangement of helix 2 and helix 3 as lambda repressor. In P22, however, the "shared phosphate" data suggested that the repressor surface making contact with polymerase is at the end of helix 3 farthest from helix 2. A mutant P22 repressor that cannot activate polymerase was isolated. Its altered amino acid (*color*) was found at the predicted site.

THE INPUT/OUTPUT STRUCTURE OF THE UNITED STATES ECONOMY



WHAT MAKES THE U.S. ECONOMY TICK?

The editors of SCIENTIFIC AMERICAN have prepared a wall chart displaying for the 1980's the Input/Output Structure of the U.S. Economy based on the latest interindustry study from the U.S. Department of Commerce.

The SCIENTIFIC AMERICAN Input/Output wall chart does for economics what the table of elements does for chemistry. It answers at a glance questions about the linkage between the microeconomics of the firm and the macroeconomics of the system; about the web of technological interdependencies that tie industry to industry; about the industry-by-industry direct and indirect consequences of swings in public and private spending; about the impact of change in technology, and about any other topic you can think of. You are rewarded by surprise as well as by confirmation of your hunches. For teaching and practical and theoretical studies, here is a powerful, graphic tool.

In the familiar format of the SCIENTIFIC AMERICAN Input/Output wall charts for the 1960's and 1970's, the wall chart for the 1980's measures 65″ × 52″ and is printed in eight colors. Each of the nearly 10,000 cells in the 97-sector interindustry matrix shows (1) the interindustry commodity flow, (2) the direct input/output coefficient and (3) the "inverse" coefficient. Where the direct input/output coefficient exceeds .01, the cell is tinted in the color code of the industrial bloc from which the input comes. This device, combined with triangulation of the matrix, brings the structure of interindustry transactions into graphic visibility.

A supplementary table displays, industry by industry, the capital stock employed; the employment of managerial, technical-professional, white-collar and blue-collar personnel; the energy consumption by major categories of fuel, and environmental stress measured by tons of pollutants.

The editors of SCIENTIFIC AMERICAN are happy to acknowledge the collaboration, in the preparation of this wall chart, of Wassily Leontief, originator of input/output analysis—for which contribution to the intellectual apparatus of economics he received the 1973 Nobel prize—and director of the Institute for Economic Analysis at New York University.

Packaged with the chart is an index showing the BEA and SIC code industries aggregated in each of the 97 sectors.

SCIENTIFIC AMERICAN
415 Madison Avenue, Dept. I/O, New York, N.Y. 10017

YES, send me the new SCIENTIFIC AMERICAN 1980's INPUT/OUTPUT wall chart—printed in eight colors on heavy paper measuring 65″ × 52″.

I understand my chart(s) will be shipped prepaid, uncreased*, flat-rolled and in a sturdy mailing tube. (Allow 4-6 weeks for delivery)

I enclose a check for $____ for ____ chart(s) at $35 each, saving me $5 each in handling charges.

Bill me for $____ for ____ chart(s) at $40 each.

Name_____

Company_____

Street Address_____

City, State, Zip Code_____

*Charts shipped international require one fold. 11/82

Make check payable to SCIENTIFIC AMERICAN. Please add sales tax for California, Illinois, Massachusetts, Michigan and New York.

Glueballs

They are "atoms of color," bound states of the particle that transmits the color force, the strongest force known. A few of them may have been detected in high-energy experiments

by Kenzo Ishikawa

Is it possible to imagine an atom of light? The photon, the quantum unit of light, is also the carrier of the electromagnetic force that holds together an ordinary atom. Any particle of matter that has an electric charge can emit or absorb a photon; in an atom the electrons are bound to the nucleus by a continual exchange of photons. In an atom of light two photons might be bound to each other by the exchange of additional photons.

As it happens, such an atom cannot be created. The reason is that the photon itself has no electric charge, and so a photon cannot emit or absorb another photon. An analogous bound system may well exist, however, at the next-finer level in the structure of matter. Indeed, it may have been observed already. The analogue of the atom of light is made up of gluons, which are the carriers of the basic force of nature called the strong force or the color force. Ordinarily gluons act to bind together quarks, which are the constituents of protons, neutrons and many related particles. A quark has a property called color charge, and any particle with such a charge can emit or absorb a gluon. In this respect the role of the gluon resembles that of the photon; the two particles are also alike in being massless and in moving at the speed of light. Whereas the photon is electrically neutral, however, the gluon has a color charge. As a result the "glue" that sticks quarks together can also stick to itself. Two gluons should be able to form a composite particle held together by the exchange of other gluons. Physicists have taken to calling such particles glueballs.

If glueballs exist, it should be possible to make them in experiments with the same particle accelerators that give rise to high-energy combinations of quarks. The recent reports that glueballs may have been detected are based on such experiments, but some uncertainty remains about the identification of the particles. The reason for the uncertainty is ironic: it seems these most exotic states of matter are so prosaic in their outward properties that it is difficult to distinguish them from ordinary particles made up of quarks.

The idea that a force must be carried or transmitted by an intermediary particle is closely related to the much older idea that there can be no action at a distance. The idea of intermediary particles was first incorporated into a quantum-mechanical theory in 1934 by the Japanese physicist Hideki Yukawa. Yukawa was trying to understand the force that binds protons and neutrons in the atomic nucleus, which was then the only known example of the strong nuclear force. He suggested that the force is transmitted by a particle with a mass about 200 or 300 times the mass of the electron.

The basis of Yukawa's estimate of the mass was his hypothesis that the range of a force is inversely proportional to the mass of the particle that mediates it. The interaction between the proton and the neutron was known to have an extremely short range, on the order of 10^{-13} centimeter, which implied a comparatively large mass. In 1947 a particle with a mass about 275 times that of the electron was discovered in cosmic radiation and shown to interact strongly with the proton and the neutron. The particle is called the pi meson and its discovery was a dramatic confirmation of Yukawa's conjecture.

The magnitude of the electromagnetic force between two electrically charged particles is given by Coulomb's law: the force is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. The range of the Coulomb force seems to be infinite, and so according to Yukawa's theory the rest mass of the photon is zero.

Since the gluon also has a rest mass of zero, one would expect the color force mediated by the gluon to be a force of infinite range. In a formal sense the range of the color force may indeed be infinite, but the interactions mediated by gluons have never been observed at a range of more than about 10^{-13} centimeter, or roughly the same range as the force mediated by the pi meson. The similarity of range is not coincidental: the interaction mediated by the pi meson is thought to be the net result of events that can be described on a finer scale as interactions mediated by gluons, just as an interatomic bond in a molecule is the net result of electromagnetic interactions that are ultimately caused by the exchange of photons between electrons and protons. The observed range of the color force remains puzzling, however, and it now seems that in order to understand the observation it is necessary to postulate the existence of glueballs.

In 1964 Murray Gell-Mann and George Zweig of the California Institute of Technology independently proposed that all particles subject to the strong nuclear force are made up of more elementary constituents: the particles Gell-Mann named quarks. Particles subject to the strong force are called hadrons, and the quark model was introduced in order to classify the proliferating new hadrons being generated in experiments with accelerators. Gell-Mann suggested that all the hadrons in ordinary matter are made up of two flavors, or kinds, of quark, the up, or *u*-flavored, quark and the down, or *d*-flavored, quark. The proton, for example, is made up of two *u* quarks and a *d* quark (*uud*), whereas the neutron is made up of a *u* quark and two *d* quarks (*udd*). A third quark called the strange, or *s*-flavored, quark was invoked to explain the existence of certain particles with strangely long lifetimes. Three corresponding antiquarks were postulated: antiup (*u*), antidown (*d*) and antistrange (*s*). The positively charged pi meson is made up of a *u* quark and a *d* antiquark (*ud*). At least two more quark flavors have since been discovered; they are called charm (*c*) and bottom (*b*).

One distinctive feature of the quark model is that each quark carries a fractional electric charge. The charge of the

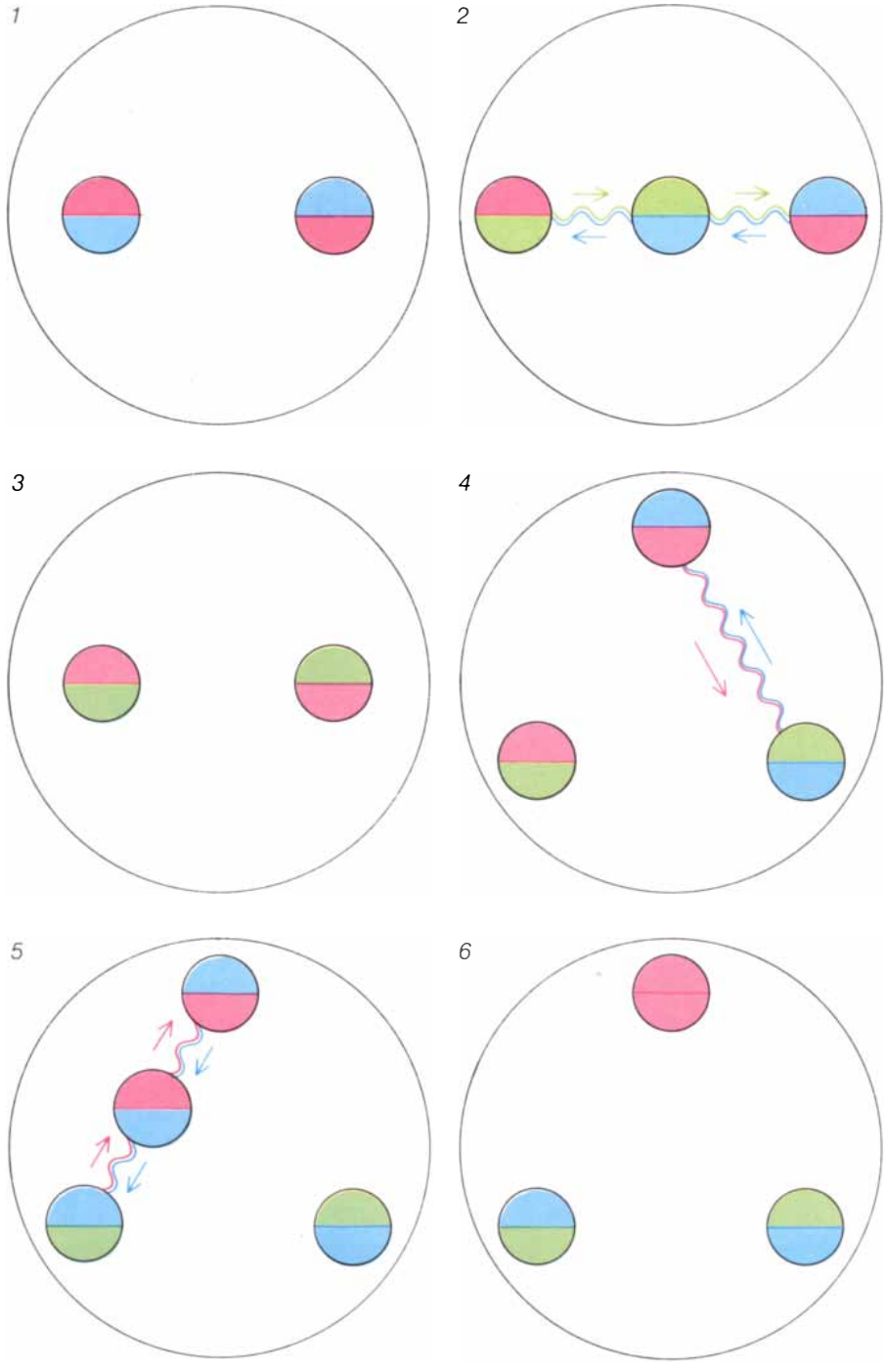
u quark is $+2/3$ (in units of the proton's charge) and that of the *d* quark is $-1/3$. In a hadron the quarks combine in such a way that the electric charge of the bound system invariably turns out to be an integral multiple of the proton's charge. The charge of the proton itself is $2/3 + 2/3 - 1/3$, or $+1$; the charge of the neutron is $2/3 - 1/3 - 1/3$, or 0.

In this way the electric charge of every hadron known can be accounted for as a sum of quark charges. With the exception of a few somewhat controversial measurements, however, a fractional charge has not been observed in nature. If a particle with a fractional charge could be isolated, it would seem comparatively easy to distinguish it from all the surrounding particles with integer charge. Because of the failure to detect fractional charges, many physicists were at first unwilling to accept the existence of quarks as more than a convenient but fictional device for making predictions about hadrons. As more hadrons were discovered, however, and as more of their features were shown to fit the quark model, the reality of quarks seemed much less at issue. The question was not whether quarks exist but why they are never detected in isolation.

A related issue arises when one considers the spin, or intrinsic angular momentum, of the quarks. The spin of a particle is like the spin of a top except that the spin of the particle is quantized: it must take on integer or half-integer values when it is expressed in fundamental units. Particles whose spin is an integer (such as 0, 1 or 2) are called bosons; examples are the pi meson (with a spin of 0) and the photon and the gluon (with a spin of 1). The energy of a collection of bosons is divided among the individual bosons according to a statistical distribution called Bose-Einstein statistics. Particles whose spin is a half-integer (such as $1/2$, $3/2$ or $5/2$) are called fermions; the electron, the proton, the neutron and all the quarks are fermions with a spin of $1/2$. The energy of a collection of fermions is distributed according to Fermi-Dirac statistics.

The two kinds of statistics become important when a number of particles are considered as a single system, as the quarks are in a hadron. It is possible for all the bosons in such a system to share the same values of energy and spin. A group of fermions, on the other hand, must obey the fundamental principle of quantum mechanics called the exclusion principle, which was first stated by Wolfgang Pauli. The exclusion principle forbids any two fermions from sharing the same quantum-mechanical state, that is, the same values of energy, spin and other quantum numbers that identify the fermion. The exclusion principle is troublesome for the quark model because there are hadrons that can be explained only as a bound state of three identical quarks. The hadron designated omega minus, for example, is made up of three *s* quarks and all three quarks must have the same energy and spin. Two identical quarks could be accommodated by ensuring their spins point in opposite directions, but in the omega minus two of the quarks must occupy the same state of energy and spin.

In order to resolve the impasse Moo-Young Han of Duke University, Yoichiro Nambu of the University of Chicago and Oscar W. Greenberg of the Univer-

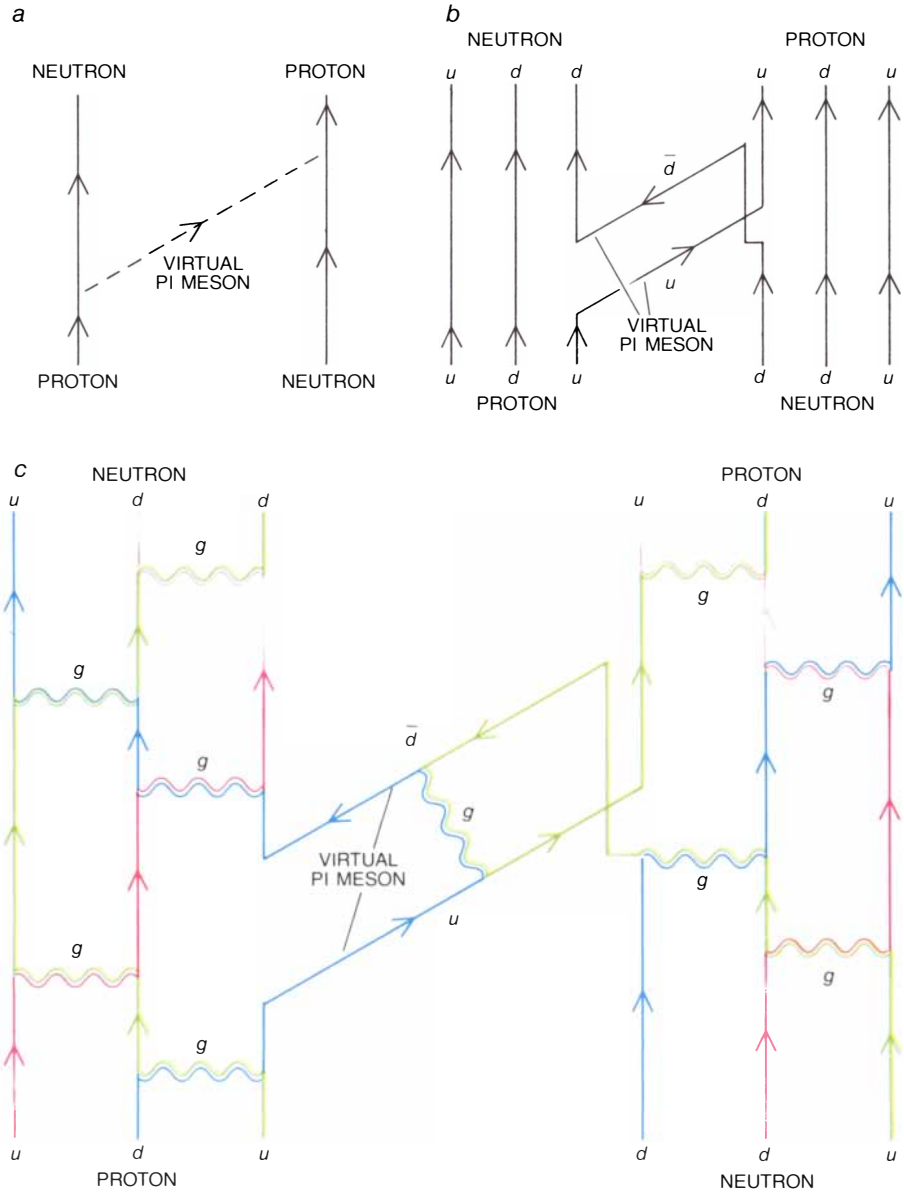


CONSTITUENTS OF GLUEBALLS are the particles called gluons, whose role in the structure of matter is ordinarily to bind together quarks, which are the components of the proton, the neutron and many related particles. In a glueball the gluons are bound to one another in a composite structure without quarks. Each gluon has a property called color; indeed, a gluon can be represented as having both a color (shown here in the upper half of each circle) and an anticolor (lower half). The colors are arbitrary labels for mathematical properties and have no relation to ordinary colors. The gluons continually exchange additional colored gluons. Moreover, when a gluon has been emitted, it can emit still another gluon in turn. As a result a glueball initially made up of two gluons can become a bound state of three or more; the number of gluons in a glueball is not a well-defined quantity. Any combination of colors and anticolors can be exchanged among the gluons; the only constraint is that no net color can be generated. In this way the glueball as a whole remains "colorless," or neutral with respect to color.

sity of Maryland at College Park introduced the idea that quarks are distinguishable not only by flavor, spin and electric charge but also by the new attribute called color. If the three *s* quarks in the omega-minus particle are thought of as, say, red, blue and green, they do not occupy exactly the same quantum-mechanical state and so they do not violate the exclusion principle. (The term color and the color values red, blue and green are arbitrary labels for distinctions that are essentially mathematical, and they have nothing to do with real colors.)

At first, postulating the existence of color seems to lead to more difficulties than it resolves. Color, like fractional charge, has not been detected in nature. All independent particles are colorless, and so the colors of the constituent quarks must somehow cancel one another. For the colors to cancel in a hadron made up of three quarks (such as the proton) there must be one quark in each of the colors red, blue and green. For hadrons made up of a quark and an antiquark (such as the pi meson) the requirement that the particle be colorless is met if the constituents assume a color and its anticolor, say red and antired.

The apparent short range of the color force, the failure to detect fractional charge and the failure to detect color have not led to the abandonment of the quark hypothesis; it has been far too successful in explaining the properties of hadrons to be easily dismissed. Instead the three observations taken together suggest that quarks do exist but are permanently confined within hadrons. One of the major challenges for any theory of quark interactions, therefore, is to explain quark confinement.



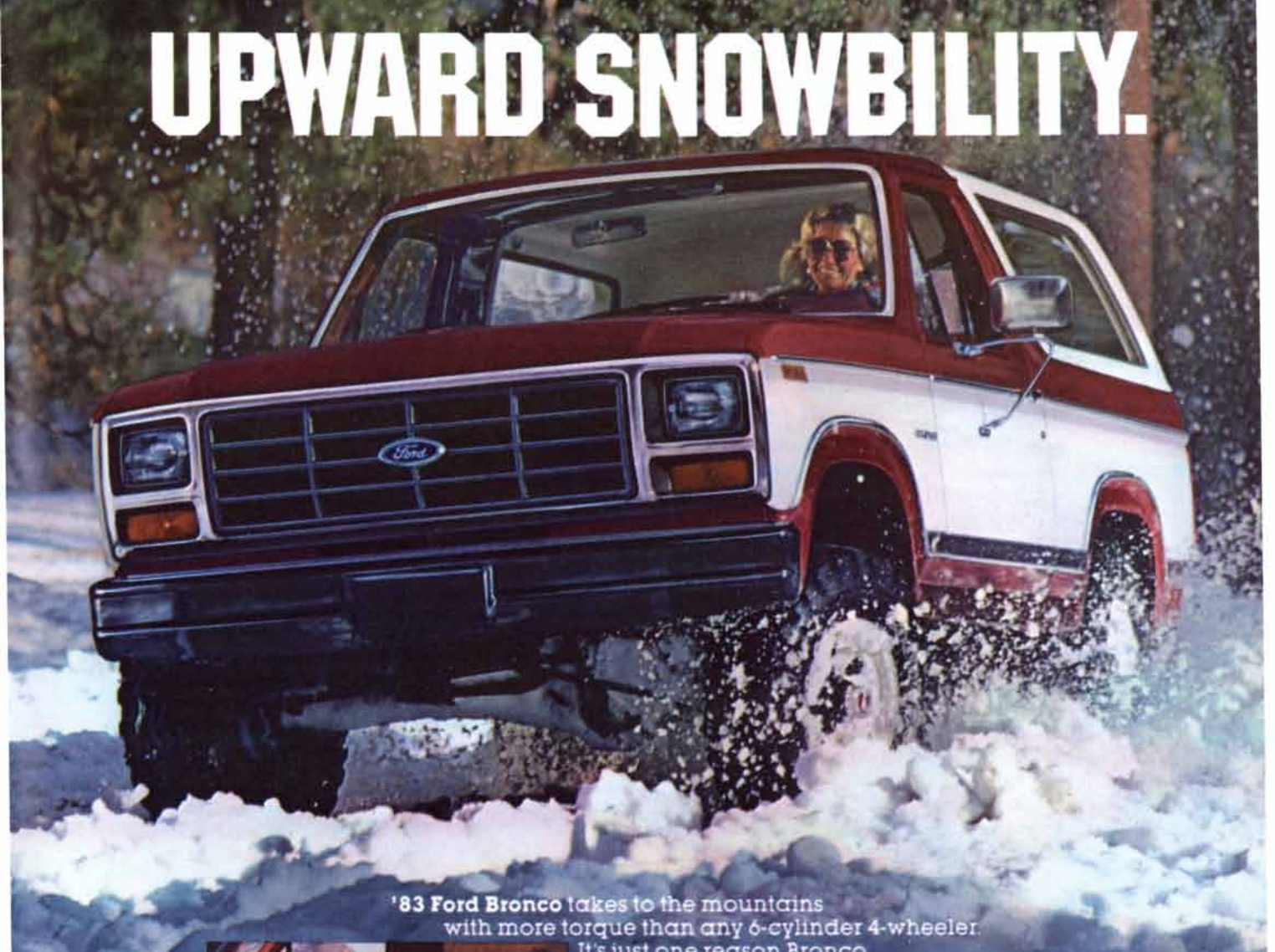
STRONG FORCE that binds the proton and the neutron in the nucleus of the atom can be understood at three increasingly fine-grained levels of explanation. At the first level the force can be thought of as acting through the exchange of a pi meson, which causes the proton and the neutron to exchange identities (*a*). At the second level the proton, the neutron and the pi meson are all regarded as being made up of the more elementary particles called quarks. In this scheme the pi meson in effect transfers an up, or *u,* quark from the proton to the neutron and transfers a down, or *d,* quark from the neutron to the proton (*b*). At the third level of explanation the strong binding force between the proton and the neutron is considered to be the net result of the action of the color force, which binds quarks together and is mediated by the exchange of gluons, the wavy lines designated *g* in the diagram (*c*). Because the gluons are colored their transfer can change the colors of the quarks. Although color is continually interchanged among the quarks that make up a free particle, the particle has no net color. The combination of red, blue and green and the combination of blue and antiblue both represent colorless states, just as the combination of ordinary light in such colors gives rise to white, or colorless, light.

Although the idea of color was first proposed in order to make the quark model consistent with the Pauli exclusion principle, color has since been given a central place in the model as the basis of the theory that describes the interactions of quarks. It is the color charges of quarks that give rise to forces acting between them, just as it is the electric charge of electrons and protons that generates the electromagnetic force in an atom. Indeed, the theory of the color force was constructed by direct analogy with the theory of the electromagnetic force.

The fundamental theory of the electromagnetic interactions of particles is quantum electrodynamics, or QED. It was developed over a 20-year period beginning in the late 1920's. The idea that the force between two electrically charged particles can be accounted for by an exchange of photons was introduced by QED. Only particles with an electric charge can take part in such an exchange; on the other hand, since the photon is electrically neutral, the exchange does not alter the charge of a particle that emits or absorbs a photon.

The theory of the color force is called quantum chromodynamics, or QCD. The mathematical framework of the theory was developed in 1954 by C. N. Yang of the State University of New York at Stony Brook and Robert L. Mills of Ohio State University. It was first applied to the physics of strong interactions by Jun J. Sakurai of the University of Chicago. QCD states that one colored particle interacts with another by exchanging gluons. Because there are three kinds of color, however, QCD is substantially more complicated than QED. Furthermore, because the gluons themselves carry a color charge, the color of a particle that emits or absorbs a gluon can be changed. With three possible initial colors and three possible final colors, providing for all the color trans-

UPWARD SNOWBILITY.



'83 Ford Bronco takes to the mountains with more torque than any 6-cylinder 4-wheeler.

It's just one reason Bronco is the No. 1 seller in its class.† Inside, there's room and comfort for six with optional twin bench seats. Or go with standard bucket seats up front. Even underneath, Bronco's up on the competition. It's the only full-size, American-built sport utility with independent front suspension. Tough Ford Bronco. It's a beautiful way to go! Get it together — Buckle up.

†Based on R.L. Polk & Co. calendar year registrations as of May, 1982.

Optional Captain's Chairs shown

27 EST HWY **18** EPA EST MPG 4.9L Six and optional overdrive. Use for comparison. Your mileage may differ depending on speed, distance and weather. Actual highway mileage lower. California ratings may be less. See your Ford Dealer for the 1983 EPA Gas Mileage Guide.

FORD BRONCO

FORD DIVISION Ford

AMERICA'S TRUCK

TOUGH FORD BRONCO

formations would seem to require nine kinds of gluon. Actually the three transformations that do not change the color of either the emitting or the absorbing particle can be accounted for by only two gluons. Hence there are eight kinds of gluon in all.

Each gluon is designated by the effect it has on the quark by which it is emitted. For example, when a red-to-blue gluon is emitted by a red quark, the red quark becomes blue. A blue quark that absorbs the red-to-blue gluon becomes a red quark. The colors of the gluon are such that when they are subtracted from those of the red quark, the red quark becomes blue, and when they are added to those of the blue quark, the blue quark becomes red.

If the color force is confined to a small region of space, the gluon may not be a directly observable aspect of QCD. Nevertheless, there is every reason to suppose the colors carried by the gluons enable them to form glueballs, or colorless bound states similar to the hadrons, the colorless bound states of quarks. The most direct way to observe the properties of the gluons may be to study glueballs. The existence of the gluon and the glueball were predicted by Harald Fritzsch of the California Institute of Technology and by Gell-Mann.

Because gluons have no property comparable to the flavor of quarks, gluons can form fewer distinctive bound states than quarks can. Moreover, because a glueball must be colorless any bound state of the gluons that exhibits net color must be disallowed. With eight kinds of gluon it would seem that 64 kinds of glueball might be made by combining the gluons in pairs, but most of the combinations would have a net color. The only pairs of gluons that can form colorless glueballs are the eight pairs in which the colors cancel. For example, a red-antiblue gluon must be paired with a blue-antired one.

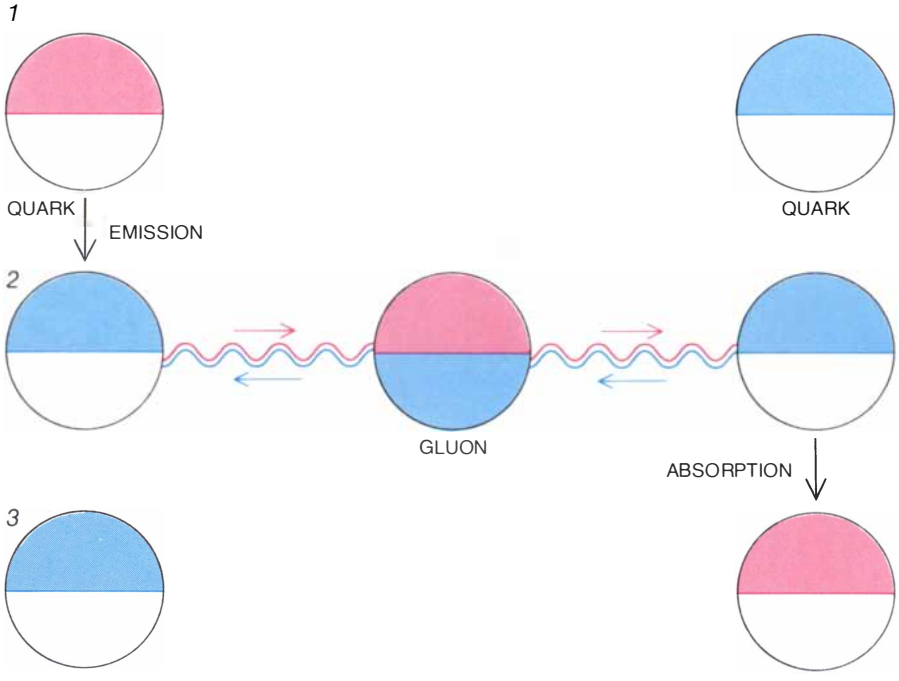
As it turns out, these eight pairs freely exchange their colors and form a so-called mixed state in which any one of them is equally likely to be found. Indeed, because the exchange of color amounts to the emission of a third gluon, glueballs made up of three or more gluons can be generated as long as color neutrality is preserved. Glueballs made up of different numbers of gluons may not be experimentally distinguishable.

Even though there is only one basic kind of glueball it should exist in several states with different quantum numbers. In all the states the constituent gluons are the same, but they have different modes of motion. The quantum numbers most important for classifying the various states are the angular momentum, the parity and the charge-conjugation quantum numbers.

The total angular momentum of a glueball could in principle have any one of many possible values. One contribution to the total angular momentum is the intrinsic spin of one unit carried by each of the gluons. If the spins point in opposite directions, they cancel and the glueball has a total angular momentum equal to 0. If the spins point in the same direction, they add and the total angular momentum is equal to 2. There are other ways for the spins to combine, and in addition the glueball can have orbital angular momentum associated with the revolution of the gluons about their common center of mass; these refinements give rise to mixed spin states in which each possible value of the total angular momentum has some probability of being observed. The spin-0 and spin-2 states, however, are the ones most likely to be detected. It has become customary to refer to a spin-0 particle as either a scalar or a pseudoscalar particle; the one with a spin of 2 is called a tensor particle.

Both the parity and the charge-conjugation quantum numbers can be either positive or negative. The parity of a glueball is positive if in all its interactions the particle cannot be distinguished from its mirror reflection; otherwise the parity is negative. Similarly, the charge-conjugation number of a glueball is positive if the quantum-mechanical description of the particle is unchanged when every particle is replaced by the corresponding antiparticle. Among the spin-0 glueballs the scalar one has positive parity and the pseudoscalar one has negative parity. The tensor glueball can have either positive or negative parity. All three states can have either positive or negative charge conjugation.

The description of a hadron or a glueball as a composite of two colored particles that occasionally exchange a third colored particle is not entirely adequate. In QCD the vacuum in which the particles exist is itself an active contributor to their properties. Surrounding every quark and every gluon is a cloud of particles that are briefly materialized from the vacuum. They are called virtual particles because they cannot be detected directly; they owe their ephemeral ex-



GLUON EXCHANGE between two quarks can result in the transfer of color from one quark to the other. The colors are arbitrarily designated red and antired, blue and antiblue and green and antigreen. The color of a quark or a gluon is represented by the color of the upper half of each circle, whereas the anticolor of the particle is represented by the color of the lower half of the circle. The anticolors can be thought of as negative colors: thus a red-antiblue gluon has the red color value +1 and the blue color value −1. The absence of a color or an anticolor indicates that the numerical value of the color is 0. A gluon emitted by a quark carries away a discrete quantity of each color. The colors that remain on the quark after the emission of the gluon are obtained by subtracting the numerical value of each color carried by the gluon from the corresponding value of the color of the original quark. The color red of a red quark is reduced from 1 to 0 by the emission of a gluon that carries away a red color of 1 (that is, 1 minus 1 is equal to 0); the color blue, which has the value 0 in the red quark, becomes 1 when a gluon carries away a blue color of −1 (that is, 0 minus −1 is equal to 1). Similarly, when a quark absorbs a gluon, the color values of the gluon are added to the corresponding color values of the quark. The color blue of the blue quark is reduced to 0 when a gluon that carries a blue color of −1 is absorbed (that is, 1 plus −1 is equal to 0); the color red, which has the value 0 in the blue quark, becomes 1 when a gluon that carries a red color of 1 is absorbed (that is, 0 plus 1 is equal to 1).

STATE·OF·THE·ART

The Kodak Carousel 5600 projector

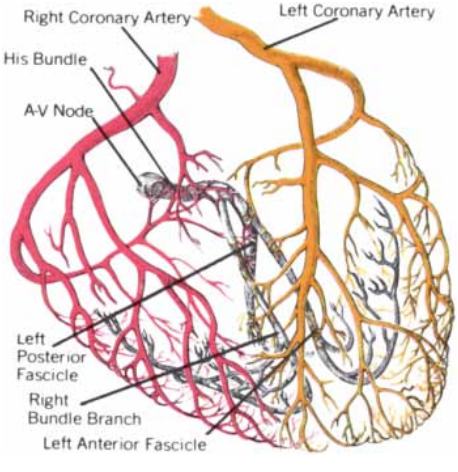
Slide viewing with a Kodak projector has never been as easy as it is now with the Kodak Carousel® 5600 projector. Because no other slide projector has all these features. Our exclusive Slide-Scan™ built-in screen, for example, can turn any room in the house into a screening room. And no matter what room you're in, the illuminated control panel and built-in reading light eliminate fumbling around in the dark. There's also a lamp that lasts up to 70 hours. Plus our auto-focus feature that helps make the slide you're projecting look crisp and sharp. And, amazing but true, the projector even turns the lights off. The Kodak Carousel 5600 projector. It's a gift anyone would love.

From Kodak
The Pro in Projectors

Physician, did you miss any of these significant developments in medical science?

- ***Campylobacter fetus* subsp. *jejuni* is associated with a colitis that can clinically and sigmoidoscopically resemble acute idiopathic ulcerative colitis. Stool cultures are in order for *C. fetus* before beginning nonspecific anti-inflammatory therapy.**
- **Coumarin derivatives cross the placenta. A recent study shows that the consequences for the fetus can be severe. These include embryopathy, stillbirth, and premature delivery.**
- **Nonsteroidal anti-inflammatory drugs may produce a marked reduction in glomerular filtration rate; with termination of the drug, GFR returns to normal.**
- **The first documented incident of indigenous transmission of dengue in the continental United States since 1945 has been reported in Brownsville, Texas.**

IF THESE ITEMS are familiar you must be a prodigiously energetic or prodigiously lucky reader. With 2,000 or more journals published each year, information that significantly affects patient management all too easily slips by. Textbooks are out-of-date before they are published.



Branches of the right and left coronary arteries supply blood to the A-V node and intraventricular conduction system.

SCIENTIFIC AMERICAN *Medicine* is lucidly illustrated with drawings and photographs. Some examples are seen here and on the facing page.

SCIENTIFIC AMERICAN *Medicine* is the busy clinician's answer to this problem.

Because its authors update SCIENTIFIC AMERICAN *Medicine* every month, it is always current. Because the new information appears in a single source, it is there when you need it.

This 2,500-page, innovative union of publishing and electronic technology is the work of leading scholar-practitioners from Harvard and Stanford. The editors are Edward Rubenstein, M.D., F.A.C.P., and Daniel Federman, M.D., F.A.C.P.

Each month as authors update their contributions, revisions are entered on the magnetic tape on which the text and index are stored. The tape drives high-speed phototypesetting equipment so that subscribers receive about eight new chapters and a new index every four weeks; a bulletin highlights new developments.

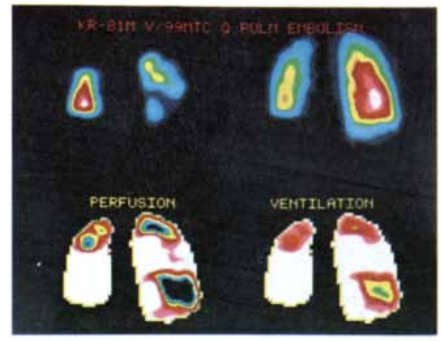
New material replaces old material in the living text, so that the information is there — up-to-date, at your fingertips.

A CME program of eight patient management problems offered over a 12-month period is available at no extra cost. As an organization accredited for continuing medical education, the Stanford University School of Medicine designates this continuing medical education activity as meeting the criteria for 32 credit hours in Category 1 for Educational Materials for the Physician's Recognition Award of the American Medical Association, provided it has been completed according to instructions. This program has been reviewed and is acceptable for 32 prescribed hours by the American Academy of Family Physicians. This program has been approved by the American College of Emergency Physicians for 32 hours of ACEP Category 1 credit.

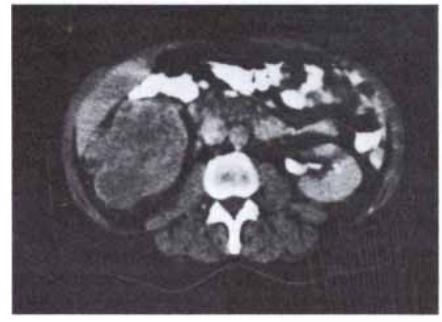
Trial Offer

We invite you to try SCIENTIFIC AMERICAN *Medicine* — for two months at no cost. Send us the coupon and you will receive the two-volume text and two monthly updates. You may also take a CME test for credit. At the end of 60 days, if you decide to continue the subscription, we will bill you for $220 for the full 12 months (renewal is currently $170); otherwise return the two volumes.

Please mail the coupon today and let us take the hassle out of keeping up.



Computerized scintigraphy reveals pulmonary thromboembolism.



Abdominal computed tomogram reveals large renal carcinoma replacing part of right kidney.

THE DISTINGUISHED AUTHORS AND THE FIFTEEN SECTIONS OF SCIENTIFIC AMERICAN ***MEDICINE***

1. Cardiovascular Medicine

Edgar Haber, M.D., Harvard Medical School and Massachusetts General Hospital

E. William Hancock, M.D., F.A.C.P., Stanford University School of Medicine

Roman W. DeSanctis, M.D., Harvard Medical School and Massachusetts General Hospital

Adolph M. Hutter, Jr., M.D., F.A.C.P., Harvard Medical School and Massachusetts General Hospital

Eve Elizabeth Slater, M.D., Harvard Medical School and Massachusetts General Hospital

2. Dermatology

Eugene M. Farber, M.D., Stanford University School of Medicine

Elizabeth A. Abel, M.D., Stanford University School of Medicine

3. Endocrinology

Daniel D. Federman, M.D., F.A.C.P., Harvard Medical School

4. Gastroenterology

Gary M. Gray, M.D., Stanford University School of Medicine

Peter B. Gregory, M.D., Stanford University School of Medicine

John Austin Collins, M.D., Stanford University School of Medicine

Douglas Wilmore, M.D., Harvard Medical School and Brigham and Women's Hospital

5. Hematology

Stanley L. Schrier, M.D., Stanford University School of Medicine

6. Immunology

John David, M.D., Harvard Medical School and Harvard School of Public Health

7. Infectious Disease

Thomas C. Merigan, M.D., Stanford University School of Medicine

Morton N. Swartz, M.D., F.A.C.P., Harvard Medical School and Massachusetts General Hospital

Cyrus C. Hopkins, M.D., Harvard Medical School and Massachusetts General Hospital

Adolf W. Karchmer, M.D., F.A.C.P., Harvard Medical School and Massachusetts General Hospital

Robert H. Rubin, M.D., F.A.C.P., Harvard Medical School and Massachusetts General Hospital

Harvey B. Simon, M.D., F.A.C.P., Harvard Medical School and Massachusetts General Hospital

Peter F. Weller, M.D., Harvard Medical School; Beth Israel Hospital, Boston; and Brigham and Women's Hospital

8. Intensive and Emergency Care

Edward Rubenstein, M.D., F.A.C.P., Stanford University School of Medicine

9. Metabolism

George F. Cahill, Jr., M.D., Harvard Medical School, Howard Hughes Medical Institute; and Brigham and Women's Hospital

10. Nephrology

Roy H. Maffly, M.D., Stanford University School of Medicine and Palo Alto Veterans Administration Medical Center

William Bennett, M.D., Health Sciences University, Portland, Oregon

11. Neurology

Robert W. P. Cutler, M.D., Stanford University School of Medicine

12. Oncology

Saul A. Rosenberg, M.D., F.A.C.P., Stanford University School of Medicine

13. Psychiatry

Ned H. Cassem, M.D., Harvard Medical School and Massachusetts General Hospital

14. Respiratory Medicine

Eugene D. Robin, M.D., F.A.C.P., Stanford University School of Medicine

15. Rheumatology

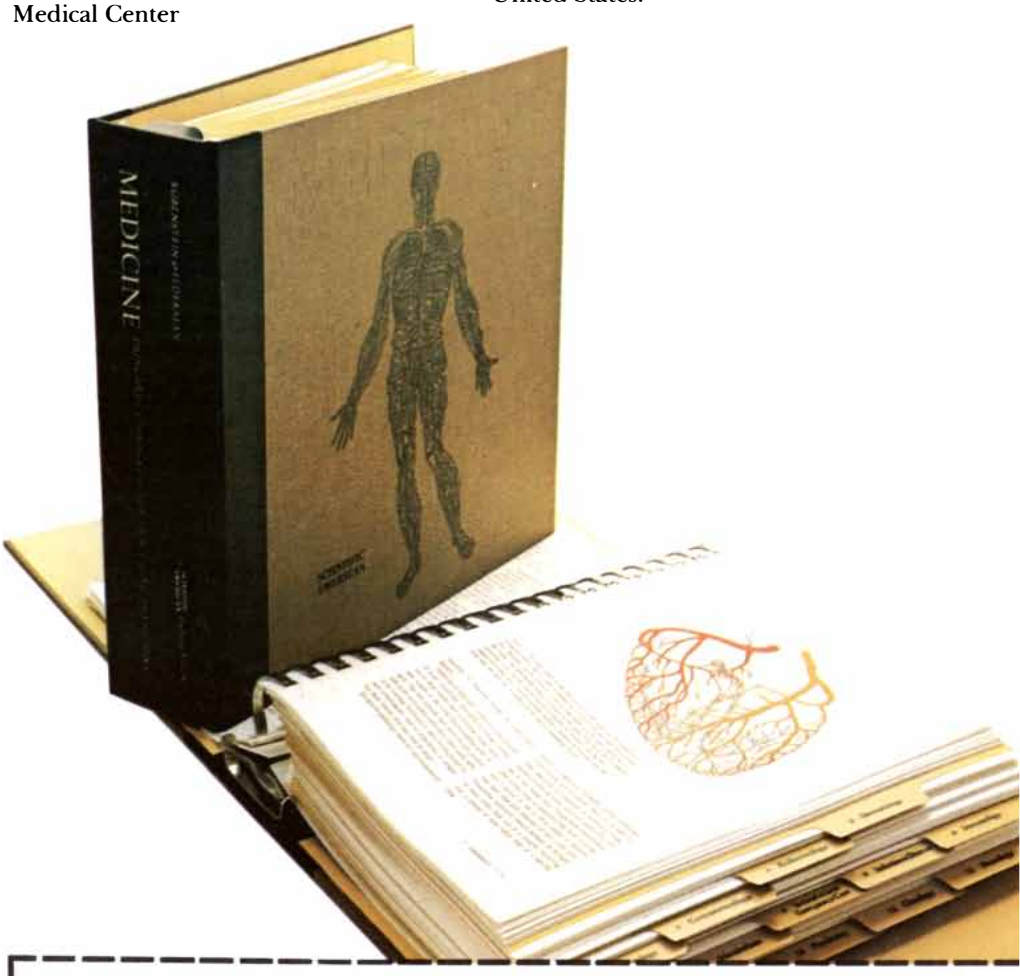
Stephen M. Krane, M.D., Harvard Medical School and Massachusetts General Hospital

Dwight R. Robinson, M.D., Harvard Medical School and Massachusetts General Hospital

Andrei Calin, M.D., M.A., M.R.C.P., Stanford University School of Medicine and Palo Alto Veterans Administration Medical Center

Order by Phone

You can order SCIENTIFIC AMERICAN *Medicine* by telephone. **Please call this toll-free number: 1-800-345-8112 (in Pennsylvania, call 1-800-662-2444);** you will be billed after your subscription begins. Toll-free calls are acceptable only for orders placed in the continental United States.



SCIENTIFIC AMERICAN MEDICINE

415 Madison Avenue, New York, N.Y. 10017

Please enroll me as a subscriber to SCIENTIFIC AMERICAN *Medicine*. On receipt of this coupon you will send me the advanced two-volume text described in your announcement and update it regularly by sending me new monthly subsections. I understand that the price of $220 for first year of service is tax deductible, as is current renewal at $170. If I am not entirely satisfied, I may cancel at any time during the first 60 days, returning all materials for a *complete refund.*

☐ Please enter my subscription for SCIENTIFIC AMERICAN *Medicine*
☐ I shall also enroll in the CME program
☐ I enclose a check made out to SCIENTIFIC AMERICAN *Medicine* for $220*
☐ Bill me ☐ VISA ☐ MasterCard

Expiration Date_____ Account Number_____

*Please add sales tax for California, Illinois, Massachusetts, Michigan and New York

Name_____

MD Specialty_____

Address_____

City_____ State_____ Zip_____

Signature_____

Please allow six to eight weeks for delivery. All payments must be in U.S. dollars. CME is available outside the U.S. and its possessions for an additional $65. Surface routes used unless airmail delivery is prepaid.

U1

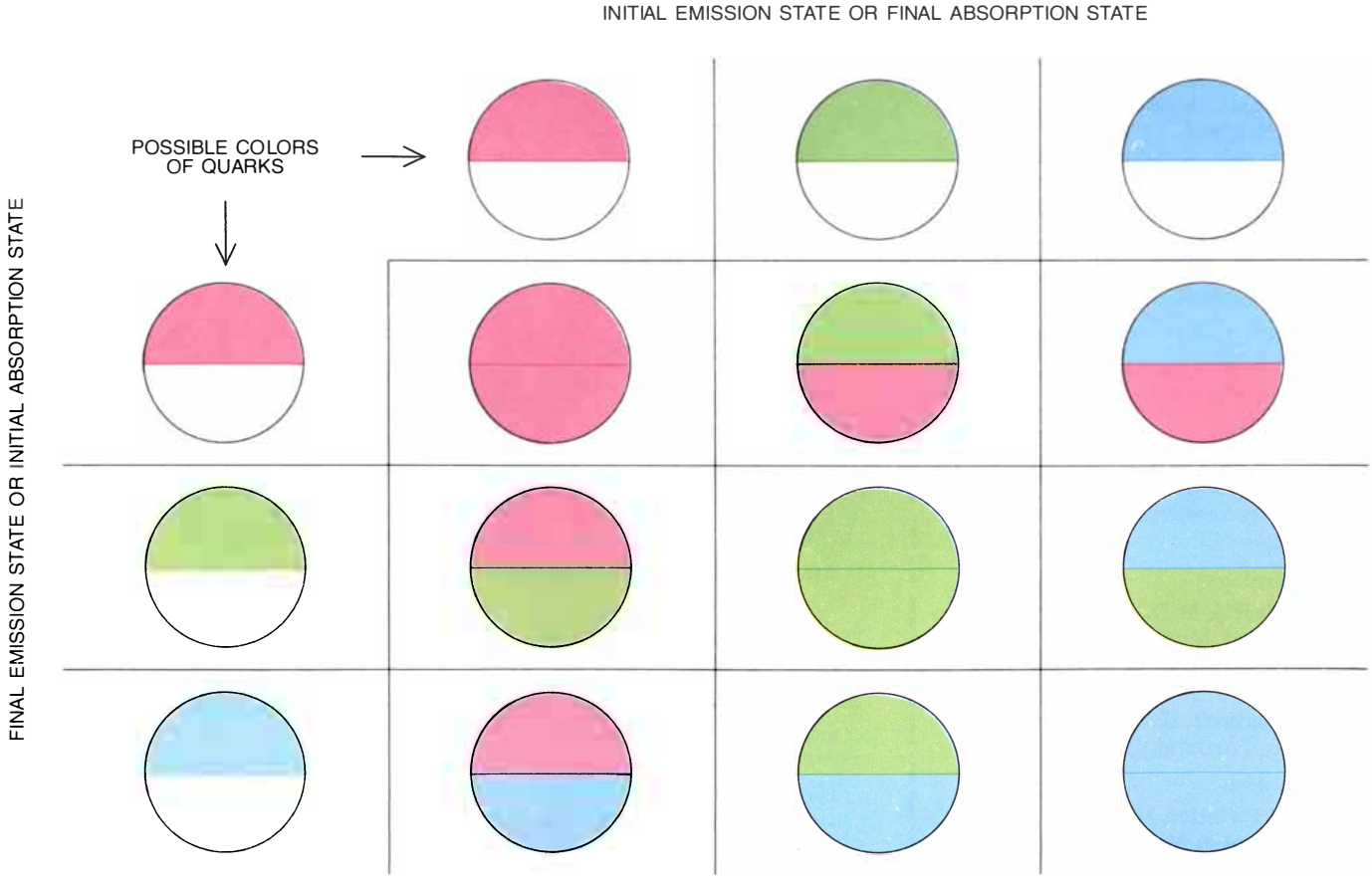
istence to the uncertainty principle of Werner Heisenberg.

According to the uncertainty principle, the law of conservation of energy can seemingly be violated if the violation is brief enough to go "unnoticed." The energy needed to create virtual particles can be "borrowed" from the vacuum surrounding the quark or the gluon because there is some uncertainty about the average energy level of the vacuum over any interval of time. The shorter the interval, the more uncertain the energy, and so more energy becomes available for materializing virtual particles. The spontaneous creation and subsequent annihilation of virtual particles in the vacuum is called the fluctuation of the quantum field. The virtual particles of importance to the color force are gluons and quark-antiquark pairs. The only constraint on their creation is that the sum of the three colors remain constant throughout the interaction.

One consequence of quantum fluctuations is a substantial reduction in the magnitude of the color force at close range. The virtual colored particles surrounding a quark or a gluon account for a large part of the color force that is "felt" by a test particle outside the cloud of virtual particles. As the test particle is moved inside the cloud, however, the effective color force diminishes. At a range of about 10^{-13} centimeter, which corresponds roughly to the diameter of a hadron or a glueball, quarks and gluons can move about almost freely in one another's presence. This loosening of the bonds between colored particles at close range is called asymptotic freedom; it was first discussed by Kurt Symanzik of the Deutsches Elektronen-Synchrotron (DESY) in Hamburg and was later shown to follow from QCD by Gerard 't Hooft of the University of Utrecht, H. David Politzer of Harvard University and David Gross and Frank Wilczek of Princeton University.

One of the most important early successes of QCD was a prediction of the experimental consequences of asymptotic freedom. When an electron and a positron are made to collide head on at high energy, a focused jet or shower of hadrons with relatively coherent flight paths is frequently observed in the products of the collision. Both double and triple jets have been seen; the puzzle is why the hadrons should be bunched in the jets rather than distributed more uniformly. When asymptotic freedom was shown to be a consequence of QCD, the jet events could be explained.

The positron is the antiparticle of the electron, and so when the two particles collide, they annihilate each other. When the particle and the antiparticle have been accelerated to a high energy, all that energy as well as the energy equivalent of their mass is released in a small volume. If the energy density is sufficient, a quark and an antiquark materialize in the small volume. Because momentum must be conserved the momentum of the center of mass of the quark-antiquark pair must be the same as the momentum of the center of mass of the colliding positron and electron, namely zero. Hence the quark and the



CLASSIFICATION OF GLUONS is based on their effects on the colors of the quarks that emit or absorb them. Because the effects of the emission of a colored gluon are the reverse of the effects of absorption, the table can be read two ways. If the circles colored red, green and blue across the top row represent the possible color states of a quark before it emits a gluon, the circles in the left column represent the color states of the same quark after the emission. The colors of the emitted gluon are diagrammed at the intersection of the column and the row corresponding to the initial and the final colors of the emitting quark. (The colors and anticolors are represented as they are in the illustration on page 146.) If one of the colored circles in the left column represents the initial color state of an absorbing quark, one of the circles in the top row represents the same quark's color state after the absorption of a gluon. The gluon that takes part in the interaction lies at the intersection of the row and the column to which the initial and the final absorption states belong. The three solid-colored gluons along the main diagonal of the table can be expressed mathematically as combinations of two independent matrixes that can each be associated with a gluon. Hence there are generally considered to be eight distinct gluons instead of nine.

antiquark begin to move apart in opposite directions.

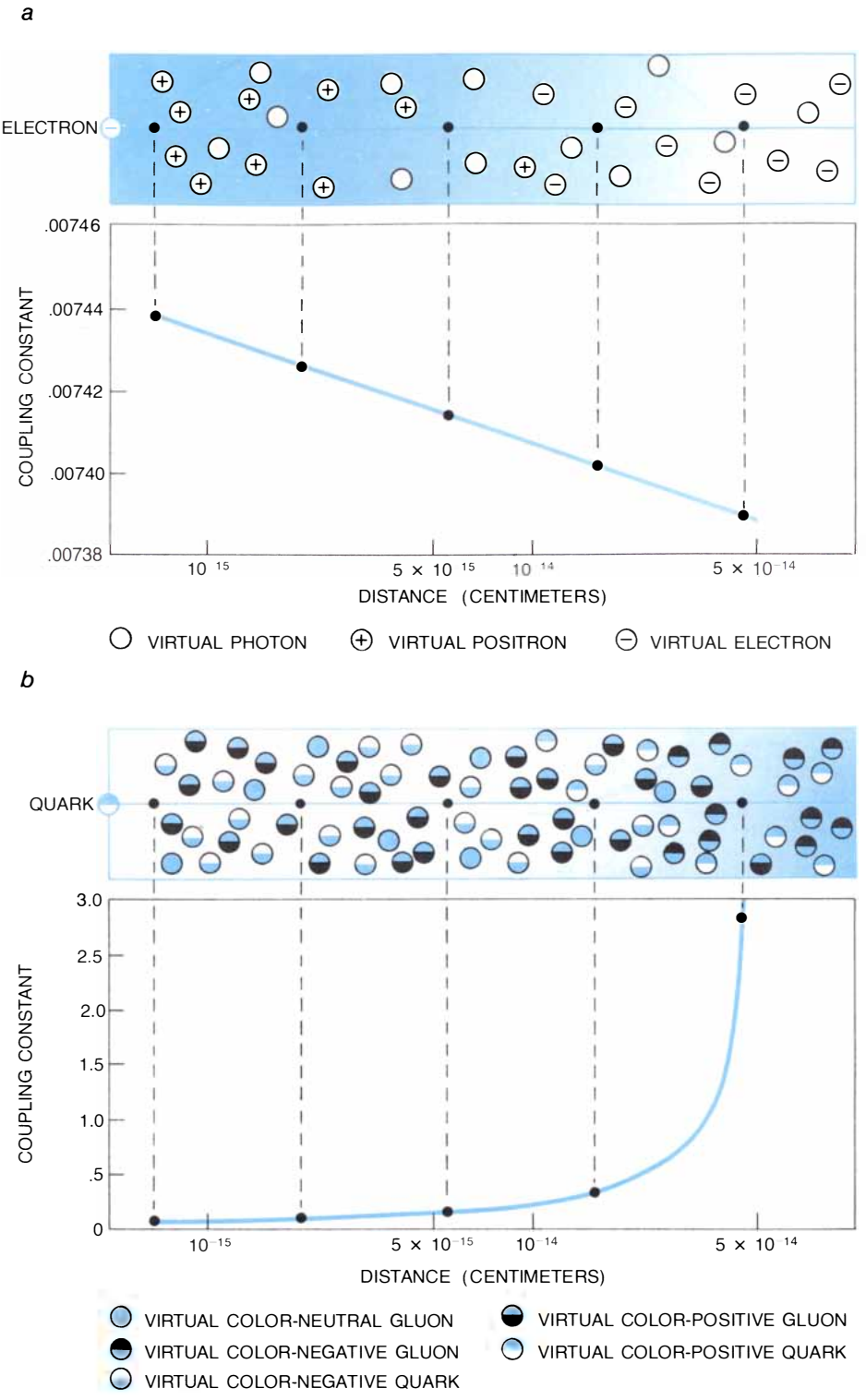
As long as the two particles remain within about 10^{-13} centimeter of each other their trajectories do not come under the influence of the color force because of asymptotic freedom. When the quark and the antiquark begin to feel the color force, however, the energy of the interaction causes new quarks and antiquarks to materialize and subsequently to combine with the initial quark and antiquark to form hadrons. Many of the hadrons are unstable, but they decay into longer-lived hadrons that can be detected. The net result is a double jet of hadrons that retains the signature of the freely divergent motion of the initial quark and antiquark.

In some instances one of the quarks formed after a collision emits a gluon, which moves along a free trajectory as long as it stays within the range of asymptotic freedom. As the gluon moves away from this region, however, it too begins to feel the influence of the color force; the gluon's energy is thereby converted into pairs of quarks and antiquarks and ultimately into a third jet of hadrons. Three-jet events have been observed in several detectors at DESY.

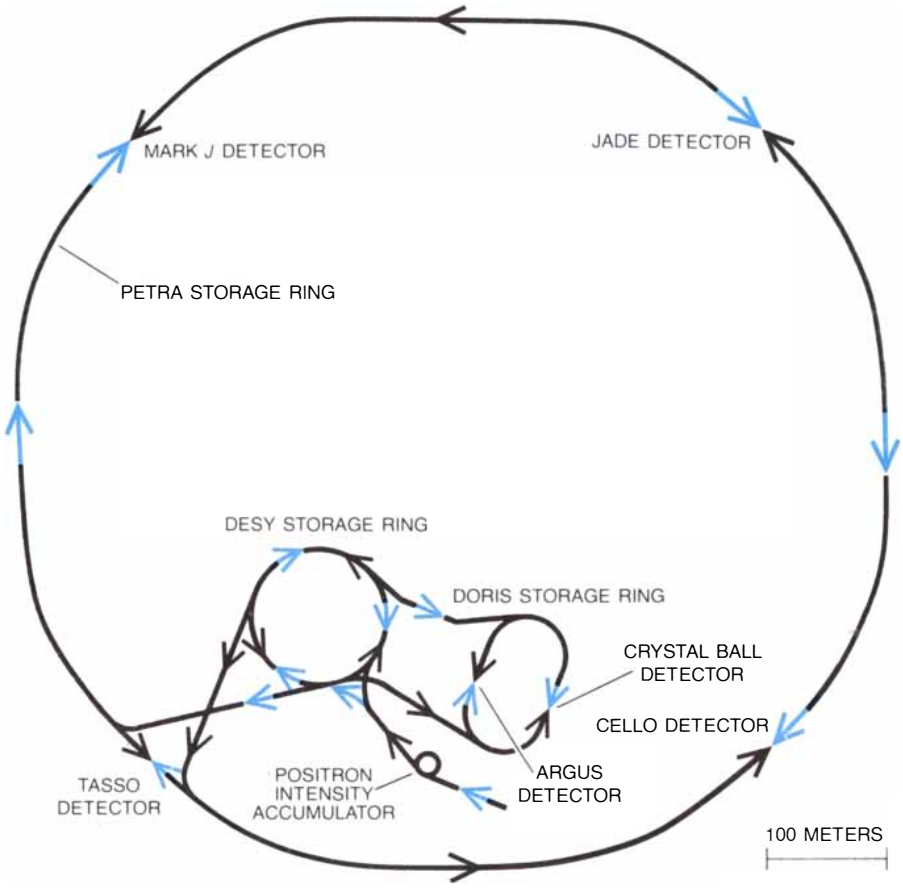
In spite of the success of QCD in explaining the negligible strength of the color force over short distances, theoretical prediction of the effects of the force over longer distances has presented formidable difficulties. Indeed, a demonstration that the permanent confinement of quarks and colors is a consequence of QCD has not yet been forthcoming. A number of phenomenological models have therefore been suggested that simplify the calculations and still predict the confinement of quarks. Within the models it is possible to calculate the energy of bound quarks and gluons in the various states of excitation allowed by quantum mechanics. The calculations are analogous in principle to the determination of the energy states of the electron orbitals in an atom, and they yield predictions of the mass of particles that correspond to the various energy states of the bound quarks and gluons.

In one such model, called the string model, the quarks that make up a hadron are attached to one another by a string that has a fixed energy (or mass) per unit length. When the quarks are close together, the string is slack, and so the quarks move about freely. If the distance between the quarks is increased, however, the string must elongate and the energy of the system must increase proportionally. In the string model a single free quark corresponds to a quark at the end of an infinitely long string, and so the quark must acquire infinite energy in order to exist as a free particle.

The string model can also be applied to the glueball simply by substituting



CLOUD OF VIRTUAL PARTICLES envelops a charged particle and causes the intrinsic strength of the force associated with the charge to vary with distance at extremely short range. The intrinsic strength of the force is defined by a coupling constant. In quantum electrodynamics (QED), the theory that describes the electromagnetic force, an electron is surrounded by virtual photons and by virtual electrons and positrons. The virtual photons are electrically neutral, and so they do not affect the electromagnetic force. The positively charged virtual positrons, however, are attracted to the negatively charged real electron, whereas the negatively charged virtual electrons are repelled. The net effect is that at distances greater than about 10^{-13} centimeter the intrinsic strength of the force generated by the real electron is screened by the cloud of virtual positrons. At distances of less than 10^{-13} centimeter the effect of the screen of charge diminishes and the coupling constant becomes larger, perhaps indefinitely large (*a*). In quantum chromodynamics (QCD), the theory that describes the color force, the effects of the virtual particles that surround a quark are reversed. The colors of the virtual quark and antiquark pairs screen the real color charge much as the virtual electrons and positrons screen the real electron charge. The virtual gluons, however, act differently: they tend to cluster around a real quark that has a like color, and so the color is spread out in space. The ultimate result is that the coupling constant associated with the color force diminishes with distance (*b*).



PLAN OF THE STORAGE RINGS at the Deutsches Elektronen-Synchrotron (DESY) in Hamburg shows the paths along which electrons and positrons can be accelerated in opposite directions and made to collide; it is in the aftermath of such collisions that possible evidence of glueballs has been detected. A beam of electrons (*colored arrows*) can meet a beam of positrons (*black arrows*) at any of several detecting stations. When the particles collide, they annihilate one another and their kinetic energy as well as the energy associated with their mass becomes available for the creation of new particles. The detectors labeled in the diagram are constructed to be highly sensitive to various kinds of signals given off when the newly created particles decay. The electrons and positrons can be accelerated to a wide spectrum of energies.

gluons for quarks at the ends of the string. In the case of the glueball the entire mass of the particle is embodied in the mass of the string, since the gluons themselves are massless. The model predicts that the least energetic glueballs should have masses of between 1 and 2 GeV. (A GeV is a billion electron volts, the energy acquired by an electron that is accelerated through a potential difference of a billion volts.)

Kenneth G. Wilson of Cornell University has developed a method of calculating the mass of hadrons and glueballs that does not depend on phenomenological models but relies instead on successive numerical approximations. The method is called the lattice gauge theory, and it is particularly well suited to simulating the effects of the color force by means of a digital computer. A grid or lattice of points is imposed throughout the space and time occupied by the particles, and the values of the variables needed for describing the motions of the particles are calculated only at the lattice points. The numerical approximations of continuous space and time can be improved by making the mesh of the lattice progressively finer. Michael J. Creutz of the Brookhaven National Laboratory recently showed that both quark confinement and asymptotic freedom are predicted by the lattice gauge theory.

In the past year my colleagues and I have calculated the mass of several possible glueball states and have suggested several experimental contexts in which they might be observed. The masses can be calculated in two independent ways, depending on what underlying mathematical assumptions are made to describe the interactions. Asao Sato of the University of Tokyo, Gerrit Schierholz of the University of Hamburg, Michael J. Teper of DESY and I have calculated the mass of three of the glueball states, assuming that the mathematical group that represents the gluons is either the one called $SU(2)$ or the one called $SU(3)$. Mathematical groups enter the theory of elementary particles as a way of describing the possible transformations among particles. The group $SU(2)$ applies to particles that have two kinds of charge and whose transformations can therefore be classified in a two-by-two matrix. Of course, colored particles have three kinds of color charge, and so QCD is based on the group $SU(3)$. Nevertheless, the results we obtained by assuming that the theory was based on the group $SU(2)$ were almost the same as they were in $SU(3)$. The $SU(2)$ calculations can usually be employed for pilot studies, and they are considerably less time-consuming.

We found that the mass of the scalar glueball (the one with a spin of zero and positive parity) is about 1 GeV, whereas the mass of the pseudoscalar (spin-0, negative-parity) glueball is about 1.5 GeV; the mass of the tensor (spin-2) glueball that has both positive parity and positive charge conjugation is between 1.5 and 2 GeV. The values are consistent with the ones determined through phenomenological models such as the string model. They also agree quite closely with the masses calculated by two other groups of investigators: Giorgio Parisi and his collaborators at the University of Rome and Bernd Berg of the European Organization for Nuclear Research (CERN), Alain Billoire of the Saclay Nuclear Research Center and Claudio Rebbi of the Brookhaven National Laboratory.

Schierholz, Teper and I have also investigated the spatial structure of the scalar and the tensor glueballs. We have found that the gluons in the scalar glueball tend to distribute themselves evenly in a sphere surrounding the center of the glueball. In the tensor glueball they tend to cluster in a toroidal region and only rarely occupy the center.

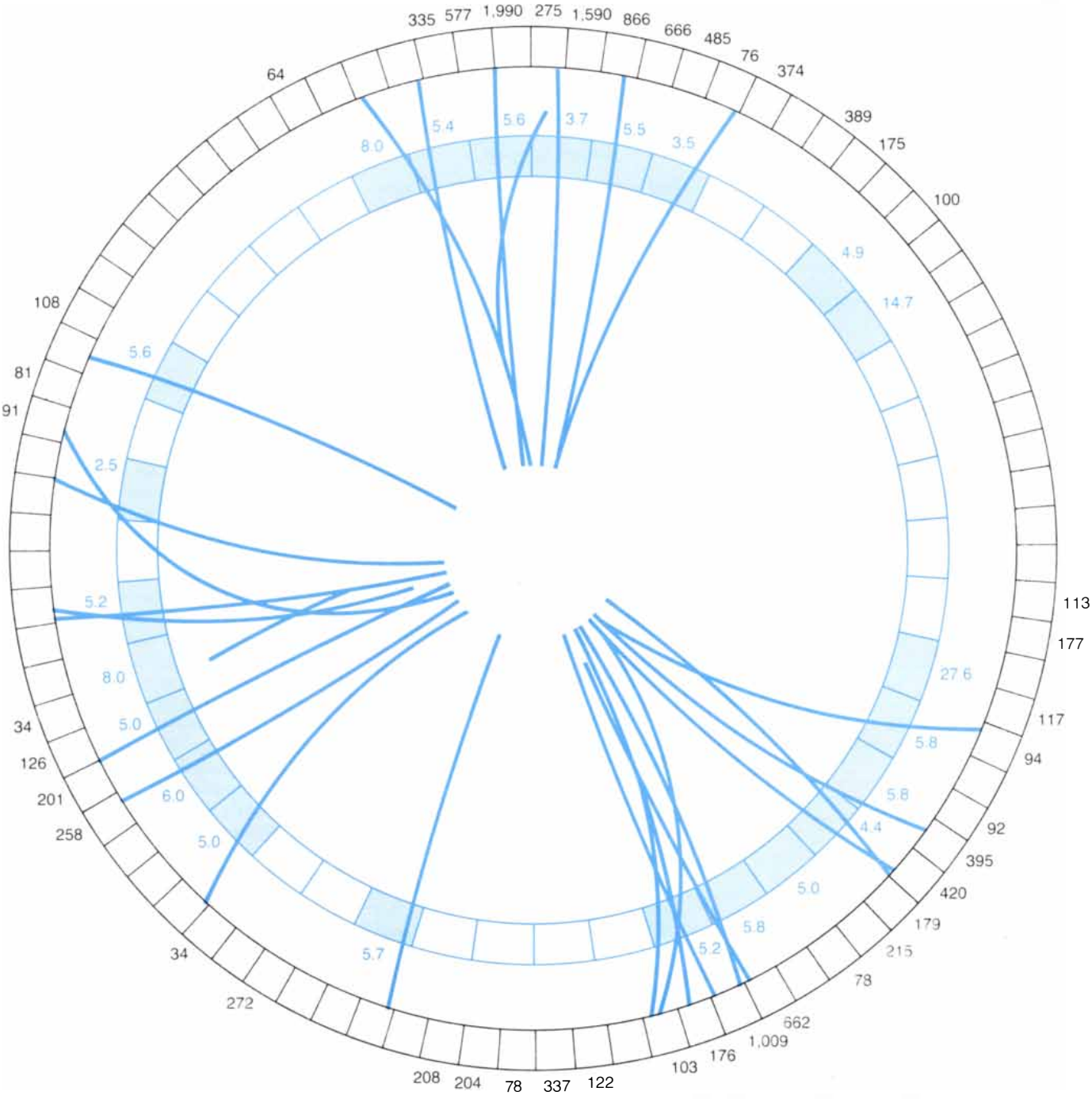
In order to identify glueballs when they are generated, their properties, their mode of production and their most likely channels for decaying into more-stable particles must be clearly understood. The problem is not only one of finding a few glueball signatures in a welter of background noise; it is also one of determining exactly how to distinguish the glueball signatures from the signatures of hadrons that have not yet been assigned a classification in the quark model.

It is not possible to generate glueballs alone. In the method of generating particles that is most suitable for observing glueballs a beam of electrons and a beam of positrons are accelerated in opposite directions and allowed to collide at a controlled energy. The lifetime of a glueball produced in the collision is extremely short: on the order of 10^{-25} second. Hence it is not possible to observe glueballs directly; one can only infer their short-term existence from the properties of the daughter particles into which they decay. The signature or sig-

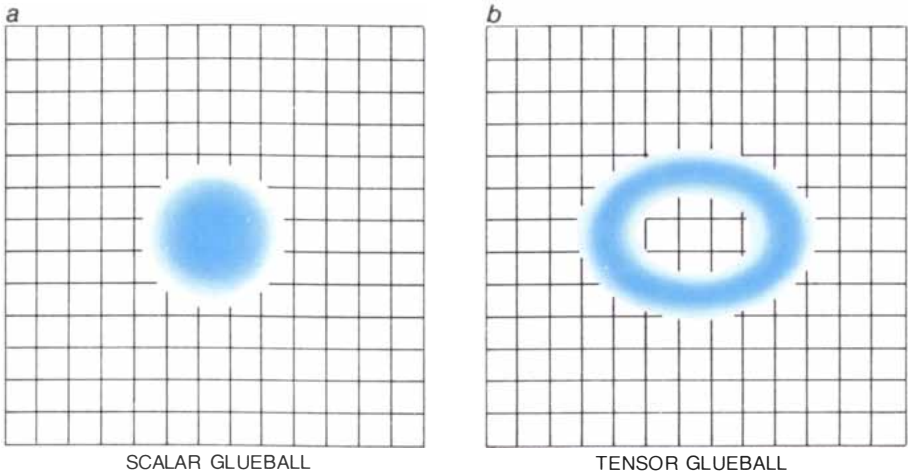
nal of a glueball is observed as a resonance: a peak in the number of hadrons detected when the energy of the colliding particles is adjusted to match the mass of the glueball.

Since a glueball has no internal quantum number corresponding to the flavor of quarks, every glueball candidate must be a flavorless particle. The absence of flavor is not a sufficient condition for identifying a glueball, however; there are ordinary hadrons, such as the eta-prime meson, that have no flavor either. Moreover, glueballs can assume every possible value of the spin, parity and charge-conjugation quantum numbers, so that any glueball whose set of quantum numbers is shared by a hadron is difficult to identify unambiguously.

On the other hand, there are a few predicted glueball states whose quantum numbers do not match those of any hadron. Sato, Schierholz, Teper and I have recently calculated the masses of



THREE-JET EVENT demonstrates the existence of the gluon and confirms the weakening of the color force at close range. Both the gluon and the weakening effect, which is called asymptotic freedom, are predicted by QCD. When an electron and a positron collide head on, they annihilate each other. The kinetic energy as well as the energy associated with the mass of the particle is converted by the collision into a high-energy photon, and a quark and an antiquark materialize from the energy of the photon. Because the electron and the positron move in opposite directions just before the collision, their total momentum is zero. In order to conserve momentum after the collision the quark and the antiquark begin to move away from each other in opposite directions. A gluon emitted by one of the quarks moves off in a third direction. The trajectory of each particle is a straight line during the initial stages of flight because of asymptotic freedom; the color force does not appreciably influence the motion of the particles at a range of less than about 10^{-13} centimeter. As the particles decay each gives rise to a shower of daughter particles. The initial divergence of the three particles is therefore reflected in the observed divergence of the jets. Each number in colored type gives the time of flight in nanoseconds of the detected particle to which the number corresponds. The time is measured from the moment of the electron-positron collision to the moment of the detection. Each number in black type gives the energy, in megaelectron volts (MeV), of the particle. The event shown was recorded by the JADE detector at DESY.



DYNAMIC STRUCTURE of a glueball can be pictured much as the structure of the electrons in an atom can, namely by plotting the wave function of the gluons that make up the glueball. In the diagram are plotted the wave functions of two glueball states that have been tentatively identified among the by-products of electron-positron annihilations: the scalar, or spin-0, glueball (*a*) and the tensor, or spin-2, glueball (*b*). The density of the shading at every point corresponds to the amplitude of the wave function at that point. The square of the amplitude of the wave function is the probability that a gluon will be found in a small region of space.

two such states. We found the masses to be about 1.5 to 2 GeV, low enough to be produced in the decay of the *J*/psi meson, the hadron made up of the charm quark and the anticharm antiquark, which is readily generated in an electron-positron storage ring. (Recall that charm, like up, down and strange, is a quark flavor.) If particles having such masses and quantum numbers are ever detected, they could be unambiguously identified as glueballs.

Because of the similarity of many glueball states to ordinary hadrons it is good experimental strategy to focus attention on processes that are thought to give rise to significant numbers of glueballs. One likely process is the creation of a quark and the corresponding antiquark that subsequently annihilate each other; the products of the annihilation can take many forms, including two gluons with opposite color charges. In many reactions quark-antiquark pairs are formed, but relatively few pairs annihilate each other. The empirical rule of thumb that suppresses the annihilation is called the OZI rule, after Susumu Okubo of the University of Rochester, Zweig and Jugoro Iizuka of Nagoya University. When the OZI rule is violated, gluons are emitted copiously and glueballs are likely to form. A violation of the OZI rule can also give rise to the time-reversed reaction: the decay of a glueball can lead to the formation of new quark-antiquark pairs.

One reaction that violates the OZI rule is the decay of the *J*/psi meson. Another reaction is the formation of the phi meson, a hadron made up of a strange quark and an antistrange antiquark. Phi mesons are emitted when pi mesons bombard a fixed target of protons. In both reactions signals have been detected that may indicate the presence of glueballs.

When a glueball is created, there are several ways it can decay to yield detectable particles. For example, the pseudoscalar glueball, which has zero spin and negative parity, can decay into an eta meson and two pi mesons or into a K meson, a $\bar{K}$ meson and a pi meson. The former mode, however, can be observed in great quantities from the decay of other particles, and so the signal from the glueball is almost completely washed out. The latter signal, however, in which the K and $\bar{K}$ mesons are present, is known to be favored by the pseudoscalar glueball; even a few such detected events could be discerned.

One decay channel in which a glueball could be distinguished from hadrons with identical quantum numbers is the decay into two photons. Because quarks are electrically charged and gluons are electrically neutral it turns out that particles made up of quarks are more likely to decay into photons than glueballs are. Accordingly I have estimated that there should be fewer instances in which a glueball emits two photons than there are in which a hadron does.

Of all the reactions that might give rise to glueballs the ones most likely to lead to an unambiguous glueball candidate are the decays of the *J*/psi meson that include photons among the detected products. A survey of events of this kind was made at the Stanford Linear Accelerator Center (SLAC) and two glueball candidates emerged. One candidate was a particle observed two years ago by experimenters working with the Mark II detector; its mass was 1.44 GeV, but at the time of its detection its spin and parity were not determined. Because the resonance was discovered in a reaction that closely matched the reac-

SPIN	PARITY	CHARGE CONJUGATION	TWO-GLUON STATE	MANY-GLUON STATE	QUARK AND ANTIQUARK
0	+	+	.72 GeV		
0	+	−			
0	−	+	$1.37 \pm^{.35}_{.26}$ GeV		
0	−	−		$1.4 \pm^{.6}_{.4}$ GeV	
1	+	+			
1	+	−		3.22 ± .16 GeV	
1	−	+		$2.36 \pm^{.217}_{.21}$ GeV	
1	−	−			
2	+	+	1.6 ± .085 GeV		
2	+	−			
2	−	+			
2	−	−		$3.6 \pm^{.03}_{.02}$ GeV	

POSSIBLE QUANTUM NUMBERS of glueball states and states of ordinary mesons (in which a quark and an antiquark are bound together) can be calculated theoretically and compared with values determined experimentally. Colored squares in the table indicate the states, or particles, for which certain combinations of the three quantum numbers spin, parity and charge conjugation are theoretically possible. Many combinations are possible for both glueballs and ordinary mesons, and so the determination that a particle has such quantum numbers would still leave the identity of the particle in doubt. For the combinations of quantum numbers that are possible only in the glueball state the experimental determination of the quantum numbers would be unambiguous evidence for the existence of a glueball. The theoretical energy values of the glueball states listed were calculated recently by the author and his co-workers.

HOW TO BEAT TODAY'S HARDCOVER PRICES

You don't judge a book by its cover, so why pay for the cover?

QPB books are softcover editions in hardcover sizes, durably bound and printed on fine paper. But they cost up to 65% less than their hardcover counterparts.

Now you know how to beat today's prices: Join QPB.

672. Unfinished Tales of Númenor and Middle-earth
J. R. R. Tolkien
Hardcover: $15 **QPB: $6.95**

673. Ernest Hemingway
Selected Letters, 1917-1961.
Edited by Carlos Baker
Hardcover: $27.50 **QPB: $10.95**

286. A Book of Five Rings
Miyamoto Musashi
Translated by Victor Harris
Hardcover: $12.95 **QPB: $4.95**

308. Economics Explained. Robert L. Heilbroner and Lester C. Thurow
Hardcover: $12.95 **QPB Ed: $6.95**

447. Myths of Greece and Rome
Thomas Bulfinch. Compiled by Bryan Holme. **QPB: $8.95**

351. The American Medical Association's Handbook of First Aid and Emergency Care
Developed by the American Medical Association. **QPB: $4.95**

392. The Nine Nations of North America. Joel Garreau
Hardcover: $14.95 **QPB: $6.50**

398. The Dinosaurs. Illustrated by William Stout, Edited by Byron Preiss, Introduction by Dr. Peter Dodson
QPB: $10.95

401. The Mapmakers. John Noble Wilford. Hardcover: $20 **QPB: $7.95**

424. The Electronic Cottage
Everyday Living with Your Personal Computers in the 1980s. Joseph Deken
Hardcover: $14.95 **QPB Ed: $7.50**

111. The Search for Alexander
An Exhibition. Contributions by Nicholas Yalouris, Manolis Andronikos, and Katerina Rhomiopoulou. (Photographs)
Hardcover: $24.95 **QPB: $9.95**

124. A Field Guide to American Architecture. Carole Rifkind
Hardcover: $19.95 **QPB: $7.95**

151. The Lord of the Rings
(3 Vols., Boxed) J. R. R. Tolkien
Hardcover: $35.95 **QPB: $9.95**

222. The Mismeasure of Man and **The Panda's Thumb** (2 Vols., Boxed)
Stephen Jay Gould
Hardcover: $27.90 **QPB Ed: $11.95**

283. The Structures of Everyday Life. Fernand Braudel
Hardcover: $30 **QPB Ed: $12.95**

427. Other Worlds: A Portrait of Nature in Rebellion; Space, Superspace and the Quantum Universe. Paul Davies
Hardcover: $11.95 **QPB: $4.25**

Join now. Pick any 3 books or sets for $1 each–with no obligation to buy another book.

596. The Solar Age Resource Book
Editors of 'Solar Age' magazine
QPB: $7.95

267. The Timetables of History
Bernard Grun
Hardcover: $29.95 **QPB: $11.95**

444. Dictionary of Philosophy and Religion: Eastern and Western Thought. William L. Reese
Hardcover: $29.95 **QPB: $10.95**

182. Ah, But Your Land Is Beautiful
Alan Paton
Hardcover: $12.95 **QPB Ed: $6.95**

414. The Life and Times of Joe McCarthy. Thomas C. Reeves
Hardcover: $19.95 **QPB Ed: $9.95**

421. Life on Earth: A Natural History. David Attenborough
Hardcover: $22.50 **QPB Ed: $9.95**

574. The Foundation Trilogy
(3 Vols.) Isaac Asimov
QPB: $6.95

519. Modern Art: 19th and 20th Centuries. Meyer Schapiro
Hardcover: $20 **QPB: $9.95**

594. Dover Math Books: *Challenging Mathematical Teasers, Fun With Figures, Mathematical Brain-Teasers,* J. A. H. Hunter; *Mathematical Diversions,* J. A. H. Hunter and Joseph S. Madachy. (4 Vols.)
QPB: $9.75

163. Conceptual Blockbusting
A Guide to Better Ideas (Second Edition). James L. Adams
Hardcover: $10.95 **QPB: $3.95**

Compare

Hardcover: $15.50 **QPB Softcover: $7.95**

507. Megatrends. John Naisbitt
Hardcover: $15.50 **QPB Ed: $7.95**

524. Science Observed: Essays Out of My Mind. Jeremy Bernstein
Hardcover: $16.95 **QPB Ed: $8.95**

483. Nova: Adventures in Science. WGBH Boston
Hardcover: $27.95 **QPB: $11.95**

614. The Woodwright's Shop
A Practical Guide to Traditional Woodcraft. Roy Underhill
Hardcover: $19.95 **QPB: $9.50**

632. Dover Logic Books: *Puzzles in Math and Logic,* Aaron J. Friedland; *My Best Puzzles in Logic and Reasoning,* Hubert Phillips ("Caliban"); *Test Your Logic,* George J. Summers; *Recreations in Logic,* D.G. Wells. (4 Vols.)
QPB: $7.50

659. The Film Encyclopedia
Ephraim Katz
Hardcover: $29.95 **QPB: $11.95**

671. The Origin of Consciousness in the Breakdown of the Bicameral Mind. Julian Jaynes
Hardcover: $16.95 **QPB: $7.95**

108. Build Your Own Furniture
Peter Stamberg. **QPB: $7.95**

465. Taking the Quantum Leap
The New Physics for Nonscientists. Fred Alan Wolf. **QPB: $7.95**

473. Space, Time & Medicine
Larry Dossey, M.D.
Foreword by Fritjof Capra
Hardcover: $15.95 **QPB: $7.95**

Let's try each other for 6 months.

Quality Paperback Book Club, Inc., Middletown, Pa. 17057.

Please enroll me in QPB and send the 3 choices I've listed below. Bill me $3, plus shipping and handling charges. I understand that I am not required to buy another book. You will send me *QPB Review* (if my account is in good standing) for 6 months. If I have not bought and paid for at least 1 book in every six-month period, you may cancel my membership. A shipping and handling charge is added to each shipment. QB170-11

Indicate by number the 3 books or sets you want ☐ ☐ ☐

Name _____ 2-16
(Please print clearly)

Address _____ Apt. _____

City _____ State _____ Zip _____

How membership works.

1. You receive **QPB Review** 15 times each year (about every 3½ weeks). Each issue reviews a new **Selection,** plus scores of Alternates.
2. If you want the **Selection** do nothing. It will be shipped to you automatically. If you want one or more Alternate books—or no book at all—indicate your decision on the Reply Form always enclosed and return it by the date specified.
3. **Bonus books for Bonus Points.** For each QPB book or set you take (except for the books in this offer), you earn Bonus Points which entitle you to choose any of our softcover books. You pay only shipping and handling charges.
4. **Return privilege.** If *QPB Review* is delayed and you receive the **Selection** without having had 10 days to notify us, you may return it for credit at our expense.
5. **Cancellations.** You may cancel membership at any time by notifying QPB. We may cancel your membership if you elect not to buy and pay for at least one book in every six-month period.

Prices generally higher in Canada.

The first book club for smart people who aren't rich.

SPIN	PARITY	CHARGE CONJUGATION	$\pi\ \pi$	$K\ \bar{K}$	$\eta\ \eta$	$\pi\ \pi\ \pi$	$K\ \bar{K}\ \pi$	$\eta\ \pi\ \pi$	$\rho^0\rho^0$
0	+	+							
0	−	+							
2	+	+							

POSSIBLE CHANNELS for the decay of a glueball in any of three energy states into more stable particles that can be detected are indicated by the colored regions in the table. Blank regions indicate decay channels that can be ruled out on theoretical grounds. The relative abundance of the particles detected after the collisions of electrons and positrons in a storage ring, together with theoretical predictions of the probability that the decay will follow a given channel, makes it possible to identify certain decay products as signals of glueball candidates.

tion one would expect from a glueball, several of my colleagues and I suggested it was the pseudoscalar glueball.

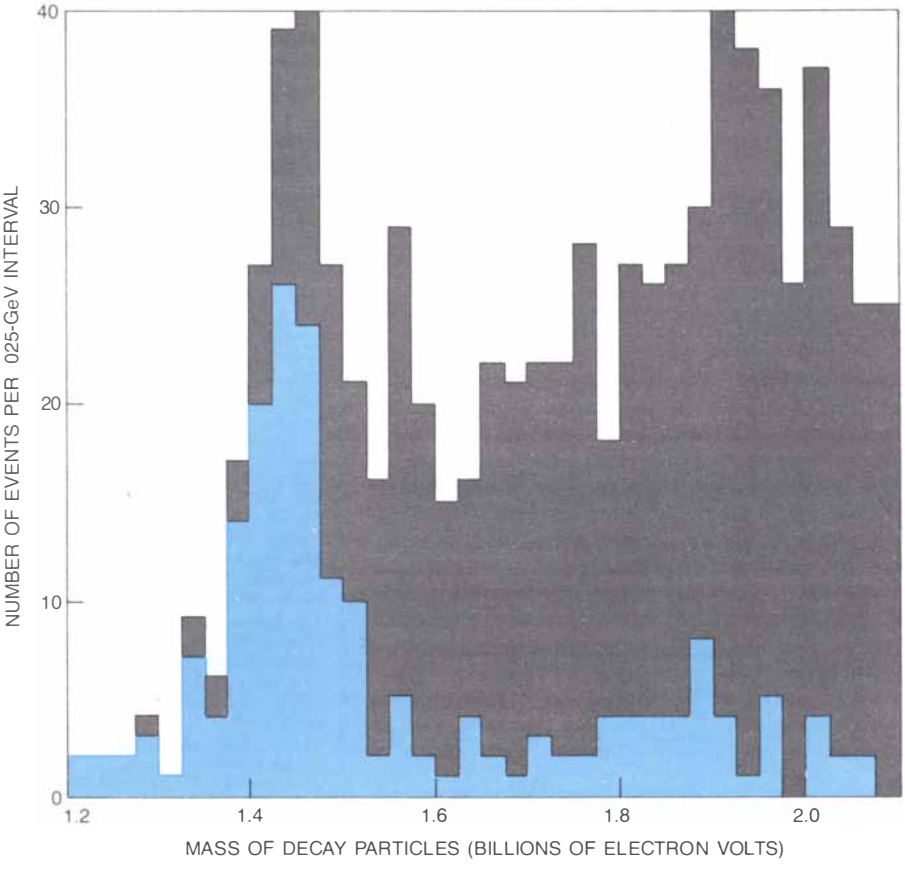
A number of other investigators, however, were disinclined to accept the glueball interpretation. The same reaction can also signal the decay of a hadron called the *E* meson, whose mass is 1.42 GeV. The resolution of the resonance peak, they argued, was not sharp enough to distinguish two particles whose masses are so nearly equal.

To ascertain the identity of the particle Michael S. Chanowitz of the University of California at Berkeley and I suggested that the spin and the parity of the new resonance be measured; I noted that the rate at which pairs of photons were released by the decay might be measured also. About a year later a detector then at SLAC called the Crystal Ball measured the photon production in the reaction with great sensitivity. The particle having a mass of 1.44 GeV was found to have zero spin and negative parity; in other words, it is a pseudoscalar particle. The *E* meson, on the other hand, is a spin-1 particle with positive parity. The spin-0 particle is therefore likely to be the first confirmed glueball.

The second glueball candidate was also observed at SLAC by workers using the Crystal Ball detector. It has a mass of 1.67 GeV and a spin of 2, so that it may be a tensor glueball. The particle decays to yield two eta mesons, which then decay to yield four photons. Its mass is in agreement with the mass predicted for the tensor glueball by the lattice gauge theory, but the number of photon quadruplets that are detected is much smaller than the theory requires.

A tensor glueball emitted during the decay of the *J*/psi meson is expected to have another possible mode of decay: in some instances it should yield two neutral rho mesons. The number of rho mesons recently observed by the Mark II detector is in agreement with the theoretical production rate of rho mesons in the decay of the tensor glueball. The evidence therefore slightly favors the existence of the tensor glueball, but more data are needed before the identification of the particle can be secure.

The lattice gauge theory also predicts the existence of a scalar glueball, which should be the least massive one of all. Most low-mass particles are relatively stable, and so the resolution of a resonance in their decay products is clear. The scalar glueball, however, has not yet been seen. My guess is that the particle exists, but that its unusual properties give rise to a wide but low resonance that is quite difficult to detect.



EVIDENCE FOR A GLUEBALL is the sharp resonance, or peak, found when the number of detected events of a certain kind is plotted against the energy released by the collision of an electron and a positron. The resonance indicates that the energy of the collision is momentarily bound up in the mass of a particle just after the collision, instead of being distributed throughout a range of energy values. Although the original particle decays spontaneously into longer-lived particles and energetic photons, the energy of the decay products can still be determined. In the experiment from which the data in the graph were taken the total energy of every decay that created a K^+ meson, a K^- meson, a neutral pi meson and a photon was determined. The number of such events in each energy interval was then plotted (*gray region*). A second graph was constructed (*colored region*) including only those events in which the mass of the K^+ and the K^- mesons did not exceed 1.125 billion electron volts (GeV). The added constraint served as a noise filter; a resonance at 1.44 GeV stands out clearly. Because the resonance agrees with the predicted mass of the glueball and because the predicted low-energy states of bound systems of quarks have already been accounted for by other particles, the data strongly suggest that glueballs are actually being materialized. The data were obtained from the Crystal Ball detector while the detector was installed at the Stanford Linear Accelerator Center (SLAC).

The discovery of a glueball, like the discovery of any new particle, is a remarkable event in its own right. For the theory of strong interactions, however, the glueball is a find of special significance. Its positive identification would confirm one of the most important distinctions between quantum chromodynamics and its parent theory, quantum electrodynamics, namely the nature of the relation between the charge associated with an interaction and the particle that mediates the interaction. The tentative identification of the pseudoscalar glueball is a success of QCD that is not directly inherited from QED. Our work for the near future will surely be to consolidate the success and continue the search for new glueballs.

FOR THE WET

FOR THE WHITE

FOR THE WINDING

FOR THE WILD

FOR THE WARM

FOR THE WEEKEND

FOR THE WALLET

W is for Eagle Wagon. And for the wherever. Because Eagle is the only automobile in the world that lets you go from 2-wheel drive to full-time 4-wheel drive at the flick of a switch. 2-wheel drive for high mileage on the highway. 4-wheel drive for worry-free traction and security when the roads weave, the weather worsens, or when you just want to wander where there is no road.

And Eagle's well-appointed interior makes the going all the more wonderful. Why not see the 1983 Eagle Wagon today. Wherever you're going, whatever the weather, it'll fit you to a **W.**

The 2-wheel/4-wheel drive EAGLE

FROM AMERICAN MOTORS

*Optional 5-speed stick. Use these figures for comparison. Your results may differ due to driving speed, weather conditions and trip length. Highway and California figures lower.

The Ecological Physiology of a Garter Snake

In order to survive in the harsh environment of western Canada the red-sided garter snake has evolved a precisely timed cycle of physiology and behavior with several spectacular features

by David Crews and William R. Garstka

The red-sided garter snake (*Thamnophis sirtalis parietalis*) is found farther north than any other reptile in the Western Hemisphere. It ranges into western Canada, where the winter temperature is often below −40 degrees Celsius and the snow cover is often continuous from late September through May. Throughout the long winter it takes refuge in sinks and caverns in the limestone that characterizes much of western Canada. Each such hibernaculum, or den, harbors as many as 10,000 snakes. In the den the overwintering garter snakes undergo a set of profound physiological changes. Their blood becomes as thick as mayonnaise. Occasionally they move, but only sluggishly.

Late in the spring the garter snakes emerge. Although males and females hibernate together in equal numbers, the males come out more or less en masse. Neither food nor water is available at the den. Nevertheless, the males stay nearby. Then the females come out. Some of them emerge as early as the males. Unlike the males, however, the females emerge singly or in small groups. The difference in the timing of their emergence means that at the opening of the den males may outnumber females by as many as 5,000 to one; each female is vigorously pursued and courted by a multitude of suitors.

The typical result is a writhing mass of snakes called a mating ball, consisting of as many as 100 males all trying simultaneously to align themselves with a single female. Within 30 minutes of the female's emergence she has mated, and the unsuccessful males are awaiting the appearance of another female. Meanwhile the mated female sets off on a migration to summer feeding grounds. Migrations of as much as 15 kilometers are known. The males will follow at the end of the mating season, which may last for only three days or for as long as three weeks. Early in the fall each female gives birth at the feeding ground to as many as 30 living young; then the adult snakes return to their den and reenter hibernation. (It is not known where the newborn spend their first winter.)

The question addressed in our research, first at Harvard University and now at the University of Texas at Austin and the University of Alabama, is how a species such as the red-sided garter snake, which lives in a region where the climate is extreme, comes to have its physiology and its behavior synchronized with the demands of its environment. In the case of the red-sided garter snake the young must be born before the adults reenter winter dormancy; hence the species must mate, migrate and feed, give birth to its young and return to hibernation on a precise schedule spanning three summer months. In trying to understand this cycle much of what is known about the physiology of other vertebrate animals that have a breeding season turns out not to be relevant. In advance of the breeding season the gonads of such an animal typically get bigger and the blood level of sex hormone rises. The gonads prepare gametes (sperm or eggs), and the rising concentration of circulating sex hormone acts on the brain to trigger mating behavior. The red-sided garter snake is different. When the snakes emerge from their den for their short, intense mating season, their gonads are at their smallest and their hormones are at an ebb.

The springtime increase in temperature that allows the red-sided garter snake to emerge from its den is known to trigger its mating behavior. Alexander Hawley and Michael Aleksiuk of the University of Manitoba have shown that the snakes will mate in the laboratory only if the dormant animals are exposed to a temperature of at least 25 degrees C., which simulates spring. Few males will try to mate at temperatures of less than 20 degrees. We ourselves have found that males must be exposed to a temperature of less than 10 degrees for at least seven weeks if they are to show mating behavior when they are exposed to warmth.

The mating behavior is unmistakable. Males first recognize females by means of a pheromone: a chemical released by some members of a species that controls the physiology and the behavior of other members. In this instance the female releases the chemical, a fact that G. Kingsley Noble of the American Museum of Natural History inferred more than 40 years ago by observing the snakes' behavior. Noble also found that males, which normally ignore other males, courted the males he had rubbed against sexually attractive females. The work of John Kubie and Mimi Halpern of the Downstate Medical Center of the State University of New York suggests how the pheromone acts. The male catches pheromone molecules on his tongue, which he repeatedly flicks as he nears the female, and the tongue delivers the molecules to the vomeronasal organs, which are in the roof of the mouth. The chemical-sensitive cells of the vomeronasal organs send signals along nerve fibers to the brain. (All other snakes and those lizards that have forked tongues detect chemical trails laid down by

CARPET OF MATING GARTER SNAKES covers the floor of a limestone sinkhole in Manitoba; the springtime increase in temperature has caused them to emerge through fissures from their den in a cavern under the sink. The snakes are red-sided garter snakes. The males are from 12 to 18 inches long, the females from 18 to 24 inches long; otherwise they look much the same. As many as 10,000 red-sided garter snakes may share a den through the winter. The photograph was made by Bianca Lavies. Copyright © 1975 National Geographic Society.

other members of their own species in the same way. Vomeronasal organs are found even in mammals. They are the principal means by which animals communicate chemically. In human beings they are vestigial but in the human fetus they are well developed.)

If the male red-sided garter snake finds the female sexually attractive, the tongue flicking becomes more frequent. Soon the male begins to rub his chin along the back and side of the female, rapidly and repeatedly traversing the length of her body. This chin rubbing is observed only as part of mating behavior. The male traverses the female with increasing rapidity, and then he comes to rest draped over her. The scales near the opening of his cloaca (in reptiles the combined end of the urogenital and intestinal passages) are sensitive to touch; hence the male has sensory guidance as he aligns his body with the female's.

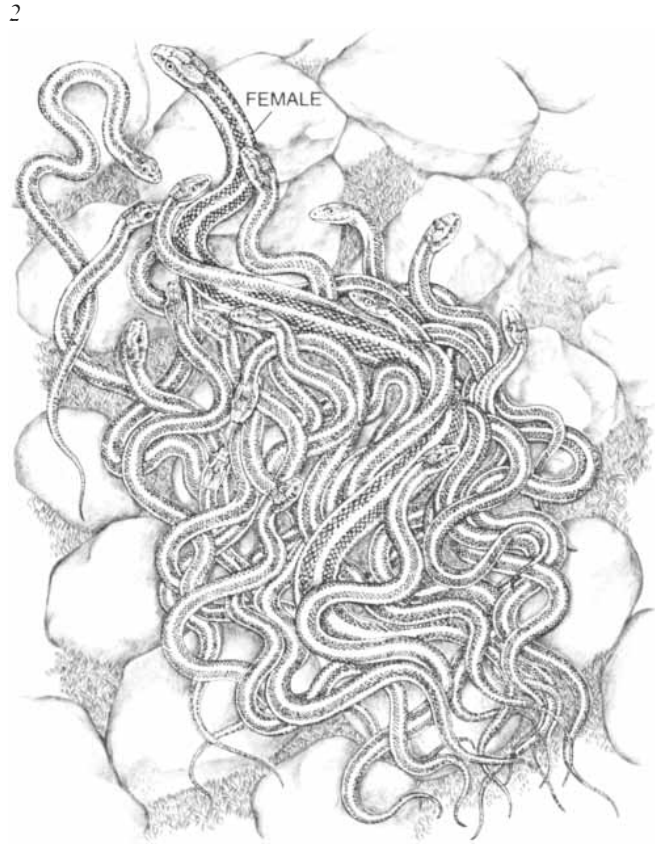
When the male is properly aligned, he initiates muscular contractions that send waves up and down the length of his body. The waves are a prelude to further maneuvers that bring the tail of the male under the body of the female so that his cloaca is apposed with hers. The male then achieves intromission. He rolls the female's tail upward and everts one of his hemipenes slightly. (The hemipenes are two saclike copulatory organs in the cloaca.) Small hooks at the base of the hemipenis engage the cloacal scales of the female, so that the female's cloaca is drawn open. Finally the male fully everts the hemipenis into the female's cloaca. Sperm enters the female by flowing along a groove in the hemipenis wall.

The female's mating behavior is also characteristic. During the courtship that leads up to intromission the female breathes more deeply than usual but not more rapidly. If she is sexually receptive, she remains stationary. Indeed, she may cooperate with the male by lifting her tail and widening the opening of her cloaca. If she is not receptive, she retreats from the male's advances and may even vibrate her tail, making intromission impossible. At intromission itself the male stops moving and is dragged about by the female. The hooks at the base of the hemipenis keep the cloacas locked together.

Intromission marks the moment when the unsuccessful males in the mating ball stop trying to court the female and disperse from the copulating pair. The copulation usually lasts for some 15 minutes. In that time the male deposits a translucent gelatinous plug in the cloaca of the female. The plug acts as a mechanical obstruction to further mating. In addition the plug contains a pheromone that makes the female unattractive to other males. Thus the female and the male produce pheromones with opposite functions. The mated female quickly leaves the site of the den.

Investigators trying to identify the nature and the source of the female's attractiveness pheromone have long been puzzled by the fact that the skin of garter snakes is devoid of any obvious glands that might produce, store or release such a chemical. An alternative possibility was suggested to us by two recent discoveries. The first was made by Josephine C. Rauch of the University of Manitoba. She described a network of capillaries along the back of garter snakes in the dermis, the deep layer of the skin. The second discovery, made by Lucas Landmann of the University of Basel and independently by Harvey Lillywhite of the University of Kansas, was that the skin of snakes is not an impermeable barrier. It allows lipids (fatty molecules) to pass through it. We reasoned that the female attractiveness pheromone might be a blood-borne substance that leaves the capillary network and percolates through the skin.

Taking advantage of the observation



MATING BEHAVIOR of the red-sided garter snake is confined to a short, intense springtime breeding season. For a period of from three days to three weeks the males sun themselves near the den from which they emerge. Females emerge singly or in small groups (*1*). Attracted by a pheromone (a messenger substance) on the back of a female, as many as 100 males form a "mating ball" (*2*). One male

by Noble that males court males that have been rubbed against attractive females, we employed a simple behavioral assay to test for the pheromone. We spread various substances on the back of males and observed the response of other males. Since chin rubbing is seen only in sexual behavior, it would be an unequivocal indication that the attractiveness pheromone was present. In our initial experiments we spread the blood serum of males on the back of other males; it had no effect. We tried estrogen, the female sex hormone; it too had no effect. Then we tried the blood serum of females that had been injected with estrogen. Estrogen is known to induce sexual attractiveness in a variety of vertebrate animals, including female garter snakes, and earlier work had established that the injection of estrogen into female garter snakes makes them attractive to males; hence the injected estrogen stimulates the production of the female attractiveness pheromone.

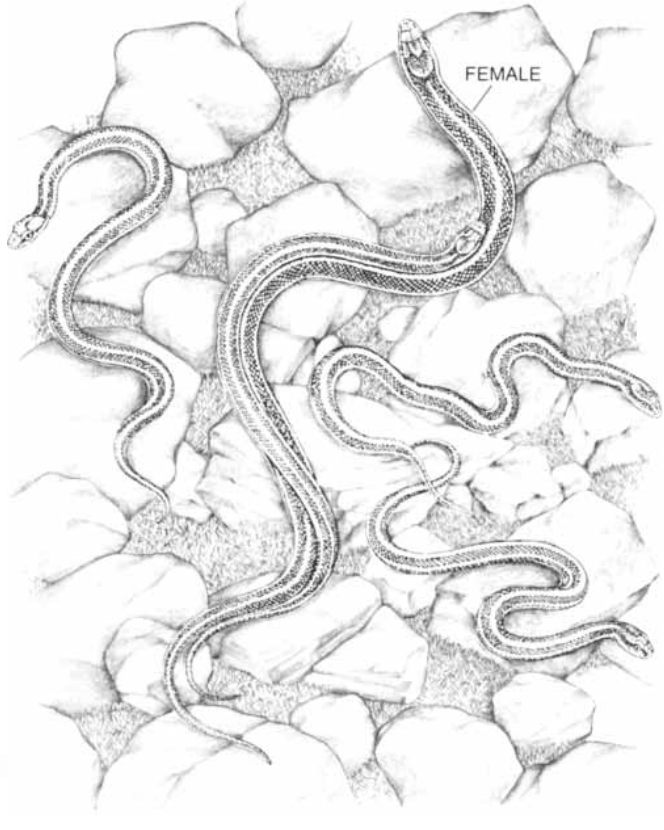
The new result was clear-cut: the blood serum of the females we had injected with estrogen elicited courtship behavior; thus the pheromone was present in the blood. Remarkably, the blood serum of males injected with estrogen also elicited courtship behavior, and yet the estrogen-treated males themselves were not attractive to other males. Perhaps the attractiveness pheromone, which normally is not present in the male, cannot percolate through the skin of the male.

In order to identify the pheromone we prepared extracts from the skin of the females we had treated with estrogen. Since the pheromone acts only on males that are in physical contact with an attractive female, we suspected it was not an airborne substance. Instead it might be a protein, which does not evaporate readily. Our behavioral assay showed that it was not a protein. Specifically, male snakes did not court the males whose back we had rubbed with the protein fraction extracted from the skin of estrogen-treated females. A further assay revealed, however, that the pheromone was in the lipids we had extracted from the skin. Certain lipids do not evaporate readily either.

We therefore turned our attention to the lipids that circulate in the blood of the garter snake. The lipids in the blood of any vertebrate animal other than a mammal contribute to the manufacture of yolk in the follicles (developing egg cells) of the female's ovary. The lipids are stored as phospholipids in organs called abdominal fat bodies; they are released into the blood when estrogen acts on the fat bodies. The estrogen is secreted by the ovaries. In the liver the phospholipids are incorporated into a lipophosphoprotein known as vitellogenin. This step too is governed by estrogen. Vitellogenin is the blood-borne precursor of yolk, and under the control of hormones from the pituitary gland it becomes yolk as it enters a growing follicle in the ovary. Although the gene that encodes the structure of the protein part of vitellogenin is in the DNA of both males and females, it is normally expressed only in the female. Nevertheless, the injection of estrogen into a male will increase the level of lipids in the blood and bring on the synthesis of vitellogenin.

With the help of Francis J. Schwende and Milos V. Novotny of Indiana University we analyzed garter snake blood by electrophoresis, the technique in which the various substances in a mixture separate from one another because they migrate at different rates through a medium (in this case cellulose acetate) to which an electric field has been applied. The blood of both male and female garter snakes we had treated with estrogen turned out to contain abundant vitellogenin. This finding meshed well with behavioral assays indicating that the liver of a female attractive to males and the liver of a female injected with

3



4

in the ball succeeds in mating with the female by inserting one of his two hemipenes into her cloaca (her urogenital opening). The other males immediately disperse (*3*). The mated female, rendered unattractive to males by a pheromone her mating partner conveys into her cloaca, immediately leaves the vicinity of the den. The males stay near the den to await the emergence of another unmated female (*4*).

estrogen both contained the attractiveness pheromone, whereas the fat bodies did not. Finally, the finding meshed with a behavioral assay in which male courtship was elicited when vitellogenin that had been extracted from the blood of estrogen-treated females was spread on the back of males.

Michael C. Devine, who was then at the University of Michigan, and Neil B. Ford of the University of Texas at Austin have each shown that male garter snakes follow females of their own species and ignore females of other species; hence the female attractiveness pheromone is specific to each species of garter snake. The molecular structure of egg yolk is also unique to each species. As vitellogenin enters the follicle it is broken down into lipovitellin and phosvitin, which are remade into yolk. The structure of lipovitellin is much the same among species; the structure of phosvitin varies among species. When egg yolk from three species of garter snake and from a lizard and a chick was made the subject of our behavioral assay, courtship by a male garter snake was elicited only by the yolk of a female of the same species.

At this point we had evidence that the female attractiveness pheromone is vitellogenin, thereby adding to its internal role as the precursor of yolk an external role as a messenger substance. We did not know how vitellogenin gets from the blood to the surface of the skin. In order to find out we froze the skin of the snake, sectioned it and stained it so that lipids would be preferentially dyed. Two distinct regions containing lipid were revealed. A dense layer of lipid appeared in the epidermis, the outer layer of the skin. The lipid is sequestered in the epidermal cells during the cycle by which the snake grows new skin and sheds old skin; the lipid aids in controlling the loss of water from evaporation and also facilitates shedding. In addition a wealth of lipid-filled sacs, or vesicles, was found deep in the skin of estrogen-treated females, in a matrix of striated muscle and connective tissue in the dermis. These sacs were absent in normal males, but we found them in the males we had treated with estrogen.

Lipid also turned up outside the skin in the hinge regions between neighboring scales. In such regions the thickness of keratin, the protein responsible for the hardening of the scales, is at a minimum. Since lipid is lost in the course of shedding, there must be a way for it to accumulate. Linking our examination of the skin with our observation that females breathe deeply as they are courted, we hypothesized that the breathing stretches the skin along the back of the female and moves the scales apart, so that lipid is exposed and (perhaps) pheromone is ejected.

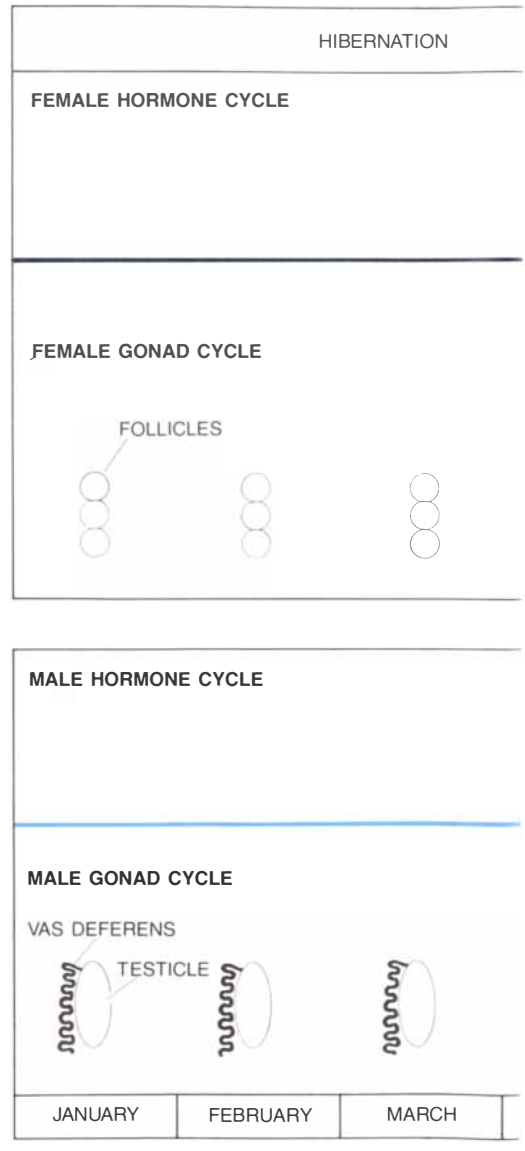
One problem persisted. Gauged by the behavior they elicit in males, female garter snakes are at their most attractive over the period of from three days to three weeks in the spring when the snakes come out of hibernation. Yet at that time the ovaries of female garter snakes are small (a fact we shall discuss more fully below). The ovaries do not begin to grow until the snakes have mated, and they are not at their largest until they have grown for about eight weeks. Since the estrogen produced by follicles growing in the ovaries promotes the synthesis of vitellogenin, the mismatch between the onset of mating behavior and the size of the ovaries is paradoxical.

A possible explanation of the paradox is that the female appears to be capable of storing in her skin the vitellogenin left over from previous reproductive seasons. As in other vertebrate animals, mating stimulates in the female the release of gonadotropin, the pituitary hormone that promotes the growth of the ovaries. In response to the gonadotropin the ovaries grow follicles and the follicles secrete increasing quantities of estrogen. This change in the hormonal balance, which rapidly follows mating, causes the vitellogenin stored in the skin to be shunted to the ovaries for deposition in the growing follicles as yolk. Mating therefore triggers the synthesis of yolk with little delay.

In this regard it should be noted that male garter snakes show a strong preference for courting large females and that large females, which are usually older than small females because snakes grow throughout life, tend to have more eggs and also more vitellogenin. Hence males attracted preferentially to females with more vitellogenin on their back would be choosing females on the basis of the female's reproductive output of the previous year. In effect the males are assessing the reproductive potential of the females and seeking to mate with the ones that are established as being fecund.

We now turn to the pheromone that makes mated females unattractive to males. Its effect is pronounced; Patrick Ross, Jr., working at Harvard, has shown that male garter snakes of the species *Thamnophis radix* will not court a recently mated female even if she receives continued injections of estrogen. Moreover, males exposed to a mated female often stop courting females for a day or longer. It is truly a male-inhibiting pheromone: it not only advertises the mated status of the female to other males but also renders the males that come in close contact with the mated female impotent.

The means by which the successful male applies the repellent pheromone to the female is well established. If the plug the male deposits in the female's cloaca is removed soon after the snakes have copulated, the female remains attractive to males. Conversely, if the material of the mating plug is spread along the back of an unmated female treated with estrogen, she is rendered unattractive. The source of the pheromone is also known: it is manufactured by the part of the kidney called the renal sex segment, which also manufactures the secretions from which the mating plug is formed. The significance of the pheromone becomes clear when one recalls the natural history of the snakes. Since mated females are unattractive to males, they are not subjected to repeated attempts at mating as they leave the vicinity of the den. Therefore the time the female is exposed to predators is reduced. The predators include crows and ravens, which prey at the dens in the



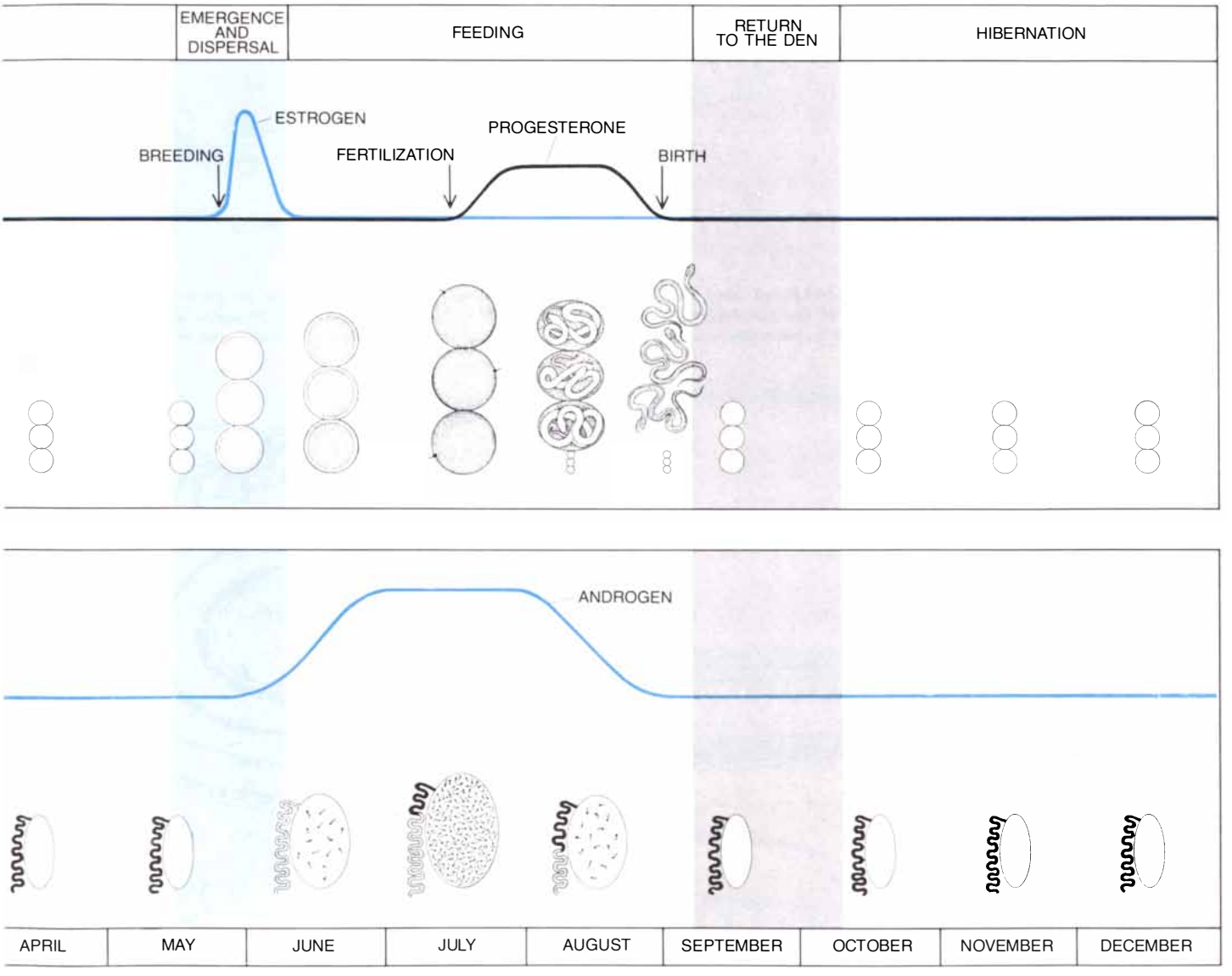
MISMATCH of physiology and behavior characterizes the reproductive behavior of the red-sided garter snake. From January through early May the snakes are in their den. In the female the blood level of the sex hormone estrogen is low, and the gonads (the ovaries) contain only small egg cells (follicles) lacking a

spring. When they catch a snake, they peck out its liver.

Although Wade Fox of the University of California at Berkeley reported nearly 30 years ago that garter snakes breed at a time when their gonads are collapsed, little has been made of the significance of the discovery. This is odd, because the discovery is startling. Almost all seasonally breeding vertebrate animals exhibit what is called a prenuptial pattern of gametogenesis: the sex cells are produced either during the mating season or just before it. In either case the sex cells are produced when the gonads are large and the sex hormones they manufacture are circulating in the blood at their highest level of the year. The sex hormones activate mating behavior. It has long been known, for example, that removal of the gonads typically causes a decline of reproductive behavior in both males and females, and that the administration of the appropriate sex hormone induces sexual behavior in sexually inactive animals and in animals from which the gonads have been removed.

Several studies of Temperate Zone lizards have revealed a similar prenuptial pattern. One might therefore assume that the control of mating behavior in garter snakes would also fit the pattern. This, it soon became clear, is not the case. Garter snakes (along with many other snakes and some species of turtles, fishes and bats) exhibit a postnuptial pattern of gametogenesis, that is, the gametes are produced only when breeding is over. In the male red-sided garter snake the testicles do not begin to grow until the end of the mating season. Over a period of six weeks the testicles attain their greatest size and the sperm they produce move into the duct called the vas deferens. There the sperm are stored until they are needed for mating the following spring. By the time the males enter the hibernaculum in the fall their testicles are fully regressed. When the males emerge in the spring, their testicles are still regressed, and their level of androgen, the male sex hormone, is low. If a male does not mate, the sperm he has stored disintegrate but his testicles begin to grow at the same time as those of males that have mated.

The female garter snake also follows a postnuptial pattern. When the female mates in the spring, her ovaries contain

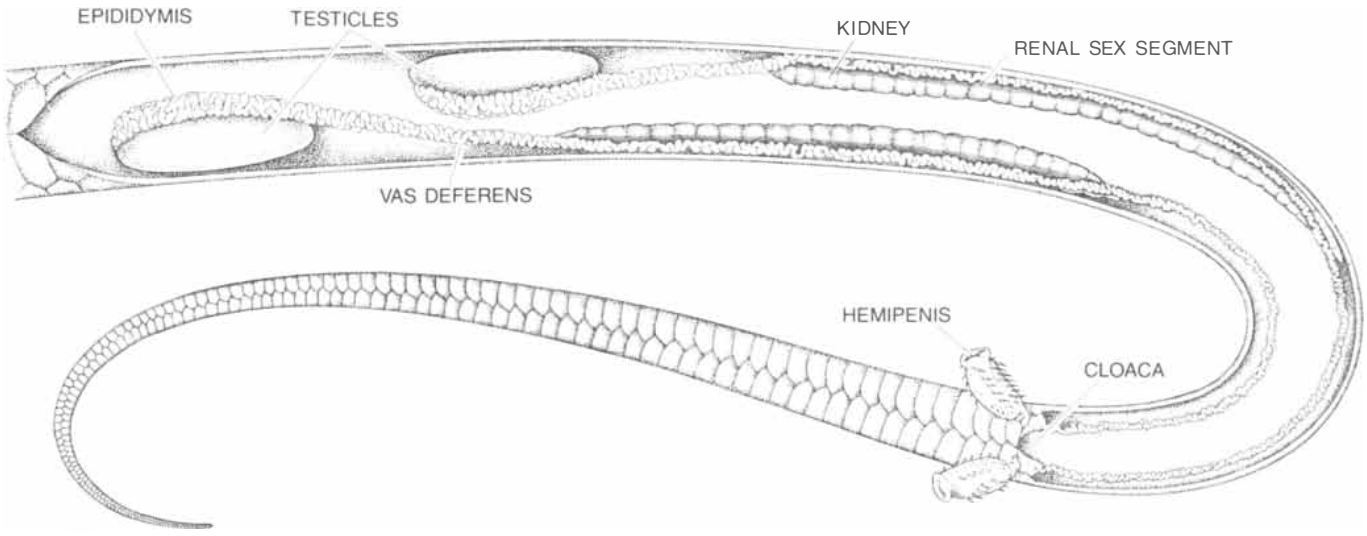


yolk. In the male the blood level of the sex hormone androgen is low, and the gonads (the testicles) are small. The male's vas deferens, or sperm duct, is packed with stored sperm. The snakes emerge and mate late in May. Their gonads are still small and their sex hormones are still at an ebb. Only after mating are changes observed. In the female the mating causes the level of estrogen to rise. In response the eggs grow large and are filled with yolk. In the middle of July the eggs are fertilized by sperm the female has stored for six weeks. Then the level of progesterone, the pregnancy hormone, rises. In the male the level of androgen starts to rise at a time when the females have left the vicinity of the den. During the summer the testicles grow large and produce the sperm the male will need the following spring. In August or early September the female gives birth, and by about the end of September both the male and the female have returned to their den.

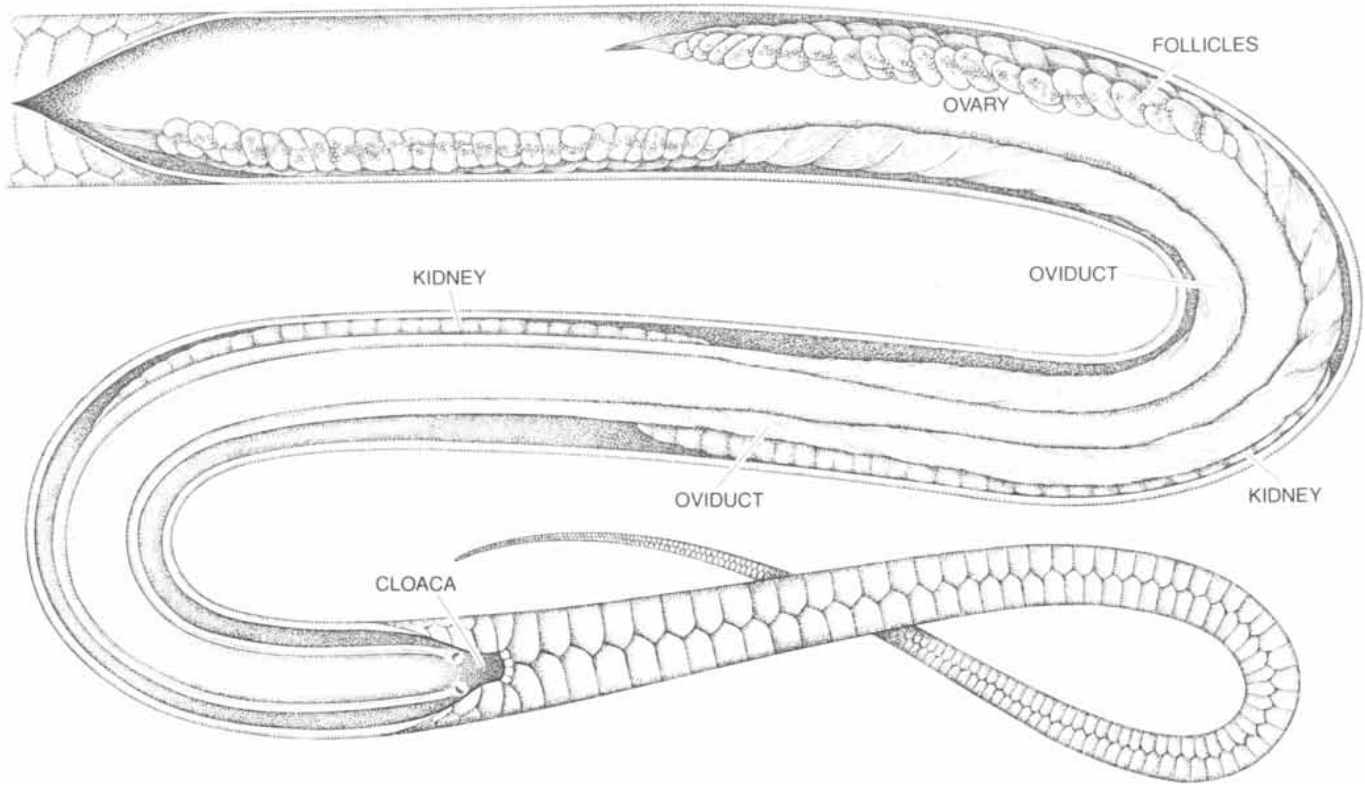
small follicles lacking yolk. It is the act of mating that induces the follicles to grow and fill with yolk. (In this we have confirmed a finding first made by Antonella Bona-Gallo and Paul Licht at Berkeley.) Working at Harvard, Andrew P. Halpert has discovered that the female stores sperm in specialized regions of the oviduct, the passage from the cloaca to the ovaries. After a period of from six to eight weeks the follicles are ready to be fertilized. Halpert also discovered that the spring mating initiates the degeneration and expulsion of all sperm remaining in the oviduct from the mating of the previous year. A similar displacement of old sperm by new has been reported in a variety of insects and rodents.

The organisms that exhibit postnuptial gametogenesis present intriguing questions. For example, how are the sexual activities of male and female garter snakes controlled without the hormonal changes that characterize prenuptial gametogenesis? The control cannot be exercised by the pheromones alone. If it were, the attractiveness pheromone could always elicit courtship behavior on the part of the male. Yet a male will not court females after the spring mating season until he has hibernated again.

In initial studies of the control of sexual behavior in garter snakes five males



REPRODUCTIVE ANATOMY OF THE MALE red-sided garter snake includes the epididymis, the segment of the vas deferens in which sperm is stored over the winter. It also includes the renal sex segment, the part of the kidney that makes the pheromone by which a mated female is rendered unattractive to males. Each hemipenis is a saclike organ the male everts to transfer sperm to the female.



REPRODUCTIVE ANATOMY OF THE FEMALE red-sided garter snake includes the ovaries, which in the streamlined body of the snake are long files of follicles. The sperm the female gets by mating in the spring take some six weeks to travel the length of the oviduct and reach the developing eggs. Both the male and the female snake are shown approximately 1.5 times life size in these drawings.

Osborne™ brings you the comparison IBM® and Apple® don't want you to see.

Other computer companies dazzle buyers with an array of options and add-ons that makes the final price hard to determine and makes the computer hard to buy, complex to assemble, and very difficult to carry.

We believe in making personal computers that are easy to learn and use. And that starts with making computers easy to *buy*.

The Osborne 1™ Personal Business Computer. One simple price, $1795, buys it all.

And it all comes in a portable case you can take with you wherever you work. Because once you go to work with an Osborne, you won't want to work any other way.

For your nearest dealer, call (in California) 800 772-3545, ext. 905; (outside California) call 800 227-1617, ext. 905.

OSBORNE™
COMPUTER CORPORATION

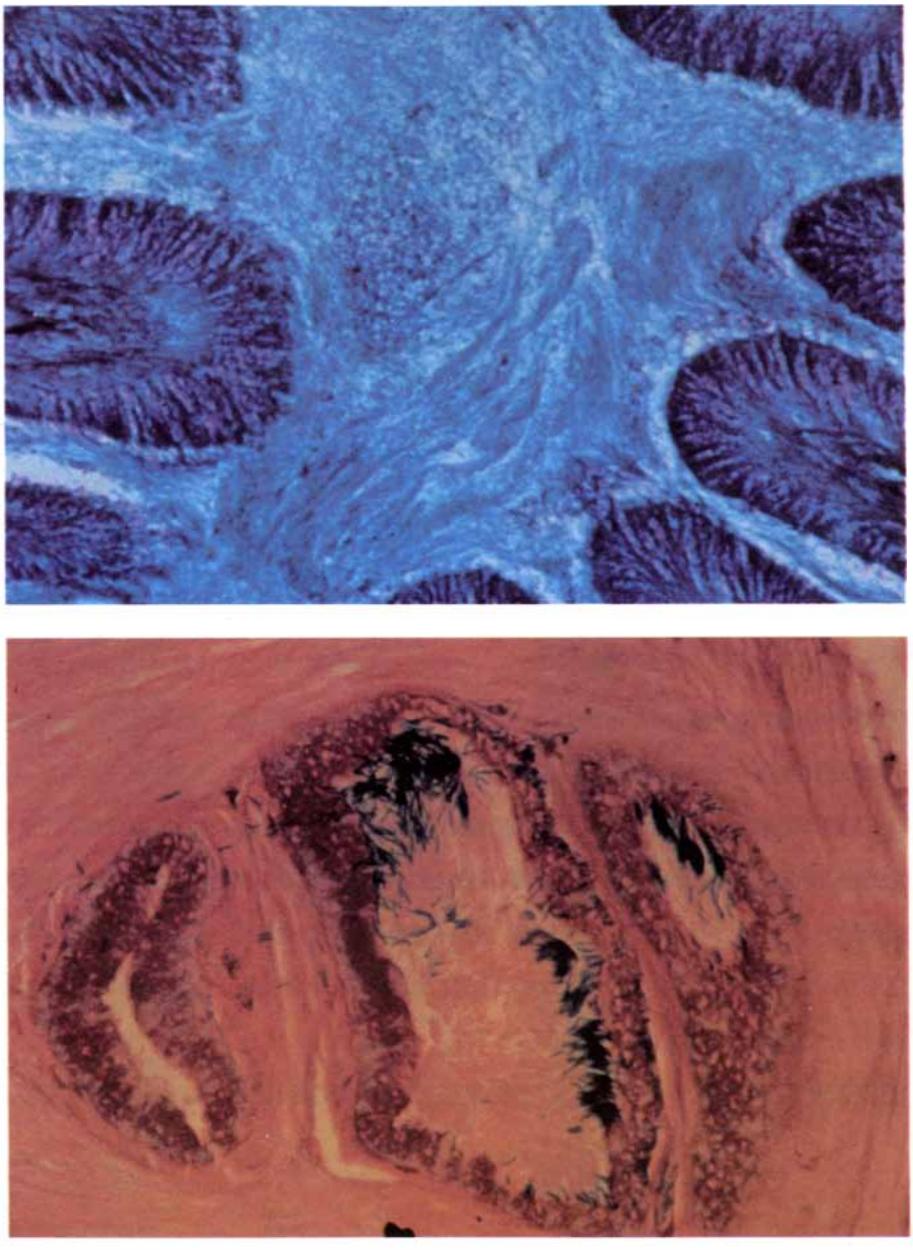
	OSBORNE 1™	IBM PERSONAL®	APPLE II®
Computer with 64K RAM, two floppy drives[A], keyboard and CRT:	$1795	$3240[B]	$3120[C]
Serial communications:	INCLUDED	EXTRA COST	EXTRA COST
Modem Connection:	INCLUDED	EXTRA COST	EXTRA COST
IEEE 488 Instrument communications:	INCLUDED	EXTRA COST	EXTRA COST
BASIC interpreter[D]:	INCLUDED	INCLUDED	INCLUDED
Business BASIC[E]:	INCLUDED	EXTRA COST	EXTRA COST
CP/M® Control Program:	INCLUDED	EXTRA COST	F (see below)
Word Processing[G]:	INCLUDED	EXTRA COST	EXTRA COST
Electronic Spreadsheet[H]:	INCLUDED	EXTRA COST	EXTRA COST
Carrying Case:	INCLUDED	EXTRA COST	EXTRA COST
TOTAL PRICE[I]:	**$1795**	**$4000–4700**	**$4000–4700**

A. The Osborne 1™ includes two built-in 100K byte floppy disk drives. The IBM® and APPLE II® drives provide approximately 160K bytes of storage. **B.** From the IBM Product Center Personal Computer Price Schedule. **C.** From the Apple Computer Suggested Retail Price List. **D.** The Osborne includes MBASIC® from Microsoft. **E.** The Osborne includes CBASIC®, a business-oriented BASIC language from Digital Research.™ **F.** The Osborne includes CP/M®, the industry-standard control program from Digital Research. The list of software packages which will run with CP/M is considerable. IBM offers CP/M 86 (a version of CP/M) at extra cost. There are optional hardware systems which allow the Apple II to run CP/M; the Apple II control program is highly comparable to CP/M. **G.** The Osborne includes WORDSTAR® word processing with MAILMERGE®—products of MicroPro™ International. **H.** The Osborne includes SUPERCALC™, the electronic spreadsheet system from Sorcim Corporation. **I.** Exact price comparisons cannot be presented, because the software and hardware options chosen to create the "equivalent" of the Osborne 1 Personal Business Computer vary in price. The range indicated was computed using price lists from IBM and Apple. Documentation of the computations are available on request from Osborne Computer Corporation. Trademarks: OSBORNE 1: Osborne Computer Corporation; SUPERCALC: Sorcim Corporation; Digital Research: Digital Research, Inc.; Registered Trademarks: WORDSTAR, MAILMERGE: MicroPro International Corporation of San Rafael, CA; MBASIC: Microsoft; CBASIC, CP/M: Digital Research, Inc.; IBM: IBM Corporation; Apple, Apple II: Apple Computer Corporation.

were removed from hibernation and in each of them a slow-release capsule containing the androgen testosterone was implanted. Within four days all five of the males began to court estrogen-treated females. For seven days the males exhibited courtship behavior; then the capsules were removed and the courting stopped. The close correlation between the treatment and the behavior seemed highly suggestive. Correlation, however, is not causation. For one thing, working at Harvard, Brian Camazine discovered that males castrated soon after their emergence from hibernation, so that the testicles were no longer present and producing androgen, court females as actively as normal males do.

Then too it turned out that the administration of androgen does not induce courtship behavior in sexually inactive male red-sided garter snakes. At the time of the initial studies the snakes were in short supply, and so a control experiment in which males were simply removed from hibernation was not done. When the work was repeated with the proper controls, the untreated males showed courtship behavior. Apparently the testosterone capsules in the initial studies had been implanted at a time when the courtship behavior was about to begin and then the capsules had been removed at a time when the courtship behavior was ending.

The most conservative possibility that accords with these findings is that the brain mechanisms underlying male sexual behavior in the red-sided garter snake might be activated by androgen while the snake is hibernating. In favor of this hypothesis (or at least the possibility that something happening during hibernation promotes sexual behavior) we and Camazine have found that the longer the dormancy period, the more active the courting of the males. In order to test the hypothesis some males about to enter hibernation were castrated. Other males were castrated and a testosterone capsule was implanted; still others were merely opened surgically without being castrated. On emergence from hibernation all three groups exhibited intense courtship activity. In other words, the hypothesis was wrong.



SPERM STORED IN THE OVIDUCT of a female red-sided garter snake can be seen in stained sections of oviduct tissue. The oviduct in the micrograph at the top was removed from a female 10 days after she had mated in the spring. Purple dye marks the epithelial cells that line the oviduct; blue dye marks a mass of sperm that fills the central hollow of the duct. The oviduct in the micrograph at the bottom was removed from a female that was caught as she returned to her den in the fall. Here the heads of individual sperm are evident. The sperm are sequestered in side chambers of the duct. Mating the following spring would have caused them to degenerate and then to be expelled. The sperm embedded in the oviduct wall presumably were swept there by the microtome that sectioned the tissue. The micrographs were made at a magnification of 200 diameters by Andrew P. Halpert, working at Harvard University.

Is it possible that male mating behavior in the spring is primed by the elevated level of circulating androgen when the gonads are growing the previous year? To test this second hypothesis males were castrated when they were sexually active and thus before the postnuptial gametogenesis had begun. The males were then allowed to complete the breeding season and spend the summer feeding before they entered hibernation. Much to our surprise, these males too exhibited intense courtship activity when they emerged from the den the following spring.

The gonads of the male are not, however, the only source of androgen; the adrenal gland secretes it as well. Nevertheless, males that have had their adrenal glands and gonads removed when they emerge from hibernation continue to court females. By the same token males treated during hibernation with cyproterone acetate, a potent antiandrogen agent, court females when they emerge. It seems inescapable that male sexual behavior in the red-sided garter snake begins and then declines whether or not the glands that produce the male sex hormone are present.

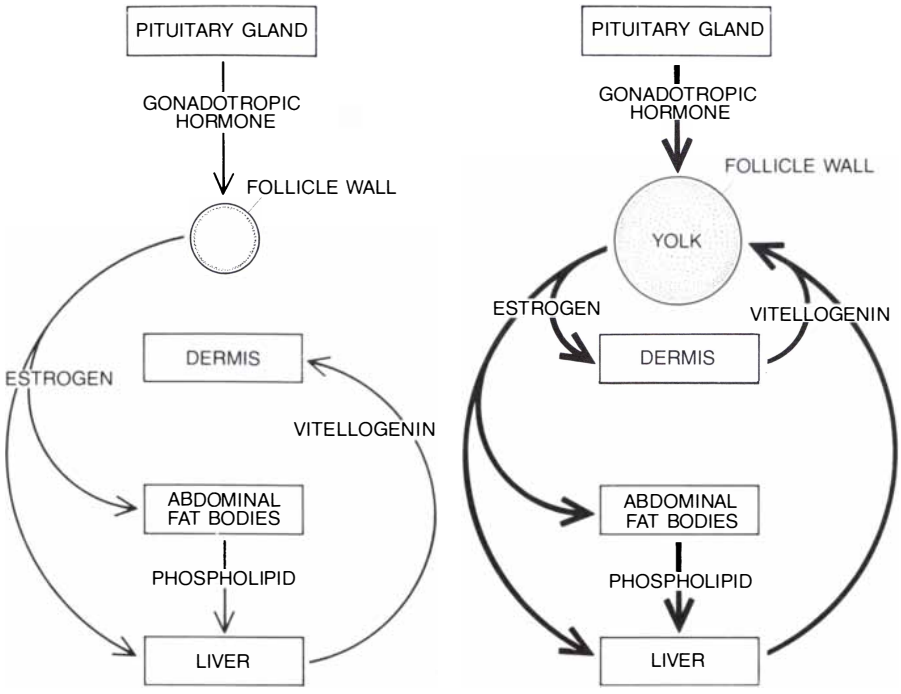
It was hypothesized next that in the red-sided garter snake the hormones secreted by the pituitary gland might control sexual activity by acting on the brain, in effect usurping the role of the hormones secreted by the gonads. Again the hypothesis was wrong. Males from which the pituitary gland had been removed before or during hibernation exhibited courtship behavior when they emerged. Conversely, males that were

DISCOVER THE TASTE OF THE RENAISSANCE.

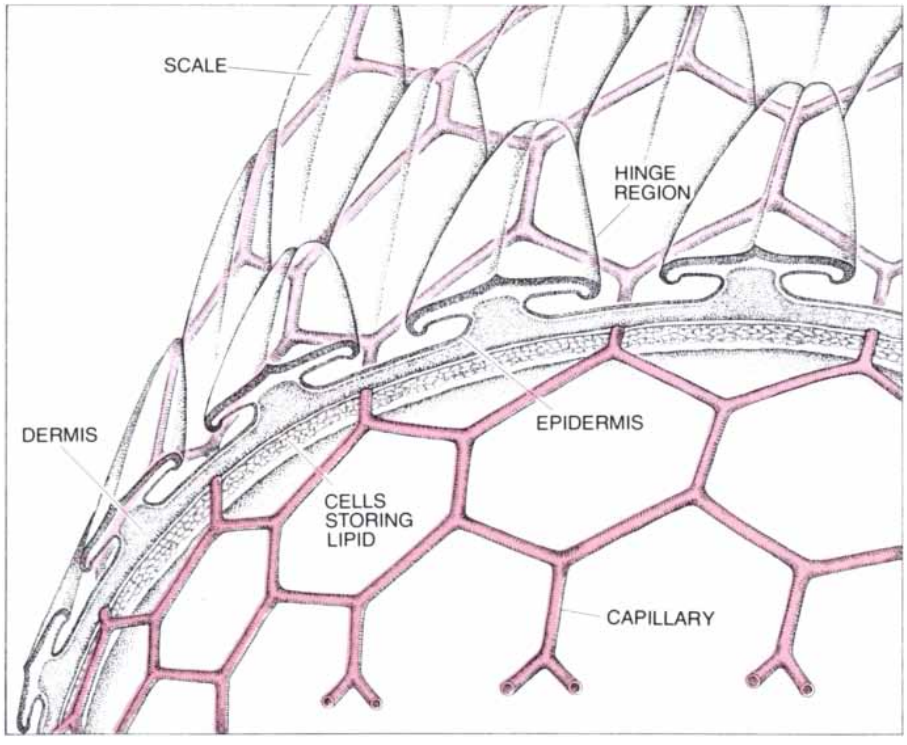
·AMARETTO DI SARONNO·ORIGINALE·1525·

FOR FREE FOOD AND DRINK RECIPE BOOKS, WRITE: BOOKLETS, P.O. BOX 99085, LOUISVILLE, KY. 40299.

LIQUEUR 56 PROOF. SOLE U.S. DISTRIBUTOR, FOREIGN VINTAGES, INC., N.Y., N.Y. © 1982. A UNIQUE PRODUCT FROM ILLVA SARONNO, ITALY



HORMONAL CHANGES induced in the female red-sided garter snake by mating in the spring may shunt the fatty substance vitellogenin from one role to another. Before mating (*left diagram*) gonadotropic hormone, which is secreted by the pituitary gland, causes the follicles in the ovary to secrete a modest flow of estrogen. In turn the estrogen causes the abdominal fat bodies of the female to release fatty molecules. It also causes the liver to incorporate the fatty molecules into vitellogenin. The vitellogenin is deposited (with other fatty molecules) deep in the skin. The authors propose that some of it gets onto the back of the female, where it serves as the pheromone that attracts males for mating. After mating (*diagram at right*) the pituitary gland responds to sensory signals to the brain that arise from the mating by secreting an increased quantity of gonadotropic hormone. In turn the ovaries secrete an increased flow of estrogen and the estrogen stimulates the liver to produce an increased flow of vitellogenin. The bloodstream carries vitellogenin from both the liver and the skin to the ovaries. There it becomes yolk of developing eggs, which will be fertilized by sperm the female has in her oviducts.



PATH OF VITELLOGENIN onto the back of the female so that it attracts males during the mating season is deduced from the presence of a network of capillaries and of cells that store fatty molecules in the dermis, the deep layer of the skin. The vitellogenin leaves the blood as it flows through the capillaries and then percolates through the hinge regions between scales.

sexually inactive did not become active when they were treated with arginine-vasotocin, a pituitary hormone important in the regulation of sexual behavior in the rough-skinned newt.

While we were at it we tested some further possibilities. The administration of a variety of hormones synthesized in the brain, including luteinizing-hormone-releasing hormone (LHRH) and melatonin, had no effect on male garter snakes that were sexually inactive. The administration of dopamine, epinephrine, norepinephrine and serotonin, all substances by which nerve cells transmit signals, had no effect. The administration of thyroxine, glucose and various types of ions, all of whose level differs markedly in dormant garter snakes from that in active ones, had no effect.

What, then, controls male sexual behavior in the red-sided garter snake? The answer is not yet known. Some recent studies, however, do provide a clue. It appears that if blood serum from a sexually active male is infused into a sexually inactive male, the inactive male will begin to court females within a few days. Serum from an inactive male, on the other hand, has no effect on another inactive male. Efforts are under way to find out exactly what it is in the blood that induces male courtship behavior.

The sexual behavior of the garter snake in the field and in the laboratory yields insight into the behavioral and physiological adaptations that suit an animal to its environment. In the case of the red-sided garter snake it is the springtime increase in temperature that makes the snakes emerge from their den and begin their precise yearly cycle of mating behavior and gonadal growth. Postnuptial gametogenesis allows them to mate as soon as they emerge from hibernation; at such times the population is concentrated and so mating is highly probable. Postnuptial gametogenesis also ensures that no energy is wasted by a female in growing eggs uselessly; she forms yolk only if she is inseminated.

In Mexico, where the range of temperatures throughout the year is not as great as it is in Canada and the indigenous garter snakes do not hibernate, we have found a somewhat different pattern. There the garter snake *Thamnophis melanogaster* has several mating seasons. Each pregnancy depletes the lipid stores of the female; at some point, however, the female regains enough weight so that her body redeploys on her skin substantial quantities of the attractiveness pheromone vitellogenin. In both the Canadian and the Mexican snakes a combination of behavior and physiology adapts the organism to its environment to promote the survival of the individual and the perpetuation of the species.

2 For the first time a music system and the listening environment have been designed together.

Second in a series on how Delco Electronics and Bose technology contribute to your enjoyment of driving.

The performance of even the best home music systems is limited by the acoustics of the environment, the placement of the speakers and the location of the listeners. These important factors are beyond the control of the designer.

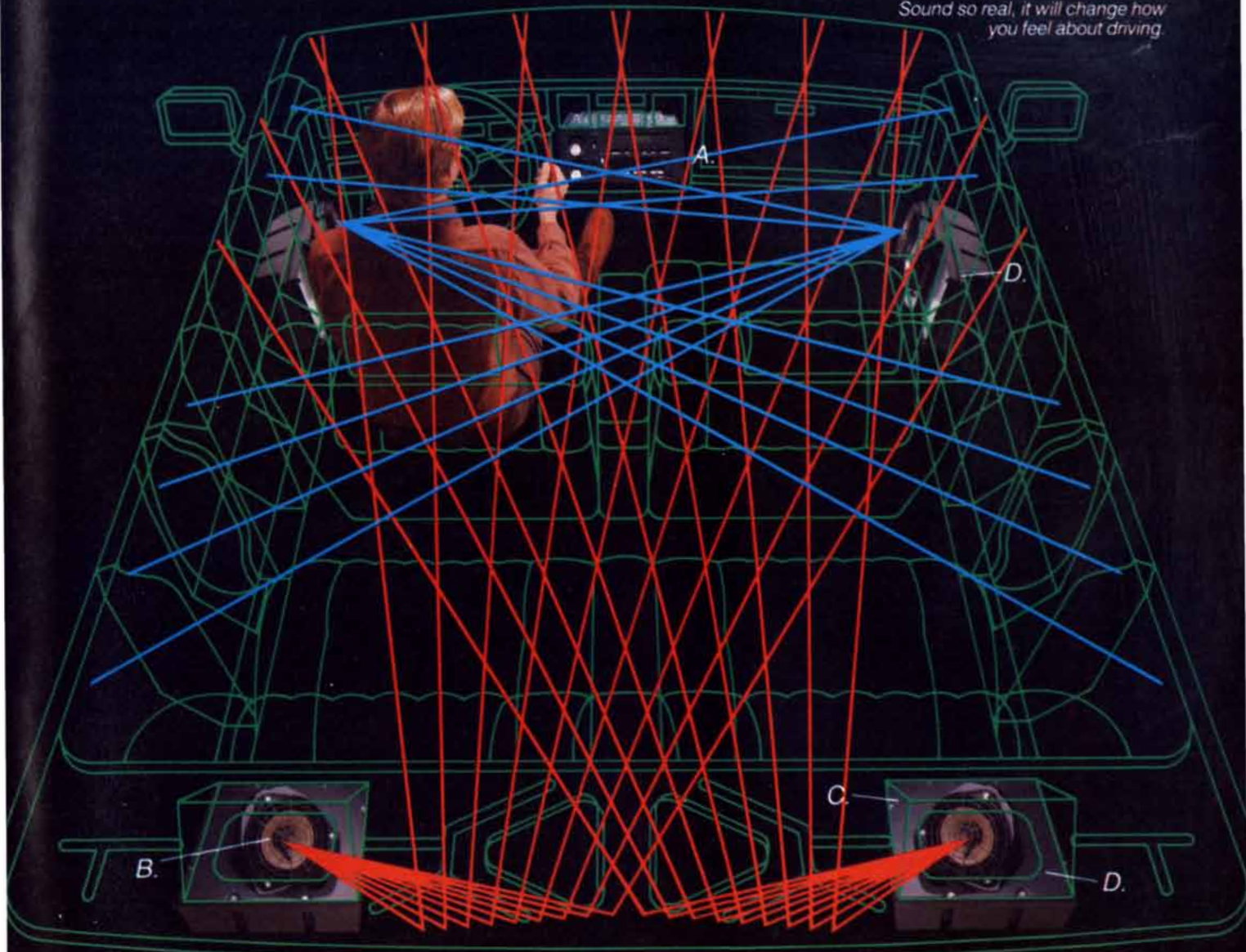
Three years ago Delco Electronics, General Motors Car Divisions and Bose Corporation began research to design a music system with, and for, its environment. The acoustics of the car were measured, the speakers precisely placed, and the known locations of the listeners were considered in the design. The result is a music system designed differently for each automobile body, but with one element in common—the performance!

And how much difference does this new design concept make? We let hundreds of people listen to the Delco-GM/Bose Music System during its development. From musicians to people who had not believed that music was important in their lives, the reaction was the same.

But if we say more we might bias the experience you will have when you visit your GM dealer.* Just try not to get excited!

Delco GM BOSE

Sound so real, it will change how you feel about driving.

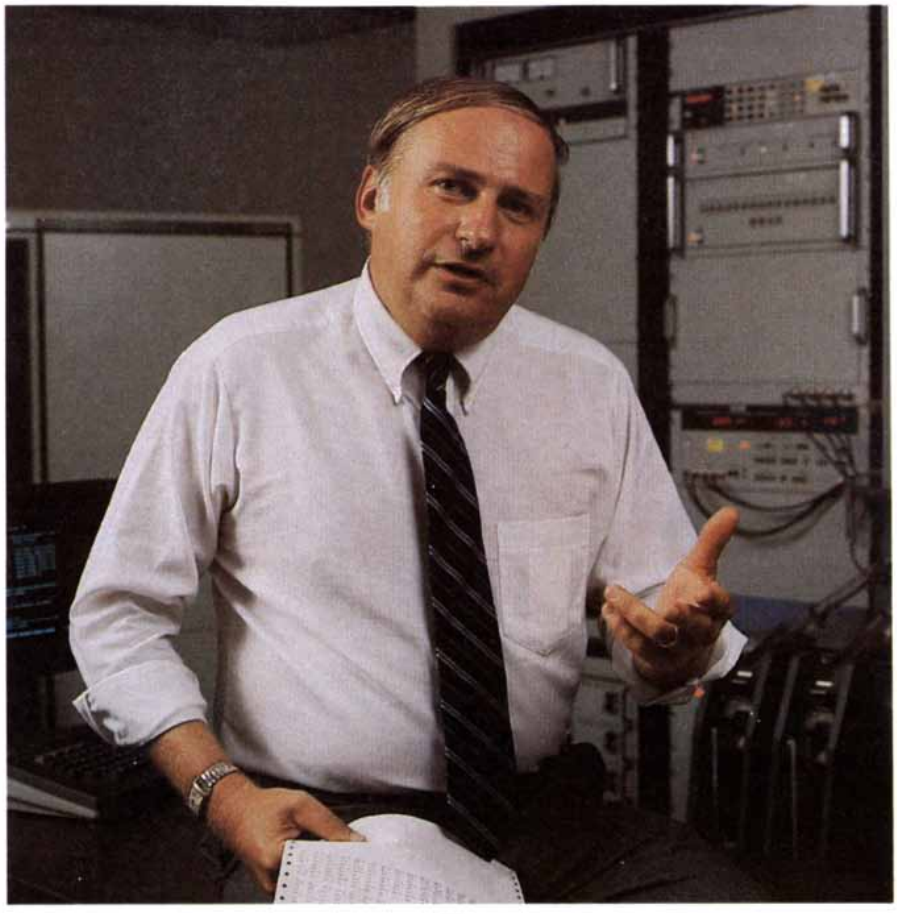


A. (ETR) Electronically tuned receiver. **B.** Helical voice coil speaker. **C.** "Digital mode" amplifier built into each enclosure. **D.** Reflex enclosure.

*Available as a factory-installed option on Cadillac Seville and Eldorado, Buick Riviera, and Oldsmobile Toronado.

A totally new class of music systems from Delco-GM.

What if you chose as a technical



"At M/A-COM, HP computers increase test speed 12-fold."

M/A-COM, Inc., is a major manufacturer of electronic products for commercial telecommunications and defense markets. Dr. Alan Carlson, Manager of the Automatic Test Equipment Group in Burlington, Mass., says: "We build automatic test systems and conduct final test on hundreds of M/A-COM products. To automate, we needed precision instruments plus computer power.

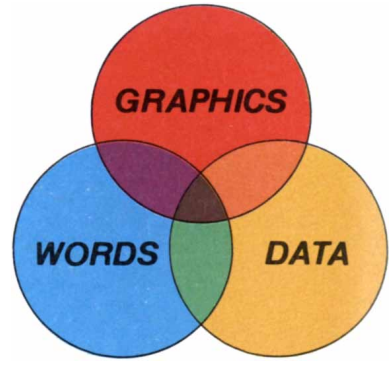
"HP was the only vendor to offer us a complete solution. With 20 HP 1000 computers driving more than 200 HP instruments, we've completely automated several product tests. And we can depend on HP's support teams to keep our entire testing network up and running.

"Now we can test sophisticated products 12 times faster than before. With these kinds of savings, each HP 1000 has paid for itself in less than one year."

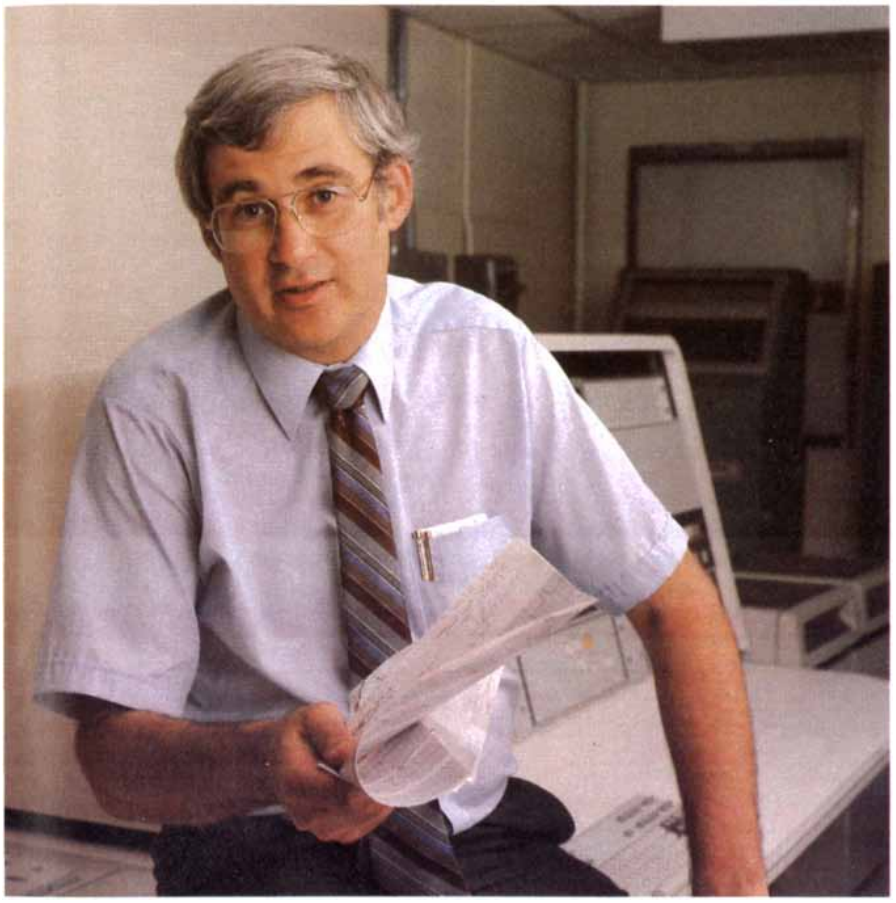
What should you expect from a computer partner in the '80s?

Integrated information management! With words, data, and graphics, HP can help you organize and integrate the many information variables that affect your day-to-day business operations. This timely, interrelated information reduces ambiguity. It sharpens decision making and provides clearer operating perspectives.

By integrating key areas of your organization through a network of personal and multi-user computer systems, you can put to work HP's application solutions for computer-aided engineering, factory automation, and operational planning and control. At the same time, in your office areas you'll have the capabili-



Hewlett-Packard computer partner?



"At Likoff Cardiovascular Institute, an HP computer processes electrocardiograms in minutes instead of hours."

Likoff Cardiovascular Institute, in Philadelphia, is a leading center for the research and treatment of cardiovascular disease. Using an HP computerized ECG management system, the Institute processes 100,000 electrocardiograms a year, 70,000 from outside facilities.

Dr. Gary Anderson, heart station director, says, "By automating the ECG processing cycle, we reduced turnaround time per test from 2½ hours to just 4 minutes—and reduced patient costs by 10%.

"With the HP Management System, we can retrieve patient records instantly, including often critical comparison data in our evaluations. And because this system handles incoming ECGs on a priority basis, we're responding to emergencies much faster than before, with better interpreted ECGs at a lower cost."

ties for word processing, document management, financial management, and electronic mail and filing. People who are not computer professionals will find them easy to use.

As a major corporation with worldwide manufacturing, marketing, and support facilities, Hewlett-Packard takes its commitment to computer partnership in the '80s seriously.

You should consider a working partnership with HP. Now.

For a free copy of our brochure explaining HP's practical, proven approach to meeting your long-term computer and information needs, write to A.P. Oliverio, Senior Vice President, Marketing, Dept. 207, Hewlett-Packard Company, P.O. Box 10301, Palo Alto, CA 94303.

When performance must be measured by results

HEWLETT PACKARD

00243

The Physics of Kettledrums

The vibrations of a violin string form a harmonic series with a distinct pitch. The vibrations of an ideal membrane do not form such a series. How, then, can a kettledrum have a pitch?

by Thomas D. Rossing

As musically inclined spectators at a parade with a marching band can testify, the bass drum makes a sound that is loud but has no pitch. This is true not only of the small bass drums, 26 to 28 inches in diameter, that are heard in marching bands but also of the substantially larger bass drums, 36 to 40 inches in diameter, heard in a concert orchestra. It is true also of the snare drum, the tenor drum and many other kinds of drum. In contrast, another group of drums, the kettledrums or timpani, convey a strong sense of pitch. So too do still other kinds of drum, such as the tabla of India. What is it about drums that divides them into such different families?

In answering this question one must begin by describing a theoretical abstraction. What all true drums (a grouping that excludes such percussion instruments as steel drums and hollow-log drums) have in common is a drumhead (or drumheads) consisting of a stretched membrane. How would an ideal membrane vibrate? Musically any membrane, real or ideal, can be considered as being analogous to the string of a stringed instrument except that a string essentially has only the one dimension of length and a membrane has the two dimensions of length and breadth. With both a string and a membrane the "restoring" force that makes the system vibrate after applied pressure has deformed it is tension. With a string the tension is applied linearly and is adjusted by means of a tuning peg; the greater the tension, the higher the string's fundamental note. With a circular membrane such as a drumhead the tension is applied around the circumference. Like a string, a membrane can be tuned by altering its tension.

There is one major difference, however, between the vibrations of an ideal string and those of an ideal membrane. The frequencies of a string's overtones are harmonics: integral multiples of the fundamental frequency. With the ideal membrane these "mode" frequencies are not harmonics. Furthermore, the nodes of a vibrating string, that is, the positions along its length that remain essentially stationary while the rest of the string is in motion, are in effect one-dimensional: they are points. The nodes of a vibrating membrane are two-dimensional: they are lines. Finally, membranes display two kinds of nodes: circles concentric with the circumference of the drumhead and diameters that bisect the circumference.

It is convenient to label the mode frequencies of a drumhead with pairs of digits. The first digit gives the number of diametric nodes in the mode frequency and the second gives the number of circular nodes. For example, when the oscillation of the membrane lacks any nodes except one at the circumference of the drumhead, the mode is labeled (01). If this mode is taken to be the fundamental mode of an ideal membrane, it is assigned a value of 1. The second mode, the one with the next-highest frequency, has one circular node and one diametric node; it is therefore labeled (11). In an ideal membrane the frequency is 1.59 times that of the fundamental mode. The third mode, with one circular node and two diametric nodes at right angles to each other, is labeled (21); its frequency is 2.14. The fourth mode, (02), consists of two circular nodes; its frequency is 2.30.

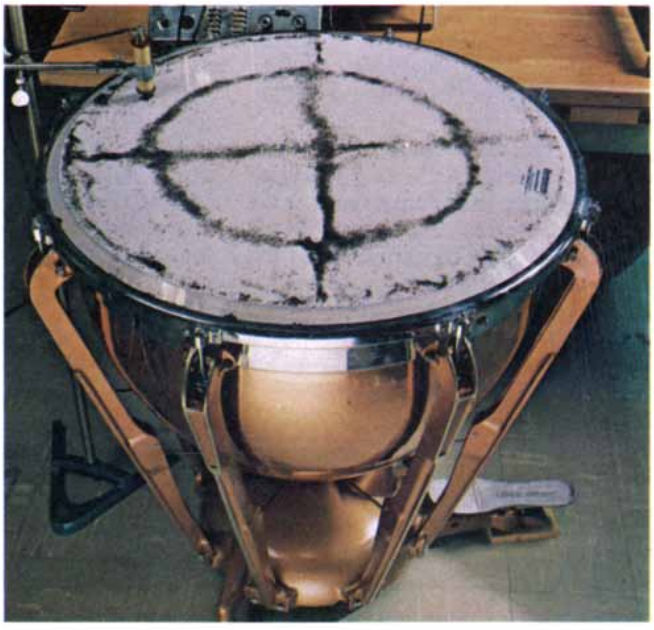
The nodal lines of course reflect the overall motion of the vibrating membrane. In mode (01) the entire membrane moves up and down. In mode (11), where the membrane is bisected by a diametric node, the two halves of the membrane move in opposite directions. In mode (21) opposing quarters of the membrane move in opposite directions; in mode (02) the inner circle of the membrane and the outer circle move in opposite directions. As the number of nodes is multiplied and the mode frequency rises the vibratory motions become increasingly complex.

The fundamental mode frequency of a membrane is determined by a number of factors. For example, doubling the tension of the membrane raises its frequency by half an octave. The diameter of the membrane also affects frequency, but inversely. For example, the fundamental frequency of a membrane 20 inches in diameter is 60 percent higher than that of a membrane 32 inches in diameter.

More than a century ago the German polymath Hermann von Helmholtz recognized that a musical tone conveying a clear sense of pitch must have several strong harmonic overtones, that is, it must have not only a fundamental frequency but also overtones with frequencies related to the fundamental in whole-number ratios. Writing on the sensations of tone, he pointed out that tones with a moderately loud series of harmonics up to the sixth mode sound rich and musical. As I have mentioned, however, the successive vibrational modes of an ideal membrane are not in the ratios of whole numbers. The ratios are 1 : 1.59 : 2.14 : 2.30 : 2.65 : 2.92,

KETTLEDRUM HEAD, sprinkled with powder, displays six of its many modes of vibration in the form of Chladni patterns. The powder collects at nodes, areas of the drumhead where the vibrations are weakest. By convention the mode frequencies are assigned pairs of digits; the first digit gives the number of diametric nodes and the second the number of circular nodes. Here, from top to bottom at the left, the modes are (01), that is, one circumferential node but no diametric node; (02), two circular nodes but no diametric node, and (12), the same two circular nodes and one diametric node. From top to bottom at the right the modes are (21), two diametric nodes but only the circumferential circular node; (22), two circular nodes and two diametric nodes, and (31), one circular node and three diametric nodes. The arm almost touching the membrane at the upper left in each photograph causes a tiny magnet fixed to the drumhead to vibrate at preselected frequencies. The patterns are named for the German physicist Ernst Chladni (1756–1827), who studied the vibrations of plates and membranes in this way.



and the vibrations of such a membrane could scarcely convey a clear sense of pitch.

This observation brings us back from the ideal to the real, because even if an ideal membrane would not convey a clear sense of pitch, a kettledrum does. If this were not so, the kettledrum would not be the most important drum in the orchestra. Kettledrums can also be tuned over a range of more than an octave, adjusting the tension of the drumhead by means of six to eight screws around the circumference of the kettle. In addition to the tensioning screws most modern kettledrums have a pedal-operated tensioning mechanism that enables the timpanist to vary the tension of the drumhead over a rather wide range above the tension already established, giving him a tuning range greater than a musical sixth. The timpanist in a symphony orchestra typically plays three to five kettledrums, but more instruments and more timpanists are not uncommon. The high-water mark is probably Berlioz' *Grand-Messe des Morts,* a piece that calls for 16 kettledrums and 10 timpanists.

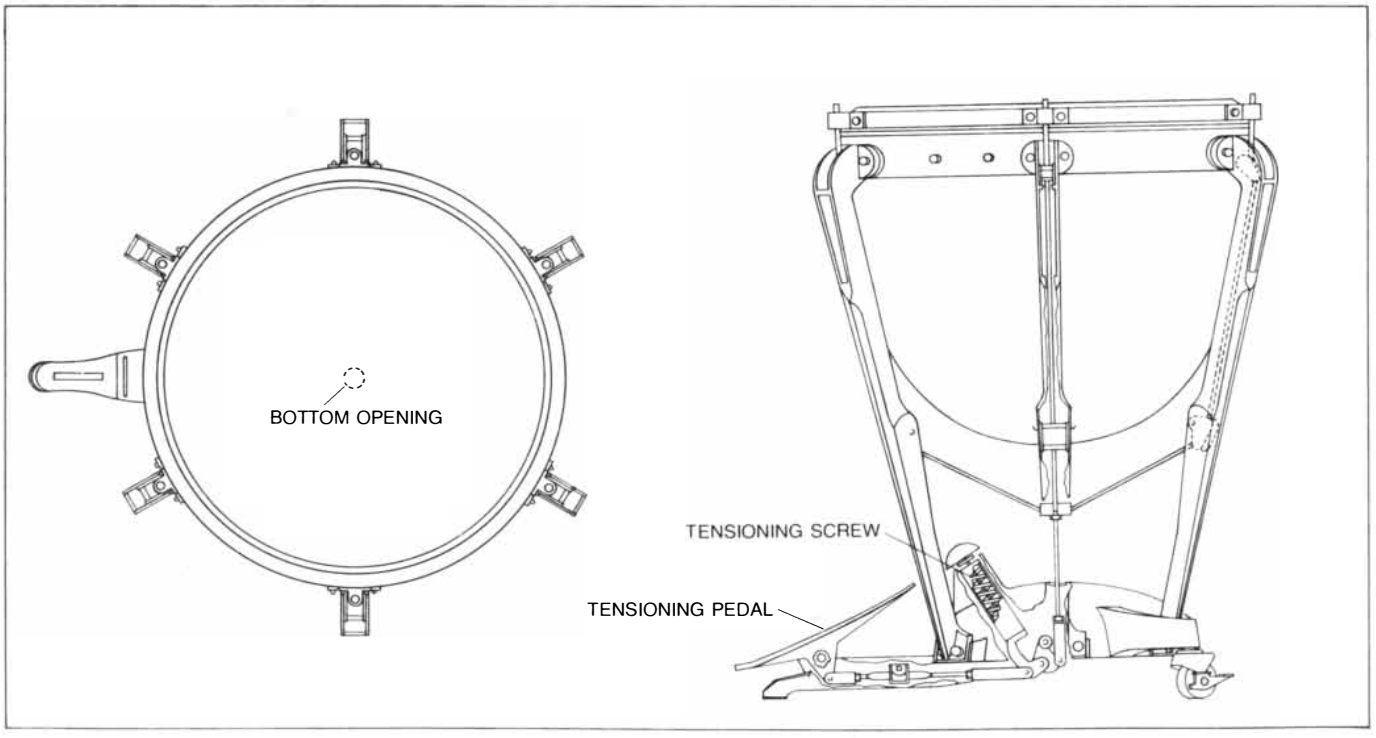
A carefully tuned kettledrum, correctly struck, sounds a strong principal tone and two or more harmonics. Late in the 19th century the British physicist Lord Rayleigh recognized that the principal tone was generated by the vibrations of the (11) mode. He further identified three successive harmonics: musically about a perfect fifth, a major seventh and an octave above the principal tone. These he ascribed respectively to vibrations in the (21), (31) and (12) modes. Their ascending frequencies, taking the (11) mode as the fundamental, are 1.50, 1.88 and 2.00 times the fundamental. In an ideal membrane the frequencies would be 1.34, 1.66 and 1.83.

Considering the fact that sophisticated acoustical apparatus did not exist in Rayleigh's day, his results are remarkable. In our acoustics laboratory at Northern Illinois University my colleagues and I have measured the various modes of kettledrums with modern instruments. These studies have led us farther along the path than Rayleigh got, but still in the same direction he pioneered a century ago. For example, we have found that the (11), (21) and (31) modes of the kettledrum have frequencies that are nearly in the ratios 1 : 1.5 : 2, and that the (41) and (51) modes typically have frequencies that are 2.44 and 2.90 times the frequency of the fundamental mode (11). These two values are within about half a semitone of 2.5 and 3. Thus a family of modes having respectively one, two, three, four and five diametric nodes radiate prominent tones with frequency ratios nearly in the whole-number sequence 2 : 3 : 4 : 5 : 6. It is these harmonics that give the kettledrum its strong sense of pitch.

How are the inharmonic modes of the ideal membrane coaxed into a harmonic relation? The main agent is the effect of air-mass loading. The imaginary ideal membrane vibrates in an ideal vacuum, and the drumhead of a real kettledrum vibrates at the bottom of an ocean of air. The mass of the air that sloshes back and forth lowers the frequencies of the modes of vibration. This downward shift, which is particularly important in the (11) mode, is mainly responsible for establishing the harmonic relations among kettledrum modes.

Two other effects may be said to "fine-tune" the drumhead frequencies, because their role is minor compared with the effect of air-mass loading. The first effect is that of the air enclosed in the kettle. The enclosed air, of course, has resonances of its own, and these have at least the potential of interacting with modes of the drumhead that have similar frequencies.

The second effect is that of the "stiffness" of the membrane. Like the stiffness of a string, that is, the string's resistance to bending, it tends to raise the frequencies of the higher harmonics. Stiffness in a "one-dimensional" string, however, differs from stiffness in a "two-dimensional" membrane, which may be characterized as resistance to shear. Like a sheet of paper, a membrane offers little resistance to the kind of distortion involved in bending it along a line. It offers strong resistance, however, to the kind of distortion that would be involved in wrapping it around a ball without wrinkling it. Neverthe-



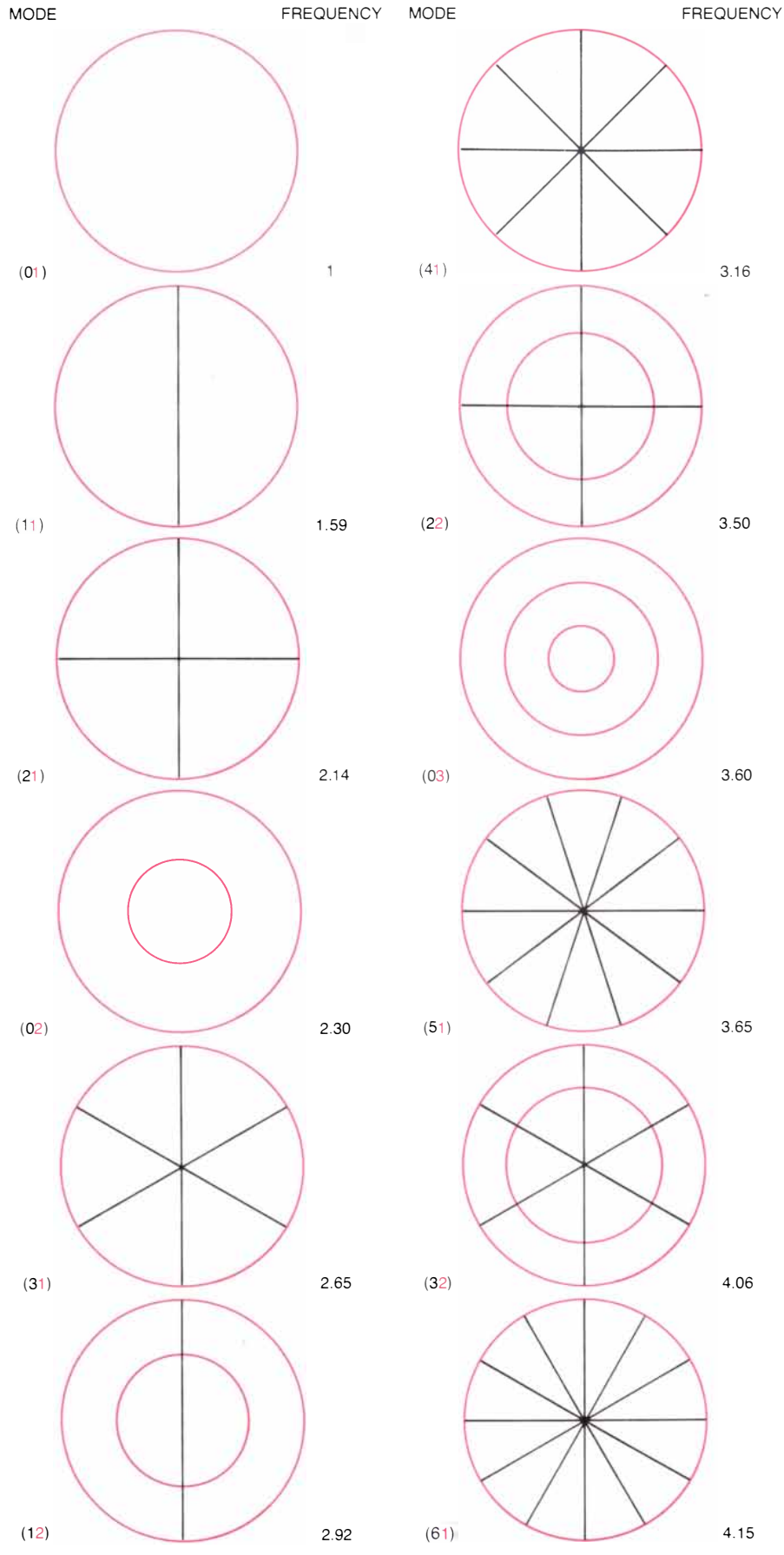
KETTLEDRUM is shown schematically in plan and elevation. Visible in the plan view are the six screws around the circumference of the kettle that make it possible to tune the drum over a range of about one octave. The broken circle indicates the opening at the bottom of the kettle (which is not present in all kettledrums). The partial cutaway view shows the pedal-controlled tensioning mechanism that enables the timpanist to alter the drum's tuning in the course of the performance. This instrument is made by Ludwig Industries of Chicago.

less, membrane stiffness or resistance to shear has the same effect resistance to bending has in a string: the frequencies of the higher harmonics rise. This is not to say that the resonance of the air inside the kettle and the drumhead's resistance to shear have no influence on kettledrum performance. Although they merely fine-tune the harmonic modes, they have a considerable effect on another component of kettledrum acoustics: the rate at which the sound of the drum decays after the drumhead is struck.

A number of conclusions about air loading can be arrived at by comparing the recorded frequencies of kettledrum modes when the instrument is in its usual condition with the frequencies recorded when the kettle has been removed. We did this in our laboratory, using a drum with a head 26 inches in diameter and comparing the ratios of the harmonic modes with the principal mode (11). Both with and without the kettle the frequencies of the (21) and the (31) modes were close to the ones measured by Rayleigh: a perfect fifth and an octave above the fundamental.

A further conclusion received support from a common acoustical model: a piston vibrating in the middle of a large baffle. Although this model is unrealistic with respect to a real kettledrum, it did show that as the frequency of vibration rises the air loading decreases markedly. A mathematical technique applied to air-loading calculations by Richard S. Christian and Arnold Tubis of Purdue University yielded results that are in even better agreement with our frequency measurements with and without the kettle than the results obtained from the simple piston model. In brief, air loading causes a considerable decrease in the frequency of the lower-frequency modes but has only a small influence on the frequency of the higher-frequency modes.

The spectrum of the sound radiated from a struck kettledrum depends on a number of factors: the point at which the drumhead is struck, the shape and the hardness of the felt-covered beater, the strength and nature of the stroke and even the position of the instrument and player in the room. The importance of striking the kettledrum membrane at the "normal" place in order to generate the desired harmonics is readily demonstrated with sound spectra: the normal place is about a quarter of the way from the edge of the drumhead to the center. If the drum is struck in the center, both the fundamental mode (01) and the immediately succeeding circular modes, (02) and (03), appear much stronger in the spectrum than the harmonics. The circular modes damp out rather quickly, however, and so do not account for much of the drum's



NODAL LINES of the 12 lowest modes of an ideal membrane are diagrammed in order of ascending frequency. The circular nodes and their mode numbers are in color; the diametric nodes and their mode numbers are in black. Frequency of vibration, calculated as a multiple of the "basic" (01) mode, appears to the right of each diagram. The sequence is not harmonic.

sound. Indeed, the membrane's response to being struck in the center is a dull thump.

A kettledrum 26 inches in diameter served for our sound-spectrum recordings. If the heavily damped (01) fundamental is ignored, the principal tone and the overtones generated by a normal stroke were very nearly in the ratios 1 : 1.5 : 2 : 2.5 : 3, a harmonic series built on a nonexistent fundamental an octave below the real one. This harmonic relation gives the sound of the kettledrum a strong sense of pitch and a pleasing timbre. Measurements on kettledrums of different sizes yielded similar results.

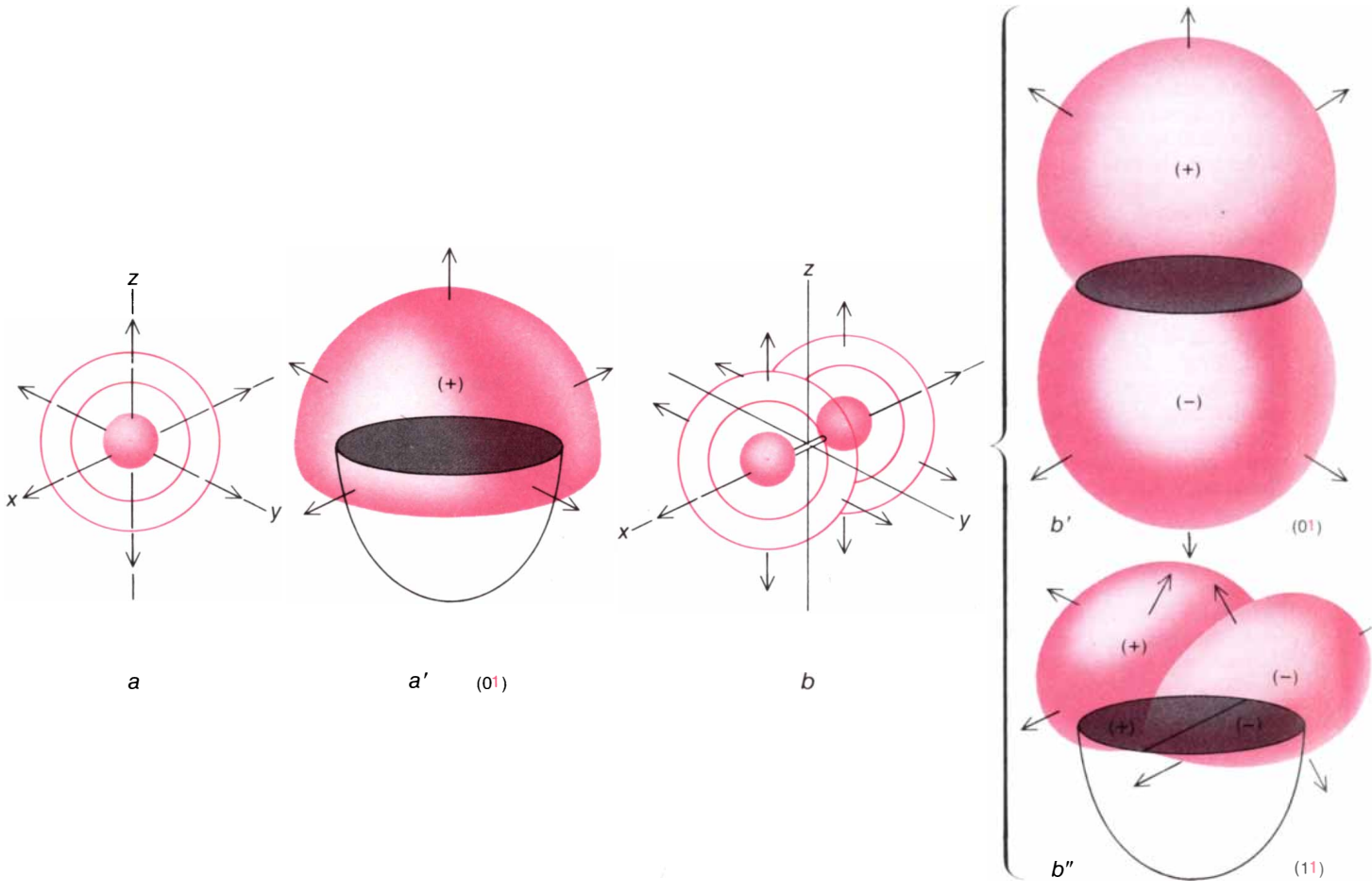
One of our observations remains unexplained. Why should the pitch of the kettledrums correspond to the pitch of the principal tone rather than to the missing fundamental of the harmonic series? Apparently the reason is that compared with the principal tone the strengths and durations of the harmonics are insufficient to establish the entire harmonic series. Some timpanists report, however, that a gentle stroke at the proper spot with a soft beater will produce a rather indistinct sound an octave lower than the kettledrum's nominal pitch.

The radiation of sound from a complex source is often described in terms of simple models consisting of oscillating spheres. The simplest of these models is a single sphere that alternately expands and contracts, sending out spherical sound waves. Such a single-sphere model is called a monopole source. The total sound power radiated from a monopole source is proportional to the square of the frequency at which it oscillates, and the sound radiates equally in all directions.

A model consisting of two oscillating spheres that expand and contract in opposite phase, separated by a given distance, is a dipole sound source. The radiation from a dipole varies greatly according to angle, being greatest along the perpendicular axis and decreasing to zero at 90 degrees from the perpendicular. The sound power of a dipole is proportional to the fourth power of the frequency; at low frequencies a dipole source radiates considerably less sound than a comparable monopole source. Two dipole sources oscillating in opposite phase constitute a quadrupole sound source. Its sound power is proportional to the sixth power of its frequency and so a quadrupole is an even less efficient radiator of sound at low frequencies than a dipole.

Consider these three models in relation to the radiation of sound by a kettledrum. When the drum is vibrating in its lowest mode, (01), all parts of the membrane move in phase, that is, they all move up at the same time and down at the same time. If the drumhead is attached to its kettle, which acts as a baffle, the sound radiating from the bottom surface cannot interact with the sound radiating from the top surface and so the drum is in effect a monopole source.

If the drumhead is not attached to the kettle, the sound radiation from the top surface of the membrane interferes with the sound radiation from the bottom surface and no sound is radiated in directions lying in the plane of the mem-



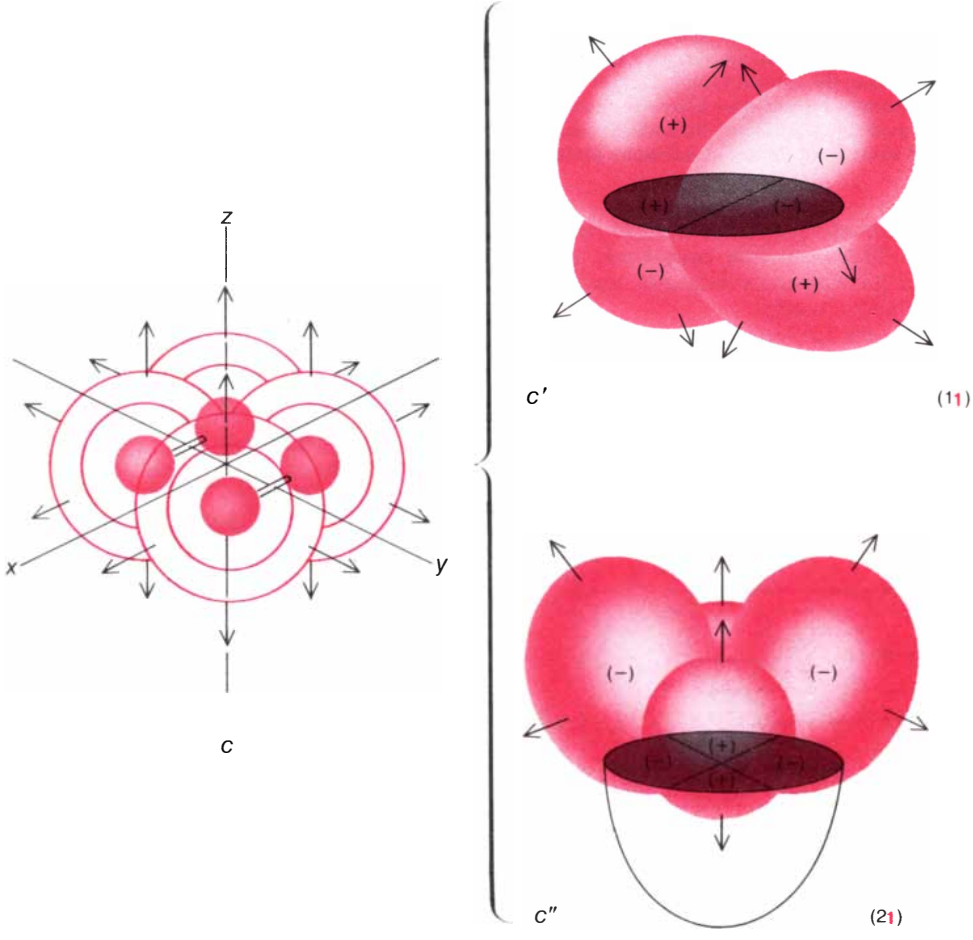
THREE SIMPLE MODELS of sound radiation are compared with their kettledrum equivalents; two are represented as drumheads alone and also as complete instruments. The first model (*a*) is a monopole source; it rapidly expands and contracts, sending spherical sound waves equally along *x*, *y* and *z* axes. The monopole is acoustically equivalent to a kettledrum (*a′*) vibrating in the (01) mode. Sound radiating from the bottom of the membrane cannot interact with the sound from the top, and so the drum is a monopole source. The second model is a dipole (*b*): the air supply in two adjacent balloons is pumped back and forth. As one source expands the other contracts; sound radiation is maximal along the dipole axis (*x*) and minimal along the axes at right angles (*y*, *z*). An unattached drumhead (*b′*) vibrating in the (01) mode is acoustically equivalent to a dipole source. The radiation from its top surface interferes with the radiation from its bottom surface, and no sound radiates in the directions along the plane of the membrane (*dipole* y *and* z *axes*). An intact kettledrum

brane. Thus the drumhead is a dipole. So too is a drumhead with its kettle when it is vibrating in the (11) mode and no sound is radiated in a direction perpendicular to the membrane. If a drumhead without a kettle vibrates in its (11) mode, radiation from the dipole source on the top surface interferes with radiation from the dipole source on the bottom surface and the drumhead becomes a quadrupole source. A drumhead with its kettle, vibrating in the (21) mode, is also a quadrupole source.

These simple models of sound radiation tell several things about the acoustical performance of the kettledrum. For example, the sound radiation of each mode has a different spatial pattern. In the concert hall the expectation is that the sound of all the patterns is mixed more or less uniformly by the many reflections from the walls and other surfaces. That is generally the case, provided the listener is several wavelengths away from the instrument. The timpanist or anyone else close to the kettledrum, however, is likely to hear a sound quite different from the one the audience hears.

The intensity of the sound radiation affects another acoustical characteristic of the kettledrum: the rate at which the sound decays. As we have seen, when a kettledrum sound damps out quickly (proof that it is being radiated efficiently), it is likely to be heard as a dull, unmusical thump. Modes that radiate as quadrupoles or higher-order multipoles radiate less efficiently than monopoles or dipoles and can therefore be expected to decay more slowly and more musically. This slow-decay effect is to a considerable extent offset, however, by the fact that the efficiency of multipole radiation increases rapidly as the frequency of the sound rises. For example, one can predict that as the tension of the drumhead (and therefore the frequency of its vibration) is increased the decay time will decrease. Measurements made by Ronald Mills in our laboratory showed this prediction to be correct.

Of the various possible mechanisms responsible for the speed of damping (that is, the rate of energy loss from the vibrating membrane) the relative efficiency of sound radiation is paramount. Nevertheless, timpanists' own subjective judgments suggest that two other mechanisms may play a part. For example, most timpanists prefer calfskin drumheads to Mylar ones, a hint that there is a greater mechanical loss in the Mylar membrane. Many timpanists also think a drum with a copper kettle sounds different from one with a kettle made out of fiberglass or some other synthetic material, implying that a higher rate of energy loss in the nontraditional kettles may also increase the speed of damping.



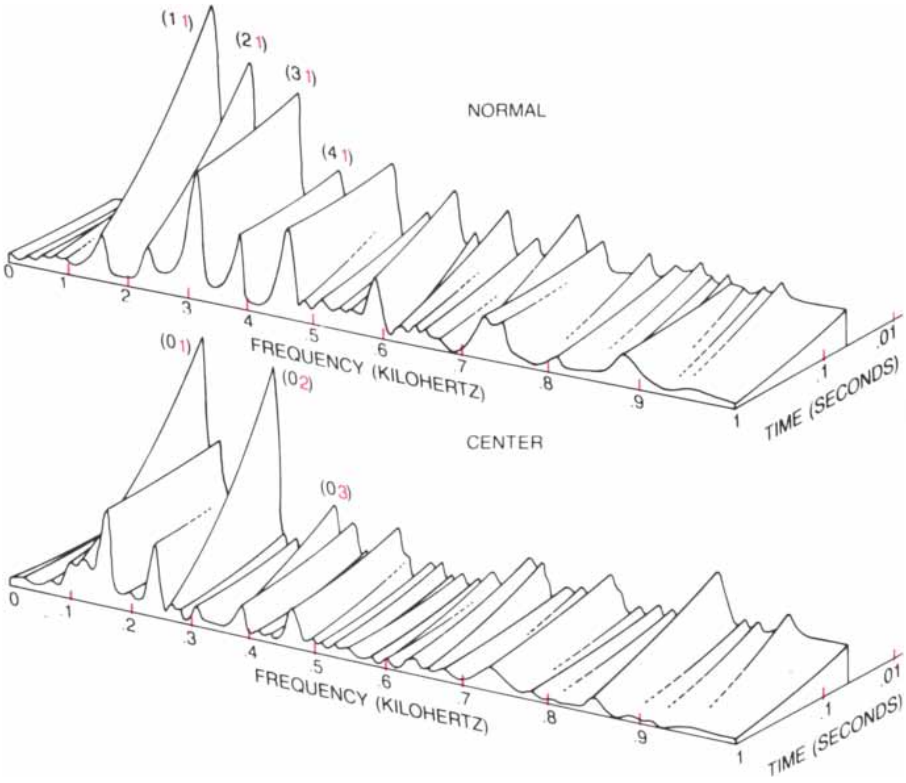
(*b*′′) vibrating in the (11) mode is also equivalent to a dipole source; no sounds are radiated in the directions perpendicular to the drumhead. The third model (*c*) is a quadrupole. The balloons at opposite ends of each dipole expand as the others contract; sound radiation is maximal along the *x* and *y* axes but minimal along the *z* axis. A solitary drumhead (*c*′) vibrating in the (11) mode is acoustically equivalent: vibrations from the top dipole surface interfere with vibrations from the bottom dipole surface. An intact kettledrum (*c*′′) vibrating in the (21) mode is also equivalent to a quadrupole. Monopole sound output is proportional to the square of its frequency, dipole output to the fourth power and quadrupole output to the sixth power.

What acoustical purpose is served by the kettle of the kettledrum, other than providing a baffle that isolates the bottom of the membrane from the top? One noticeable effect is that the presence of the kettle increases the frequency of the circular modes. The effect is strongest in the mode (01); the drumhead alone vibrates at a frequency of 82 hertz (cycles per second), and with the kettle in place the frequency is 127 hertz. The effect diminishes at higher mode frequencies but remains positive. For example, in the mode (02) the frequency of the drumhead alone is 241 hertz, compared with 252 hertz when the kettle is in place, and in the mode (03) the figures are respectively 407 and 418 hertz.

This increase in frequency comes about because in the circular modes the movement of the membrane alternately compresses and decompresses the air inside the kettle. The difference between the air pressure inside the kettle and the pressure outside acts as a restoring force of its own, over and above the restoring force inherent in the tension of the membrane. Call the effect air stiffness, similar to the action of the air enclosed in the airtight cabinet of an acoustic suspension speaker.

Just how much the air stiffness raises the frequency of a circular mode can be calculated. For a 26-inch kettle, which contains about .14 cubic meter of air, the frequency of the mode (01) is raised by about 40 percent by air stiffness if the membrane is at high tension and by about 80 percent if it is at low tension. The next mode, (02), is raised in frequency respectively by 2 percent and 6 percent; the (03) and (04) modes are raised by less than 1 percent.

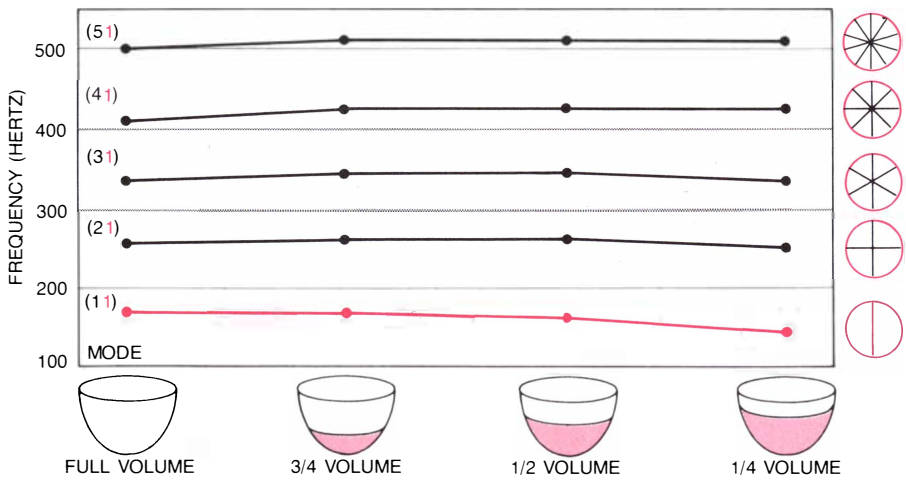
How large should the kettle of a kettledrum be? Craig A. Anderson and I looked into the question by means of a simple experiment: reducing the air volume of the kettle by partially filling it with water. We then tested the effect the changing air volume had on the various diametric modes of vibration. Except for the principal mode, (11), the changes



TWO SPECTRAL DIAGRAMS, constructed from spectra recorded soon after the instrument was struck and others recorded later, show the different mode peaks and the different decay times when a 26-inch kettledrum is struck at the "normal" point (*top*) and at the center of the drumhead (*bottom*). The normal stroke, emphasizing the related (11), (21), (31) and (41) modes, conveys a definite pitch, and the relatively protracted decay time allows the sound to "ring." The center stroke emphasizes the unharmonic modes (01), (02) and (03), all of which tend to decay rapidly. The sound that results is a kind of short-lived thump of indefinite pitch.

in the vibration pattern, as measured in hertz, were not particularly great even when the kettle was three-quarters filled with water. For the principal mode, however, the changes were substantial. When there was only a fourth of the normal amount of air in the kettle, the frequency of the (11) mode was reduced by 13 percent, from a normal 170 hertz to 148. This reduction completely destroyed the harmonic relations among the diametric modes.

Just as the kettledrum membrane exhibits a variety of modes, so does the mass of air inside the kettle. Anderson and I investigated these modes also, because in stringed instruments such as violins and guitars the vibrational modes of the confined air are known to have a noticeable effect on the modes of the wood top plate of the instrument. We wanted to learn if the same was true of the kettledrum. We determined seven air-mass modes and found that their frequencies were substantially higher than those of the corresponding membrane modes. For example, the membrane mode (11) has a frequency of 150 hertz and the equivalent air-mass mode has a frequency of 337 hertz. Similarly, the membrane mode (12) has a frequency of 314 hertz and the equivalent air-mass mode has one of 816 hertz. As a result of these large differences the vibrations of the kettledrum air mass interact only slightly with the vibrations of the drumhead, but the slight interactions do result in subtle changes in the sound of the drum.



CHANGES IN KETTLE VOLUME affect the overtones of the kettledrum slightly but significantly. When the air volume in the kettle was reduced first by a fourth and then by half, the frequencies of the four overtones were scarcely affected. When the volume was reduced to a fourth, however, frequency of the principal (11) mode was lowered both by the decreased volume and by the increased internal air loading. Its relation to the (21) mode was no longer a multiple of 1.50 but had stretched to 1.67, disrupting its harmonic relations with the overtones.

Most kettledrums have a small vent at the bottom. With another simple experiment we were able to disprove two hypotheses about the effect of the vent on the performance of the instrument. One hypothesis was that the main cause of the strong damping of the fundamental (01) mode is viscous friction of the air at the venthole. The other hypothesis was that in the absence of the vent the enclosed air mass would be "stiffer," and so the presence of the vent prevents the rise in drumhead frequency that would result from the added stiffness.

All our experiment needed was a rubber stopper that would close the venthole. We found that stoppering the kettle had little or no effect on the decay time of the mode (01). The stopper actually lowered the modal frequency, rather than raising it, by a very small amount: .4 percent. For example, in one tuning the observed frequency of the mode (01), with an open vent, was $135.4 \pm .1$ hertz and the decay time was $.29 \pm .05$ second. With the vent stoppered the frequency value was lowered to $134.9 \pm .1$ hertz and the decay time remained the same. These findings are consistent with statements made by several experienced timpanists that they could hear no consistent difference between the sound of a kettledrum with its venthole open and the sound of one with its venthole closed.

The studies in our laboratory have added to the understanding of the acoustics of kettledrums, but the acoustical properties of most other drums have not yet been carefully investigated. A notable exception is the research in the 1930's regarding the modes of the Indian tabla, a small hand-struck drum, conducted by the noted physicist C. V. Raman. It is to be hoped that in future years the fascinating subject of the physics of drums in general will receive more attention.

Radio Shack's TRS-80® is Your Best Choice in a First Computer

Why? Because you can start with our $999 Model III and easily—and economically—expand into a powerful, professional system!

- Add Up to 4 Double-Density Disk Drives—2 Internally
- Go from 16K to 48K Memory
- Add RS-232C Interface
- Or Get It **All with Our $2295 Model III Desktop Computer**

A Radio Shack Model III is a versatile, self-contained computer that can grow with you. Whether you're a beginner or a pro, there's one that fits your budget and intended use. And features you'd expect to pay extra for are standard on Model III.

The built-in "extras". Our $999 system includes: a 65-key keyboard with 12-key data pad, a 12" high-resolution monitor, and a parallel printer interface.

You get much more, including 16K memory, powerful Model III BASIC language, 500 and 1500 baud cassette operation, 16 lines of 64 or 32 upper and lower case characters, repeating keys, special graphics characters, program editor and real time clock.

Model III is ready for a wide range of professional and personal uses. Choose from our large library of user-proven programs or develop your own applications in easy-to-learn BASIC. Just add a cassette recorder to store and run programs and data. Cat. No. 26-1062. **$999**

Choose our professional Model III Desktop Computer for more sophisticated applications. You get the same basic features as the smaller model, but with 48K internal memory, two built-in double-density mini disk drives for 368K of program and data storage and a built-in RS-232 Serial Interface to communicate with other computers using an optional telephone coupler, like our new Modem II (right). Our powerful disk operating system (TRSDOS) is included along with an expanded Disk BASIC language. And we have optional programming languages to meet specific needs—choose from COBOL, Assembler, Compiler BASIC and FORTRAN. And of course the smallest Model III can be upgraded to this top of the Model III line.
Cat. No. 26-1066. **$2295**

Get a "hands-on" demonstration of the TRS-80 Model III today at more than 330 Radio Shack Computer Centers and 6400 Radio Shack stores and participating dealers nationwide. Ask about our service and leasing plans, too.

Our Direct-Connect Modem II Automatically Dials and Answers Phone

Connects Directly to Phone Line And Any RS-232-Equipped TRS-80

Now your TRS-80 can access and transfer data by telephone. Program the Modem II to dial and answer, receive and transmit, even hang-up. 300 baud. FCC registered.
Cat. No. 26-1173. **$249**

Other TRS-80 modems start at $149.

Send me a free TRS-80 catalog.

Mail To: Radio Shack
Dept. 83-A-271
300 One Tandy Center
Fort Worth, Texas 76102

NAME _____
COMPANY _____
ADDRESS _____
CITY _____
STATE _____ ZIP _____

Radio Shack®
The biggest name in little computers™
A DIVISION OF TANDY CORPORATION

Retail prices may vary at individual stores and dealers.

The First Nuclear Industry

It flourished in the first third of the 20th century, when the prized element was not uranium but radium. Tons of ore had to be mined and processed to extract a single gram

by Edward R. Landa

The primary material of the nuclear industry today is unquestionably uranium, the fuel of almost all fission power reactors. Some years before the discovery of nuclear fission, however, there was already a thriving nuclear industry. Many of the same ores that are exploited today were mined then in large quantities, but the uranium in them was discarded as waste or at best was sold as a low-value by-product. The aim of the earlier industry was the extraction of radium, an element formed by the radioactive decay of uranium.

In the first third of the 20th century the glow and the healing powers of radium captivated the world. The discoverer of the element was idolized. The value of radium exceeded that of the rarest gemstones; at one time the price approached $180,000 per gram. The most important uses were in medicine, where radium therapy offered a new form of treatment for cancerous tumors. Other applications were based on the light emitted when radium is mixed with a phosphorescent substance; luminous watch dials are a familiar example. Moreover, in an era when the nature of ionizing radiation was not widely understood and its hazards were little appreciated, the glamour associated with radium gave rise to a great variety of frivolous and possibly dangerous products.

Even at the peak of radium production no more than a few hundred grams per year were purified. Because the concentration of radium in most ores is exceedingly low, however, the recovery of these small amounts required a major industrial undertaking. In some cases 400 tons of ore had to be processed to yield one gram of radium. Ore deposits were mined on five continents, and extraction plants were set up by many companies and government-sponsored enterprises. They competed for a share of what was at times a lucrative market. After the boom, of course, came the bust. The hazards of casual exposure to radium were recognized, the novelty value of the element faded and with the development of fission reactors safer, cheaper and more effective radioactive substances became available. Today radium is no longer regarded as a precious commodity. Its use in medicine and industry has greatly diminished and substantial efforts are being made to dispose of unwanted stocks and to clean up residues left behind by the world's first nuclear industry.

Radium is the element of atomic number 88, that is, the radium atom has 88 protons and 88 electrons. At least 25 isotopes of radium have been identified; each isotope has a different number of neutrons and hence a different atomic mass number, which is equal to the sum of the number of protons and the number of neutrons. The commonest isotope and the one that was most important commercially is radium 226, whose atoms have 88 protons and 138 neutrons. When a particular isotope of the element is specified, it is called a nuclide or, since it is radioactive, a radionuclide.

Chemically radium is classified with the alkaline earths, the group of metallic elements that also includes beryllium, magnesium, calcium, strontium and barium. Radium is the heaviest of the alkaline earths and its chemical properties are most similar to those of barium, the element immediately above it in the periodic table. Radium forms carbonates and sulfates that are insoluble in water, and chlorides and nitrates that are soluble. Differences in the solubility of various salts of radium are the basis of most extraction processes.

Radium 226 is formed in nature as an intermediate stage in the decay of uranium 238 to the stable nuclide lead 206. The immediate progenitor of radium 226 is thorium 230, the nuclide with 90 protons and 140 neutrons. Thorium 230 emits an alpha particle (a helium nucleus made up of two protons and two neutrons), thereby reducing its atomic number by 2 and its atomic mass by 4; as a result the thorium atom is transmuted into an atom of radium 226. Radium itself also decays by alpha emission. Radium 226 gives rise to radon 222, the nuclide with 86 protons and 136 neutrons. Radon is a radioactive noble gas that decays by still another alpha emission to yield polonium 218. There are several more steps in the decay sequence before lead 206 is reached.

Radium 226 has a half-life of about 1,600 years; in this period half of the nuclei in any given quantity of the nuclide will have decayed. All the other isotopes of radium decay faster. The daughter products of radium decay include radionuclides that emit beta particles (nuclear particles with the mass of an electron) and gamma radiation (high-energy electromagnetic radiation). Because radium nuclei are continually decaying and thereby creating the daughter nuclides any specimen of radium gives off all three forms of radiation: alpha, beta and gamma.

On the average the abundance of radium in the earth's crust is about one part in 10^{12}. It is usually found in association with its parent material, uranium. The major radium-bearing minerals exploited during the radium boom were pitchblende, which consists of various uranium oxides, and carnotite, in which uranium oxide and vanadium oxide are combined in a salt of potassium. Other radium-bearing minerals were extracted from a variety of geologic and geographic environments. The minerals were found as cements in sandstones from western Colorado, as "pods" in gold-bearing veins in eastern Colorado, in asphalts in Utah and in ancient lake sediments in Madagascar. Most uranium ores being mined today contain about .1 percent uranium oxide. One gram of such an ore includes some 280 picograms, or 280×10^{-12} gram, of radium 226.

Uranium was mined on a small scale even before the discovery of radium, but the commercial value of the uranium had nothing to do with its nuclear properties. Instead various salts of

1983 FORD LTD

Introducing the new Ford LTD.

From the smooth ride, to the new driver-designed seating position, the quiet new LTD has one target: your comfort.

The logical placement of instruments. The handling. The feel of the seats. Every inch of the 1983 LTD has been human engineered for a uniquely comfortable driving experience.

Reshaped.

The aerodynamic hood. The cant of the rear window. Smoothness everywhere means LTD needs only 6.7 horsepower to push it through the wind at 50 mph.

Refined.

With a streamlined deep-well trunk in back and luxurious reclining front seats inside, you will find form and function, space and comfort. Optional electronics include: digital instrumentation • new electronic station seeking radio • Tripminder® computer.

The LTD Brougham standard cloth interior. Contoured reclining front seats with fold-down armrests and convenient coin tray.

Totally Redesigned.

Technology for 1983 is state-of-the-art: smooth-riding gas-filled shocks, optional 3.8 liter V-6 with automatic overdrive, or available for order, a propane-powered 4-cylinder engine.

And all of this advanced technology adds up to a totally pleasurable driving experience. Experience it for yourself in the totally new Ford LTD.

Every inch an LTD.

Get it together—Buckle up.

HAVE YOU DRIVEN A FORD...LATELY?

Ford

FORD DIVISION

When the success of your business depends on making the right connections, look to the investment banking service with connections all over the world.

Bank of America NT&SA Member FDIC ©Bank of America NT&SA 1982

In today's volatile business environment, you need connections to get ahead. And Bank of America's Investment Banking Group can help you make them.

Our vast global network and global expertise, plus our multi-currency finance experience, give us a worldwide presence few banks can match. And give us ready access to world financial markets, both public and private.

The connections we've built over the years, and all over the world, can be an important advantage for you.

As advisors, we have the expertise to guide you knowledgeably through complex project financings. We also advise corporations on mergers, acquisitions, or divestitures. As financial specialists, we can arrange syndicated loans of all types. We structure, manage and distribute Eurobond issues. We're a leader in private placements. We have an extensive, experienced leasing operation. And we can tap the full resources of Bank of America to create unique funding packages combining investment banking and commercial banking instruments.

Whether you need capital or just capital ideas, it pays to have the right connections. To find out how to make them, call your Bank of America Account Officer, or our investment banking specialists in New York, (212) 907-7746, or San Francisco, (415) 622-1698. It's the first connection to your future connections, all over the world.

Look to the Leader.™

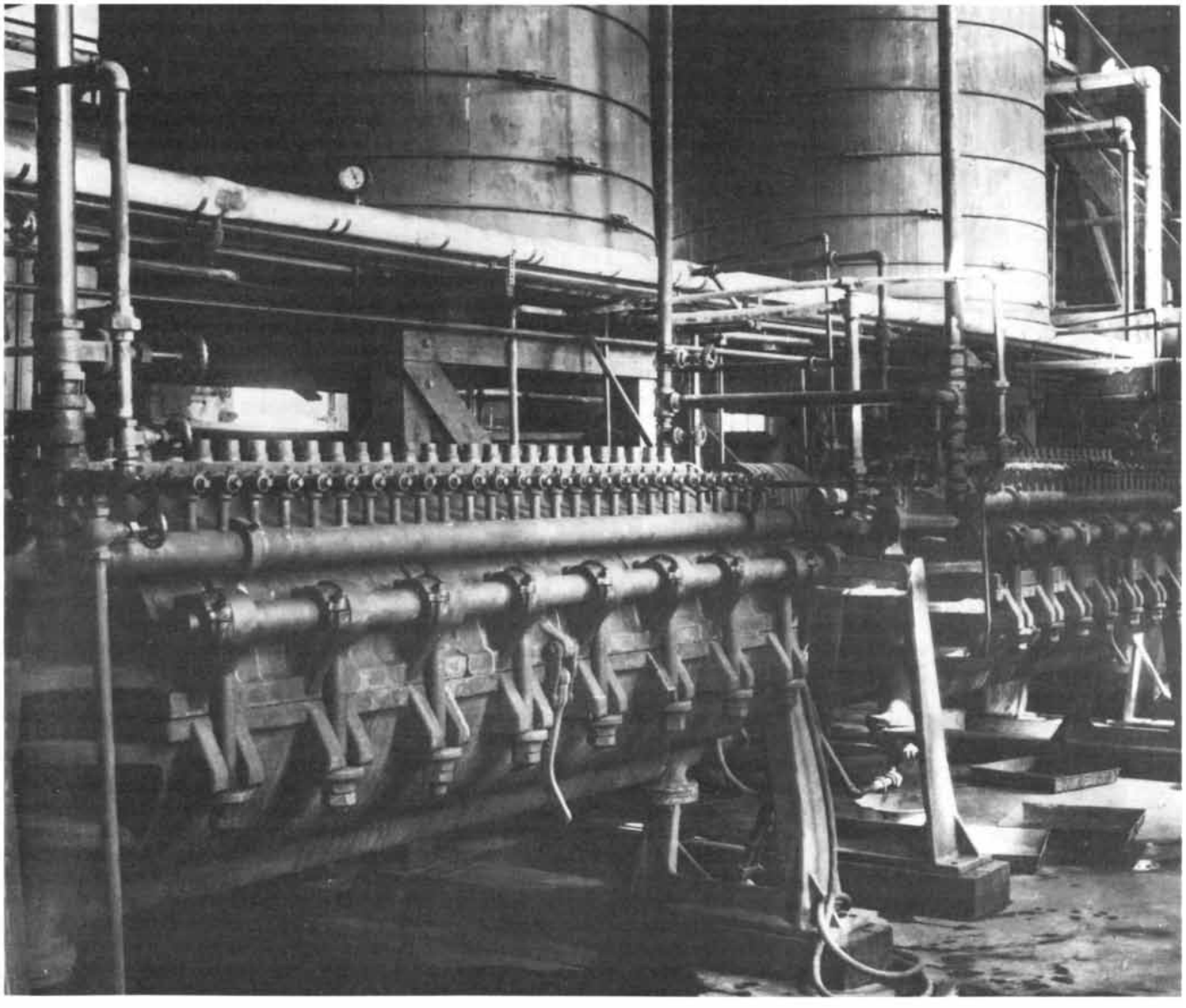
BANK OF AMERICA

uranium served as pigments, primarily for tinting glass. An important source of supply was a system of mines at St. Joachimsthal in Bohemia, which was then a part of Austria-Hungary. The St. Joachimsthal mines had been worked for silver in the 15th century, and late in the 19th century they were reopened for the recovery of uranium from veins containing pitchblende. A plant for the treatment of the ore was built by the Austrian government and residues from the plant were discarded in a nearby pine forest. Material from that waste dump was the source of the world's first purified radium.

Early in 1898 Marie Curie was screening a variety of metals, metallic compounds and minerals for radioactivity by measuring the extent to which they ionize air. She worked in the laboratory—a bare, glass-roofed shed—she shared with her husband, Pierre, in the courtyard of the School of Physics and Chemistry of the City of Paris, where he was professor. By April, Marie found that samples of pitchblende ore caused far greater ionization than comparable samples of metallic uranium or various uranium salts, suggesting that some component of the pitchblende was more radioactive than uranium. She established the existence of a new radioactive element and named it radium before the end of the year.

Marie Curie's initial work was done with a 100-gram sample of pitchblende, which was soon exhausted. Pierre wrote to colleagues and mineral dealers in Europe, Britain and the U.S. in search of additional materials, and 500 grams of pitchblende were provided without charge by the U.S. Geological Survey. The initial investigations had suggested, however, that the quantity of ore needed to isolate enough pure radium salts for study would be tons rather than grams. Through contacts with Éduard Seuss of the University of Vienna they obtained small samples of the St. Joachimsthal pitchblende ore and learned of the waste-dump residue. Through Seuss's intervention they were given 100 kilograms of the residue by the Austrian government. Between 1898 and 1902 they bought with their own money about 11 metric tons of the residue for little more than the cost of transport.

The sacks of residue were delivered to the Curies' laboratory, and the humble building with its pine tables and the adjacent courtyard became the first radium factory, with Marie the director and labor force of one. The extraction method she devised and submitted to the Faculty of Science of the Sorbonne in 1903



RADIUM INDUSTRY supported large-scale extraction plants even though worldwide production of the element never exceeded a few hundred grams per year. The apparatus shown in the photograph, which was made in 1915, was part of the plant of the National Radium Institute in Denver. The devices in the foreground are filter presses for separating wastes and by-products from the process stream.

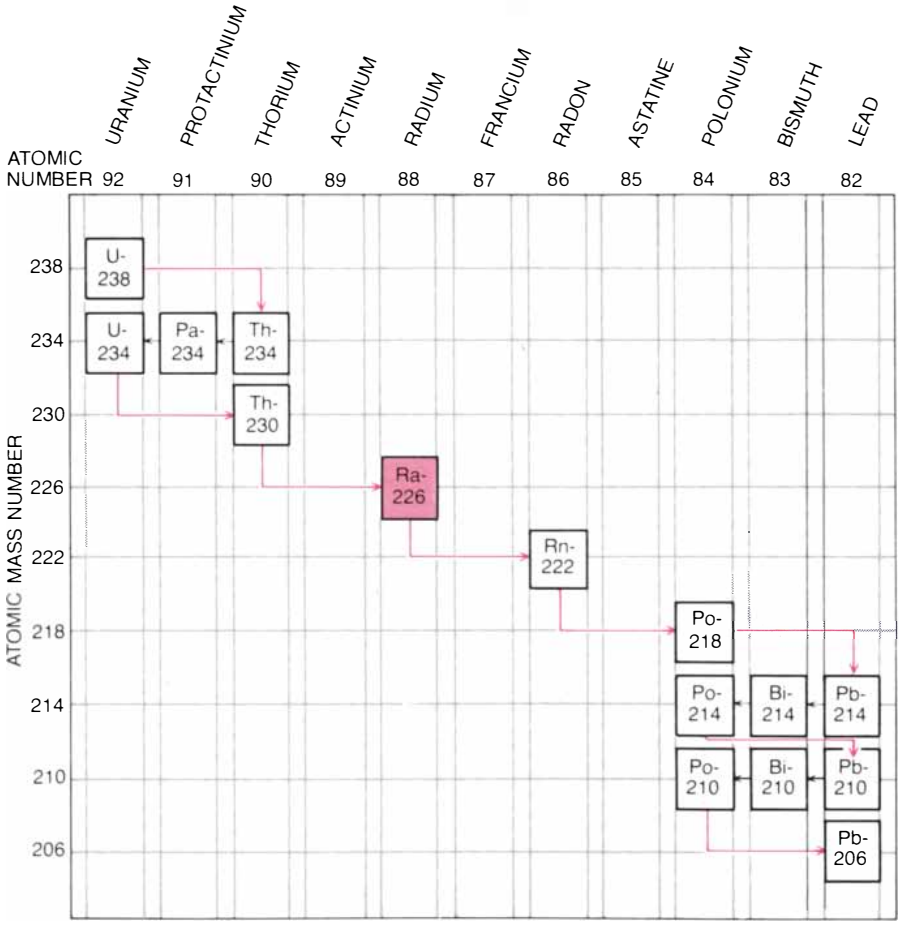
as part of her doctoral thesis is basically the same process employed some years later when the production of radium became a worldwide industry.

In Marie Curie's extraction process radium was repeatedly converted from one salt into another in order to separate it from other components of the material. At St. Joachimsthal the ore had been treated with sodium carbonate and sulfuric acid to extract the uranium, leaving the carbonate and sulfate salts of radium in the insoluble residues obtained by the Curies. The sulfates were transformed into carbonates by treating the residues with boiling sodium carbonate, and the carbonates were then transformed into soluble chlorides by treatment with hydrochloric acid. The solution was filtered to remove extraneous materials, then sulfuric acid was added, converting the radium into its sulfate form again, which precipitated. With the St. Joachimsthal residue one ton of ore yielded between 10 and 20 kilograms of the crude sulfates of radium, barium and calcium, which were from 30 to 60 times as radioactive as metallic uranium.

The crude sulfates were purified by a similar series of steps designed largely to remove calcium. The yield was about eight kilograms of mixed barium and radium chlorides per ton of ore. It then remained to extract the small quantity of radium chloride in the solution from the much larger amount of barium chloride. The method, called fractional crystallization, was again based on a difference in the solubility of the two salts. The solution in which the chlorides were dissolved was allowed to evaporate partially, so that crystals formed. Because barium chloride is more soluble than radium chloride the radium salt precipitated earlier, and so the crystals were richer in radium than the solution from which they formed. The crystals were then redissolved and the process was repeated, bringing a further enrichment. As the ratio of radium to barium increased, the crystals evolved from being colorless to yellow, orange, sometimes pink and then back to being colorless. After a number of fractional crystallizations the least soluble portion was retained; the crystals were nearly pure radium chloride.

It took Marie Curie nearly four years to reduce eight tons of the St. Joachimsthal residue to crude sulfates. The reaction vessel was a hand-stirred iron cauldron, and the ventilation of the irritating smoke and fumes was provided solely by the winds of Paris. The purification and fractional crystallization stage was then begun. The atomic mass of radium was determined in the spring of 1902 from the first tenth of a gram of the element concentrated.

As more radium was isolated—Marie Curie's toil with the eight tons of residue would ultimately yield one gram of radium—its remarkable properties became evident. Radium was found to be luminous and produced phosphorescence in diamonds exposed to its rays. The rays also disintegrated paper and cotton fibers, caused skin burns and could destroy certain forms of cancerous growth. In 1902, with a grant of 20,000 francs (about $4,000) from the French Academy of Sciences, factory-scale production of radium was initiated on a nonprofit basis at a plant of the Central Chemical Products Company in Paris. The operation was supervised by André Louis Debierne, a colleague of the Curies' and the discoverer of the element actinium.



RADIUM ORIGINATES as an intermediate product in the radioactive decay of uranium 238 to the stable nuclide lead 206. The radium atom has 88 protons and 88 electrons; its atomic number is therefore 88. At least 25 isotopes of radium exist; each isotope has a different number of neutrons and hence a different atomic mass number, which is equal to the sum of the number of protons and the number of neutrons. Radium 226 is the commonest isotope and the one that was most important commercially. Radium itself decays by emitting an alpha particle (a helium nucleus made up of two protons and two neutrons); the radium-226 atom is thereby transmuted into an atom of radon 222. Radon also decays by alpha emission. The daughter products include nuclides that emit beta particles (nuclear particles with the mass of an electron) and gamma rays (high-energy electromagnetic radiation). Alpha decays are shown by colored arrows and beta decays by black arrows; gamma emitters are lead 214 and bismuth 214.

Late in 1903 the Austrian government declared an embargo on the export of ore and residue from St. Joachimsthal. Both the public and the scientific community were captivated by the healing potential of radium; the demand for it was great and increasing rapidly. Thus the stage was set for the exploitation of new sources of radium ore and for the development of the radium-extraction industry in Europe, Asia, Australia and North America.

Exploration for radium-ore bodies was in most instances done by prospectors who relied on surface indications of mineralization, such as brightly colored outcrops. Simple chemical tests gave further evidence of uranium content. For example, adding a drop of concentrated hydrochloric acid to the yellow carnotite ore results in a red brown color; when water is then added, the color changes to green or fades completely.

The most important instruments for determining radium content, however, relied on measurements of the radioactivity of the specimen. Radiation-detection devices of various kinds were used

Breathe free.

So far, we've created 27 types of comfortable, economical masks that help people breathe free of contaminated air. They filter out dusts, pollens, germs and toxic fumes.

3M developed these lightweight, disposable masks over 20 years ago at the request of one company with a bad-air problem.

By listening to people's needs, we've developed many innovative health care products. For example, we've made a replacement lens for the eye and an x-ray film that cuts radiation exposure by 50%.

In all, 3M has pioneered over 700 health care products, from replacement joints to drugless pain control.

And it all began by listening.

3M hears you...

For your free 3M Health Care Brochure, write: Department 010711/3M, P.O. Box 4039, St. Paul, MN 55104.

Name_____

Address_____

City_____ State____ Zip_____

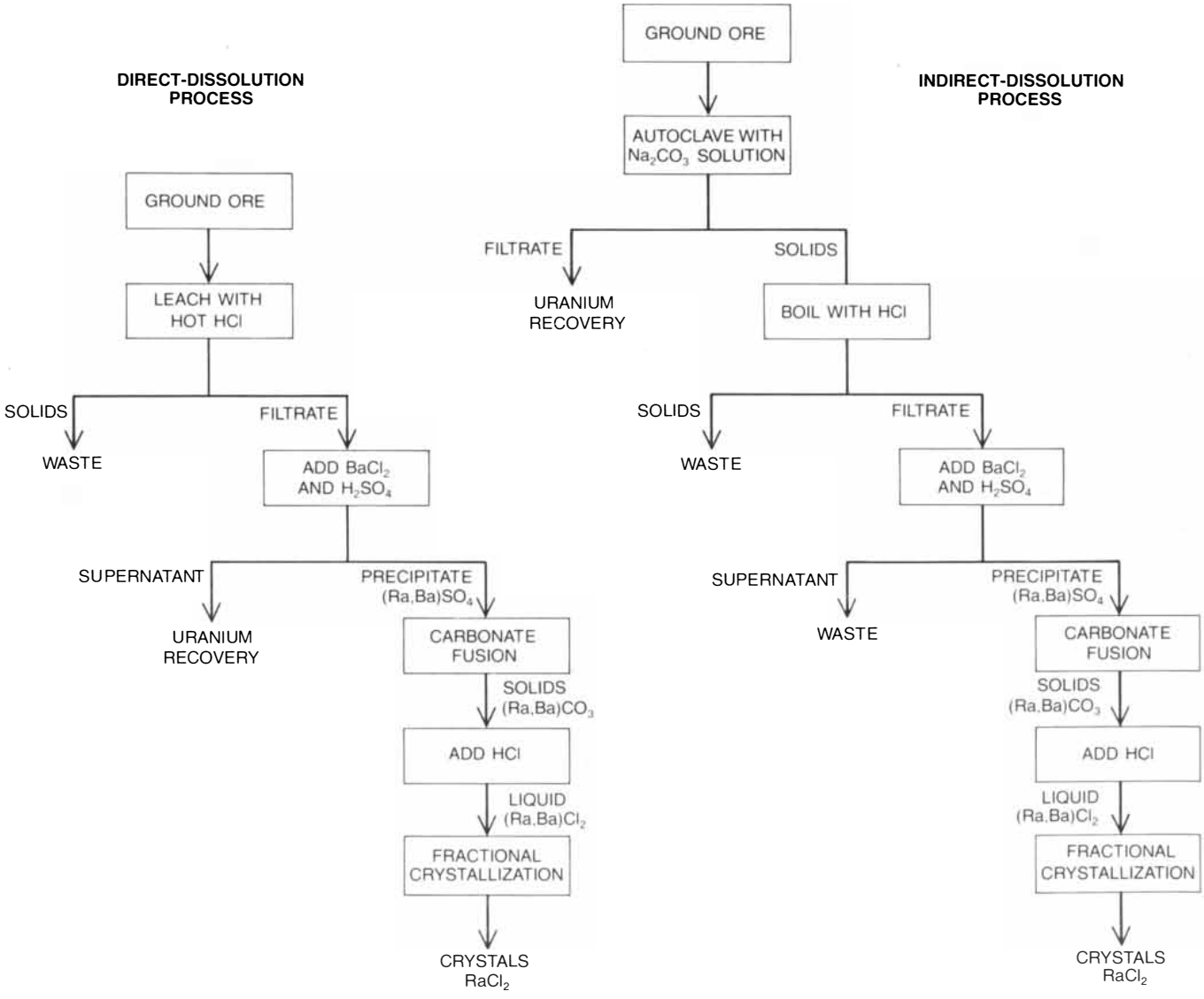
Or call toll-free: **1-800-323-1718,** Operator 361. (Illinois residents call 1-800-942-8881.)

3M

for screening and assaying ores and mill products. A photographic plate sealed in lightproof paper registered any exposure to radiation. The radioscope was a glass jar with a zinc sulfide–coated screen that emitted light when it was struck by alpha particles. A similar phosphorescent screen was employed in the spinthariscope, but it was arranged so that the light pulses could be counted in order to calculate the activity of the sample. Still another device, the electroscope, was the primary tool in radium assaying from the time of the Curies through the 1940's. A metal foil was given an electrostatic charge, so that it was repelled by another charged surface. Alpha particles from a radium sample dissipated the charge, allowing the foil to return to its original position. The rate of return indicated the radium content of the sample.

The Curies chose not to patent their radium-extraction procedure; instead they shared its details with other workers. In 1904, with the Curies' technical assistance, Armet de Lisle, a French industrialist, began commercial radium production at a factory in Nogent-sur-Marne, east of Paris. The procedure utilized was similar to the one developed by Marie Curie in the Paris shed, although by 1907 part of the initial treatment of the residue had been omitted and the efficiency of the fractional-crystallization system had been increased by converting chlorides into bromides. Furthermore, new radium-bearing ore deposits had been discovered. The plant at Nogent-sur-Marne processed pitchblende from Hungary, Sweden, Canada and Colorado; autunite (a calcium-uranium phosphate) from Autun in France and from Portugal; chalcolite (a copper-uranium phosphate) from Bohemia; carnotite from Portugal and Utah, and thorianite (a thorium-uranium oxide) from Ceylon.

The Austrian government soon built a facility for radium extraction and refining at St. Joachimsthal. By 1910 a to-



EXTRACTION METHODS were based on differences in the solubility of various radium salts and other components of the ore. The two basic procedures are diagrammed here; there were many variations. The two processes differ mainly at the start: the direct-dissolution process initially puts the radium into solution and then precipitates it, whereas the indirect-dissolution process concentrates the radium in the solid residue and later extracts it. After this first step the two processes are virtually identical. Barium chloride is added to a solution containing traces of radium chloride; sulfuric acid is then added, with the result that a mixture of radium sulfate and barium sulfate precipitates. The precipitate is treated with sodium carbonate to make it soluble in hydrochloric acid, which is then added. The filtrate from this suspension consists largely of barium chloride and radium chloride. The last step in the process is fractional crystallization, which separates the trace amounts of radium chloride from the much larger amounts of barium chloride. The chlorides are dissolved and the solution is allowed to evaporate partially, so that crystals form. Because barium chloride is more soluble than radium chloride the radium salt precipitates earlier and the crystals are richer in radium than the solution from which they formed. The crystals are dissolved again and the process is repeated. With each repetition the crystals become further enriched in radium until they are nearly pure radium chloride.

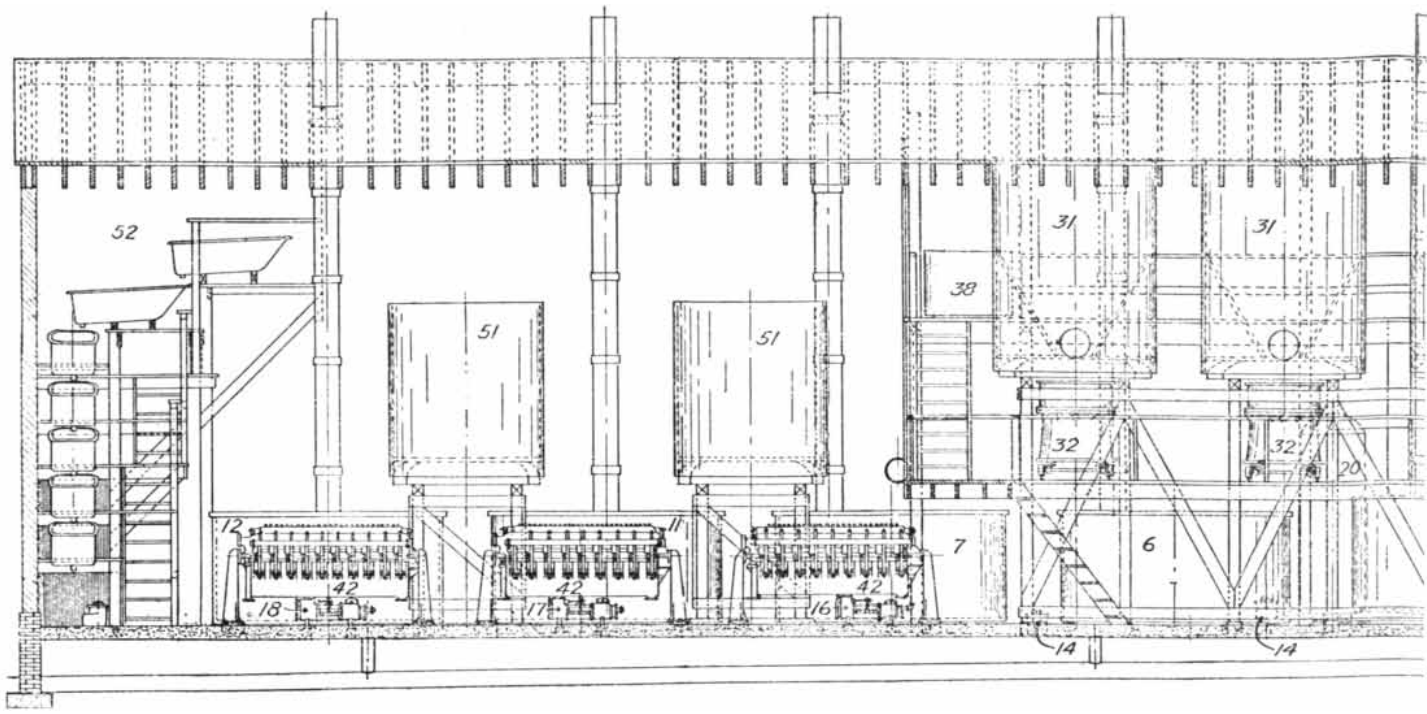
tal of 13 grams of radium had been produced there and through 1922 the output of the plant was the highest in Europe. Britain entered the market in about 1910 with the British Radium Corporation, which worked the Trenwith mine in the St. Ives district of Cornwall and shipped the ore to London for processing. Ores from Portugal, Madagascar and Cornwall were treated for radium extraction at two plants near Paris, and La Société Industrielle du Radium acquired the South Terras mine near St. Austell in Cornwall in 1913 and shipped the ore to another plant near Paris. In 1922 a plant was built at the South Terras mine site, where the processing of the low-grade ore continued until 1925.

Uranium-bearing alum shales from Sweden and pitchblende from Norway were the raw materials for radium production at a plant near Stockholm. Ore from the arid interior of South Australia was shipped to Sydney and Adelaide for radium extraction, and thorianite ore was mined in Japan. Russia also entered the radium market in about 1910, when the private Fergana Company for the Production of Rare Metals began processing low-grade ore from the Fergana region of Turkistan. Mining operations were suspended in 1914, but after the revolution a government-run extraction plant was constructed on the Kama River and a new plant was built in Moscow in 1931.

Commercial radium production in the U.S. was first attempted by Stephen T. Lockwood in 1906 but his Rare Metals Reduction Company lasted only until 1908. The efficiency of radium recovery was poor, there was little demand for the uranium and vanadium by-products and Lockwood was unable to secure adequate supplies of ore. Although this early venture failed, it helped to bring attention to vast reserves of carnotite ore in Colorado and Utah.

In 1910 Joseph M. Flannery, a former Pittsburgh undertaker, organized the Standard Chemical Company to extract radium from the Western carnotite ores. By 1913, when radium production was under way at the company's plant in Canonsburg, Pa., and its refining laboratory in nearby Pittsburgh, Standard Chemical was the leader in the American radium industry; it retained this position until the end of the American radium era. In the years that followed other extraction companies were established in Colorado, Illinois, New Jersey and Pennsylvania, and the U.S. became preeminent in the international radium market, producing some 196 grams of radium between 1913 and 1923.

American universities and their faculties gave major technical support to the radium industry. Professors associated with Princeton, Columbia and Yale uni-



EXTRACTION PLANT of the National Radium Institute processed carnotite ore by a direct-dissolution method from 1914 until 1916. In this diagram of a part of the plant, prepared by the U.S. Bureau of Mines, the flow of materials is generally from right to left. In leaching pots (*27*) radium-bearing components of the ore were dissolved in hot acid. The solid residue was removed by suction filters (*28*) and then washed and discarded. The acidic solution that passed through the filters drained into the radium-precipitation tank (*1*), where it was slightly diluted with distilled water and partially neutralized with sodium hydroxide. Barium chloride and sulfuric acid were then added in order to precipitate a barium-radium sulfate while leaving by-products such as uranium and vanadium and impurities such as calcium and iron in solution. The suspension was pumped into one of four settling tanks (*31*) and additional barium chloride was added to carry

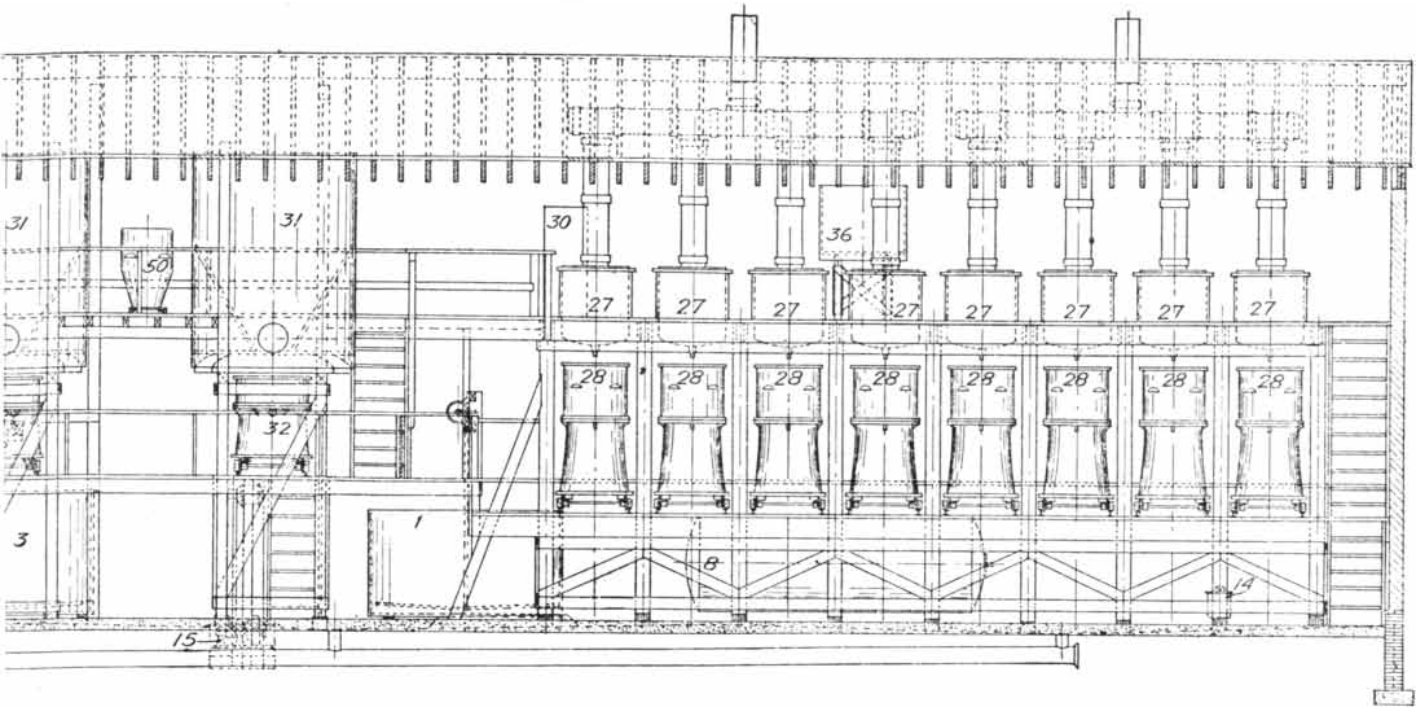
versities provided guidance to the Rare Metals Reduction Company. Herbert N. McCoy of the University of Chicago trained students in extractive technology and later established the Carnotite Reduction Company himself. One of McCoy's students, Charles Viol, went on to become the chief chemist of the Standard Chemical Company. Herman Schlundt of the University of Missouri provided technical advice on radium extraction to Government agencies including the Bureau of Mines and the Bureau of Standards and to several commercial concerns including the U.S. Radium Company. The collaboration of Henry Koenig of the University of Pittsburgh and Willy A. Schlesinger of the University of Heidelberg at the Radioactive Laboratories of Princeton in 1914 and 1915 led to the founding of the Radium Company of Colorado in Denver. Funds given by Thomas Walsh, a Denver gold magnate, to the Colorado School of Mines sponsored geologic and metallurgical work on the carnotite deposits of Colorado.

The National Radium Institute was established in 1913 by a cooperative agreement among the U.S. Bureau of Mines, James Douglas, a New York mining industrialist and philanthropist, and Howard A. Kelly, a gynecologist who operated a private hospital in Baltimore and was a member of the faculty of the Johns Hopkins University Medical School. The undertaking was intended to supply radium to the General Memorial Hospital for the Treatment of Cancer and Allied Diseases in New York and to Kelly's hospital in Baltimore and to investigate ways of reducing the cost of radium production from domestic carnotite ore. When the Denver extraction plant built by the institute closed in 1916, some 8.5 grams of radium had been purified at an average cost of about $38,000 per gram.

The cost of radium production was the subject of a dispute between the Standard Chemical Company—chiefly in the person of Charles Viol—and the Bureau of Mines. Viol, whose company was then selling radium at the market price of more than $100,000 per gram, argued that the price announced by the Bureau of Mines was unrealistically low, in part because it was based on extraction from ores richer than those generally available. The process developed by the National Radium Institute, he asserted, would not work well with finely ground ore concentrates and sulfate-rich ores. Viol also argued against calls for the conservation of radium by nationalizing radium deposits and by substituting mesothorium for radium in luminous paints. (Mesothorium is the name that was then given to what is now recognized as merely another isotope of radium, namely radium 228. It is a product of the decay of thorium 232 rather than uranium 238 and is extracted from thorium-bearing ores such as monazite.) Viol maintained that estimates of carnotite reserves in the U.S. made by the Bureau of Mines were grossly understated.

No clear winner emerged from the war of words and wills. The price of radium remained high and did not fall to $40,000 per gram until about 20 years later; the decline then was a result of market forces that were not foreseen by either party in 1919. The National Radium Institute's extraction process did not gain widespread use, probably owing to poor radium yields from carbonaceous ores. Radium deposits were not nationalized, and the reserves actually were greater than early Government estimates. Mesothorium usage in luminous products did increase, and indeed the paint used by the famous New Jersey dial painters contained a mixture of about 25 percent radium 226 and 75 percent mesothorium. The debate, however, soon became academic as developments in the jungles of central Africa and the factories of Belgium abruptly made the American radium industry uncompetitive.

Important pitchblende deposits were discovered in the Haut Katanga district of the Belgian Congo between 1913 and 1915, but wartime pressures for maximum production of copper from the



down any traces of radium remaining in the liquid. The finely divided barium-radium sulfate was allowed to settle for three or four days and then was separated from the liquid by another suction filter (*32*). The precipitate was washed and dried and taken to another building for further processing, including the conversion of the barium-radium sulfate into a solution of barium-radium chloride. The solution was returned to the building shown here for the first stages of fractional crystallization. This was done in the cascade of bathtubs (*52*) at the far left, where the liquid was allowed to flow downward from one tub to the next (becoming more depleted of radium) while crystals were transferred upward (becoming more enriched). Purification of the radium by several further stages of fractional crystallization was done in laboratories at another site. Two storage tanks (*51*) and three filter presses (*42*) were used in recovery of uranium and vanadium.

Congo prevented exploitation of the pitchblende until after the armistice. In 1921 the Union Minière du Haut Katanga began shipping the very-high-grade ore (averaging about 50 percent uranium oxide) to an extraction plant in Oolen, near Antwerp. Production began at Oolen in mid-1922 and forced an immediate and final shutdown of almost all radium-extraction operations in the U.S. Sensing the inevitable, two of the largest American companies, the Standard Chemical Company and the Radium Company of Colorado, provided guidance in setting up the Oolen plant and later served as the agents for the sale of the Belgian radium in the U.S.

Whereas it took between 300 and 400 tons of a typical American carnotite ore to produce one gram of radium, less than 10 tons of the Katanga ore was needed to yield the same amount. The Bureau of Mines chemist who had managed the National Radium Institute operation described the Oolen facility as "more like a fine kitchen than an actual metallurgical plant." Residues from the process were saved for possible future removal of other radionuclides. Because of the high grade of the ore and the completeness with which uranium and gangue were removed by the sulfuric acid and sodium carbonate treatment, the residue from the treatment of nine tons of ore could be stored in a 50-gallon barrel. Demand for new stocks of radium fluctuated widely between 1922 and 1933 and annual production at Oolen reflected this, ranging from six grams to 60 grams with a total production for the period of 326 grams.

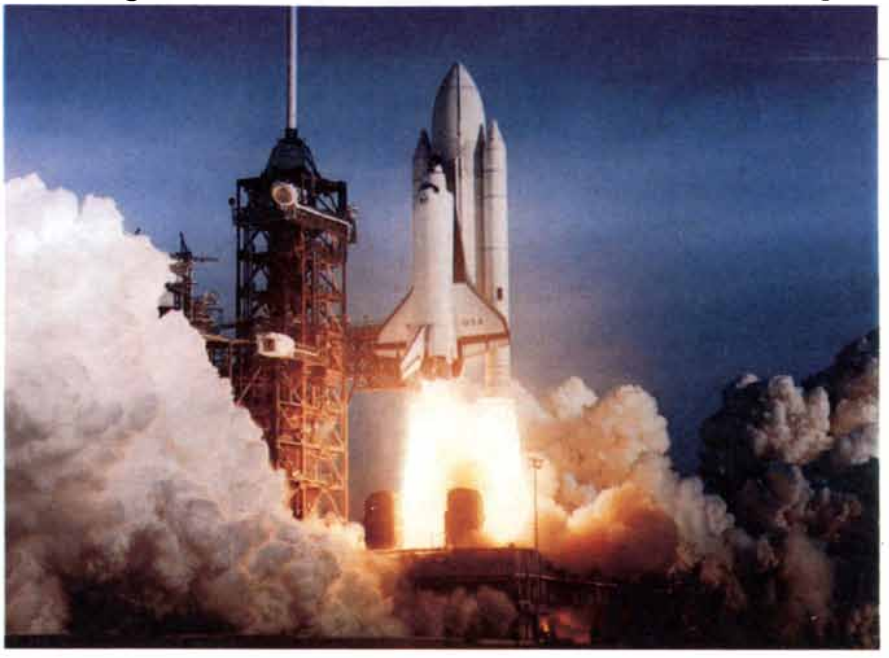
In the aftermath of the Belgian emergence the pattern of radium production throughout the world changed drastically. The U.S. Radium Company continued to extract radium until 1926. The remaining American operations were either abandoned completely or were converted to the treatment of carnotite ore for removal of its vanadium only. A limited amount of mining and extraction of radium was done in Australia through about 1930 and in Britain and France through at least 1925. St. Joachimsthal became part of Czechoslovakia after World War I and was renamed Jáchymov; radium production was sustained there through 1937. In the U.S.S.R. radium processing continued in spite of ores that now had to be classified as low grade, and it was even expanded in 1931.

The only radium-processing company that could effectively compete with the Belgian company was one that had access to another source of very rich ore. The existence of uranium in outcrops along the shores of Great Bear Lake in northwestern Canada had been discovered in 1900 by a pioneering geological survey of the area. In 1931 it was announced that the extensive pitchblende deposits included ores with from 30 to 60 percent uranium oxide. An extraction plant at Port Hope, Ont., with a production capacity of about two grams of radium per month was completed by the end of 1932. Its capacity had more than doubled by 1938. The high output from the factories at Oolen and Port Hope rapidly forced down the price of radium, and in 1938 an agreement that divided up the world market and attempted to stabilize the price at $40,000 per gram was negotiated by Belgium and Canada.

Throughout that era most of the radium produced was used in medicine. The advent of radium therapy as an alternative or adjunct to the surgical management of cancers was truly a boon to medicine in the early 20th century. Radium-filled needles, tubes or plaques were temporarily implanted, inserted or applied to affected organs. Gold capsules ("seeds") filled with radon were permanently implanted during tumor surgery; they were not removed because the half-life of radon 222 is only about four days. As the supply of radium increased in the 1930's and the price fell it became possible for hospitals to set up facilities for cancer "teletherapy," in which the affected part of the body is irradiated by an external source consisting of between four and 10 grams of radium.

Other medical and cosmetic applica-

We are building an infrared spectrometer which will work under very unusual laboratory conditions.



After 20 years of research into infrared detection, the state of the art is still advancing.

The infrared spectrometer we are building for NASA and the Jet Propulsion Laboratory will be carried on future Space Shuttle flights. The ATMOS (Atmospheric Trace Molecule Spectroscopy) instrument is currently scheduled to fly in late 1984 on the Spacelab 3 mission. Using high resolution infrared absorption techniques, this instrument will gather information on the chemistry and physics of the upper atmosphere at altitudes from 20 to 120km. Molecular concentrations of as little as a few parts per trillion will be measured.

A growing concern over the state of the earth's atmosphere has increased our need for a fundamental understanding of the forces at work in that environment. The delicate ozone layer falls within the area to be sampled by ATMOS, and is just one example of dynamic balances in the upper atmosphere which play a major role in shaping the future of our environment.

Years of progress.

The detector which allows the ATMOS spectrometer to measure infrared radiation in the 2-16 micron band is made of Mercury Cadmium Telluride ((Hg,Cd)Te). Honeywell research on this compound began more than 20 years ago, and includes the first practical process for the production of uniform (Hg,Cd)Te crystals.

Recent developments at Honeywell represent equally significant advances for (Hg,Cd)Te. We demonstrated the first successful application of liquid phase epitaxy for the fabrication of (Hg,Cd)Te crystals, reducing the time required to make the material for a detector from months to days. Liquid phase epitaxy will allow us to mass produce uniform single crystals of (Hg,Cd)Te with an optical and electrical purity in the range of a few parts per billion.

We're getting warmer.

Another breakthrough involves our demonstration of a "mosaic" detector in which several thousand (Hg,Cd)Te elements are bonded to a silicon readout chip.

Traditionally, (Hg,Cd)Te detectors have been cooled to the temperature of liquid nitrogen (77 K) in order to achieve acceptable operating efficiencies. However, our mosaic arrays are capable of operating efficiently at temperatures as high as 195 K. Having dramatically reduced cooling requirements, we are now able to consider the use of thermoelectric cooling in lieu of cryogenic refrigerants.

While our progress in infrared detection has been considerable, much remains to be done in areas ranging from molecular beam epitaxy to pattern recognition in breast cancer detection and night vision.

For more information on infrared applications, technology, or related careers in applied research, write to Larry Larson, Vice President, Honeywell Electro-Optics Operations, 2 Forbes Road, Lexington, MA 02173.

If you have an advanced degree and are interested in a career in solid state electronics, sensors, optics, or material sciences, please write to Dr. W. T. Sackett, Vice President, Honeywell Corporate Technology Center, 10701 Lyndale Ave. So., Minneapolis, MN 55420.

Honeywell

The research environment at Honeywell is enhanced by Honeywell's affiliations with universities. We have an ongoing program of seminars with Berkeley, MIT, Stanford, the University of Kiel, the University of Illinois, Cornell, Purdue and the University of Minnesota.

tions of radium were promoted by a few physicians and by many snake-oil salesmen for the relief of everything from insanity to bad breath; they were of dubious benefit and indeed were potentially harmful. Some of the would-be remedies called for inhalation of radon-charged air and others for ingestion, injection or enema with radium- or radon-bearing waters.

The unfounded medicinal claims for radium eventually led to government action and warnings, including the following press release issued in 1926 by the Bureau of Chemistry of the Department of Agriculture:

"The products analyzed for content of radium included hair tonics, suppositories, bath compounds, tissue creams, tonic tablets, face powders, ointments, mouth washes, demulcents, opiates, ophthalmic solutions, healing pads and other preparations in solid, semisolid and liquid form for which therapeutic value because of alleged radioactivity was claimed. Only 5 percent of the products analyzed and claimed to be radioactive contained radium in sufficient quantities to render them entitled to consideration as therapeutic agents and then only in certain very limited conditions, say the officials. Highly exaggerated therapeutic claims obviously designed to mislead the purchaser are being made for many of the products which contain little or no radium. One of the samples examined consisted of a short glass rod coated on one end with a yellow substance and enclosed in a glass bulb. The bulb is designed to be hung over the bed and according to the claims of the inventor causes dispersion of 'all thoughts and worry about work and troubles and brings contentment, satisfaction and body comfort that soon result in peaceful, restful sleep.'

"The distribution to the general public without discrimination or adequate supervision of highly radioactive products or the devices for rendering water or other substances highly radioactive is of very questionable propriety, since radium in active dosage is potent for harm as well as for good and should be administered with great caution."

Not content with healing the human body, the purveyors of radium sought to sell radium-bearing fertilizers on the premise that they would increase plant growth. The fertilizers were tailings from the radium-extraction process, in some cases mixed with ordinary fertilizer. In spite of disclaimers from the Bureau of Soils of the Department of Agriculture it appears the "radioactive manures" were applied to soils in the U.S., Canada and France.

As early as 1903 it was shown that mixtures of zinc sulfide crystals with small amounts of radium emit light. Luminous compounds containing from 25 to 300 micrograms of radium per gram of zinc sulfide were prepared and used on products ranging from the dials of watches and aircraft instruments to slipper buttons, roulette wheels and fish bait. The unfortunate fate of the dial painters who pointed their brushes with their lips is well known.

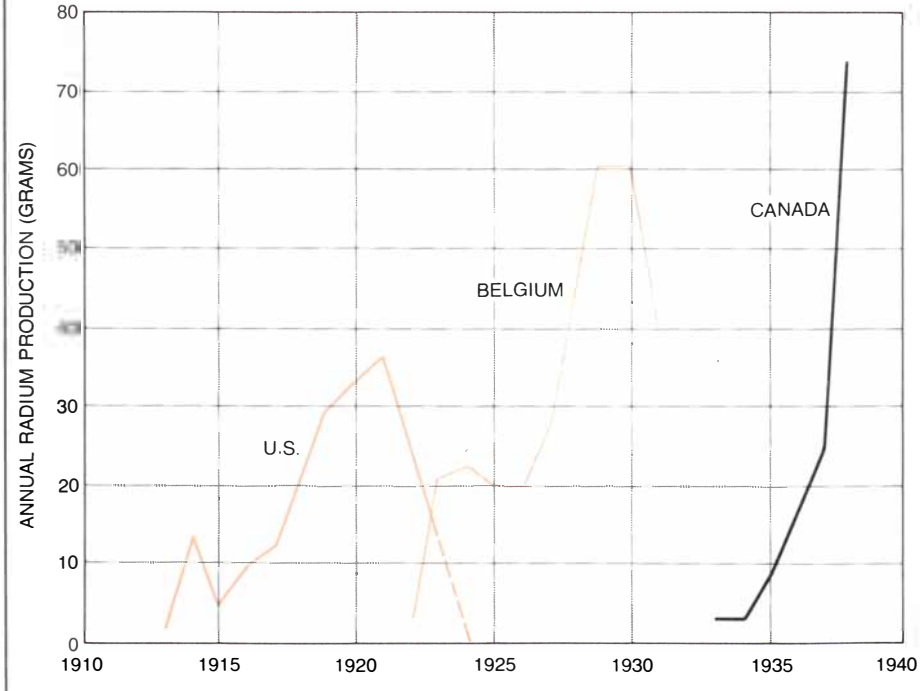
Other industrial applications relied on the ability of a radium source to ionize air and thereby dissipate a static charge. In the late 1920's radium static suppressors were employed in a Russian factory where rubber-coated fabric was manufactured to lessen the hazard of sparking and the ignition of flammable vapors. By the mid-1930's there was limited production in the U.S. of rayon fabric in which small quantities of radium were incorporated to reduce what television commercials now call "static cling."

Many hazards of radium laboratories

RADIUM MINING AND EXTRACTION was a worldwide industry in the first third of the 20th century. Sites where ores containing pitchblende and carnotite were mined are indicated in color; extraction plants are indicated in black. The first major pitchblende deposit to be exploited was the one at St. Joachimsthal in Bohemia, which was then part of Austria-Hungary; it was with residues from this ore that Marie Curie first isolated radium in 1898. The Austrian government built a radium-extraction plant at St. Joachimsthal in about 1904. Carnotite deposits in western Colorado were the world's chief source of radium from 1913 to about 1922; much of this ore was processed by the Standard Chemical Company in Canonsburg, Pa. Beginning in 1921 ore of very high grade was mined in the Haut Katanga district of the Belgian Congo and processed in a plant at Oolen in Belgium. Beginning in 1932 a new deposit of pitchblende, comparable in grade to the Haut Katanga ore, was mined along the shores of Great Bear Lake in northwestern Canada and processed in Port Hope, Ont. The Belgian and the Canadian plants soon controlled the market. A few ore deposits not shown on the map were also exploited.

and factories were already known in the first decade after the discovery of radium. Skin burns caused by handling unshielded vessels containing radium salts were noted very early by Antoine Henri Becquerel and the Curies. The effects of the ingestion of radium and the inhalation of radon and its radioactive decay products were more subtle and did not become apparent until the 1920's, following studies of the high rates of jaw necrosis in radium dial painters and lung cancer in uranium miners. Many of the early workers in the

PRICE OF RADIUM increased rapidly from the start of the industry in 1904 until about 1914. The price then began to fall as the number of American producers grew. The trend continued when the Belgian plant began operations in 1921 and the Canadian plant entered the industry in 1932. In 1938 the Belgians and the Canadians divided the world market to stabilize the price.



ANNUAL PRODUCTION OF RADIUM varied according to the quality of the ore available and the state of the world economy. The U.S. was the largest supplier until 1921. When production began in Belgium with richer ore, however, U.S. output almost stopped in just a few months. Radium-output statistics for Belgium were not published in the mid- and late 1930's, although production undoubtedly continued. Data on Canadian production were considered secret during World War II because they reflected uranium supplies available for military use.

preparation of radium salts, including Marie Curie, died of conditions that were probably a result of long-term radiation exposure. By the 1930's working conditions in the industry were improving. Shielding of concentrated preparations was upgraded, ventilation in the radium-refining laboratories was improved and workers were periodically screened for anemia and assimilated radium, the latter by means of a test that measured radon in exhaled breath. At the Great Bear Lake mines, tunnels were designed to minimize radon hazards to the miners.

During World War II the extraction of uranium as well as radium became a key part of the industry as nations sought to take military advantage of the newly discovered fission reaction of uranium. Many pioneers of the radium industry turned their attention to nuclear fission and its military applications. After the war attention remained focused on uranium, but radium production went on in Canada until 1954 and in Belgium until 1960.

Refining and reincapsulation of previously extracted radium has continued, and radium sources still have a place in cancer therapy, particularly in the short-range treatment of tumors of the skin, mouth, nasal mucosa and genitourinary tract. A large share of the market that was formerly the domain of radium and radon products, however, has been taken over by radionuclides made in particle accelerators and nuclear reactors. Radionuclides such as cobalt 60, cesium 137, tantalum 182, iridium 192 and gold 198 are now available for radiation-therapy sources, and tritium (the radioactive isotope of hydrogen) and promethium 147 have replaced radium and mesothorium in luminous devices.

The pioneering efforts of the radium industry of the early 20th century have their legacy in the present-day uranium-mining and -milling industry and in the fields of radiation therapy and industrial radiography. Many of the radiological health standards that guide today's nuclear activities have their roots either in the radium industry or in the retrospective medical study of those who worked in it.

Stocks of radium are now more than adequate to satisfy the needs of the market. Because of the long half-life of the nuclide and the diminishing demand it is unlikely that radium will ever again be extracted from ores for medical or industrial purposes. Indeed, the only extraction operations even discussed today—as alternative uranium-milling methods—would classify radium as a waste and seek to concentrate and fix it in a form suitable for long-term burial. In less than a century radium has evolved from the status of buried treasure to that of buried waste.

THE AMATEUR SCIENTIST

Simple optical experiments in which spatial filtering removes the "noise" from pictures

by Jearl Walker

Spatial filtering is a technique by which unwanted information in a picture ("noise") can be separated from wanted information. For example, a picture transmitted from a satellite might have features added by the transmission technique. With spatial filtering the noise (the added features) can be removed from the information (the picture) so that the picture is clearer.

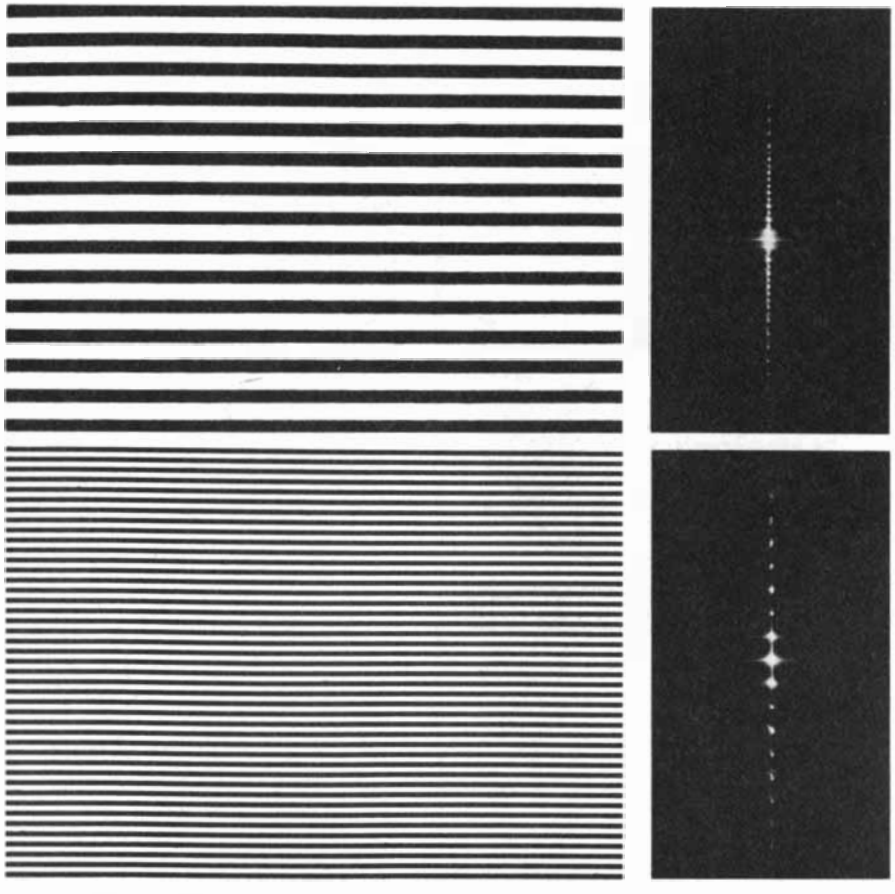
Spatial filtering is based on the diffraction and interference of light waves. Arthur Eisenkraft, who teaches physics at Briarcliff High School in Briarcliff Manor, N.Y., has designed a series of experiments by which his students can create a system that functions as an optical computer. Information from a photographic transparency is converted into a diffraction pattern and is then retrieved as a real image. Appropriate filtering of the diffraction pattern enables the students to eliminate noise from the final image. They ultimately can sharpen the image in a halftone reproduction clipped out of a newspaper.

The experimental procedure begins with filtering the light from a helium-neon laser. Light can be regarded in two ways: as rays or as waves. In the ray picture a laser beam is regarded as consisting of precisely parallel rays. In the wave picture the beam is regarded as being a succession of plane wave fronts perpendicular to the light's direction of travel. Neither picture is correct. The rays diverge somewhat, and the wave front is slightly curved. The first task in Eisenkraft's experiments is to filter the beam with a lens and a pinhole so that the nonparallel rays in the beam are eliminated. Then when the light illuminates a transparency, it more closely resembles the ideal picture of a plane wave front.

The lens (labeled L_1 in the upper illustration on page 198) should have a short focal length because it must focus the laser light onto a pinhole positioned close to it. The distance between the lens and the laser is not critical. Once the lens is in the beam the pinhole is brought into the light focused by the lens and is positioned exactly at the lens's focal point, where the beam is sharpest. The parallel rays in the original beam diffract through the pinhole. The nonparallel rays are not properly focused by the lens and do not pass through the pinhole.

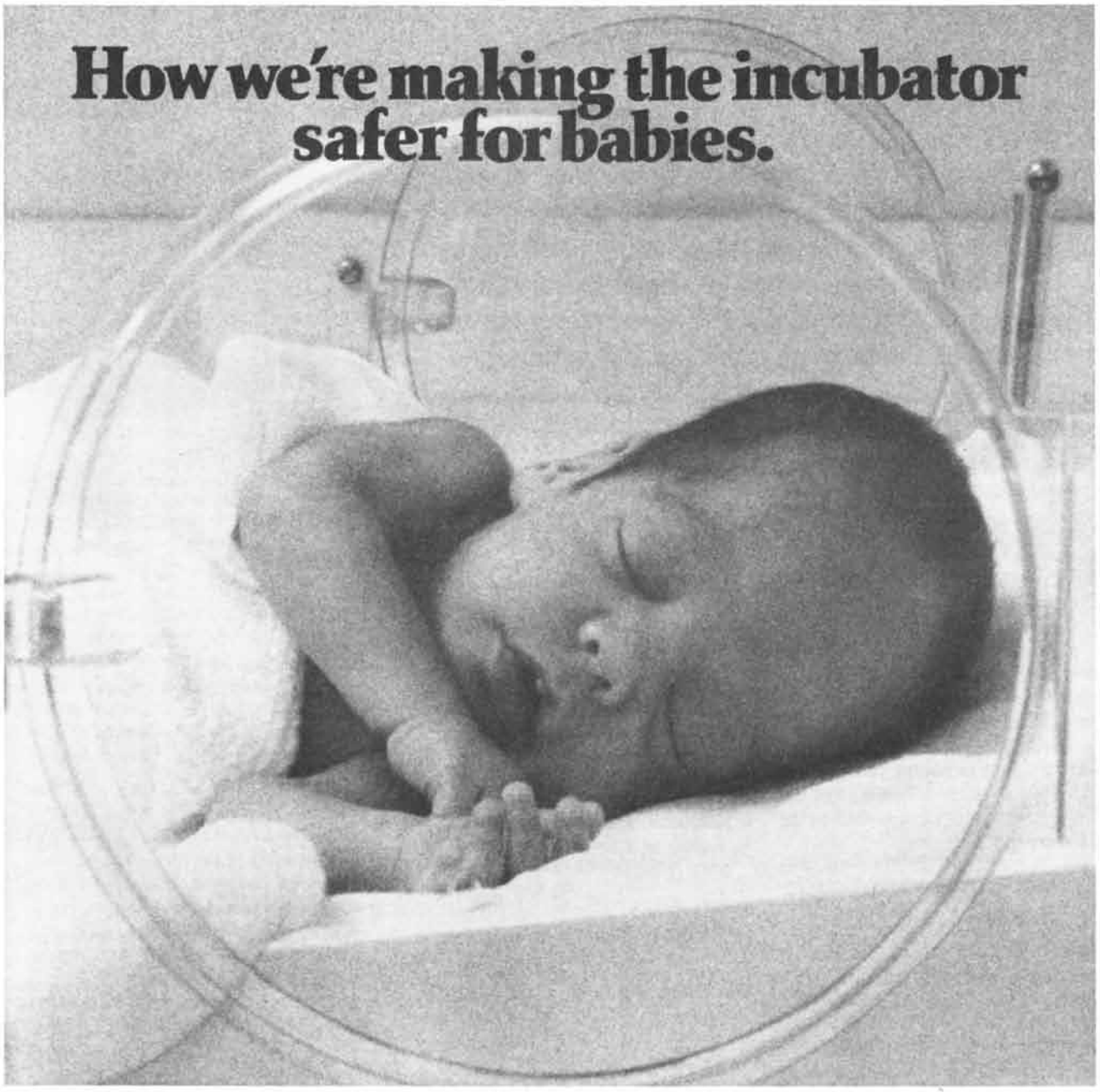
The light emerging from the pinhole forms a spherical wave front. In order to restore the plane wavefront the light is collected by a second lens, L_2. This collimating lens must be positioned carefully at a distance of one focal length from the pinhole. To achieve this positioning a mirror is placed to reflect light from the lens back through the lens and onto the screen with the pinhole in it. The returned light is initially a spot near the pinhole but not exactly at it. By adjusting the distance between the pinhole and the lens the returned light can be brought to a sharp focus on the pinhole screen. By moving the lens across the optical axis (the line running through the laser, the pinhole and the lenses) the spot of light can be positioned directly on the pinhole. The lens is then in its proper position, centered on the optical axis and at a distance of one focal length from the pinhole. The mirror is removed. The light emerging from the lens is nearly a plane wave.

The light illuminates a photographic transparency placed in front of the lens at some convenient distance. On the transparency is some kind of pattern consisting of opaque and transparent areas. These features diffract the light into a pattern in which the pattern of the transparency is coded. To illustrate the procedure the students first employ a transparency (a slide) consisting of a simple pattern of slits. Eisenkraft made several such transparencies by photographing black-and-white patterns. (All the patterns, lenses, pinholes and holders used in Eisenkraft's experiments are available individually or as a kit from



Transparencies of the geometric patterns at the left create the diffraction patterns at the right

How we're making the incubator safer for babies.



When a baby is born prematurely, even the air the baby breathes can be a menace.

It must be pure air, free of any trace of toxic substances—such as oil vapors.

Large compressors—the size of a baby's bassinet—pump the air throughout the hospital and into the incubator.

It's a fact, though, that ordinary compressors require oil for lubrication. And without careful filtration, the result can be toxic vapors.

Vapors that are pumped in with the infant's air.

Fortunately for "preemies" born today, the people of ITT have come up with a better compressor for hospitals.

It's totally oil-less. Through some new technology, ITT's Pneumotive Division has produced air compressors that do just fine without a drop of oil.

At pioneering medical centers like the Children's Hospital in Buffalo, New York, these unique compressors have already proved themselves.

And they're finding more and more use in health care and industry, wherever clean air is a must.

It's still too early to know how many babies will be helped because of these compressors.

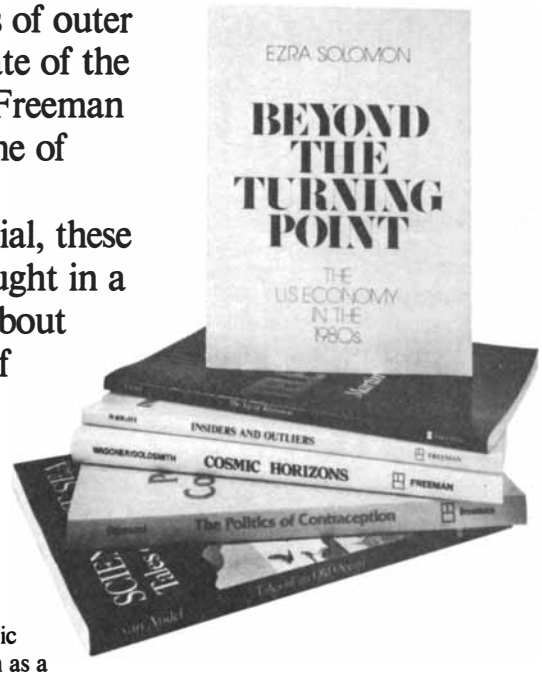
But we like to think that some of the best ideas to help people are the ones that help very little people.

The best ideas are the ideas that help people. ITT

SHOWCASE OF EXCELLENCE

From the depths of the ocean to the far reaches of outer space, from the annals of history to the present state of the economy, this selection of new books from W. H. Freeman and Company presents the pioneering work of some of today's most innovative thinkers.

Brilliant, provocative, and frequently controversial, these books communicate the best of contemporary thought in a highly readable form. For those who are curious about new ideas and appreciate intellectual stimulation of uncompromising quality, each book presents new thinking—cutting-edge ideas, breakthrough research, vanguard concepts.



COSMIC HORIZONS: UNDERSTANDING THE UNIVERSE
Robert Wagoner and *Donald Goldsmith*
Physicist Wagoner and astronomer Goldsmith have collaborated on this mind-expanding exploration of the fundamentals of cosmology and the composition of the universe as astronomers understand it today. This comprehensive study provides new insight into what we may be able to learn from the increasing variety of sophisticated techniques that allow us to probe farther out in space—and further back in time.
hardbound: ISBN 0-7167-1417-5 $18.95 (tent.)
paper: ISBN 0-7167-1418-3 $9.95 (tent.)

THE POLITICS OF CONTRACEPTION: BIRTH CONTROL IN THE YEAR 2001
Carl Djerassi
Here Carl Djerassi, who at the age of 28 led the team of scientists that synthesized the first birth control pill, provides a "why, when, and whether" exploration of the critical issues surrounding birth control "Djerassi's sophistication as a laboratory scientist is peerless, and in *The Politics of Contraception* it is matched by the clarity of his exposition. No other work in any field deals so comprehensively with the scientific foundations of human biology and with the ethical, social, and political requirements for and ramifications of scientific discovery."
—*Nobelist Joshua Lederberg*
hardbound: ISBN 0-7167-1341-1 $19.95
paper: ISBN 0-7167-1342-X $9.95

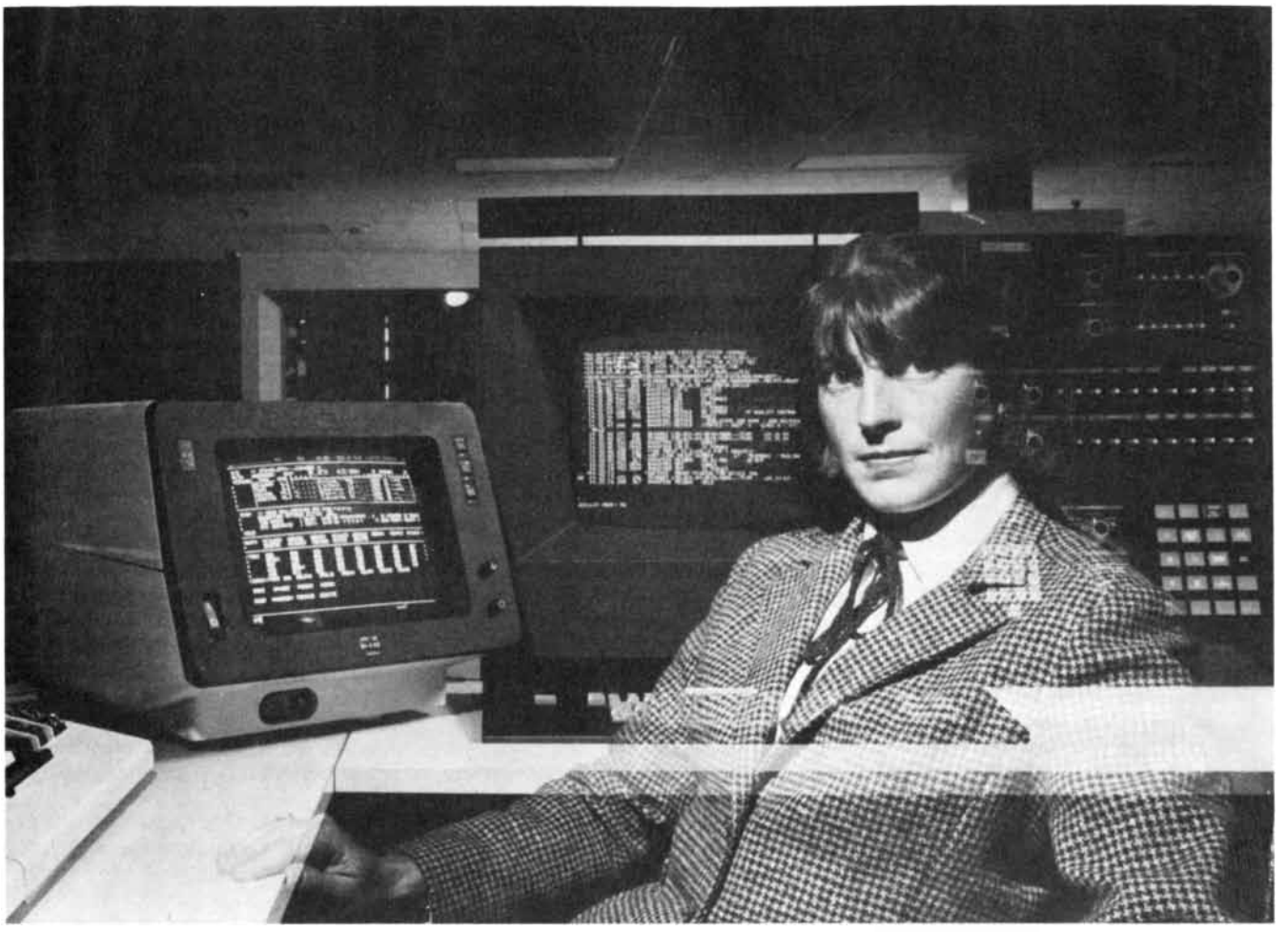
THE AGE OF TELEVISION
Martin Esslin
Here world-renowned drama critic Martin Esslin discusses television as a dramatic form of communication, pointing to the strengths and weaknesses that spring from its character, and assessing its possible impact on generations destined to grow up under its influence. How does television turn reality into fiction, fiction into reality? What long-term effects will this relatively new medium have on our abilities to reason, read, and create?
hardbound: ISBN 0-7167-1337-3 $15.95
paper: ISBN 0-7167-1338-1 $7.95

BEYOND THE TURNING POINT: THE U.S. ECONOMY IN THE 1980s
Ezra Solomon
Here the distinguished Stanford economist, a former member of the President's Council of Economic Advisers, observes that we have just witnessed a historic turning point in the thrust of U.S. economic policy. Will this bring about a corresponding change in the performance of the U.S. economy —or will the current decade be a replay of the 1970s? Can we once again move into a sustainable period of fast and noninflationary growth? Solomon's penetrating account traces the origins of many of our current problems and explores the economic outlook for our country in the 1980s in light of events of the past several decades.
paper: ISBN 0-7167-1391-8 $7.95

SCIENCE AT SEA: TALES OF AN OLD OCEAN
Tjeerd van Andel
Seafarer, scholar, and practicing oceanographer, Tjeerd van Andel combines a love for life at sea with an abiding interest in a science that in the last twenty years has revolutionized our understanding of the history of the earth. The geological revolution has come about mainly through the discoveries of ocean scientists, and *Science at Sea* offers a lively introduction to the many facets of their work and its manifold relations to human life.
hardbound: ISBN 0-7167-1363-2 $15.95
paper: ISBN 0-7167-1364-0 $8.95

INSIDERS AND OUTLIERS: THE INDIVIDUAL IN HISTORY
Gordon Wright
"Does the individual have a place in history?" asks Gordon Wright, one of the nation's most eminent historians of modern France. In this witty excursion into the past, Wright deftly answers this question, presenting a procession of exceptional individuals who truly make history come alive.
hardbound ISBN: 0-7167-1339-X $14.95
paper ISBN: 0-7167-1340-3 $7.95

To order your copies of any of the books listed above, please send a check for the total amount due (including $1.50 for postage and handling; California residents add appropriate sales tax) to: Promotion Department, W. H. Freeman and Company, 660 Market Street, San Francisco, CA 94104.



The Year 2000 . . . Where Are Your Skilled Personnel?

Government and private-sector analysts are predicting an extreme shortage of highly skilled workers to meet this country's expanding technical needs. They believe the U.S. is nurturing a society of "technological illiterates" who lack the ability to understand data, evaluate problems, and apply learned concepts to everyday living. Although there is disagreement as to the severity of the problem, no one denies that it exists and is worsening with each graduating high school and college class.

The failure to understand and pursue advanced technical studies begins early in a student's academic training. Students, particularly girls, can develop "mathemaphobia" or an aversion to science through lack of parental support, ineffective school counseling or a teacher's negative reinforcement of the student's classroom performance. And, unfortunately, society still restricts a young person's options by assuming he or she will follow a "traditional" career . . . that is, girls will be nurses and boys will be doctors.

The shortage of skilled workers will only increase if business does not begin to fight the problem now. You can encourage young women and men to develop their interests in technical work by providing technical training to all employees who desire it, coordinating after-school and summer work programs for students and informing area technical and secondary schools that you hire trained students.

There is a federal education law which can assist you in your fight for technological literacy. Passed in 1972, Title IX of the Education Amendments prohibits sex discrimination in schools and colleges receiving federal money. Among its far-reaching functions, Title IX ensures that all students are encouraged by teachers and school counselors to pursue the career which would be right for them, whether it is engineering, systems' analysis, or industrial management. Title IX also has broadened admissions' policies at colleges and vocational schools to include more women . . . your labor force of tomorrow.

For more information on how Title IX and industry can work together, contact:

Peer ***Project on Equal Education Rights***

P.O. Box 28066, Washington, D.C.
202-332-7337

A Project of the NOW Legal Defense and Education Fund

Metrologic Instruments, Inc., 143 Harding Avenue, Bellmawr, N.J. 08031.) These patterns are parallel lines, concentric circles or other geometric designs. He used Kodak High Contrast Copy Film in order to have miniature versions of the patterns in the form of slides that he could mount in the light from the collimating lens L_2.

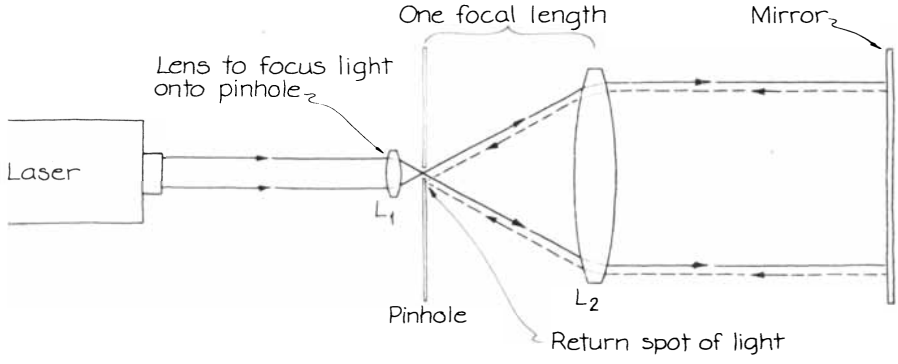
For the sake of simplicity let us now consider only the transparency consisting of evenly spaced parallel lines. This slide functions as a diffraction grating. Light falling on the dark lines in the slide is blocked. Light falling on the transparent areas between the lines is diffracted. The pattern of the lines on the slide is encoded in the way the light is diffracted. The rest of the experimental setup is for studying the coded information and retrieving from it the original pattern in the transparency.

The light diffracted by the transparency is redirected by a third lens, L_3, whose focal length should be long. The lens is positioned one focal length away from the transparency. A screen or a plate of ground glass is placed on the other side of the lens, also at a distance of one focal length. The lens brings into focus the diffraction pattern created by the transparency. Studies of diffraction are normally divided into two classes: Fresnel diffraction for when the point of observation is near the source of diffraction and Fraunhofer diffraction for when it is distant. Fraunhofer diffraction is considerably easier to understand mathematically. Hence it would be better to make the distant observation, but practical reasons prohibit it.

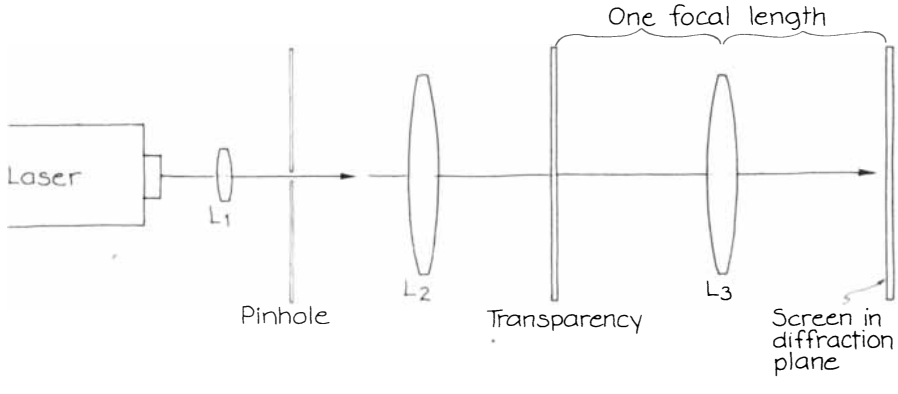
One can in effect put the point of observation infinitely far from the source of diffraction by means of a lens such as L_3. The lens must be one focal length away from the transparency, however, so that the features in the transparency will be in the lens's focal plane. Then in the focal plane on the other side of the lens the diffraction pattern redirected by the lens is the sharpest. The plane in which the Fraunhofer diffraction pattern is sharpest is sometimes called the transform plane or diffraction plane.

At some points on the screen the rays of light arrive in phase and interfere constructively. Those points are bright. At other points the rays arrive exactly out of phase and interfere destructively. Those points are dark. At points where the rays arrive with some intermediate phase relation the light is dim.

Different kinds of transparencies make different types of diffraction patterns on the screen. A photograph of broad, horizontal, evenly spaced lines yields a pattern of bright dots lying along a vertical. The screen is dark except for these bright dots where the rays of light arrive in phase with one another.



How the light of the laser is collimated into parallel rays



Sequence of elements needed to view diffraction from the transparencies

Over a million people use Microsoft® software on their microcomputers. There's a reason.

Powerful simplicity. That's the concept behind every microcomputer software program we write. Powerful programs that allow you to do more with less effort. Programs that let you spend more time thinking about your problem... and less time thinking about the computer. It's a good reason why over a million people depend on Microsoft software in their everyday computing... and why the number is growing. Rapidly.

The value of experience. Microsoft made a giant step toward putting the power of computers in the hands of non-technical people when we wrote the first BASIC programming language for the very first microcomputer. It's an English-like programming language simple enough to teach in grade schools. Yet, it's so powerful that more application programs have been written in Microsoft BASIC than any other programming language.

Tools that help you think. Microsoft is an old-timer in one of the world's youngest industries. Microsoft BASIC was just the beginning. Today, we offer a broad range of proven tools for microcomputers. A complete line of programming languages. From the original BASIC to Pascal. Operating systems like XENIX™ and MS™-DOS that allow your computer to utilize a wide variety of programs. Products like the Microsoft SoftCard™ system which dramatically extends the capabilities of Apple® II computers. Management software such as Multiplan,™ which allows you to explore more alternatives to reach more intelligent business decisions. Better tools. Because they're powerfully simple.

Building a library. The great majority of microcomputers come equipped with Microsoft software. But you'll undoubtedly want more. Specialized programs that solve your particular problems. Programs for your industry, profession, or home. Programs that do more and ask less. Look to Microsoft, or to programs written in Microsoft languages. Software that's proven on millions of computers. Worldwide.

BETTER TOOLS FOR MICROCOMPUTERS

MICROSOFT®

MICROSOFT CORPORATION
10700 NORTHUP WAY
BELLEVUE, WASHINGTON 98004

The brightest area in the pattern is at the center. The farther the dots are from the center, the dimmer they are.

A transparency pattern with more closely spaced lines yields a diffraction pattern that is more spread out. Transparency patterns of concentric circles yield diffraction patterns of concentric circles. More closely spaced circles in the transparency yield more widely spaced circles in the diffraction pattern. Grids of lines yield diffraction patterns consisting of bright points in the shape of a cross. The more closely spaced the grid lines, the more widely spaced the points in the cross.

Following Eisenkraft's instructions, his students replace the screen with various types of filters constructed to block selected sections of the diffraction patterns that pass through the diffraction plane. Each filter is an empty cardboard slide holder on which pieces of opaque tape are stuck. The opening left by the tape determines how much of a diffraction pattern passes through the filter. For example, if all but the center of the slide holder is opaque tape, then only a small section of the pattern is passed. If the filter is centered on the optical axis, that section of the pattern would be the center one. With other openings an entire row of bright dots in the pattern can be either passed or eliminated.

To observe the light passed by a filter placed in the diffraction plane an additional lens is required. It must be placed accurately one focal length away from the diffraction plane. The alignment calls for the same procedure as the one with the lens L_2. A pinhole is mounted in the diffraction plane. Light diffracted through the pinhole illuminates the last lens of the system. A mirror reflects the light transmitted by the lens back through the lens and onto the pinhole. The lens is moved either along the optical axis or perpendicular to it until the returned spot of light falls on the pinhole. Then the pinhole is replaced with a filter. The mirror is replaced with a screen, a plate of ground glass or a camera.

If the light coming through the system is not eliminated at the diffraction plane with an opaque filter, it interferes with itself on the screen to produce a real image of whatever is in the transparency. For example, if the transparency consists of parallel rows of lines, then on the screen parallel rows of lines appear as a real image. The orientation of the final image, however, is inverted from that of the transparency. With a pattern such as parallel lines the inversion is immaterial. With asymmetric patterns, of course, the inversion is quite noticeable.

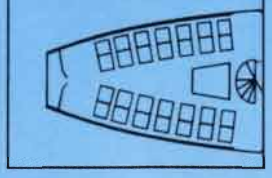
As the students experiment with various transparencies and filters they get several surprises. A slide of a grid yields a diffraction pattern consisting of bright

ON ALITALIA, BUSINESS COMES FIRST.

ARMANDO TESTA SPA

On international flights you'll find Alitalia's new Business Class right up front, where other airlines usually place first class. Why? Because our Business Class now offers all the comforts of first class at a cost only slightly higher than economy fare. For more room, Alitalia has reduced the number of seats. That's two seats per row, not three across. And our new reclinable seats invite total relaxation. For your enjoyment, there are free feature films and stereo music for good listening. Our menu offers a wide selection of authentic Italian cuisine, along with your choice of cocktails or excellent Italian wines. Our distinctively Italian ambience is enhanced by superior service and the kind of personal attention that is so rare, yet so Alitalia. Our Business Class is such a pleasure, you just might forget all about business.

Business Class B747



Alitalia

In by 9:00.

Out by 9:01.

From art shots to zygotes.

Anything you need a print of now, you can get. Now.

Because the New Vivitar Instant Slide Printer™ makes a crisp color print on Polaroid's® new professional ER series film in just 60 seconds. Or, a reproduction-quality black and white print and negative from a slide in just 30 seconds.

So, in less time than it takes to give instructions to a photo lab, you've already made your print. The Vivitar Instant Slide Printer is perfect for everything from documenting case histories and medical files, to client communications, preparation of comps and camera-ready art.

Vivitar®

Its automatic exposure control gives you perfect prints at the touch of a button. Or, you can experiment with multiple exposures, cropping, slide sandwiching, or special filter effects.

The new Vivitar Instant Slide Printer weighs 32 ounces, runs on either batteries or AC and has a built-in timer and flash. So you can use it anywhere.

Since it's also the lowest priced slide printer on the market, you can't afford not to buy one.

Or three.

The Instant Slide Printer™ by Vivitar

For further information call (800) 228-6505, or write Vivitar Corporation, Dept. ISP, P.O. Box 2100, Santa Monica, CA 90406.
In Nebraska call (800) 642-9606.

points in crossed vertical and horizontal rows. Suppose a filter with a narrow slit is mounted in the diffraction plane. By rotating the slit about the optical axis one can choose which sections of the diffraction pattern pass to the screen. Suppose one chooses to pass a vertical section of the diffraction pattern. The surprise is that the final image on the screen consists not of vertical lines but of horizontal ones. The transmitted section of the diffraction pattern is diffracted by the final lens L_4 to yield a real image of horizontal lines. The filter in the diffraction plane has eliminated the information about vertical lines in the original grid of the transparency.

If the transparency is replaced with one that has concentric circles, the filter with a slit passes only a section of the information about the circles. Suppose the slit is horizontal. Then only the vertical sections of the circles appear in the final real image on the screen. The horizontal sections of the circles are missing because the parts of the diffraction pattern carrying information about them are blocked by the filter.

Perhaps the most surprising demonstration comes when the transparency is a grid and the slit filter is oriented at 45 degrees from the vertical. The filter then passes information about both the horizontal and the vertical lines of the grid. Not all the information is being passed, however. The result is a set of parallel lines lying at 45 degrees from the vertical (and perpendicular to the slit in the filter). These lines do not exist in the original grid. They nonetheless appear with the filtering of the information carried in the diffraction pattern of the grid.

One of the advantages of spatial filtering is that it can eliminate from a picture undesired features that appear with a certain frequency as one scans across the picture. For example, the picture may have superposed on it a set of regularly spaced parallel lines. The lines can result from the transmission of the picture through some kind of information system.

In order to demonstrate how his optical equipment can remove such noise from a picture, Eisenkraft first sets up an experiment with some standard black-and-white transparencies of patterns from Metrologic Instruments. The patterns are of four types. One pattern is a set of radial lines. A second is a set of parallel lines of varying widths and lengths. The third is a set of concentric rings with varying spaces between them. The fourth is a set of nested ovals.

In the diffraction plane and centered on the optical axis Eisenkraft mounts an iris diaphragm with a variable opening. For the transparency he first chooses the pattern of radial lines. The iris diaphragm is set at less than two millimeters. Then only the center of the diffraction pattern is passed on to the screen. The result is an overall illumination of the screen with no hint of the features in the transparency.

When Eisenkraft opens the diaphragm to a diameter of two millimeters, the screen begins to show features. The image is incomplete: the outer areas of the pattern in the transparency are visible but the inner areas are missing. As Eisenkraft opens the diaphragm further more detail appears in the image. Finally with an iris diameter of 15 millimeters the image shows most of the original pattern.

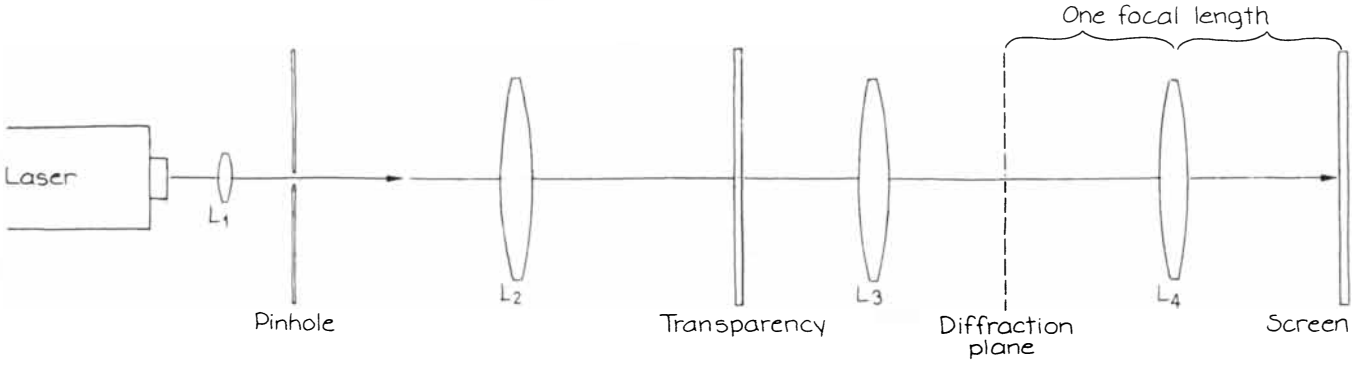
The explanation for the change in the detail of the image is subtle. The change has nothing to do with where in the transparency the features lie. Therefore the image is not merely the result of a small opening's exposing only the outer areas of the transparency. Instead the detail of the final image depends on the spacing of features in the transparency. In the outer areas of the transparency's pattern the spatial frequency of the lines is low, that is, the lines are far apart. If you were to scan the transparency in a large circle centered on the pattern, the frequency with which you crossed lines would be low. Toward the inner part of the pattern the spatial frequency of the lines is high, that is, the lines are close together. If you were to scan the transparency in a small circle, the frequency with which you crossed lines would be higher.

When the transparency diffracts the light passing through it and when the lens L_3 focuses the diffracted light onto the diffraction plane, the diffraction pattern depends on the spatial frequency in the transparency. Features with low spatial frequency pass through the diffraction plane near the optical axis. Features with high spatial frequency pass through the plane with part of their diffraction pattern farther off the optical axis.

When the iris diaphragm is mounted in the diffraction plane, it determines how much of the diffraction pattern passes through to the screen. If the opening in the diaphragm is near the optical axis, it blocks much of the diffraction pattern related to the features with high spatial frequencies. What is primarily passed is the parts of the diffraction pattern from the features with low spatial frequencies. With the radial-line transparency a small iris passes only the outer areas of the pattern. As the iris is opened more of the features of high spatial frequency are transmitted to the screen. When the iris is quite small, not enough of the diffraction pattern is transmitted to the screen for an image of the pattern to be formed.

Eisenkraft next replaces the radial-line transparency with the parallel-line one. The spacing of the lines (and thus the spatial frequency) varies across the width of the transparency. When the iris is small, only part of the pattern is transmitted to the screen. The iris blocks the section of the diffraction pattern generated by the areas of the transparency where the lines are closely spaced (high spatial frequency). The iris passes the section of the diffraction pattern generated by the widely spaced lines (low spatial frequency). As the iris is opened further, more of the features with high spatial frequency are passed. With an iris diameter of 15 millimeters most of the features of the original pattern appear on the screen.

Eisenkraft now inserts the transparen-



Sequence of elements needed to view real images from diffraction patterns

KEY THINGS TO REMEMBER IF YOU'RE TRYING TO SELL THE JAPANESE.

One of the most difficult challenges facing American business has been to find a way to sell to the Japanese. We think we have a solution.

It's a simple strategy and involves only a few basic steps. But it has worked for us.

Instead of just talking about building quality products, years ago we committed our entire company to doing it. And in living up to that commitment we've proven that with the right approach American manufacturers can meet the Japanese on their own home grounds

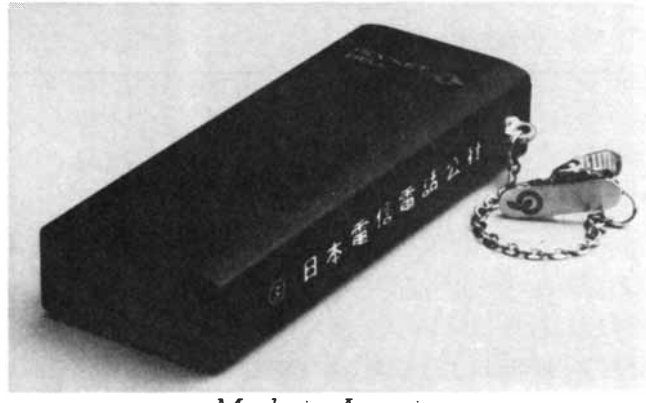
A big key to success is having a strong enough commitment to get through the tough initial stages. We learned this in 1978 when, with the encouragement of the U.S. government, Motorola decided to compete for some of the electronics business traditionally awarded only to Japanese companies by Japan's giant Nippon Telegraph and Telephone Public Corporation.

It was a bold undertaking that required substantial investments of time and money. In fact, just to enter the competition it was necessary to complete an exhaustive survey of competitive products and to translate and study all the pertinent Japanese specifications.

But if you want to sell to the Japanese you have to make the effort. So we did it.

Then we did something even tougher. We committed ourselves to exceeding the quality standards they set for us.

And succeeded. In early 1982, after competing with a number of Japanese electronics manufacturers, Motorola demonstrated in rigorous testing that our pagers exceeded NTT's reliability standards, while complying with their strictest price and delivery requirements.



Made in America.

As a result, Motorola was officially qualified by NTT as a supplier of pocket pagers. The first and only non-Japanese firm ever admitted to this heretofore closed group.

Orders for over 50,000 Motorola pocket pagers are expected this year alone.

In striving to exceed quality and reliability standards, though, it is equally important to maintain high standards of customer service.

We are convinced that this success in the Japanese market is due largely to the way we approach every one we serve.

It's a simple common sense way of doing business that says we pay as much attention to the wants and needs of our customers as we do to the quality of the products we make for them.

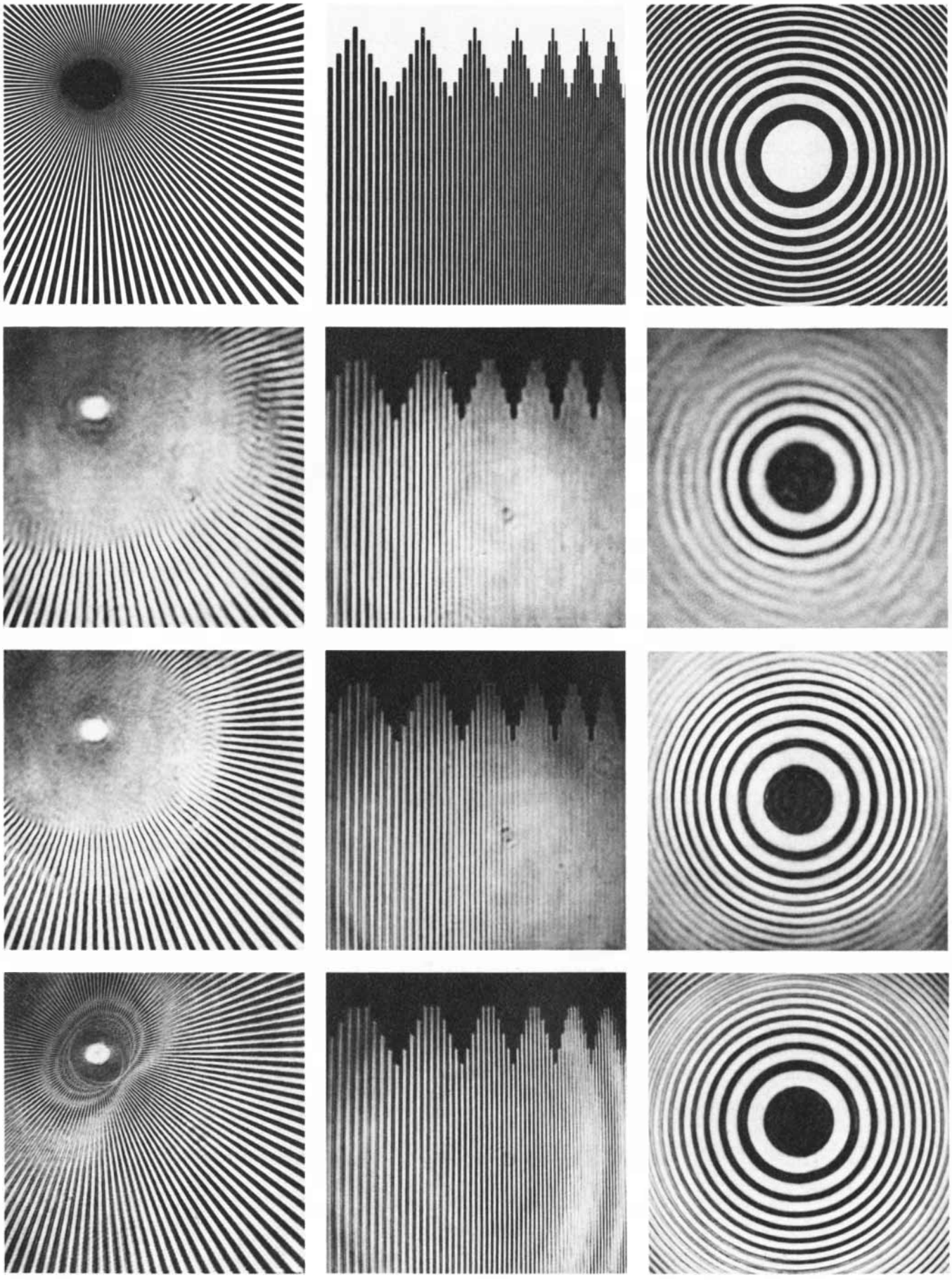
We think there's one other basic factor that's also responsible for Motorola's success in selling to the Japanese. Our participative management attitude

One of our goals is to make every Motorola employee in every Motorola plant an effective part of the management team of our company. And because employees are motivated by this chance to participate and are rewarded for their efforts, we've found we're able to bring to bear on every product we make the enthusiasm, the dedication, and the attention to detail that result in the highest kind of quality.

The kind of quality that has allowed an electronics company like Motorola to sell in a country where they make some fine electronics themselves.

MOTOROLA A World Leader in Electronics

Quality and productivity through employee participation in management.



The effects of spatial filtering **(second, third and fourth from top)** *on transparencies of three geometric patterns* **(top)**

cy with concentric circles. When the iris is small, only the areas of the original pattern near the center survive to reach the screen. These areas have a low spatial frequency because the spaces between the circles are relatively wide. In the outer areas of the pattern the spaces between the circles are narrower. In order for these areas of the pattern to contribute to the image on the screen the iris must be opened wider.

In a halftone photograph the tones (shades) of black are determined by the spatial distribution of tiny dots. Reproductions of photographs in newspapers and magazines are a common example. Eisenkraft made a transparency of a halftone portrait photograph, enlarging the photograph so that the halftone dots would be more apparent. He mounts the transparency in the usual place in his apparatus. To demonstrate spatial filtering to his students he first inserts into the diffraction plane a filter with a slit. When the slit is horizontal, the image on the screen consists of vertical lines. That the image is a portrait of a man is apparent, but so are the vertical lines making up the image. When the slit is vertical, the image consists of horizontal lines. When the slit is at some intermediate angle, the image has lines perpendicular to the orientation of the slit and is therefore also slanted.

The filter with a slit is then replaced with an iris diaphragm. If the iris is considerably smaller than two millimeters, only the center of the diffraction pattern coming from the transparency is transmitted to the screen. The result is a featureless illumination of the screen.

When the iris has a diameter of two millimeters, most of the features of the photograph appear in the final real image produced by the apparatus. The features are not sharp but are still recognizable. Missing entirely, however, is the pattern of halftone dots that is quite apparent in the original transparency. Those dots have a spatial frequency that is higher than most of the features in the photograph. When the iris is small, they are eliminated by the apparatus.

As the iris is opened, more of the features with high spatial frequencies reach the screen. Eventually the dot array becomes apparent. With the iris set at 12 millimeters the image is essentially that of the original photograph. The image with the best quality might be considered to be an intermediate one. Some of the sharpness of the features in the photograph are lost but so is the disturbing pattern of dots. With spatial filtering Eisenkraft can decrease or eliminate noise (the dot pattern) from the information (the portrait of the man photographed).

With spatial filtering one can store more than one photograph on the same transparency. Eisenkraft recommends the following procedure. Over a contin-

uous-tone photograph (as opposed to one reproduced in halftone dots) place a black-and-white grating of thin parallel lines. Photograph this sandwich of the photograph and the grating. Now replace the photograph being copied with another photograph but rotate the grating 90 degrees. Reexpose the film in the camera.

After the film is processed you have a transparency bearing two photographs. To retrieve either of the photographs place the transparency in the apparatus for spatial filtering. With no filter in the diffraction plane both photographs contribute real images to the screen and the composite double exposure is visible. The diffraction pattern cast by the composite transparency consists of horizontal and vertical dots of light. The vertical dots come from the photograph made when the grating was horizontal; the horizontal dots come from the other photograph, which had the grating up and down in the camera's field of view. If the filter mounted in the diffraction plane passes the center dot, both photographs contribute to the real image on the screen. If, however, the filter passes only an off-center vertical dot, then only the photograph responsible for that dot appears on the screen. When more off-center vertical dots are allowed to pass, the image is sharper and brighter. If instead only off-center horizontal dots pass through the filter, then only the other photograph appears on the screen.

The series of photographs on page 204B illustrates how one can spatially filter at selected frequency ranges. The first photograph is the transparency that is to be filtered. The rest of the photographs show the results of the filtering.

The second photograph was made through a narrow-band-pass filter, that

The effects of spatial filtering **(middle and right)** *on a transparency of a halftone picture* **(left)**

SCIENCE/SCOPE

Delivery of the first production Joint Tactical Information Distribution System (JTIDS) terminal has been called a milestone achievement by the commander of the U.S. Air Force's Electronic Systems Division. Lt. Gen. James W. Stansberry congratulated Hughes for its efforts in delivering the first production JTIDS Class 1 terminal 31 days ahead of schedule. He said the delivery and acceptance "demonstrably establishes jam-resistant, secure digital data links as a viable medium for tactical command, control, and communications (C^3) systems."

Infrared scanning has paid off both monetarily and educationally for a financially hard-pressed Washington school district. Faced with a tight budget and increased need to conserve energy, the district used the Probeye® infrared viewer to survey its 19 buildings for energy leaks in insulation, roofing, windows, and doors. Although some of the buildings were as much as 30 years old, the results of the survey brought solutions that will save between 5% and 15% in fuel costs next year. The Hughes-developed Probeye viewer also proved to be an effective educational tool as students participated in the energy-scanning evaluation as part of semester-long energy conservation assignments.

Landsat 4, the new second-generation Earth-watching satellite, is studying crops and other resources in greater detail than ever before possible. The spacecraft carries two primary instruments. One is a multispectral scanner like the ones on previous Landsat missions. The other is a thematic mapper, whose remote-sensing capabilities are a considerable improvement over the scanner's. The new mapper gathers different kinds of data and has a spatial resolution of 30 meters versus 80 meters of earlier scanners. Hughes and its Santa Barbara Research Center subsidiary built both instruments for NASA.

The largest domestic communications satellite network is being operated by Western Union now that Westar V is relaying messages from its equatorial slot approximately on a line with San Francisco. The Hughes-built satellite is providing video, facsimile, data, and voice communications throughout the United States, including Alaska, Hawaii, Puerto Rico, and the Virgin Islands. Westar V has an expected lifetime of 10 years. Each of its 24 transponders is capable of carrying 2,400 one-way voice channels or one color television transmission.

Hughes Missile Systems Group in Tucson, Arizona, has built a reputation for the development and manufacture of sophisticated electronics. We have enhanced our leadership in this field with these missiles: the electro-optical/laser/infrared-guided Maverick, the radar-guided Phoenix, the wire-guided TOW, and now the radar-guided AMRAAM. We have openings for microwave specialists, circuit designers, hybrid microelectronic engineers, and production support test engineers. Send your resume to Professional Employment, Dept. SE, Hughes Missile Systems Group, P.O. Box 11337, Tucson, AZ 85734. Equal opportunity employer.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA 90230

(213) 670-1515 EXTENSION 5964

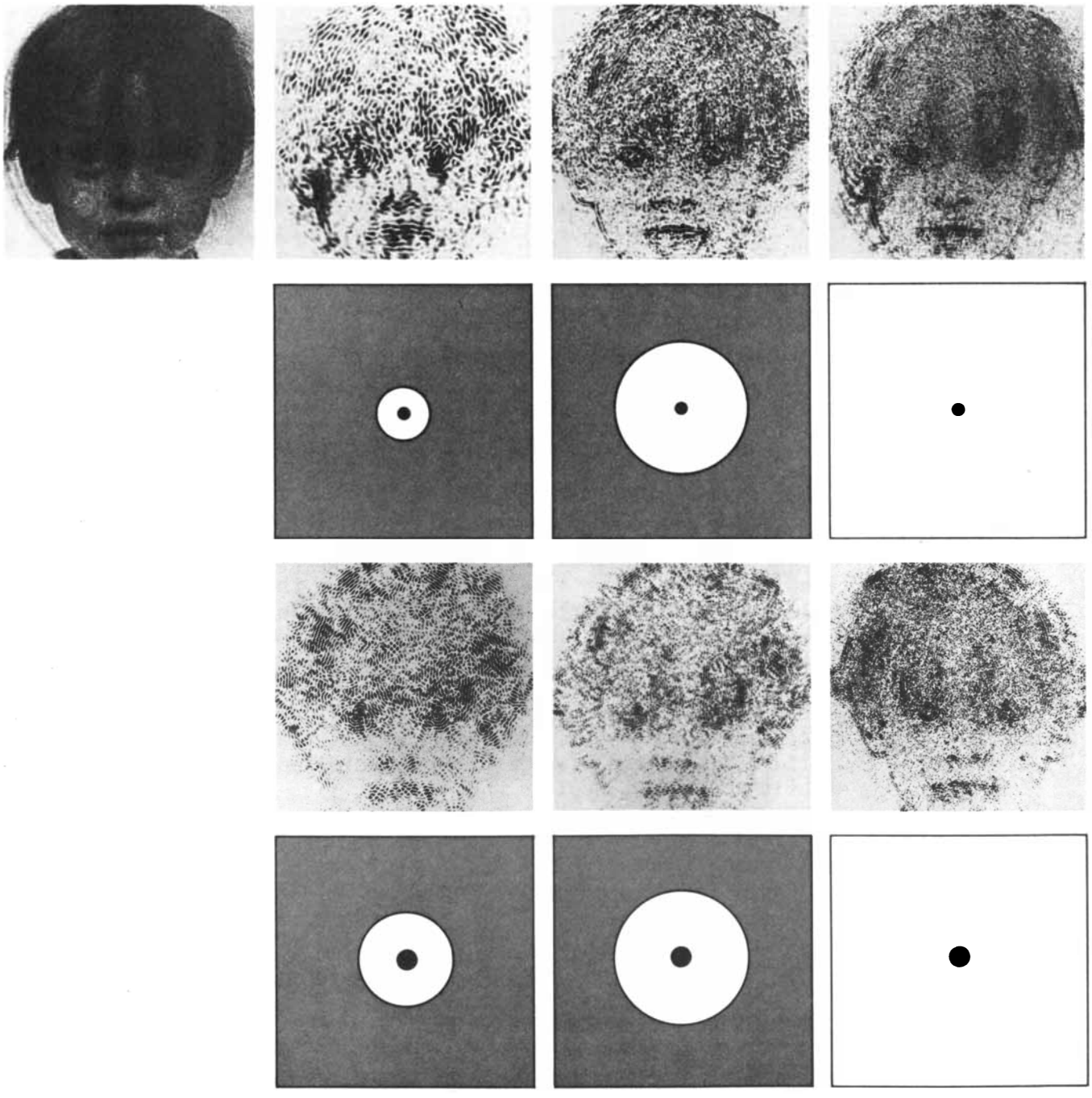
is, the filter allowed to pass to the screen features with spatial frequencies in a narrow middle range. A drawing of the filter is adjacent to the filtered result. The filter has an opaque dot at its center to block the lower range of spatial frequencies. Transmission of somewhat higher spatial frequencies is allowed by a narrow transparent ring. Still higher frequencies are blocked by the opaque region surrounding the transparent ring.

In the third photograph the filter passed frequencies over a larger range. The transparent ring is larger. The opaque dot at the center still blocks the lower frequencies. The outer opaque region still blocks the higher frequencies. More detail is apparent in the final image falling on the screen because of the broader band of frequencies passed by the filter.

In the fourth photograph only the low frequencies are blocked. Many fine details can be seen in the resulting filtered image. Enough information is available in the high-frequency range for the viewer to see that the original photograph was one of a man with a mustache.

The last three photographs are similar to the preceding three except that the opaque dot at the center of the filter is larger. Therefore the low frequencies contribute less to the final image. Comparisons between the two sets of three photographs are interesting. For example, the loss of information is apparent when one eliminates more of the low frequencies. Some general features of the face disappear. The mustache, however, remains clearly visible, apparently because its image depends primarily on high-frequency information.

The optical system set up by Eisenkraft can be regarded as an optical computer. The diffraction of the light by an object (the transparency) is in a sense computed by the lens L_3 so that the



Spatial filters in second and fourth horizontal rows produced the images above them. Unfiltered picture is at top left

diffraction pattern is available in the diffraction plane. Whatever is passed through that plane by a filter is then recomputed by the lens L_4 so that a real image is created on the screen.

The production of the diffraction pattern from the features of the original object can be regarded as the mathematical procedure known as a Fourier transform. The diffraction pattern is a representation of the spatial frequencies of the features in the object. If the object has many features that are spaced close to one another, the diffraction pattern will have fairly bright spots well spread around the optical axis. If the object has many features that are spaced farther apart, the pattern will fall closer to the optical axis. The shape of the pattern and its spatial extent with respect to the optical axis encodes the information in the object. To retrieve the information (or part of it) in order to make a real image, another Fourier transform must be done. This transformation is accomplished by the last lens in the system. It receives the light passed through the diffraction plane and creates a real image.

Both the diffraction patterns and the real images resulting from them can be photographed. Mount a 35-millimeter single-lens reflex camera in either the diffraction plane or the image plane. The lens should be removed and the film, not the front of the camera, should be in the plane of interest. Eisenkraft recommends Kodak Panatomic-X film because its fine grain holds the details of the patterns. The camera is triggered with a cable release to minimize jarring. The internal meter indicates the approximate exposure needed, but he takes several photographs at both higher and lower *f* stops.

Eisenkraft makes the transparencies the same way, except of course with a lens in the camera. Of the several exposures he made of a pattern, he chooses the one with the densest black lines, the most transparent clear regions and the least "bleeding" along the edges of the black lines. For the grid transparencies he double-exposes his film to a pattern of parallel black lines. The first exposure has the lines in one direction. The second exposure has them turned 90 degrees. Transparencies with finer grids are made by moving the camera farther away from the pattern.

With an apparatus similar to Eisenkraft's you can explore many features of spatial filtering. Numerous ideas can be found in Eisenkraft's publications listed in this month's bibliography [*next page*]. In particular you might want to investigate how to store several sets of image information in the same transparency. Some sets might be limited to different ranges of spatial frequencies, so that the images can be retrieved with filters having the appropriate passbands.

BIBLIOGRAPHY

Readers interested in further explanation of the subjects covered by the articles in this issue may find the following lists of publications helpful.

METAMAGICAL THEMAS

A FRAMEWORK FOR REPRESENTING KNOWLEDGE. Marvin Minsky in *The Psychology of Computer Vision,* edited by Patrick H. Winston. McGraw-Hill Book Company, 1975.

THE HANDBOOK OF NONSEXIST WRITING: FOR WRITERS, EDITORS AND SPEAKERS. Casey Miller and Kate Swift. Barnes & Noble, 1980.

A BILATERAL NUCLEAR-WEAPON FREEZE

CALL TO HALT THE NUCLEAR ARMS RACE. National Freeze Campaign, 4144 Lindell Boulevard, St. Louis, Mo. 63108, April, 1980.

SOVIET MILITARY POWER. U.S. Department of Defense. U.S. Government Printing Office, September, 1981.

THE PRICE OF DEFENSE. The Boston Study Group. W. H. Freeman and Company, 1982.

THE HARVESTING OF INTERACTING SPECIES IN A NATURAL ECOSYSTEM

SEALS AND WHALES OF THE SOUTHERN OCEAN. R. M. Laws in *Philosophical Transactions of the Royal Society,* Vol. *B*279, pages 81–96; 1977.

MANAGEMENT OF MULTISPECIES FISHERIES. Robert M. May, John R. Beddington, Colin W. Clark, Sidney J. Holt and Richard M. Laws in *Science,* Vol. 205, No. 4403, pages 267–277; July 20, 1979.

THE GROWTH OF WESTERN NORTH AMERICA

PALEOMAGNETISM AND PLATE TECTONICS. M. W. McElhinny. Cambridge University Press, 1973.

AGE AND STRUCTURAL SIGNIFICANCE OF OPHIOLITE AND ADJOINING ROCK IN THE UPPER CHULITNA DISTRICT, SOUTH-CENTRAL ALASKA. D. L. Jones, N. J. Silbering, Béla Csejtey, Jr., W. H. Nelson and Charles D. Blome. U.S. Geological Survey Professional Paper 1121-A, U.S. Government Printing Office, 1980.

CORDILLERAN SUSPECT TERRANES. Peter J. Coney, David L. Jones and James W. H. Monger in *Nature,* Vol. 288, No. 5789, pages 329–333; November 27, 1980.

PALEOMAGNETIC RECORD OF PLATE-MARGIN TECTONIC PROCESSES ALONG THE WESTERN EDGE OF NORTH AMERICA. Myrl E. Beck, Jr., in *Journal of Geophysical Research,* Vol. 85, No. B12, pages 7115–7131; December 10, 1980.

CONTINENTAL ACCRETION: FROM OCEANIC PLATEAUS TO ALLOCHTHONOUS TERRANES. Z. Ben-Avraham, A. Nur, D. Jones and A. Cox in *Science,* Vol. 213, No. 4503, pages 47–54; July 3, 1981.

A GENETIC SWITCH IN A BACTERIAL VIRUS

HOW THE λ REPRESSOR AND CRO WORK. M. Ptashne, A. Jeffrey, A. D. Johnson, R. Maurer, B. J. Meyer, C. O. Pabo, T. M. Roberts and R. T. Sauer in *Cell,* Vol. 19, No. 1, pages 1–11; January, 1980.

λ REPRESSOR AND CRO—COMPONENTS OF AN EFFICIENT MOLECULAR SWITCH. Alexander D. Johnson, Anthony R. Poteete, Gail Lauer, Robert T. Sauer, Gary K. Ackers and Mark Ptashne in *Nature,* Vol. 294, No. 5838, pages 217–223; November 19, 1981.

THE OPERATOR-BINDING DOMAIN OF λ REPRESSOR: STRUCTURE AND DNA RECOGNITION. Carl O. Pabo and Mitchell Lewis in *Nature,* Vol. 298, No. 5873, pages 443–447; July 29, 1982.

THE MOLECULAR BASIS OF DNA-PROTEIN RECOGNITION INFERRED FROM THE STRUCTURE OF CRO REPRESSOR. D. H. Ohlendorf, W. F. Anderson, R. G. Fisher, Y. Takeda and B. W. Matthews in *Nature,* Vol. 298, No. 5876, pages718–723; August 19, 1982.

GLUEBALLS

QUARKS WITH COLOR AND FLAVOR. Sheldon Lee Glashow in *Scientific American,* Vol. 233, No. 4, pages 38–50; October, 1975.

THE CONFINEMENT OF QUARKS. Yoichiro Nambu in *Scientific American,* Vol. 235, No. 5, pages 48–60; November, 1976.

GAUGE THEORIES OF THE FORCES BETWEEN ELEMENTARY PARTICLES. Gerard 't Hooft in *Scientific American,* Vol. 242, No. 6, pages 104–138; June, 1980.

THE ECOLOGICAL PHYSIOLOGY OF A GARTER SNAKE

INFLUENCE OF THE SEMINAL PLUG ON MATING BEHAVIOR IN THE GARTER SNAKE. Patrick Ross, Jr., and David Crews in *Nature,* Vol. 267, No. 5609, pages 344–345; May 26, 1977.

EFFECTS OF CASTRATION AND ANDROGEN REPLACEMENT ON MALE COURTSHIP BEHAVIOR IN THE RED-SIDED GARTER SNAKE (*THAMNOPHIS SIRTALIS PARIETALIS*). Brian Camazine, William Garstka, Richard Tokarz and David Crews in *Hormones and Behavior,* Vol. 14, No. 4, pages 358–372; December, 1980.

FEMALE SEX PHEROMONE IN THE SKIN AND CIRCULATION OF A GARTER SNAKE. William R. Garstka and David Crews in *Science,* Vol. 214, No. 4521, pages 681–683; November 6, 1981.

THE PHYSICS OF KETTLEDRUMS

CONTEMPORARY PERCUSSION. Reginald Smith Brindle. Oxford University Press, 1970.

PERCUSSION INSTRUMENTS AND THEIR HISTORY. James Blades. Frederick A. Praeger, Publishers, 1970.

ACOUSTICS OF PERCUSSION INSTRUMENTS. Thomas D. Rossing in *The Physics Teacher,* Part I, Vol. 14, No. 9, pages 546–556, December, 1976; Part II, Vol. 15, No. 5, pages 278–288, May, 1977.

PERCUSSION INSTRUMENTS. Thomas D. Rossing in *The Science of Sound.* Addison-Wesley Publishing Co., 1982.

ACOUSTICS OF PERCUSSION. Special issue of *Percussive Notes: The Percussionist,* Vol. 19, No. 3; Fall, 1982. Percussive Arts Society, Department of Music, University of Tennessee, Knoxville, Tenn. 37996.

THE FIRST NUCLEAR INDUSTRY

URANIUM COUNTRY. Kathleen Bruyn. University of Colorado Press, 1955.

RADIOACTIVITY IN AMERICA—GROWTH AND DECAY OF A SCIENCE. Lawrence Badash. The Johns Hopkins University Press, 1979.

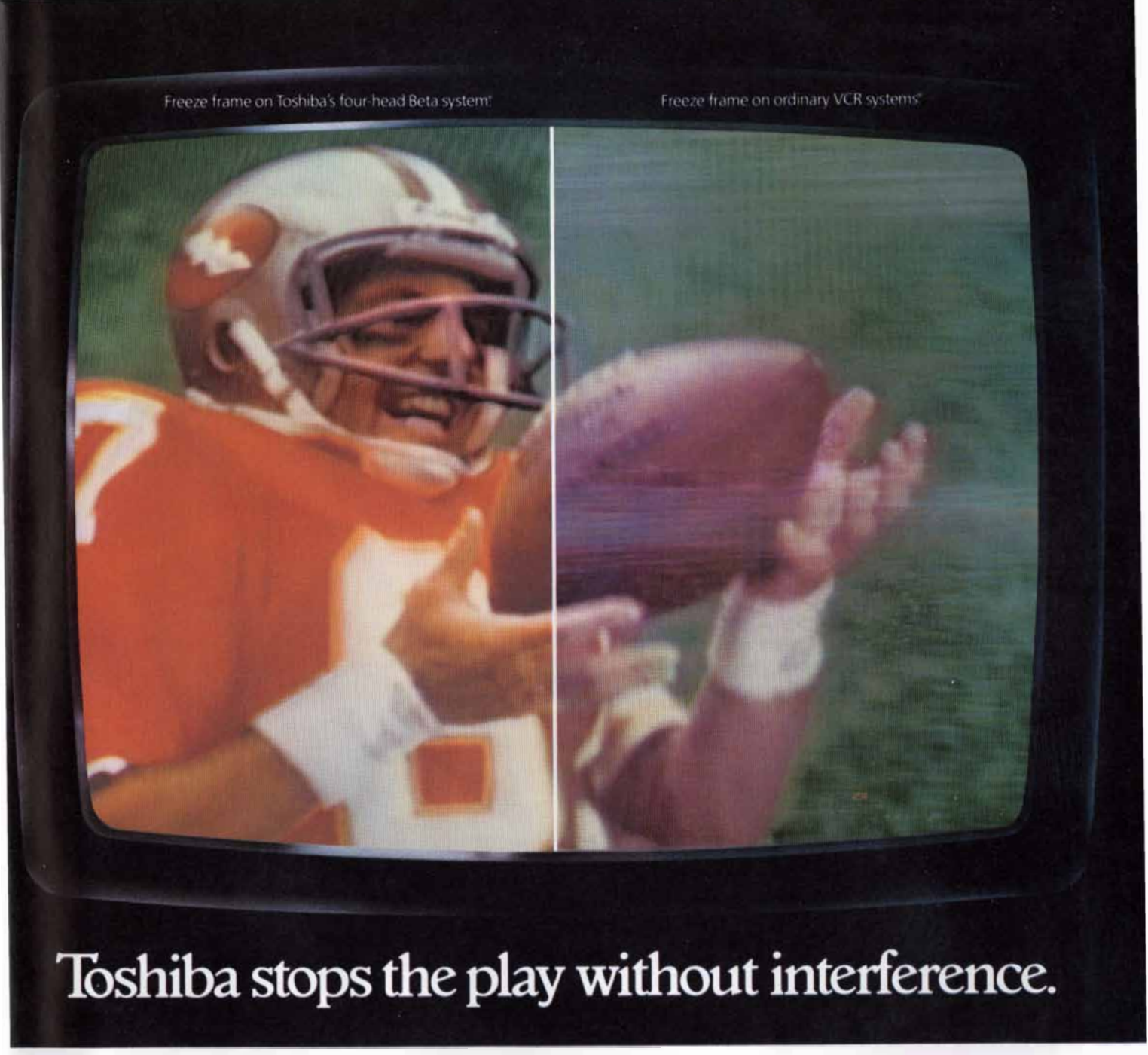
HISTORICAL REVIEW OF THE RADIUM-EXTRACTION INDUSTRY IN THE UNITED STATES (1906–26)—ITS EXTRACTION PROCESSES AND WASTE PRODUCTS. Edward R. Landa in *Proceedings of the Fourth Symposium on Uranium Mill Tailings Management.* Colorado State University, 1981.

THE AMATEUR SCIENTIST

TWO-DIMENSIONAL TRANSFORMS. Jurgen R. Meyer-Arendt in *Introduction to Classical and Modern Optics.* Prentice-Hall, Inc., 1972.

A CLOSER LOOK AT DIFFRACTION: EXPERIMENTS IN SPATIAL FILTERING. Arthur Eisenkraft in *The Physics Teacher,* Vol. 15, No. 5, pages 199–211; April, 1977.

PHYSICAL OPTICS USING A HELIUM-NEON LASER. Arthur Eisenkraft. Metrologic Instruments, Inc., 1980.



Toshiba stops the play without interference.

When you press the still/slow motion button on the average VCR, you're hit with an automatic penalty: bands of fuzzy, jumpy, offensive interference.

While this is unfortunate, it isn't really surprising. Most VCRs still rely on just two video heads, which is prehistoric compared to the four-head system perfected by Toshiba.

With two extra heads devoted solely to the still and slow motion tracks, Toshiba's new V-9500 delivers still and slow motion pictures with amazing clarity.

To match it, you'd have to go to a television studio. Which is also where you'd have to go to find equipment that consistently matches the performance level of the V-9500.

With its digital synthesized tuner, you have access to 117 broadcast and cable channels.

Visual search offers near limitless flexibility. You can make fast searches at twice normal speed or, with variable search, from five to twenty times normal speed.

Variable slow motion shows you one frame at a time or creeps along anywhere from 1/3rd to 1/30th normal speed.

And you get all these search capabilities in Beta II and Beta III. Plus an 18-function wireless remote control and easy front loading.

In short, Toshiba has designed everything into the V-9500 to enhance your viewing. And nothing to interfere with it.

*Actual TV picture.

A federal court has ruled that recording copyrighted materials off the air without consent is in violation of existing copyright laws.

TOSHIBA

Toshiba America, Inc., 82 Totowa Road, Wayne, NJ 07470

THE CAR YOU C
ONE THIR

If you're about to go shopping for a new car, get a grip on yourself. Prices are astronomical.

But if you buy a Volvo, you'll get more than your money's worth.

Studies show Volvo's life expectancy is now one third longer than the average of all other cars on the road.*

Besides getting more years for your money,

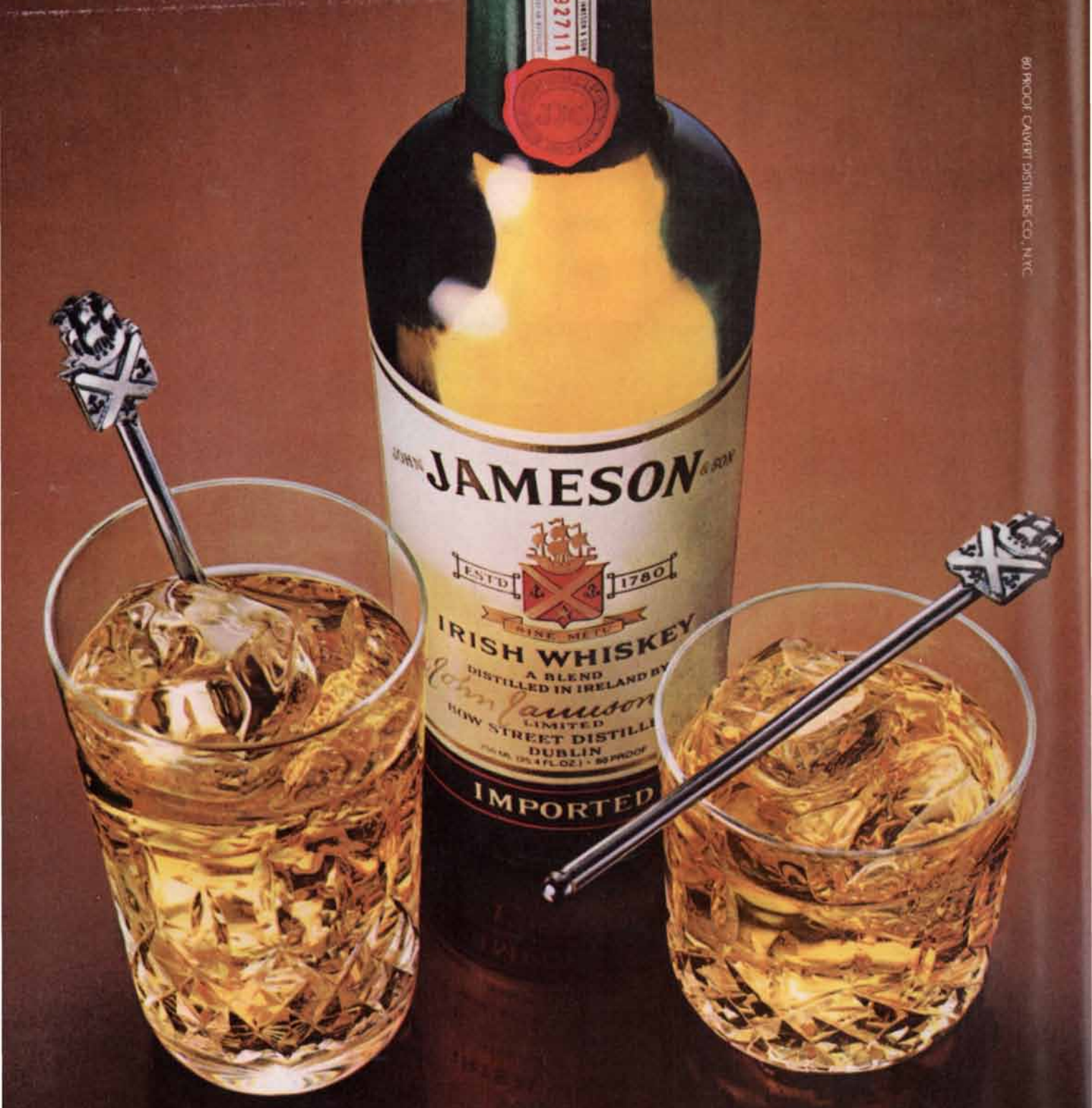
*Analysis conducted by Ken Warwick & Associates, Inc. Based on a comparison of U.S. registration data for Volvo and for the automobile industry as a whole and not by individual make. This is not, however, an expressed or implied warranty, but it's comforting to know. © 1982 Volvo of America Corporation.

AN HOLD ON TO
D LONGER.

you get more car. All Volvos come with power assisted brakes and steering, fuel injection, radials, even reclining front bucket seats with adjustable lumbar supports.

So in addition to being the car you can hold on to longer, you'll find Volvo is also the car you won't want to let go of.

VOLVO
A car you can believe in.



Now that you're ready for a change of pace it's time to try John Jameson.

Take a sip of John Jameson. Note the light, delicate taste. Luxurious and smooth as you would expect a premium whiskey to be. But with a distinctive character all its own. Set a new pace for yourself. Step ahead of the crowd with John Jameson, the world's largest selling Irish Whiskey.