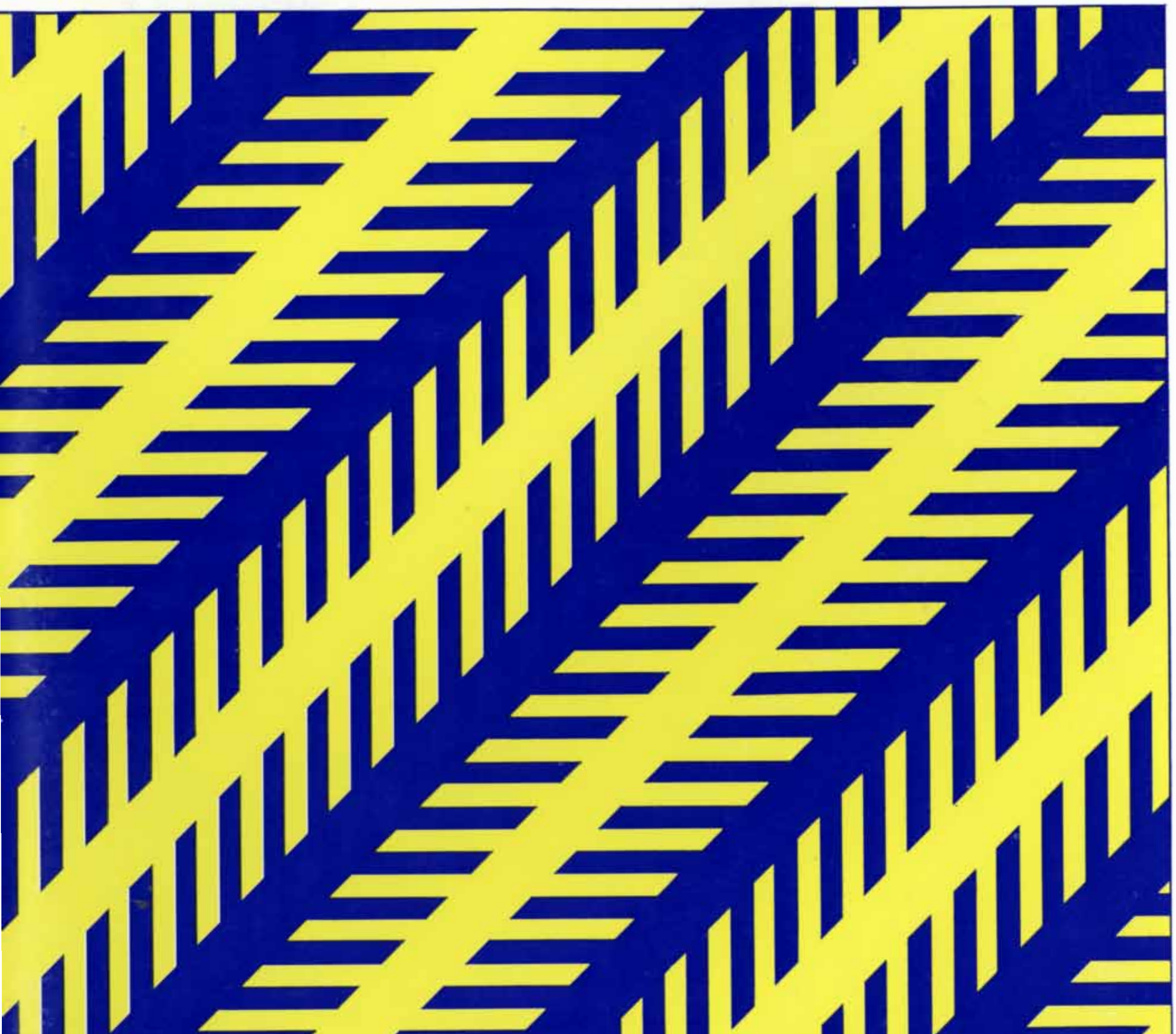
SCIENTIFIC AMERICAN



VISUAL ILLUSIONS

SEVENTY-FIVE CENTS

November 1968

Sometimes a publisher needs a bank that'll throw away the book.

A newspaper editor shouts, "Stop the presses!"

A national magazine scraps an entire front-cover story.

And a runaway bestseller is suddenly as stale as last month's cocktail chatter.

The publishing industry is first to feel the shock waves of today's fast-changing events.

Before we can assess the consequences of one momentous event, another topples on top of us.

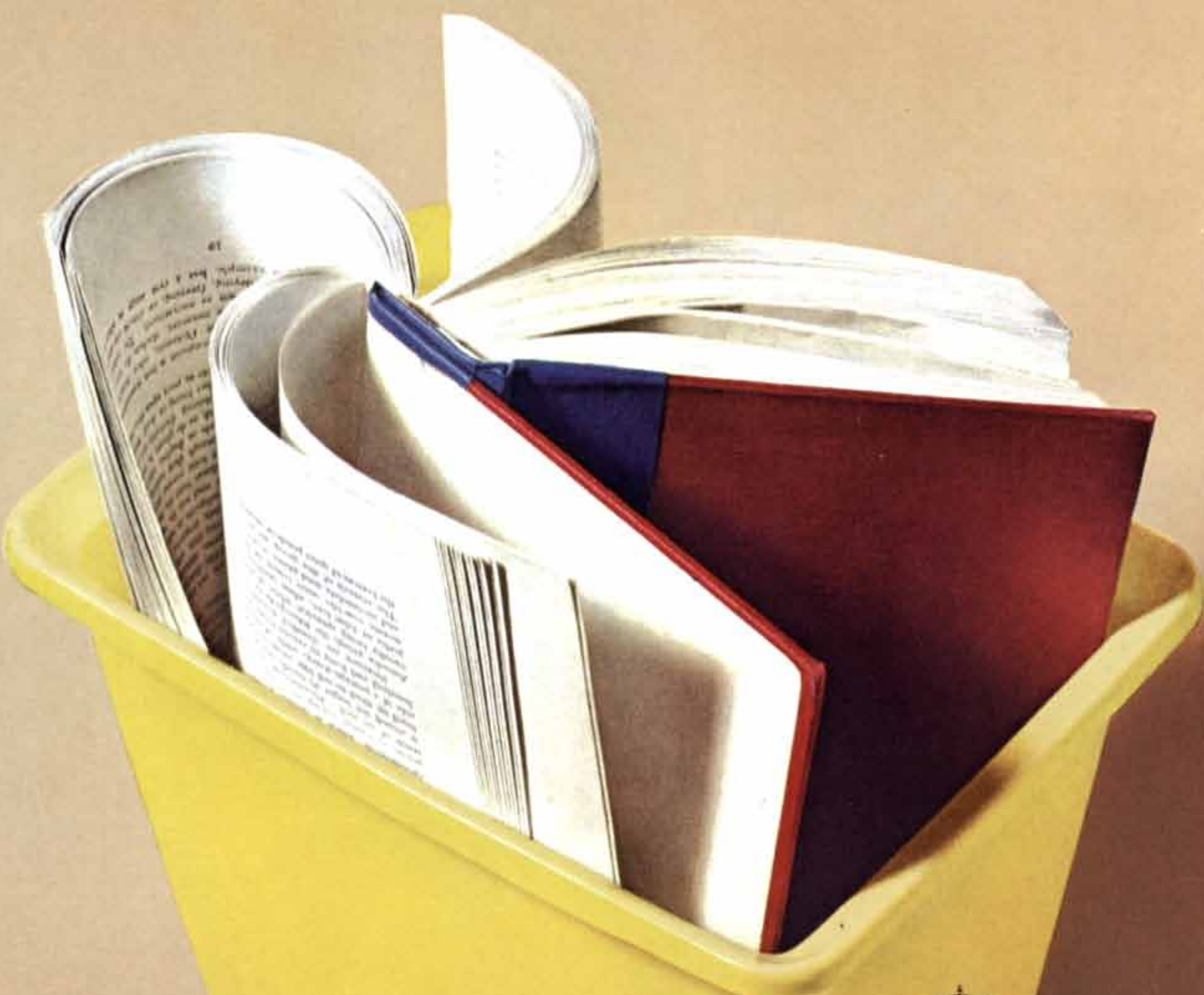
Times are changing dramatically, and the smart money is changing with them.

This is the time to search the imagination, welcome ideas, innovate, try things that have never been tried before.

For our part at Citibank, we start with an open mind and try to create the kind of imaginative banking that an innovative business needs.

Our motto for times like these is: If you always go by the book, soon you may go by the board.

First National City has been known to throw away the book.



FIRST NATIONAL CITY BANK

399 PARK AVENUE, NEW YORK, N.Y. 10022 · MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

Ontario, Canada: Mother of invention?

Ontario, Canada, has already delivered everything from insulin to the electron microscope. Perhaps in the research and development race, we could be your prize find.

We recognize that necessity, not Ontario, may be the real mother of invention. But in Ontario, we've developed an almost uncanny knack of recognizing a need and serving up a solution.

Perhaps with your needs and our facilities, something may develop. To that end, you may want to do a little basic research of your own. If so, the following facts may explain how Ontario got to be good.

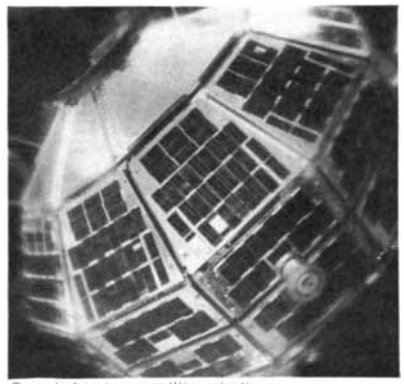
R. and D. Where it's at.

Ontario has become a sanctuary for science. Only minutes from Toronto, and within a short drive of nine universities, we have a 350-acre science city named Sheridan Park. By 1970, thousands of researchers will be finding answers for many industries in this multi-million dollar complex. But we don't keep all our research eggs in one basket. We hatch interesting agricultural ideas in Guelph, explore outer space in Toronto and solve a myriad of industrial research problems at the National Research Council in Ottawa.

Even our government digs research.

Canadian government aids include tax deductions on 100% of current and capital expenditures, bonus incentives and shared-cost programs for selected projects. Other development opportunities rest in joint-venture agreements with industry and universities.

Who knows what discoveries lie around the corner at Ontario's Sheridan Park?



Canada has two satellites circling... and a third coming up.

Research data by return mail.

We don't expect you to consider doing business in Ontario without a little research of your own. To this end, the Ontario Government's economists, industrial experts and researchers can give you answers about sites, financing and any other information you desire about Ontario, Canada.

Write to: Department of Trade and Development, Special Projects and Planning, Suite 706, 950 Yonge Street, Toronto 5, Ontario, Canada.

Offices in New York, Chicago Los Angeles, Cleveland, Boston, Atlanta.

Government of Ontario–Province of Opportunity

Established 1845 **SCIENTIFIC AMERICAN** November 1968 Volume 219 Number 5

ARTICLES

DEPARTMENTS

PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK, N.Y. 10017. COPYRIGHT © 1968 BY SCIENTIFIC AMERICAN, INC. ALL RIGHTS RESERVED. 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: $8 PER YEAR.

THE COVER

The herringbone pattern on the cover is a visual illusion devised by Johann Zöllner, a German astrophysicist, in 1860. It illustrates how the eye can be deceived by certain simple figures, which are discussed by Richard L. Gregory in his article "Visual Illusions" (page 66). The pattern on the cover creates the illusion that the broad light-colored bands are not parallel. An even stronger illusion is that the dark-colored bands between the light herringbones are tapered. That both impressions are false can easily be demonstrated by holding the cover at an angle and sighting along the light and dark bands. What is curious about this test is that the parallelism of the lines is established by viewing the lines under conditions in which they are palpably not parallel. When viewed obliquely, the lines produce retinal images that are convergent rather than parallel. As Gregory explains, the eye's familiarity with perspective may lie at the basis of most visual distortions.

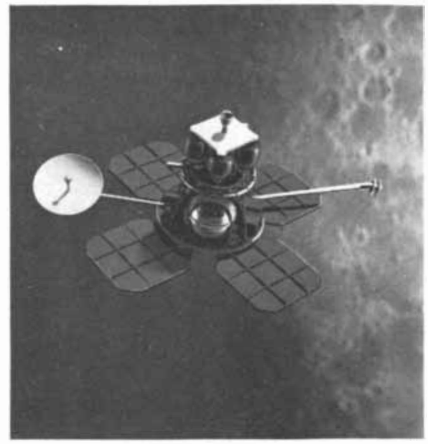
THE ILLUSTRATIONS

Cover painting by Jerome Kühl

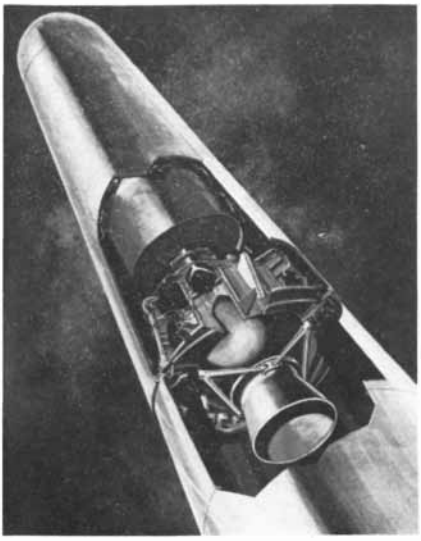
Page	Source
28–29	Thomas Prentiss
30–32	Chieko Yoshida
33–35	Joan Starwood
37	Department of Mineral Technology, University of California
38	Allen Beechel (*top*); Department of Mineral Technology, University of California (*bottom left*); Allen Beechel (*bottom right*)
39	Department of Mineral Technology, University of California
40	Allen Beechel
41	Allen Beechel (*top left*); Department of Mineral Technology, University of California (*top right*); Allen Beechel (*bottom*)
42–43	Allen Beechel
44	Department of Mineral Technology, University of California
45	Department of Mineral Technology, University of California, and Allen Beechel (*top*); Allen Beechel (*bottom*)
47	Flossie Cohen, Child Research Center of Michigan
48–52	Thomas Prentiss
67	Philip Clark
68–70	Jerome Kühl
71	Sol Mednick
72	Jerome Kühl
73	Philip Clark
74–76	Jerome Kühl
80	Gerhard Haerendel and Reimar Lüst, Max Planck Institute for Physics and Astrophysics
82–91	Dan Todd
96	Lee Boltin
98	Eric Mose (*top*), Enid Kotschnig (*bottom*)
99	Enid Kotschnig
100–101	Rex Barritt (*top*), Enid Kotschnig (*bottom*)
102–104	Enid Kotschnig
111	Bunji Tagawa
112	Heinz Tobler, University of Zurich
113–116	Bunji Tagawa
118	Heinz Tobler, University of Zurich (*left*); Bunji Tagawa (*right*)
120	Heinz Tobler, University of Zurich (*left*); Bunji Tagawa (*right*)
124–127	Felix Hess, Mathematical Institute, University of Groningen
128–131	Jim Egleson
132–136	Felix Hess, Mathematical Institute, University of Groningen
150–152	Roger Hayward

Minuteman I, II, III Boeing designs and builds maximum reliability into its products. Minuteman I's first launch, for example, was one of the most successful first flights in U.S. missile history. Minuteman II's first flight was perfect. So was that of the advanced Minuteman III. Successful launches to date: More than 200. As weapon system integrator, Boeing assembles, tests, installs and delivers the complete Minuteman weapon system to the U.S. Air Force. Minuteman went from drawing board to operational status in four years.

Saturn V Boeing builds the first stage booster of NASA's Saturn V moon rocket, largest in production in the U.S. It generates 7.5 million pounds of thrust. Record to date: Two firings—two successes.



Lunar Orbiter Designed and built by Boeing for NASA, Lunar Orbiter made five spectacularly successful moon photo flights, producing data far exceeding initial objectives. The record: Five flights. Five flawless performances. Orbiter's on-board flight programmer, built by Boeing, performed perfectly in responding to more than 24,000 commands from Earth. In addition to flight programmers, Boeing electronics activities include advanced research, complete launch control systems, targeting digital computers, scanning and homing radar, electronic countermeasures, communications.

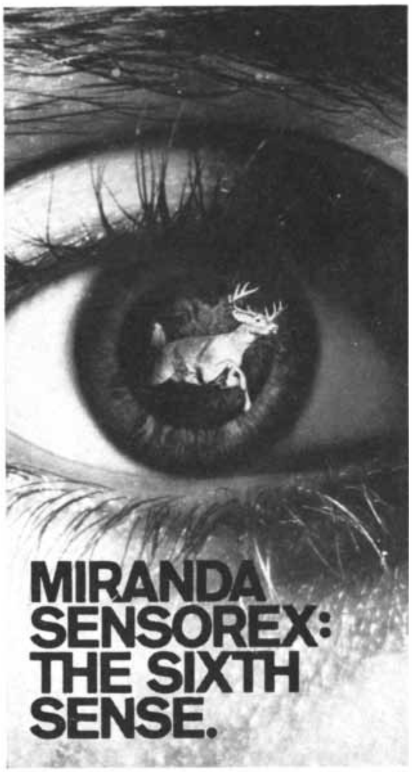


Burner II The first solid-fuel upper stage with full control and guidance capability, Burner II was designed and built by Boeing for the U.S. Air Force. It provides final kick needed to put small-to-medium payloads into precise orbits. Of seven flights, six were successes.

Boeing Jets Boeing jets earned world aviation leadership for the U.S. First flights of 707, 720, 727 and 737 models were successes exceeding expectations. In more than six billion miles of service with 69 airlines around the globe, Boeing jets have demonstrated outstanding dependability. Flying Boeing equipment, airline customers have achieved utilization averages as high as 16½ hours a day, and dispatch reliability scores as high as 99.89%. Boeing jets, like all Boeing products, combine the benefits of advanced design, structural integrity, and massive testing.

Reliability...a matter of record at

BOEING



LETTERS

Sirs:

One of the illustrations in Pierre Connes's article "How Light Is Analyzed" [SCIENTIFIC AMERICAN, September], continues the popular imputation that Newton's apparatus for the dispersal of white light into a spectrum consisted of a small round hole in a window shutter through which sunlight entered a darkened room and fell on a prism.

In his *Opticks* Newton describes a lengthy series of careful experiments with different lenses, prisms and differently shaped apertures. At first, indeed, he used a round quarter-inch hole, "yet, instead of the Circular Hole F., 'tis better to substitute an Oblong Hole shaped like a long Parallelogram, with its Length parallel to the prism ABC. For if this Hole be an Inch or two long, and but a tenth or twentieth of an Inch broad, or narrower; the Light of the Image . . . will be as simple as before, or simpler, and the Image will become much broader, and therefore more fit to have Experiments tried on its light than before." He also employed lenses of various focal lengths and of sufficiently high quality "as may serve for optical uses" and a variety of glass and liquid-filled "prismatick vessels."

Newton, therefore, employed a prism spectroscope in nearly its modern form for his experiments and obtained a dispersion (but not resolution) equal to that of a present-day large prism spectrograph. . . .

WILLIAM H. DENNEN

Cabot Spectrographic Laboratory
Department of Geology
University of Kentucky
Lexington, Ky.

Sirs:

It may seem ungrateful of me to criticize James Marston Fitch's interesting article "The Control of the Luminous Environment" in your September issue when he was nice enough to list the first edition of my *Primer of Lamps and Lighting* in the bibliography, but I should like to make a few points.

Within the past four or five years lighting engineers have joined physicists in using *luminance* for what the author calls *brightness*. This would not be worth mentioning if it were only a change of name, but it is more than that. In current usage luminance is the physical result of lumens from a surface reaching the eye, whereas brightness is the subjective reaction of the observer. As an example, consider two areas that have the same luminance but one of which is seen against a dark background while the other is seen against a light background. The former will appear to be brighter, that is, its apparent luminance will be greater. . . .

I agree with Professor Fitch on the undesirability of windowless buildings, but I do not think that large window areas are either necessary or economic. No matter how large the windows are, a working interior must have a full-size electric lighting installation for dark days and late afternoons in winter. Thus the only saving through using daylight when it is available is in the somewhat lower bills for electricity. These are more than offset by the additional installation costs of windows or skylights, their maintenance costs and the heat losses they allow. The author cites as an advantage the additional heat entering through windows in the winter, but this is a drawback in the summer. When the fad for glass walls fades, I believe architects will give us vision strips for view-

Scientific American, November, 1968; Vol. 219, No. 5. Published monthly by Scientific American, Inc., 415 Madison Avenue, New York, N.Y. 10017; Gerard Piel, president; Dennis Flanagan, vice-president; Donald H. Miller, Jr., vice-president and treasurer.

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

Advertising correspondence should be addressed to Allan Wittman, Advertising Manager, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York, N.Y. 10017.

Offprint correspondence and orders should be addressed to W. H. Freeman and Company, 660 Market Street, San Francisco, Calif. 94104. For each offprint ordered please enclose 20 cents.

Change of address (or other subscription correspondence) should be addressed to Circulation Manager, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York, N.Y. 10017. Please notify us four weeks in advance of change. If possible, kindly furnish an address imprint from a recent issue. Send both old and new addresses or complete and mail post office Form 357B.

Please enter change of address ☐
Please enter subscription ☐
☐ 1 year, $8 ☐ 2 years, $15 ☐ 3 years, $21

NAME

NEW ADDRESS

OLD ADDRESS

Basic Research at Honeywell
Research Center
Hopkins, Minnesota

The generation of digital information from solid state sensors

Computers demand digital information; but, up until the present time, sensors have had analog outputs. A new solid state transducer has now been developed which generates digital signals.

Computers, whether in the control loop of a chemical processing plant, a jet aircraft or a space flight monitoring system, feed on information originating at different sensors. These sensors detect changes in variables such as temperature, pressure and flow. Until now, the information generated by the sensors has been in the form of analog signals. In order to be used by the computer, these signals must be converted to digital form. Typically, the analog signal is transmitted to the computer, where it is converted. During transmission, it is subject to noise and to distance limitations.

A frequency or time signal, on the other hand, cannot be distorted by the intervening medium. Thus, a digital signal is inherently more accurate. When generated at the source, it eliminates the need for conversion and its associated gear. A complete system using a digital transducer would be smaller, lighter, cheaper and more reliable.

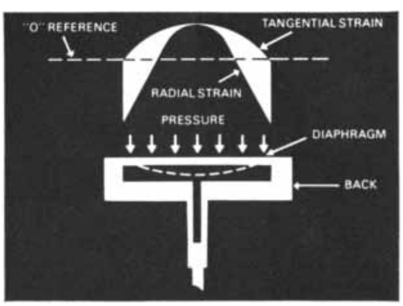
For several years, Honeywell scientists and engineers have been following different approaches in the development of a digital transducer.

One approach pairs the piezoresistance characteristics of semiconductors with a phase shift oscillator. It has proven very successful.

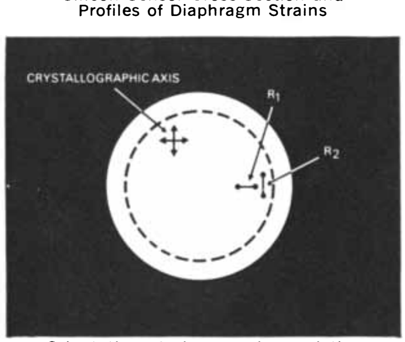
The Honeywell scientists and engineers use a silicon diaphragm which incorporates piezoresistive sensing elements. The resistance of a piezoresistive element changes considerably with strain, producing a large signal variation for a small pressure variation. If a resistor is properly positioned on a crystal, relative to its crystallographic orientation, and is subjected to a transverse strain, its resistance changes by an amount equal in magnitude, but opposite in sign, to the change resulting from the application of the same strain in a resistor in the longitudinal direction.

Referring to the diagrams, two resistance capacitance elements (RC elements) are oriented radially and tangentially on a silicon diaphragm. (Actually the elements are formed monolithically by integrated circuit techniques.) If, for example, the diaphragm is subjected to a pressure causing a tensile radial strain near the edge, the resistance of the radial RC element, R_1, will increase by an amount δR. This radial strain, acting transversely to the tangential RC element, R_2, will cause it to decrease in resistance by the same amount, δR. It is assumed for simplicity that the two resistances are equal at zero pressure.

Conventionally, the resistors would be used in a balanced bridge circuit to determine resistance change. Instead, Honeywell scientists have used them in a feedback loop of phase shift oscillators to control oscillator frequencies. When used this way, the RC elements can be related to oscillator frequency as $f = \frac{1.78}{RC}$ cycles per second.



Silicon Sensor Cross-Section and Profiles of Diaphragm Strains



Orientation of Diffused Piezoresistive Elements on Diaphragm

Upon application of pressure the resistance becomes $R + \delta R$ and $R - \delta R$ and the resulting frequencies are then:

$$f_1 = \frac{1.78}{(R+\delta R)C} \quad \text{and} \quad f_2 = \frac{1.78}{(R-\delta R)C}$$

When the two signals are combined, the resulting difference in frequency constitutes a digital signal directly proportional to the strain.

The oscillator circuit has been designed to optimize short-term (frequency jitter) and long-term stability. Thus, the frequency outputs remain repeatable relative to a set of calibration constants.

Results from tests conducted to date show that the digital pressure transducer can withstand: overload, extreme temperatures, humidity, vibration and acceleration. The unit is extremely sensitive to low pressures and for sizable loads needs only to be fabricated with a thicker diaphragm to minimize distortion.

Honeywell's first application is in an air data computer where the transducer is transmitting pressures reflecting altitude and air speed to an airborne computer. Many other uses are easily foreseen, particularly in the continuous process industries where real time computers are being inserted in the control loop.

Honeywell scientists are working with other characteristics of semiconductors so that additional variables such as temperatures and flow can be sensed and digital signals obtained.

If you are working in the field of solid state transducers and are interested in knowing more about Honeywell's work you are invited to correspond with Dr. Carl Nomura, Honeywell Solid State Electronics Center, 600 Second Street No., Hopkins, Minnesota 55343. If you are interested in further details about Honeywell's Air Data Computer, you are invited to write Mr. John Wagner, Honeywell Aeronautical Division, 2600 Ridgway Road, Minneapolis, Minnesota 55413.

Honeywell

ing the outdoors, but without wasteful attempts to depend partly on such a variable source as daylight.

WILLARD ALLPHIN

Danvers, Mass.

Sirs:

In the 1920's William Pepperell Montague, a philosopher at Columbia University, unknowingly foresaw the molecular basis of heredity as being "analogous" to a "twisted rope":

"If the reader will be kind enough to grant that my twisted rope is strikingly analogous to protoplasm in respect to the primary property of *preserving the past,* and the resultant secondary property of *irritability,* I will at once reciprocate the kindness by confessing that there the analogy ends."

Montague applied his twisted-rope analogy to the molecular storage and reproduction of genetic information long before the roles of DNA and RNA were discovered:

"It is not until the coming of the type of carbon compound called protoplasm that we find a material system that is capable not only of storing [energy patterns] but also of propagating them or imposing them by a kind of induction upon new matter. This capacity of a thing for preserving *and reproducing* its past history is the definitive property of a living being. Once started, it tends to spread and inform more and more of its environment. It tends also to increase the richness of its own organization, and so to evolve new and higher types of itself. It is definitely anti-entropic . . . and history . . . becomes internal and causally operative as such. . . . We may assist our imagination to appreciate the nature of such a system if we think of a rope upon which there has been imposed in succession a long series of twists on twists . . . and if there was a medium suited for the purpose, it might convey to that medium by a kind of induction its own pattern."

Montague was extremely well versed in the sciences as they existed in his time, and he postulated a cosmology compatible with modern astronomy. The major writings of this little-known philosopher of seemingly prophetic insight are collected in his book *The Way of Things* (Prentice-Hall, 1940).

HENRY C. EVERETT, M.D.

Cambridge, Mass.

RECENT FINDINGS

RESEARCH LABORATORIES

Ford

On the way to a better understanding of the Mechanical Spectroscopy of Macromolecules.

The mechanical behavior of polymers—creep, relaxation, and flow—is neither purely viscous nor elastic but somewhat in between. Consequently, the stress response of these viscoelastic materials depends on the temperature and time of the experiment.

Viscoelastic properties of dilute polymer solutions have been explained successfully by assuming a mechanically equivalent system of non-interacting springs and beads. An exact mathematical treatment is given by the Rouse model: The motions of the molecule are described by its "normal modes," i.e., rotation of the entire molecule or vibrational modes of large co-operating chain segments; each mode requires a certain response time, or relaxation time. A density distribution of normal modes along a time axis—the "relaxation spectrum" H(t)—thus is obtained which characterizes the viscoelastic properties of a polymer system.

This model is inadequate at high polymer concentrations—conditions approximating bulk behavior—or when branching and crosslinking are present. Such interactions between chains in this more complex arrangement have been treated using a more realistic molecular model developed at Ford Motor Company's Scientific Research Staff *(1,2)*. "Entangled" or cross-linked networks are represented by a mathematically

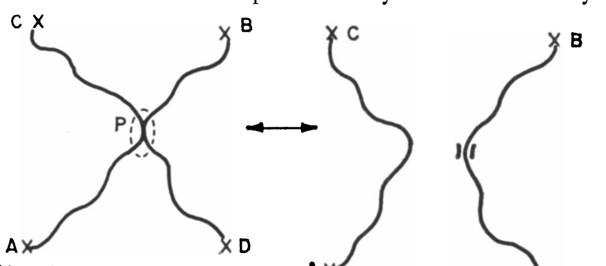


Figure 1
A model of an entanglement (left) in a two chain network and its mechanical equivalent (right)—two "decoupled" chains, one of which carries a point of increased friction.

equivalent model of dissociated chains (Fig. 1). This mathematical device permits calculation of the relaxation spectra over a significantly greater time range than previously possible. The relaxation spectrum derived from this approach represents a distribution of the normal modes of motion of the subchains between entanglements, superimposed on the normal modes of slowly slipping entanglements.

The number of entanglements per molecule—an important structural parameter—now can be determined unambiguously from experiments; and viscoelastic behavior of such network systems can be predicted.

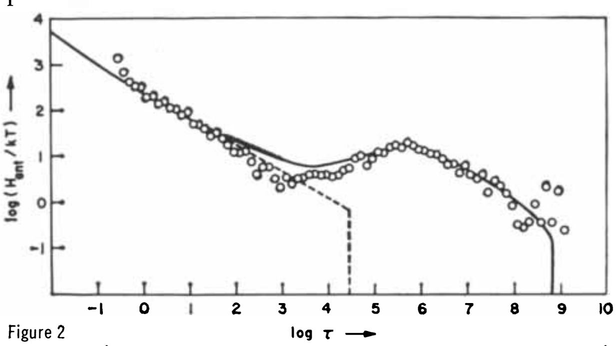


Figure 2
Comparison between the log of the relaxation spectrum, theoretically derived (circles are computer calculated points), with experimental data for poly-n-octyl methacrylate of molecular weight 3.6 x 10^6; limited applicability of the older treatments are shown as a dashed line.

An example of the excellent agreement between the Ford model and experimental data from a variety of laboratories is shown in Figure 2.

This is only one example of Ford's efforts to understand the structure of materials with the ultimate goal of improving their application to products and processes.

References: 1. A. J. Chompff and J. A. Duiser, J. Chem. Phys. *45*, 1505 (1966). 2. A. J. Chompff and W. Prins, J. Chem. Phys. *48*, 235 (1968).

PROBING DEEPER FOR BETTER IDEAS

Ford

General Electric is demonstrating the only 3-dimensional information system

Maybe you're already doing batch processing, remote batch, and time-sharing. But you're using several independent computers. Watch what happens when you replace them with a single GE-600, the *only* information system today that can operate in all three dimensions of information processing:

You'll improve throughput. The GE-600 can handle 63 jobs concurrently through multiprogramming. With multiprocessing, you can handle these jobs even faster.

You'll do more with less system. The GE-600 can flex itself to handle any variety of workload — from 100% batch processing to 100% time-sharing, and any combination between. You don't need several systems, all big enough to handle specialized peak loads. The GE-600 adapts to your changing job mix.

You'll save money at satellite facilities. Compact GE-115 computers and keyboard terminals at your remote operations link up with the central GE-600. This gives your small satellite systems big system capability.

You'll put your organization on line. All your files are contained in a common data base. Every computer, every terminal, in every mode has access to it. With time-sharing, you can give your technical people fingertip access to an on-line computation capability. You can give management immediate access to the facts of the business. You can give your salesmen their order-entry system . . . your warehouses their dynamic inventory system.

You'll put your programmers on line too. They can develop their programs at time-sharing terminals. They can maintain their source program files in the system. They can initiate time-sharing or batch-mode jobs in debugging mode or for production processing.

No waiting for key punch, collation, and batch-mode turn-around.

Discover the three-dimensional world of the GE-600. Ask your General Electric Sales Representative for a demonstration. Or write Section 290-25A, General Electric, 1 River Road, Schenectady, N. Y. 12305.

GENERAL ELECTRIC

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

NOVEMBER, 1918: "The wave of hysterical rejoicing that swept over the United States when our President announced the signing of a truce had many impulses, but none was stronger than the conviction that, with the death of German militarism, there had died also the ever present threat of war and the ever accumulating burden of naval and military armaments. In view of these conditions, we learn with astonishment that Mr. Daniels, Secretary of the Navy, wishes to commence the immediate construction of 156 new war vessels, including 10 superdreadnaughts and six battle cruisers, and that in addition to all this he is asking the debt-ridden people of the United States to give him a further sum of $600,000,000 for the construction of another lot of 156 vessels, which will duplicate the first lot. Verily, the ways of some men are past finding out."

"In the closing days of the great war the Germans were bombarded not only with the ever increasing fire from thousands of guns but also with countless booklets and leaflets and other forms of propaganda. The American Propaganda Department has maintained a big printing establishment in Paris under the command of Captain Arthur Page, formerly editor of *The World's Work*, while the editorial work was carried on under the direction of Walter Lippmann, formerly of *The New Republic*. The American propaganda has been mostly in the form of the speeches and notes of President Wilson, together with interesting facts concerning General Pershing and his legions."

"In a detailed scientific discussion of the German long-range gun which bombarded Paris last spring Major J. Maitland-Addison, writing in the *Journal of the Royal Artillery*, takes a peep into the future and considers the possibility of a gun capable of shooting projectiles entirely off the earth into space, à la Jules Verne. The requisite velocity of such a gun is not, he says, so very much higher than what has already been

Report from

BELL LABORATORIES

A New Use for the Sun

Radio frequencies in the range of 10 to 40 GHz are of interest for satellite communications. But signals at these frequencies—including millimeter wavelengths at 30 to 40 GHz—are attenuated by rain, snow, fog, and other weather conditions. To study these effects, we needed a source of millimeter waves in the sky. What could we use?

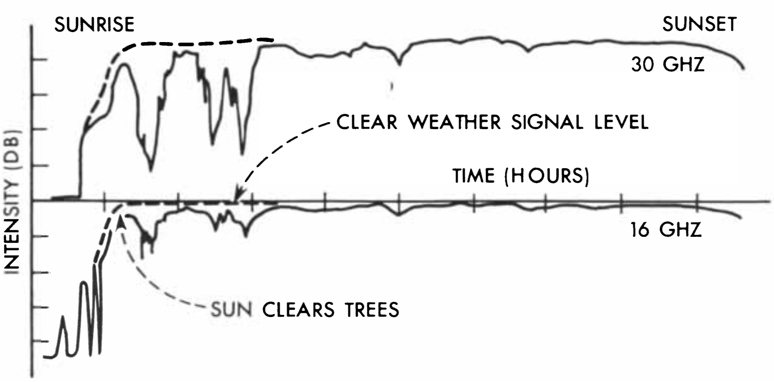
Putting up a research satellite would be difficult and expensive. But fortunately a millimeter-wave transmitter in the sky already exists ... the sun. By tracking the sun and correlating the signal losses with atmospheric effects, we are gaining valuable insight into the problems and possibilities of maintaining reliable communications at millimeter-wave frequencies in all kinds of weather.

Our apparatus includes a steerable, plane metal mirror that reflects solar energy into a stationary horn-reflector antenna (photo). The signals are processed and recorded in a temperature-controlled equipment house. The system automatically follows the sun on its daily path across the sky by a clock mechanism which can be set for a full week's automatic observation.

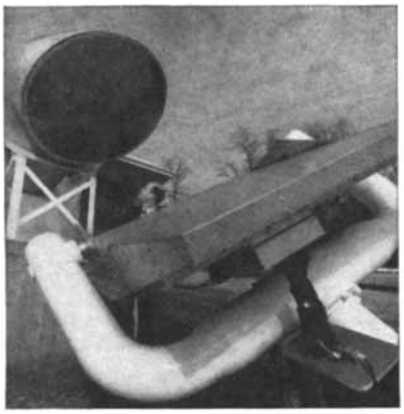
The sun emits radio signals at a great many frequencies, but the sun-tracker is tuned only to signals at 16 and 30 GHz. The received energy has two significant components: one due to the sun and one due to the atmosphere (which attenuates solar energy but also radiates energy of its own). To allow for the atmospheric component, we tilt our mirror away from the sun once each second, thus getting a sky-only reading. We subtract this from the sun/sky total and plot the difference. The equipment responds to and records signal changes as rapid as 30 dB in 15 seconds.

The graphs (left) indicate that there are periods when rain will attenuate the received signal by 30 to 40 dB. Such attenuation would seriously impair communications signals from satellites. The problem can be solved by spacing several ground terminals far enough apart that at least one of them would always have a clear path to the satellite. This would be done at both receiving and transmitting terminals.

Data from the sun-tracking experiments will help us determine how many terminals might be needed for communication systems operating at high frequencies, and how these terminals might be spaced to achieve maximum efficiency and economy.



Intensity of solar radiation at two frequencies, recently observed at Bell Laboratories' installation at Holmdel, N.J. Graphs show one 9-hour period out of months of study. Note attenuation due to rain early in the day.



Bell Laboratories' station for studying atmospheric effects on solar radio energy. The flat mirror has two axes. One is parallel to the earth's polar axis—for daily rotation. The other is perpendicular—for seasonal variation. Experiment designer R. W. Wilson checks the horn antenna into which signals are reflected.

Bell Telephone Laboratories
Research and Development Unit of the Bell System

achieved, namely a muzzle velocity of a mile per second. When we are able to increase this to five miles per second, the projectile, if fired at a suitable angle, will travel around the earth as a grazing satellite, completing its orbit between 17 and 18 times daily. With a velocity of about seven miles a second, it will move off into space, never to return."

"Too many drivers of cars are obsessed with the idea that they own the earth, and nowhere is this so apparent as in their procedure when they approach a railroad crossing. A Western railroad made observations of 20,000 drivers at crossings, which are summed up as follows: 525 drivers smashed through the crossing gates when the gates were down and bells were ringing; 69.5 per cent of the 20,000 drivers looked neither to the right nor left; 27.8 per cent looked one way along the track while going at reckless speed; 2.7 per cent took pains to look both ways. Only 35 drivers out of the 20,000 stopped their machines before crossing the tracks to make certain that no trains were approaching."

SCIENTIFIC AMERICAN

NOVEMBER, 1868: "The election has taken place. Gen. U. S. Grant is chosen President for four years from March 4th, 1869, and Schuyler Colfax is chosen Vice-President. During the past months of scramble and partizan jostle, we have been silent although not uninterested spectators of the contest. Although many of our Southern people may regard the election of General Grant as a misfortune, we greatly mistake if events do not prove it a blessing. We have erred in our estimate of the man, and have misinterpreted the motives which governed him at the time of General Lee's surrender, and still govern him, if he does not mean when he says, 'Let us have Peace,' peace not for one section only but for all sections."

"One of the most important meetings held in this city for years took place on the 20th October, the object being to initiate measures for furthering the project of a ship canal across the isthmus of Darien. It was attended by a large number of gentlemen prominent in the great enterprises of the age. Peter Cooper was appointed chairman and the Hon. A. F. Conklin secretary. Among those who took a prominent part in the proceedings were the Hon. Wm. H. Seward, Secre-

Canon invents the first electronic calculator for people scared of electronic calculators.

We call it the Canon 163. It's our answer to people who thought they couldn't use one.

This is the first *true* Integrated-Circuit (IC) calculator; the first to use more IC's* (170 of them) than transistors and diodes combined.

We did it for reliability. By using IC's, we were able to keep the number of components in the Canon 163 to a minimum (it has thousands fewer than any other electronic calculator—including those that use IC's).

Fewer components mean fewer sources of heat, fewer solder connections, fewer things that can go wrong—and a smaller and lighter calculator (the Canon 163 is about the size and weight of a small portable typewriter).

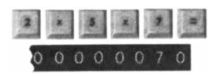
We added more capability. Simple and compact as it is, the Canon 163 incorporates several exclusive capabilites, such as: switch-selected round-off, drop-off *and* round-up of digits following the last decimal place; and a memory with item count and sum-of-multiplicand features as well as ordinary storage. The other memory automatically accumulates subtotals without re-entry, and an additional register allows multiplication and division by constants.

The Canon 163 divides, multiplies, adds and subtracts any 16-digit numbers of up to 10 decimal places, raises them to any integral power, and automatically finds square roots. Instantly, accurately, silently.

And it has a host of safeguards to prevent, catch and correct human mistakes. These include an exclusive illuminated, automatic comma indicator every three places before and after the decimal point, automatic credit balance indication and an exclusive glare-preventing polarized display panel.

If you can write it, you can do it. Despite all its capabilities, the Canon 163 is a breeze to use. You "key" most problems just the way you'd write them.

To multiply 2 x 5 x 7, is as simple as



The answer shows up in lights almost before the last key is released.

More complicated problems are just as easy, just as fast; some take even less time to calculate than you'd take to write them down.

Another new Canon IC calculator. The Canon 163 sells for $1,395. For those who don't need so much calculator, we offer the new Canon 161S, for only $1,195. It has a single memory, and offers all the other features of the Canon 163 except square root, automatic comma indication, item count and sum of multiplicand.

We'll be happy to arrange a demonstration of either Canon. Just mail in the coupon. ***There's nothing to be scared of.***

Canon ELECTRONIC CALCULATORS

*IC's manufactured for Canon by Texas Instrument.

Canon 163. Shown one-half actual size.

tary of State of the United States, and the Hon. Wm. M. Evarts, Attorney General. An estimate of the cost of the canal was made as being $100,000,000. A committee to obtain subscriptions was appointed. Surveys of the proposed route were submitted by several eminent engineers, and an assurance of the final success seemed to prevail in the minds of all the gentlemen present."

"The cannon foundry of Krupp in Essen, Prussia, extends over 920 acres, 246 of which are occupied with buildings. It has 12 miles of railroad, six locomotives, 150 wagons and 50 horses. There are 9,000 jets of gas, consuming about five millions of cubic feet per day; 10,000 men are employed in the foundry, 1,200 at the mines and forges. The wages amount to 3,100,000 thalers per annum. The motive power consists of 160 engines of 6,000 horse-power each. The daily consumption is 13,000 bushels of coal, 32,500 bushels of coke and coal and 200,000 cubic feet of water."

"John Stuart Mill, the celebrated political economist, has written a letter to the *Illustrated Weekly News* upon co-operation. He says: 'I am quite of the opinion that the various forms of co-operation (among which the one most widely applicable at present to production, as distinguished from distribution, is what you term the system of small percentage partnerships) are the real and only thorough means of healing the feud between capitalists and laborers, and while tending to supersede trade unions, are meanwhile a natural and gradually increasing corrective of their operation. I look also with hope to the ultimate working of the foreign combination."

"The velocipede mania is beginning to set in, and with the opening of the spring months we may expect to see our parks and highways thronged with this cheap and agreeable substitute for the horse. The two-wheeled velocipede is not exactly the thing wanted for general use, as it will be somewhat difficult for novices to keep upright upon it. A nicely adjusted vehicle with a double hind wheel would be most desirable for all classes."

"A society has been formed in Paris to oppose the use of tobacco. Each member pledges himself to abstain, and to use his efforts to induce others to abstain, from tobacco in all forms. The society already numbers 1,200 members."

■ A mass-made automobile is started for the first time when it is dropped off the end of the production line. It is driven a few feet to the haulaway truck, and then a few more feet later into the showroom. That's its break-in period. The car may be good or flawed. The customer won't know until he buys it. Mass production means fast production, fast delivery.

We at Porsche build fast cars slowly. It takes the customer more time to get one because we don't take short cuts.

When the final bit of hand assembly has been done on the Porsche engine, it's not quickly bolted into a car. First, it's hooked to a dynamometer, a device that tells if it is putting out its full rated horsepower. Speed and power ratings are taken and noted in a permanent card file. (Now and then an engine fails. Bad news for somebody.)

If the engine passes, it goes to its matching body, which has passed dozens of inspections (eight for metal-work alone.) The car gets another dynamometer test, this one reading power at the rear wheels.

Then, an entirely new series of tests and inspections begins before the car is shipped. There are *three* different road tests by the same driver. First, an overall check-out, next, a high-speed, long *autobahn* run; and, finally, a rough-road test. The driver turns in a signed report.

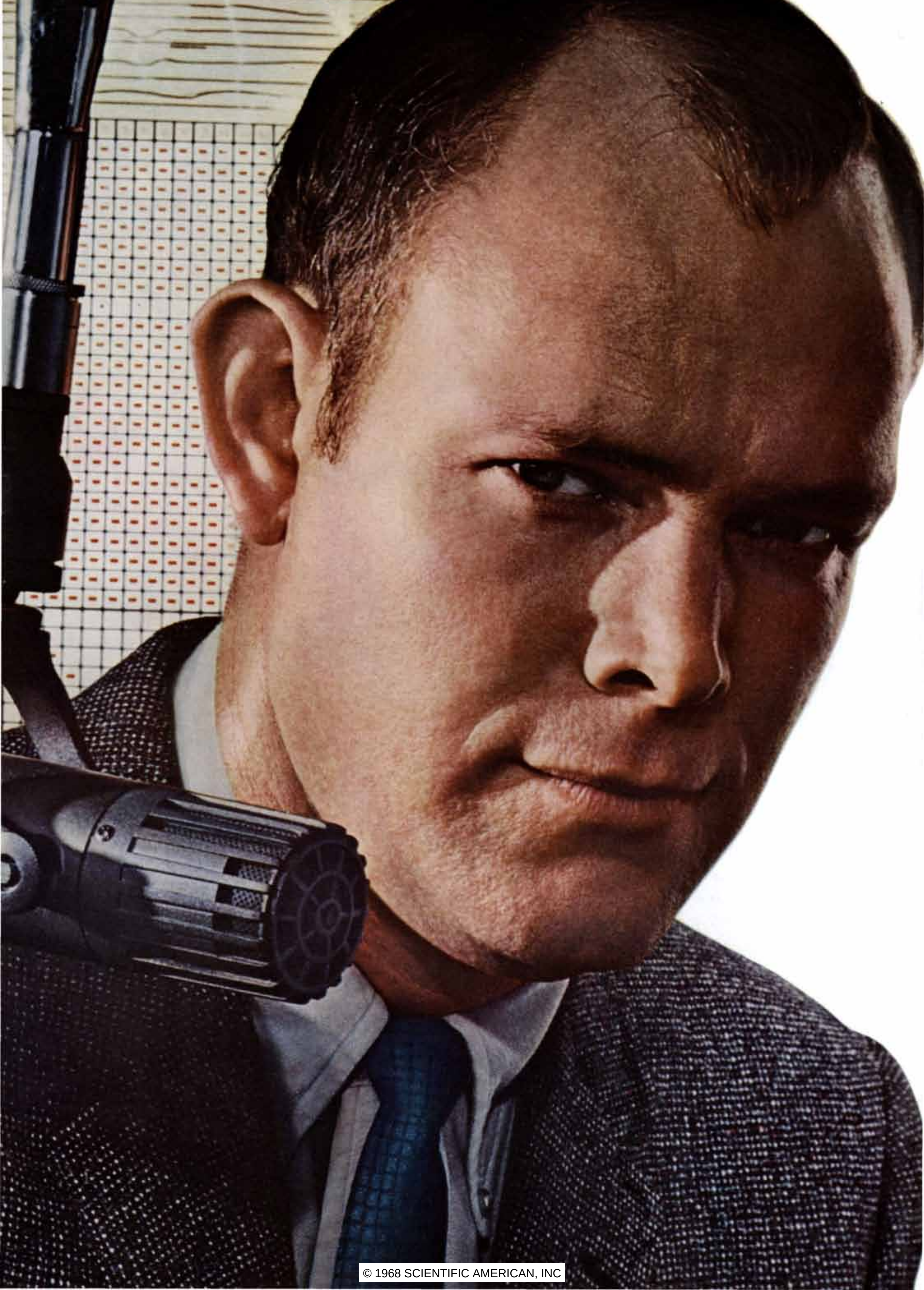
There's nothing anonymous about building a Porsche. We know who built your engine; we know who tested your car. And they know we know.

What's the Porsche in the picture wearing? It's a *steinschlagschutzhülle,* according to the catalog. A canvas shield to protect the finish from flying stones and sand during testing. The drivers simply call it a bra.

Prices start at about $5,100, East Coast P.O.E. See your Porsche dealer or write to the Porsche of America Corporation, 100 Galway Place, Teaneck, N.J. 07666.

PORSCHE

Why should you do our work for us?



THE AUTHORS

DAVID SIMPSON ("The Dimensions of World Poverty") is a lecturer in political economy at University College London. He was graduated from the University of Edinburgh in 1959 and then spent five years as a graduate student and teacher at Harvard University, where he served as an assistant to Wassily Leontief in the Harvard Economic Research Project. Simpson prepared for the United Nations a monograph on input-output analysis as an instrument of economic planning. After leaving the U.S. he spent two years at the Economic Research Institute in Dublin. "I think," he writes, "that economic development constitutes the last great economic problem and that small economies make good laboratories for the testing of economic theory."

EARL R. PARKER and VICTOR F. ZACKAY ("Strong and Ductile Steels") are professors of metallurgy in the College of Engineering at the University of California at Berkeley. Each is also associated with the inorganic materials research division of the Lawrence Radiation Laboratory; Zackay is associate director of the division and Parker is a principal investigator. Their research, which is supported by the U.S. Atomic Energy Commission, is directed toward ascertaining the principles that control the properties of high-strength materials. Parker was graduated from the Colorado School of Mines and did research with the General Electric Company for several years before going to Berkeley in 1945. Zackay, who took his degrees at Berkeley, did research for the Ford Motor Company for several years before joining the University of California faculty in 1962. They describe themselves as "vitally interested in coupling science and technology" and as "concerned with the social ramifications that such coupling engenders."

C. A. CLARKE ("The Prevention of 'Rhesus' Babies") is professor of medicine at the University of Liverpool. He is also director of the Nuffield Unit of Medical Genetics at the university and consulting physician to the United Liverpool Hospitals. Clarke, who has a doctorate in science from the University of Cambridge, received his medical qualification at Guy's Hospital in London in 1932. During World War II he served as a medical specialist in the Royal Naval Volunteer Reserve. Clarke is the author of *Genetics for the Clinician,* published in 1962.

RICHARD L. GREGORY ("Visual Illusions") is chairman of the department of machine intelligence and perception at the University of Edinburgh and director of the Bionics Research Laboratory, which is concerned with the development of new scientific instruments and with research on problems of visual perception. Gregory was graduated from the University of Cambridge and remained there for a number of years as, successively, a member of the staff of the Applied Psychology Research Unit of the Medical Research Council, demonstrator in psychology and lecturer in charge of the perception laboratory. He went to the University of Edinburgh last year, when his department was established. He is the author of the book *Eye and Brain* and the inventor of several instruments, including the "solid image" microscope, three-dimensional drawing machines and a method for reducing the effects of atmospheric disturbance on telescopic images.

GERHARD HAERENDEL and REIMAR LÜST ("Artificial Plasma Clouds in Space") are at the Institute for Extraterrestrial Physics of the Max Planck Institute for Physics and Astrophysics near Munich. Haerendel is senior scientist and group leader, and Lüst is director of the institute and also honorary professor at the Institute of Technology in Munich. Haerendel studied physics and astrophysics at several German universities, obtaining his Ph.D. from the University of Munich in 1963. He has been at the Max Planck Institute since then except for a year as a research fellow at the California Institute of Technology. Lüst was graduated from the University of Frankfurt in 1949 and received his Ph.D. from the University of Göttingen in 1951. On three occasions since 1955 he has spent extended periods in the U.S. as a Fulbright fellow or as a visiting professor. In 1963 and 1964 he was scientific director of the European Space Research Organization.

DEXTER PERKINS, JR., and PATRICIA DALY ("A Hunters' Village in Neolithic Turkey") are respectively a zoologist and an archaeologist. Perkins, who was graduated from Harvard College in 1949 and obtained his Ph.D. from Harvard University 10 years later, has been staff zoologist for Columbia University archaeological expeditions in the Sudan, Syria, Iraq and Turkey, New


NO

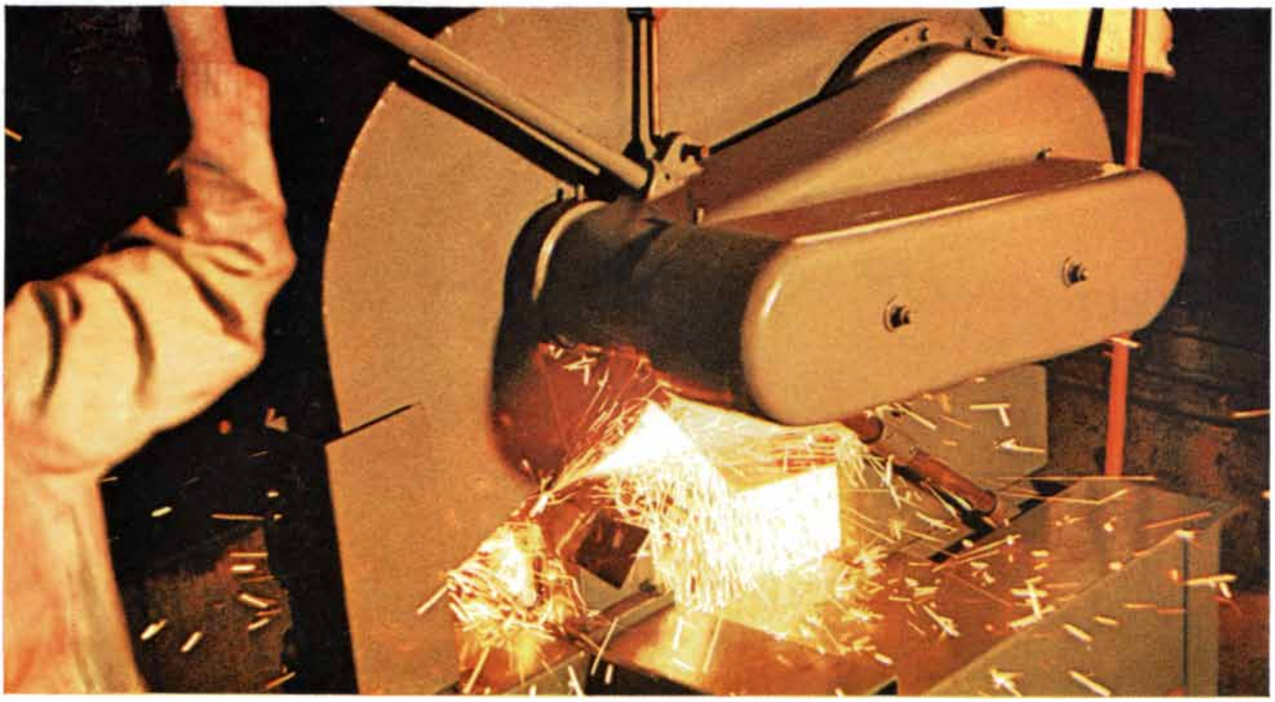
York University expeditions in Turkey, a University of Cambridge expedition in Turkey, University of London expeditions in Turkey and Jordan and Pennsylvania State University expeditions in Afghanistan. "My father," he writes, "is the leading authority on the Monroe Doctrine, and my mother was the author of the *Fannie Farmer Cookbook.*" Mrs. Daly was graduated from the Carnegie Institute of Technology in 1948. She is now a doctoral candidate in the department of anthropology at Columbia University. In 1964 she did fieldwork with a Columbia expedition in the Near East, and in 1965 she was with a New York University expedition in Turkey. She writes that she finds her work of analyzing animal bones in the archaeological context in which they were found "much more entertaining than pottery or stone tools."

ERNST HADORN ("Transdetermination in Cells") is professor of zoology and comparative anatomy at the University of Zurich, with which he has been affiliated since 1939. From 1962 to 1964 he acted as rector of the university. Hadorn received his Ph.D. from the University of Bern in 1931 and lectured there for several years. He then spent a year as a Rockefeller fellow at Harvard University and the University of Rochester before taking up his work at Zurich. His research deals with problems of experimental embryology and physiological and biochemical genetics. Among his writings are a book, *Developmental Genetics and Lethal Factors,* and the article "Fractionating the Fruit Fly" in the April 1962 issue of SCIENTIFIC AMERICAN.

FELIX HESS ("The Aerodynamics of Boomerangs") is in the department of applied mathematics at the University of Groningen in the Netherlands. He received there last December his doctoral degree, which is equivalent to a master's degree in the U.S., and now is working toward a Ph.D. by means of his studies on the aerodynamics of boomerangs. Hess also did his undergraduate work at Groningen, receiving the "candidate" degree that is equivalent to the baccalaureate in the U.S.

AMOS DE-SHALIT, who in this issue reviews the Ciba Foundation Symposium *Decision Making in National Science Policy,* is Herbert H. Lehman Professor of Theoretical Physics at the Weizmann Institute of Science in Israel. He is also director general of the Weizmann Institute.

What keeps speed and feed from burning up dollars in cut-off and grinding operations?



R/M composite abrasive wheels.

Ever wonder what keeps a spinning abrasive wheel from flying apart? Or what keeps it cool while it throws off hot sparks?

R/M achieves both objectives through its long-time experience in the field of composites.

In grinding, snagging, finishing, and cut-off wheels, for example, R/M builds in a number of cost-cutting features. Special fabrics to improve resistance to centrifugal shattering. Special bonds to promote and prolong cutting action, prevent heat buildup and bond breakdown. More durable bonds to minimize feathering and preserve effective wheel contour. Specially selected abrasive grains to provide desired cutting action and finish.

R/M uses combinations of asbestos, rubber, sintered metals, specialized plastics, and other man-made and natural materials to create exciting composites that solve perplexing problems for the homeowner, the businessman, industrial workers, and the military.

How can R/M's composite capability help you? Ask us.

Specializing in creative composites

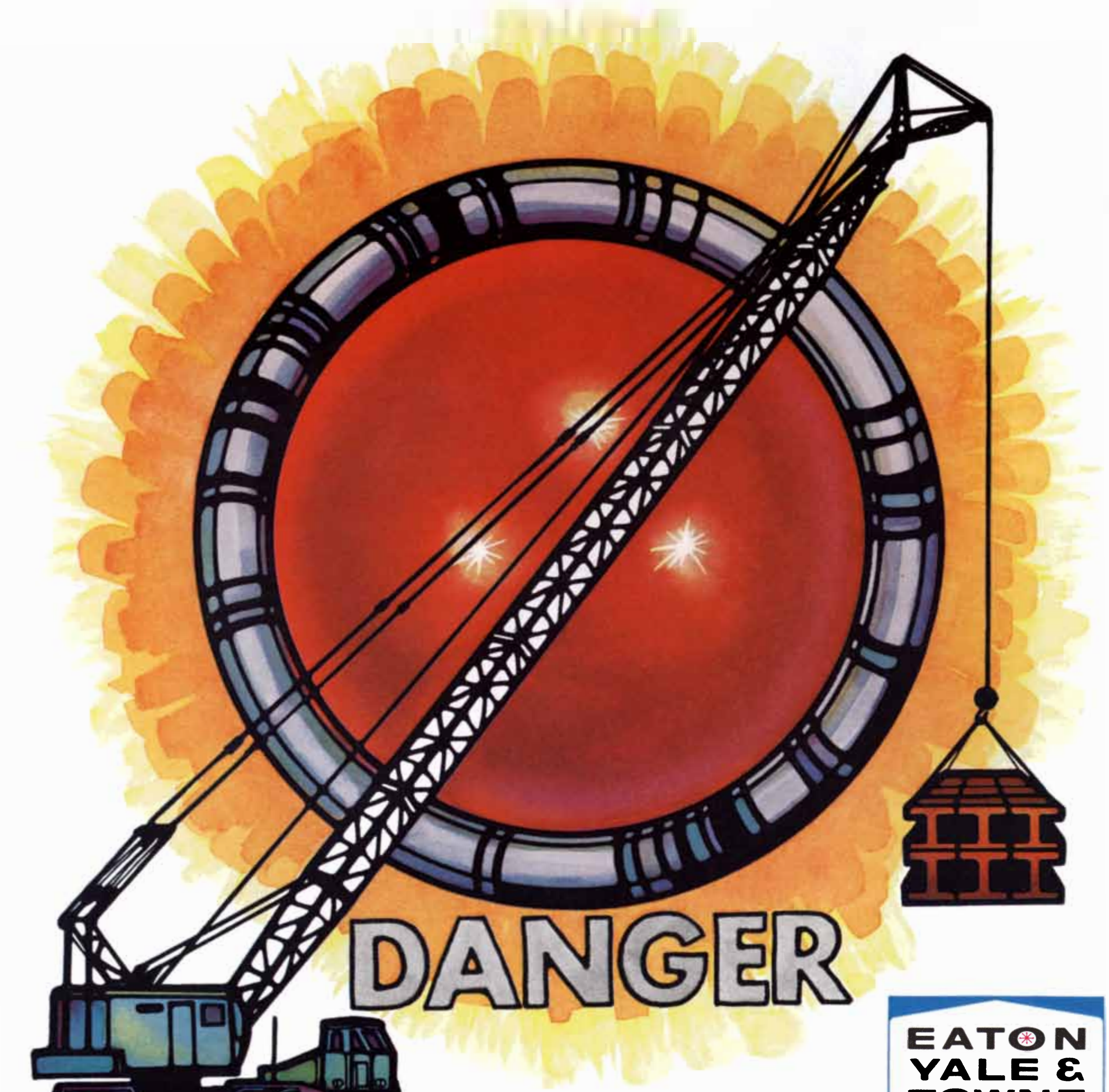
Raybestos-Manhattan, Inc.

Passaic, N.J. 07055

R/M

ELECTRONICS: flashing safety signals to warn of crane overloads. The idea turned us on.

Cranes – from small ones up to giants that tower 20 stories or more in the air – face the common danger of overloads. □ Turned on by this safety problem, Eaton Yale & Towne technologists utilized electronic load cells to create a unique load sensing computer. This computer constantly monitors the crane load and the boom angle, flashes red danger signals and rings warning bells when critical load limits are approached. Can even be programmed to stop the crane's operation. □ In the materials handling field, our technologists have come up with other unusual electronic load cell devices that instantly report the weight of loads lifted by fork lift trucks. Eliminate separate weighing. Warn of overloading. □ Practical application of advanced technology is what Eaton Yale & Towne engineers do best. Special emphasis is given to the dynamics of control systems, materials movement, transportation, metallurgy, construction, security systems, and to products for your comfort, convenience and safety. □ For more about Eaton Yale & Towne, write today for our 28-page book, "PANORAMA."



Applying advanced technology to bring you exciting new products

EATON YALE & TOWNE INC.

100 ERIEVIEW PLAZA • CLEVELAND, OHIO 44114

Established 1845 SCIENTIFIC AMERICAN November 1968 Volume 219 Number 5

The Dimensions of World Poverty

Two-thirds of the people in the world live in countries whose annual income per capita is less than $300. The pressing problem is hunger, and under present plans it will remain critical for at least 20 years

by David Simpson

The economic gulf that has divided the poorer countries of the world from the richer countries is rapidly widening. Whereas the affluent nations continue to become richer, the impoverished nations continue to increase in population without raising their food production fast enough to reach a state of self-sustaining growth. Even though there have been recent gains in their agricultural production, and even if one makes the most optimistic assumptions about the programs instituted to limit the growth of populations, the prospect remains bleak. It is highly probable that for at least the next 20 years most of the people in the world will continue to exist at the margin of subsistence.

Where is poverty the most serious? How many people are critically deprived of food and the other necessities of life? In this review of the available evidence concerning world poverty I shall attempt to answer these questions, concluding with some proposals as to what can be done about the groups that are critically underfed.

There is no single statistical indicator by which one can distinguish people who are seriously deprived from those who are merely poor. One can make only rough estimates based on a number of indicators, all of them crude. The justification for using such necessarily uncertain statistics is that, in Gunnar Myrdal's words, "it is better to paint with a wide brush of unknown thickness than to leave the canvas blank."

The measure of a country's material progress that has been most widely adopted is per capita national income, which is to say the net value of goods and services produced by a nation within one year per head of population. As a comparative measure of the standard of living or of the degree of well-being, it nonetheless has at least three weaknesses. The first is the difficulty of measurement: A comparison between the national incomes of two countries essentially involves valuing two bundles of goods. Inasmuch as similar goods have different prices depending on the country, two answers are possible according to which set of prices is used in the valuation. The second weakness is more fundamental: The satisfactions that people in different societies gain from similar goods are not comparable. It is argued that even if a Burmese peasant and an American housewife consumed similar goods at the same prices, and the American consumed 40 times as much as the Burmese, it would not follow that the American was 40 times better off. Finally, per capita income is an average measure; it cannot reflect the distribution of income within a country.

In spite of these shortcomings per capita income can be defended as an indicator of the level of output of goods and services within a country, and indeed it is widely used as such. Even when the estimate of income can only be crude, it nevertheless reveals differences in the order of magnitude of the incomes of the rich and the poor regions of the world. Thus on the basis of figures for 1965 (or the most recent year available) the average per capita income of the poorest region of Latin America is more than twice that of the poorer regions of Asia and Africa. The countries of Europe have average incomes that are 10 times greater than those of the poorer regions of Asia and Africa; in Oceania national incomes are larger by a factor of 14 and in North America they are larger by a factor of 28. It should be mentioned, however, that the way these estimates are prepared tends to overstate the differences between the richest and the poorest regions of the world.

It is clear that within continents there is considerable variation between regions and countries. South Asia and Indonesia have much lower incomes than East Asia or West Asia. The average income of the North African region is more than twice that of eastern and southern Africa. On both continents there are rich countries such as Japan, Singapore, Israel, Cyprus, Libya and the Republic of South Africa, whose average incomes approach European levels or even surpass them.

If we regard per capita income as a first approximation to the identification of the poorest regions of the world, it indicates that these regions include eastern, northeastern, southern, western and central Africa together with South and Southeast Asia and Indonesia. This impression is confirmed when one ranks the countries of the world whose average incomes are less than $300 per head according to relative wealth, dividing them into four classes.

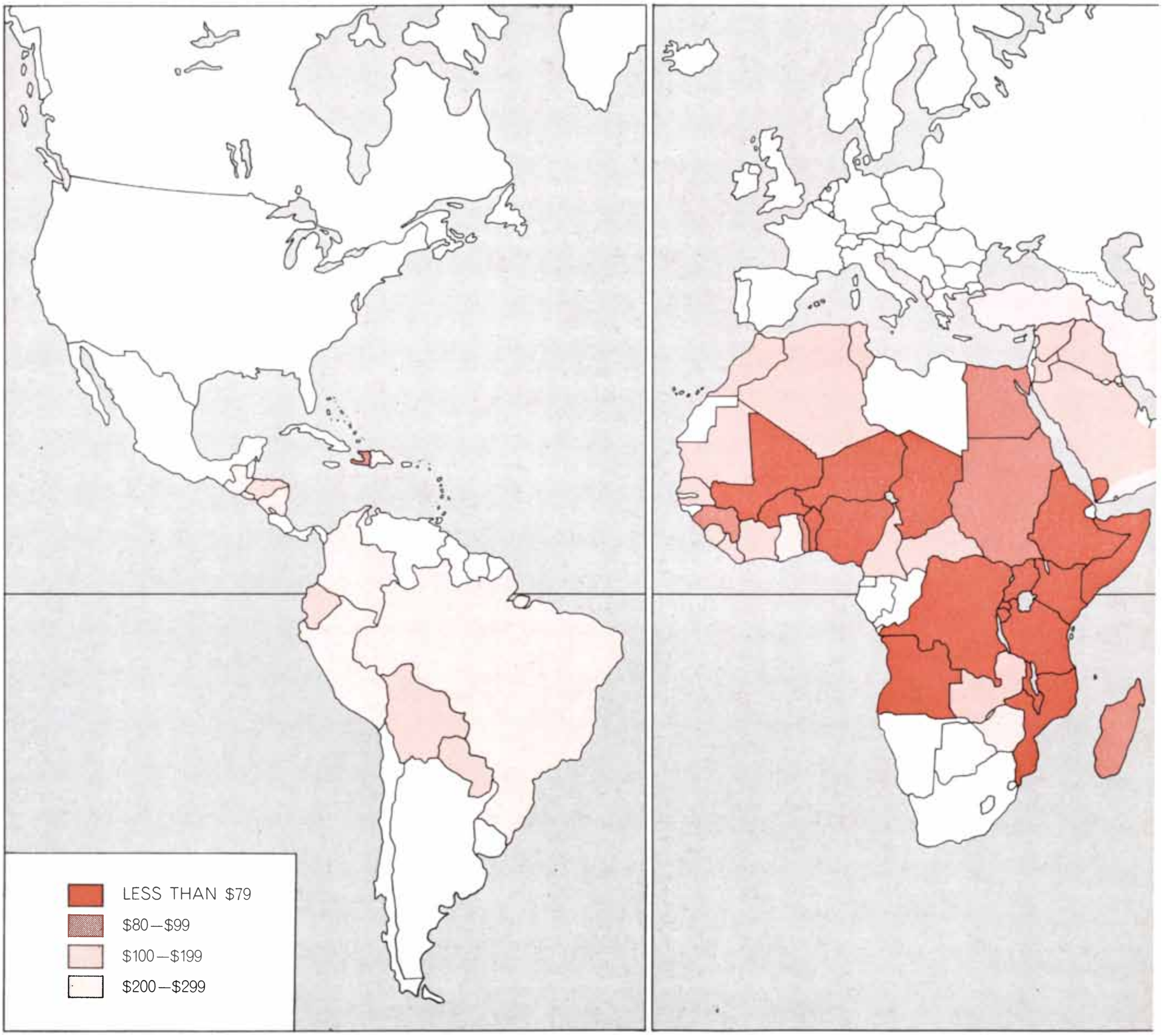
First of all are countries with the lowest average incomes, namely a range from $30 to $79 per head. Of the 22 countries, 17 are African and account for more than half of the continent's population, or about 167 million people. In this class there are only five Asian countries: Afghanistan, Burma, Laos, Nepal and Yemen, with a population totaling less than 60 million.

The next income class ($80 to $99) is important because it includes India, Indonesia and Pakistan, the three major countries of South Asia, whose population amounts to almost 700 million.

In the third class ($100 to $199) fall China, most of the Arab countries and four countries of Latin America (Bolivia, Ecuador, Honduras and Paraguay). The estimate of the per capita income of China is extremely uncertain, but I feel reasonably confident in placing China within this range.

The fourth and relatively highest income range ($200 to $299) includes Iran, Turkey, the Philippines and Brazil but only two African countries, Ghana and Rhodesia. The countries in this range could be described as being on the threshold of economic development: all the countries in the range below them ($100 to $199) are clearly not developed, whereas Cuba, Costa Rica, Portugal and Yugoslavia, whose incomes fall in the range above them ($300 to $399), clearly are.

It would be unwise to propose any single value of per capita income above which a country can be judged to have passed out of the stage of economic backwardness or underdevelopment, both because of the uncertainty of the estimates and the variation in circumstances among countries. If a line must nevertheless be drawn for practical purposes, then $300 would appear to be a reasonable level at which to draw it. Whereas there are many countries clustered below $300, there are relatively few spread



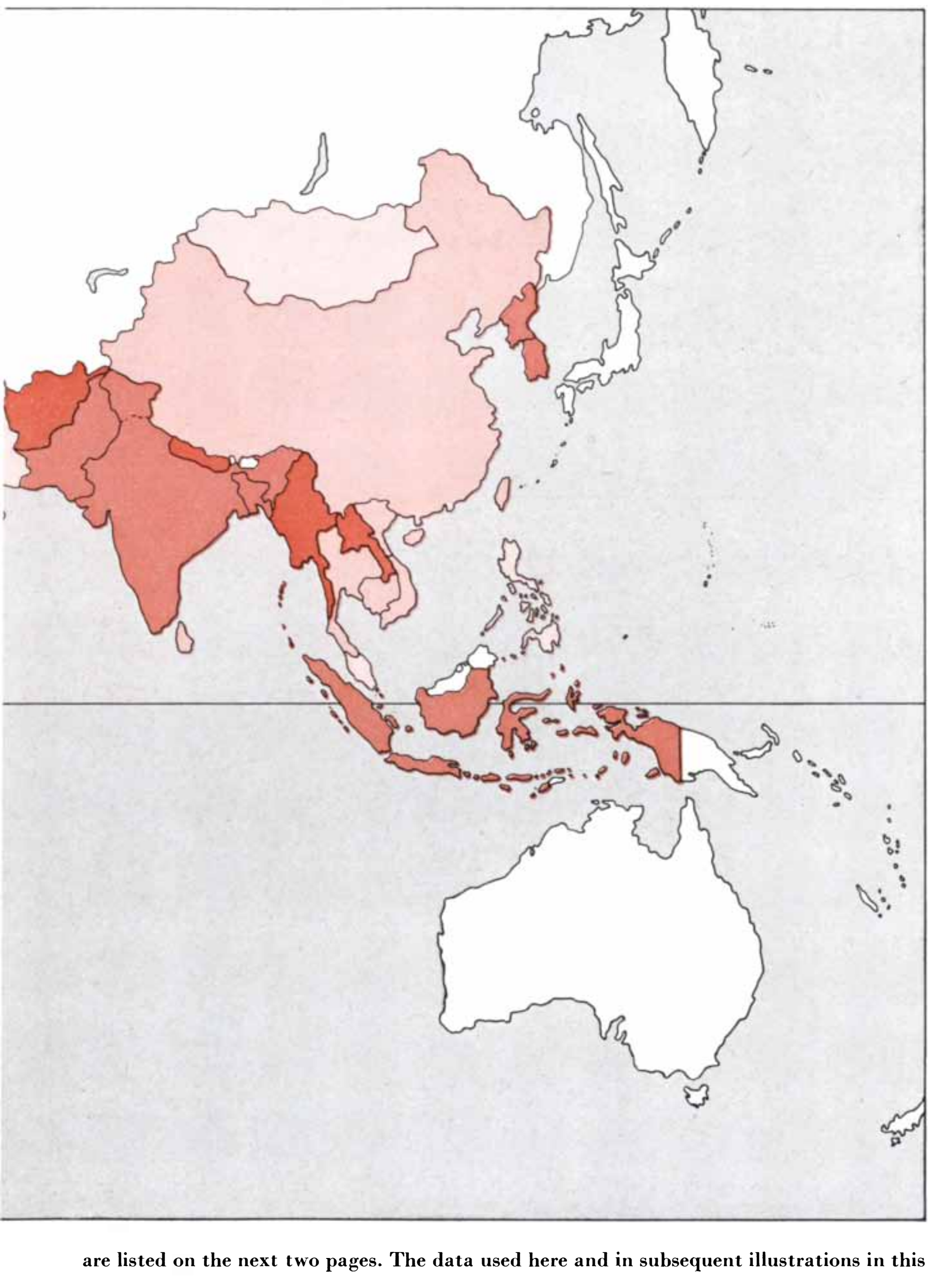
IMPOVERISHED COUNTRIES are grouped according to their average per capita income for 1965 (or the most recent year available). Estimates have not been made for some of the smaller countries. The income and population of the larger countries over the wide range of incomes between $300 and $700. About 2.1 billion people, or 64 percent of the world's population, live in countries whose average income is less than $300, and almost 1.9 billion of these people live in countries whose average income falls below $200. A world poverty line at $300 is of course far below the level at which the poverty line would be drawn in the richer regions of the world. Taking four people as the average number in an American family, the simple U.S. poverty line works out at $750 per head.

An interesting characteristic of the countries with incomes less than $300, which we shall now call the low-income countries, is that their distribution in terms of population is extremely skewed. About 67 percent of the people in this group live in only four countries: China, India, Indonesia and Pakistan. At the other end of the scale, 50 small countries of Africa, Asia and Latin America account for less than .6 percent of the people in the group. These facts alone suggest that there are no simple universal prescriptions for economic development.

As an index of the economic progress of the low-income countries, the level of per capita income is of course less important than the rate of its growth. Estimates of the annual growth rates of per capita income are available for only a few of these countries. Statisticians at the United Nations have, however, estimated the average growth rate of per capita income (at constant prices) of developing, or poorer, countries as a group. During the 1950's their growth rate was 2.3 percent, and it dropped slightly to 2.2 percent during the period from 1960 to 1964. The corresponding figures for the developed countries were 2.7 percent and 3.7 percent, thus the widening gap between rich and poor. Naturally these averages conceal a wide variety of experience in different countries. Per capita income actually dropped in Morocco, Haiti and Syria in the 1950's and in Guyana and Uruguay from 1960 to 1965. On the other hand, the annual rate of growth of per capita income was 4.3 percent in Burma in the 1950's and 3.5 percent in Iran between 1960 and 1965. Over the same two periods the incomes of India and Nigeria grew modestly but steadily, whereas Pakistan moved from an annual growth rate of .6 percent in the 1950's to a rate of 3.2 percent in the 1960's.

It should be remembered that a growing per capita income is quite compatible with a simultaneous increase in the absolute number of people in the country who are subsisting at the lowest income level. The statistics used in the calculation of the level and rate of growth of income are national averages. For an appreciation of the extent of poverty within a country a knowledge of the distribution of income is essential. Unfortunately the available statistics of income distribution in the low-income countries are seriously limited in both quantity and quality. The most thorough analyst of these data, Simon Kuznets of Harvard University, draws the conclusion that the upper-income groups in the countries below the $300 line receive a larger share of total income than their counterparts in the rich countries do; below the top-income groups there is a greater equality in the distribution.

If we interpret poverty to mean sustained deprivation, then per capita income is not necessarily the best measure, and it is certainly not the only measure, of such poverty. It is possible, for example, to envision a society that has a very low per capita income as a result of a low level of material production but at the same time is not seriously deprived of the basic necessities of life: food, shelter, clothing and reasonable conditions of health. What precisely constitutes sustained deprivation or serious poverty is a matter that could be discussed at length. Fortunately such a discussion is unnecessary, because the number of statistical indicators that are relevant to any rea-



are listed on the next two pages. The data used here and in subsequent illustrations in this article are based on statistics of United Nations agencies and estimates of the author.

sonable definition of serious poverty and also are actually available is quite limited. It is therefore simpler to consider these indicators in turn and to allow the impression of poverty to be formed by them.

As far as the lack of shelter is concerned, the available quantitative evidence does not allow us to draw any conclusions that are relevant to our purpose. We know the average number of inhabitants per room for some segments of the population, but we do not know the number of inhabitants per square foot. A country with a high proportion of dwellings without electricity or without a piped-in water supply can be considered poor, but this does not necessarily represent serious hardship. Dwellings are not easily comparable from country to country, and needs vary. Similar considerations apply to the availability of clothing as a measure of poverty.

In the cities of the poorer countries there is of course dramatic and visible evidence of the qualitative inadequacy of housing. The population of such cities as Nairobi, Calcutta, Caracas, Bogotá and São Paulo is growing faster than the rate at which even rudimentary housing facilities can be provided. A recent account of housing conditions in Calcutta illustrates the magnitude of the problem there. The 1966 development plan of the Calcutta Metropolitan Planning Organisation states that adequate housing is "not within the bounds of feasible achievement over a 25-year period." The

COUNTRY	INCOME PER CAPITA (U.S. DOLLARS)	POPULATION (MILLIONS)
AFGHANISTAN	47	15.7
ALBANIA	239	1.9
ALGERIA	195	11.9
ANGOLA	56	5.2
ARGENTINA	740	22.4
AUSTRALIA	1,620	11.4
AUSTRIA	970	7.3
BELGIUM	1,406	9.5
BOLIVIA	144	3.7
BRAZIL	217	82.2
BRUNEI	1,395	.1
BULGARIA	691	8.2
BURMA	56	24.7
BURUNDI	38	3.2
CAMBODIA	112	6.1
CAMEROON	104	5.2
CANADA	1,825	19.6
CENTRAL AFRICAN REPUBLIC	123	1.4
CEYLON	130	11.2
CHAD	60	3.3
CHILE	515	8.6
CHINA	147	700.0
COLOMBIA	237	18.1
CONGO (KINSHASA)	66	15.6
COSTA RICA	353	1.4
CUBA	319	7.6
CYPRUS	623	0.6
CZECHOSLOVAKIA	1,482	14.2
DAHOMEY	55	2.4
LAOS	59	2.6
LEBANON	204	2.4
LIBERIA	148	1.0
LIBYA	636	1.6
MADAGASCAR	83	6.4
MALAWI	38	3.9
MALAYA	257	8.0
MALI	57	4.6
MAURITANIA	106	1.1
MEXICO	412	42.7
MONGOLIA	250	1.1
MOROCCO	174	13.3
MOZAMBIQUE	40	7.0
NEPAL	66	10.1
NETHERLANDS	1,265	12.3
NEW ZEALAND	1,706	2.6
NICARAGUA	298	1.7
NIGER	78	3.3
NIGERIA	63	57.5
NORWAY	1,453	3.7
PAKISTAN	89	102.9
PANAMA	425	1.2
PARAGUAY	186	2.0
PERU	218	11.7
PHILIPPINES	219	32.3
POLAND	904	31.5
PORTUGAL	351	9.2
PUERTO RICO	959	2.6
RHODESIA	206	4.3
ROMANIA	691	19.0

WEALTH OF NATIONS is expressed in annual income per head of population. The impoverished countries, those with per capita income less than $300 (*color*), are seen to be predominant. Countries with a population under one million are omitted from this

dimensions of the problem are so enormous that the plan does not anticipate the provision of houses but rather the construction of open-sided sheds to serve as shelters. One estimate suggests that 77 percent of the families in Calcutta at present have less than 40 square feet (an area a little more than six feet square) of living space per person. Nevertheless, the problem of housing in the cities may be not so much a problem of shelter as a problem of sanitation, and therefore of disease. In cities such as Calcutta the lack of housing means that the spread of disease in the slum areas is literally uncontrollable.

The problem of disease in the poorer countries is inextricably linked to other social conditions: lack of sanitation, lack of food and lack of medical facilities. It would therefore seem that the incidence of particular diseases would be a useful indicator of levels of poverty. Although diseases such as hookworm, trachoma and malaria, respiratory diseases (tuberculosis, whooping cough), intestinal diseases (typhoid, dysentery, gastroenteritis) and deficiencies arising from malnutrition (kwashiorkor, anemia, goiter, beriberi, rickets) are known to be prevalent in some of the poorer countries, there is no reliable evidence of their incidence. The reason is that the countries require notification of only a limited number of illnesses and the reporting of these is incomplete. It is of interest, however, that the global incidence of malaria, a disease that is prevalent in tropical Africa, East Asia and South America, has been esti-

DENMARK	1,652	4.8
DOMINICAN REPUBLIC	**212**	**3.6**
ECUADOR	**183**	**5.2**
EL SALVADOR	**236**	**2.9**
ETHIOPIA	**42**	**22.6**
FINLAND	1,399	4.6
FRANCE	1,436	48.9
GERMANY, EAST	1,458	17.1
GERMANY, WEST	1,447	59.0
GHANA	**245**	**7.7**
GREECE	566	8.6
GUATEMALA	**281**	**4.4**
GUINEA	**83**	**3.5**
HAITI	**80**	**4.4**
HONDURAS	**194**	**2.3**
HONG KONG	**291**	**3.7**
HUNGARY	1,031	10.1
INDIA	**86**	**486.8**
INDONESIA	**85**	**104.5**
IRAN	**211**	**24.8**
IRAQ	**193**	**8.2**
IRELAND	783	2.9
ISRAEL	1,067	2.6
ITALY	883	51.6
IVORY COAST	**188**	**3.8**
JAMAICA	407	1.8
JAPAN	696	98.0
JORDAN	**179**	**2.0**
KENYA	**77**	**9.3**
KOREA, NORTH	**88**	**12.1**
KOREA, SOUTH	**88**	**28.4**
KUWAIT	3,184	0.5
RWANDA	**38**	**3.1**
SAUDI ARABIA	**125**	**6.8**
SENEGAL	**149**	**3.5**
SIERRA LEONE	**123**	**2.4**
SINGAPORE	508	1.9
SOMALIA	**48**	**2.5**
SOUTH AFRICA	509	20.3
SPAIN	594	31.6
SUDAN	**90**	**13.5**
SWEDEN	2,046	7.7
SWITZERLAND	1,928	5.9
SYRIA	**156**	**5.3**
TAIWAN	**185**	**12.4**
TANZANIA	**64**	**10.8**
THAILAND	**105**	**30.6**
TOGO	**82**	**1.6**
TUNISIA	**179**	**4.4**
TURKEY	**244**	**31.2**
UGANDA	**77**	**7.6**
U.S.S.R.	1,195	231.0
UNITED ARAB REPUBLIC	**96**	**29.6**
UNITED KINGDOM	1,451	54.6
U.S.	2,893	194.6
UPPER VOLTA	**35**	**4.9**
URUGUAY	537	2.7
VENEZUELA	745	8.7
VIETNAM, NORTH	**113**	**19.0**
VIETNAM, SOUTH	**113**	**16.1**
YEMEN	**36**	**5.0**
YEMEN, SOUTH	**246**	**1.1**
YUGOSLAVIA	319	19.5
ZAMBIA	**174**	**3.7**

chart and subsequent ones; exceptions here are Brunei, Cyprus and Kuwait, whose high incomes in relation to nearby countries illustrate the variation in wealth within geographic regions. There are fewer poor countries in Latin America than in Africa and Asia.

mated to be about 140 million cases per year, from which result just under a million deaths per year.

Perhaps the most useful single index of the health conditions prevailing in a community is the infant death rate. Deaths, unlike illnesses, are usually reported, at least in towns, and the death of children under the age of one year reflects a multitude of diseases and the entire spectrum of social and economic conditions. Currently the highest infant mortality rate is that of Cameroon, which has 137.2 infant deaths per 1,000 live births; for comparison the average rate in North America and western Europe is fewer than 25 deaths per 1,000 live births. These figures are national averages, and one would expect the rates in particular localities to be much higher. For example, in a recent year the infant mortality rate in the state of Alagoas in northeastern Brazil was 266.9. On the whole, infant mortality is higher in African countries than it is in most Asian countries. What may be surprising is that the rate in many Latin-American countries is higher than it is in Asian countries; Chile, Ecuador, Peru and Guatemala, all with rates close to 100, are the outstanding examples.

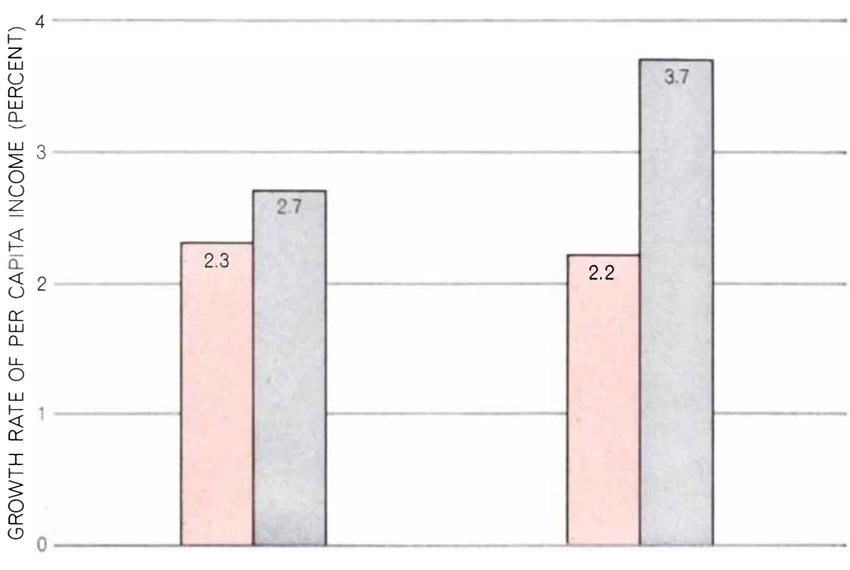
Another indication of the extent of poverty in a country is the number of inhabitants per physician. Whereas Indonesia and all the African countries except those in the north have more than 30,000 inhabitants per physician, South, East and West Asia have 6,000 people or fewer for each physician. The differences between individual countries are great: in thousands of population per physician Upper Volta has 63, Niger 65, Ethiopia 69 and Rwanda 97; yet countries with only slightly higher levels of per capita income, such as Burma, Pakistan, India and South Korea, have figures of 11.7, 6.2, 5.8 and 2.7 respectively. With the exception of Haiti all the Latin-American countries have rates lower than 5.2, and the rates of most of them are less than 3.0, as are those of North America and Europe. This indicator thus underlines the impression created by the others, namely that the impoverished countries of Africa are worse off than their Asian counterparts, and that the impoverished Latin-American countries are in general much better off than their Asian counterparts.

Let us now consider one other measure of poverty: nutrition. If there is one form of deprivation in the interdependent pattern of poverty that could be described as fundamental, it is the deprivation of food. Hunger weakens an individual's resistance to disease, lowering his ability to perform work, and therefore his ability to provide himself and his family with food for the future. The most widespread nutritional diseases arise from the lack of calories and the lack of protein. Whereas calorie deficiency (undernutrition) is due to an insufficient quantity of food, protein deficiency (a form of malnutrition) reflects the inadequate quality of a diet. Since proteins are one source of calories (the others are fats and cereals), a diet that contains enough proteins is also likely to provide enough calories. The reverse is not true. Calorie deficiency, then, is much less common than protein deficiency but much more serious.

Since calorie deficiency is precisely measurable, at least in principle, and also the mark of sustained deprivation of food, it is potentially a good indicator of the existence of serious poverty. A deficiency of calories, however, means a shortage of supply in relation to requirement, and in the measurement of both supply and requirement there are ambiguities. During the several stages between the production of food in the poorer countries and its consumption by an individual there is wastage varying from 20 to 50 percent of the calorie content. The estimate of calorie supply therefore depends on the stage at which the estimate has been made, and on the allowance that has been made for losses at later stages. On the other hand, the definition of the number of calories required varies according to the weight, sex, age and other characteristics of the individual, including the intensity of his activity and the climate in which he is working. Even the standard requirement for a reference individual, worked out by the Food and Agriculture Organization (FAO), has been revised (downward) over the years (inspiring the remark that physiology is "even more inexact a science than economics").

In spite of these recognized difficulties, the FAO has estimated calorie supplies by country and calorie requirements by region, and these data upset the hierarchy of poverty established by the previous indicators. They show the lowest-calorie regions to be not in Africa but in Asia and in parts of Latin America. Almost 1.8 billion people live in the calorie-deficient regions and 1.6 billion of these people are in Asia. As we shall see, this does not mean that so large a number of people are suffering from undernutrition, nor does it mean that we can ignore the possibility of undernutrition in the calorie-surplus regions. In order to reach an estimate of the number of people who are suffering from calorie deficiency, one must first know something about the distribution of calories within countries.

The problem of the distribution of food within a country has a space dimension and a time dimension. The movement of food from the food-surplus regions of a country to the food-deficit regions may be restricted by lack of



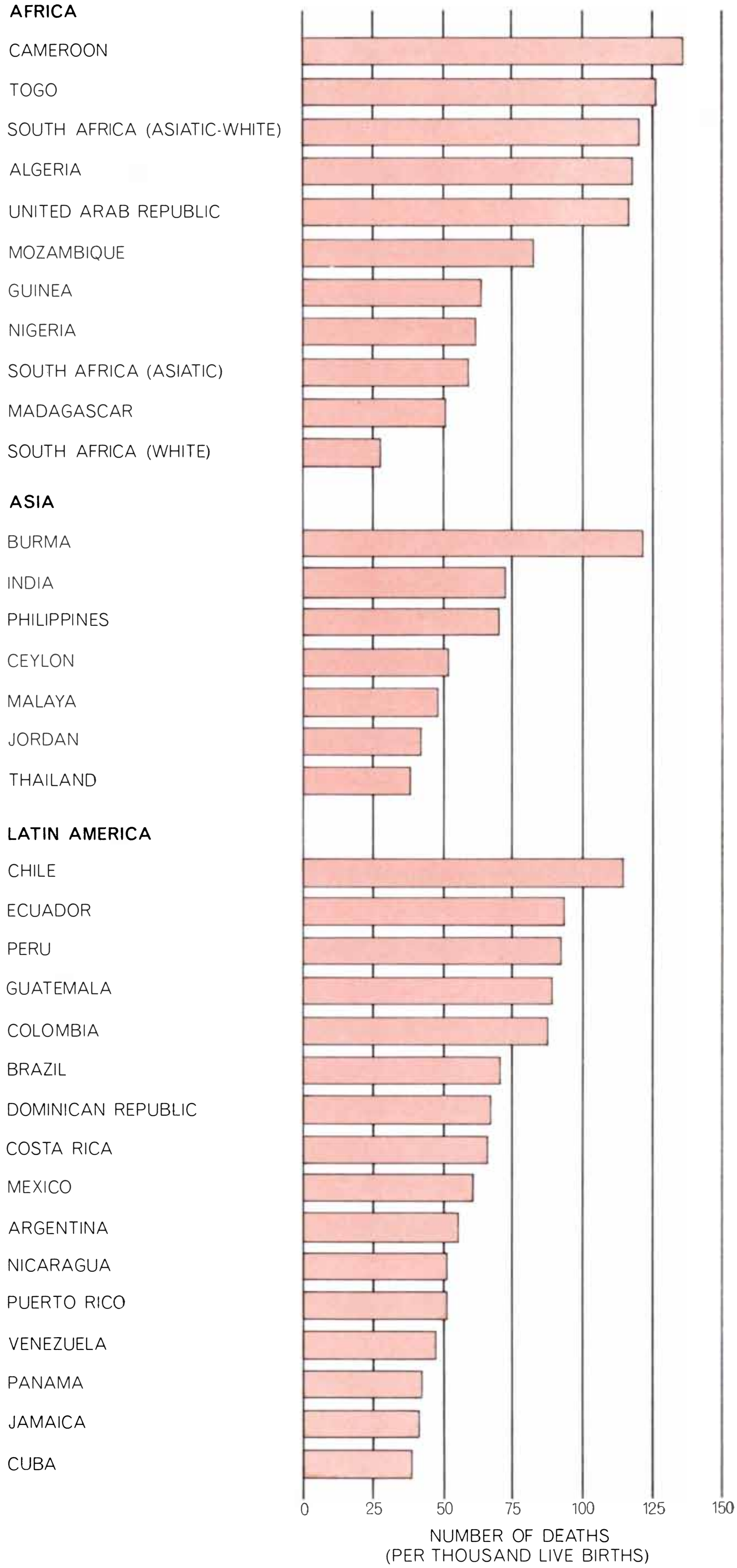
DIFFERENTIAL INCOME GROWTH indicates a widening economic gap between the poorer countries of the world (*color*) and the richer countries (*gray*). The average per capita income of the poorer nations actually grew somewhat more rapidly during the 1950's (*left*) than from 1960 to 1964 (*right*). Constant prices were used in estimating income growth.

transportation facilities, by political difficulties or both. Within regions the distribution of food is obviously limited by the distribution of purchasing power; even if a distribution to households in proportion to each household's needs were somehow ensured, there is no guarantee of an appropriate distribution within the household. Indeed, in many impoverished societies custom dictates that those who require the most calories (women of childbearing age, children aged one to four and adolescents) receive less than their requirement and the adult male receives more than his requirement.

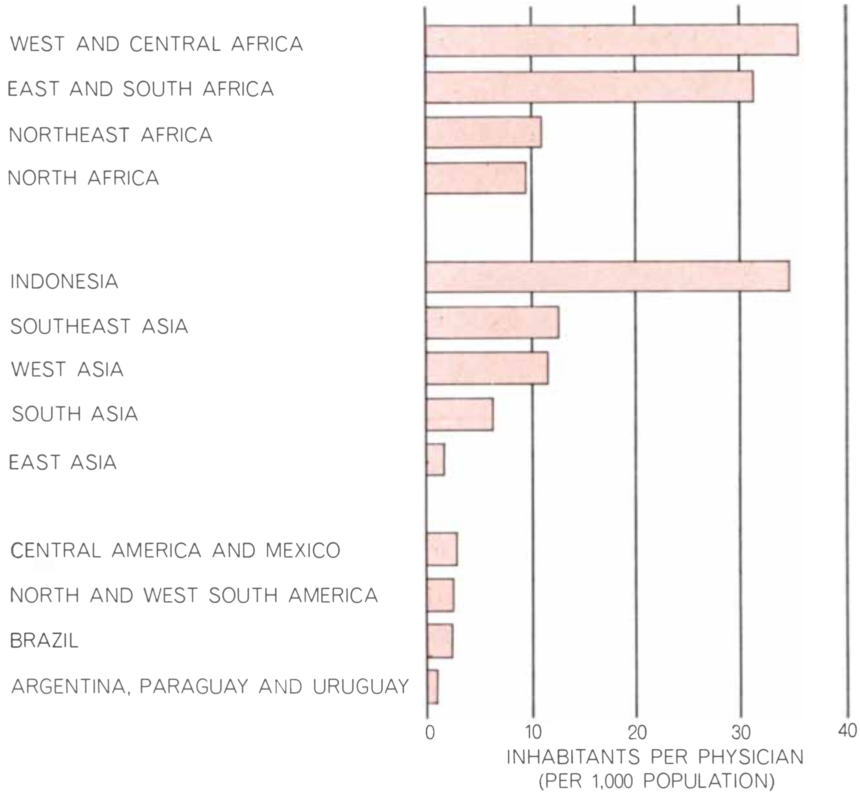
An unequal distribution of calories over a period of time arises from inadequate methods of storage, so that the "hungry months" before harvest are a familiar feature of poor societies. Again, a harvest may fail in one year, or a succession of years, leading to a temporary drop in the food supply below the level of requirements. The availability of food grains in India is estimated to have fallen from 19 ounces per head per day in 1965 to 16.5 in 1966.

Putting together the results of household-diet surveys of India, Pakistan, Ceylon and Burma, and certain hypothetical distributions of calorie requirements for these countries, P. V. Sukhatme made a pioneering estimate of the numbers of people in the world who suffer from calorie deficiency. He put the total figure at between 300 and 500 million. It is important to emphasize that these figures refer only to the numbers suffering from undernutrition as distinct from protein deficiency. Sukhatme estimates the number of the latter to be between a third and half of the world's population.

Where are the 300 million or more people in the world who are undernourished? For the reasons given above, their number and location vary from year to year as circumstances change. Nonetheless, one can use such indicators as child mortality (age one to four years), not to be confused with infant mortality (from birth to one year), and crop yields



INFANT DEATH RATES (birth to one year) reflect social and economic conditions and thus are an index of poverty. The average rate in North America and western Europe is fewer than 25 deaths per 1,000 live births. Rates for Algeria, Brazil, Burma and Nigeria refer only to towns. The death rate of Bantu infants in South Africa is not known.



PROPORTION OF PHYSICIANS in a population also indicates the level of poverty. In this breakdown rich countries are omitted, as are China, Ghana, North Korea, North Vietnam, Somalia, South Yemen, Yemen and part of Rhodesia. There are fewer than 1,000 people per physician in Australia, Europe, New Zealand, North America and the U.S.S.R.

per acre to identify some of the more critical areas. Child-mortality rates are particularly sensitive to protein and calorie deficiency.

Any estimate of the total number and distribution of the underfed in the world must lean heavily on the assumptions that are made about China, a country for which little reliable information has been available for the past 10 years. Sukhatme estimated that 20 percent of the population of China (some 140 million people) were undernourished, but this fraction appears rather high if one considers food production in China in 1965. The total cereal production per head of population appears to have been almost 50 percent higher in China than in India in that year, and one also expects there to be a more equal distribution of food in China. For these reasons it would seem unrealistic to suggest that more than 100 million people are undernourished in China, and the true figure might be nearer 50 million.

There is no reason to doubt Sukhatme's estimate that 25 percent of the population of India and Pakistan is underfed. A careful nutrition survey of East Pakistan recently carried out by the Office of International Research of the U.S. National Institutes of Health discovered that "46 percent of the households studied had an inadequate calorie intake." Hence India and Pakistan together could account for between 100 to 150 million of the undernourished of the world. Indonesia, where Java is a critical area, might provide about 20 million more people, and the rest of Asia—East, Southeast and West—perhaps another 20 million. In Africa there may be about 40 million underfed people. West Africa and Ethiopia are the most serious areas, although the high child-mortality rate in West Africa may reflect a deficiency of protein rather than of calories. In Latin America the hungriest areas would appear to be in Guatemala, Honduras, Bolivia and Ecuador and in northeastern Brazil. Taken together, these areas could account for the remaining 20 million people.

The evidence we have reviewed suggests that hunger is primarily an Asian problem, and that more than two-thirds of the people in the world who are undernourished are to be found in four countries: India, Pakistan, China and Indonesia. On the other hand, material poverty and health conditions appear to be worse in African countries. As we have seen, 17 countries, representing more than half the population of Africa, are in the very lowest income range. All the indicators suggest that, with the exception of one or two countries or areas within countries, Latin America is much better off than either of the other two continents.

It would be inappropriate to conclude this review of world poverty without commenting on the prospects for its alleviation. What can be done?

If we take hunger as the most urgent form of poverty, then the prospects of achieving a solution range from the euphoric to the cataclysmic. The difference between the two extreme views—that there is a world food surplus and that famine is just around the corner—turns on the question of distribution. The world's calorie supply slightly exceeds the world's calorie requirement. Given the continuation of present trends in food production, a worldwide food shortage is improbable. In this sense it is true to say that there is a world food surplus. This fact, however, is of little comfort to the low-calorie countries if their rate of food production cannot keep pace with their food requirements, and if balance-of-payment considerations place a limit on the amount of food they can import from the high-calorie countries. Similarly, a country's total food production may be growing fast enough to meet total requirements, but maldistribution may mean that grave food shortages can be expected in certain regions. In many respects the food problem is really a distribution problem rather than a production problem. Nonetheless, it may be easier to achieve increases in production than improvements in distribution.

It would be fair to say of the national and international plans designed to increase food production in the low-calorie countries that they have concentrated on long-run solutions. This is so because it is recognized that a significant increase in agricultural production presupposes changes in habits and attitudes, which can seldom be altered rapidly. The production of food in these countries is not expected to match their nutritional requirements for 15 to 25 years. The programs to control the growth of populations must also be classed as long-run solutions. It has been estimated that even if current birth-control programs are extremely successful, the overall food requirements of the low-calorie countries in 1985 will be at most 11 percent lower.

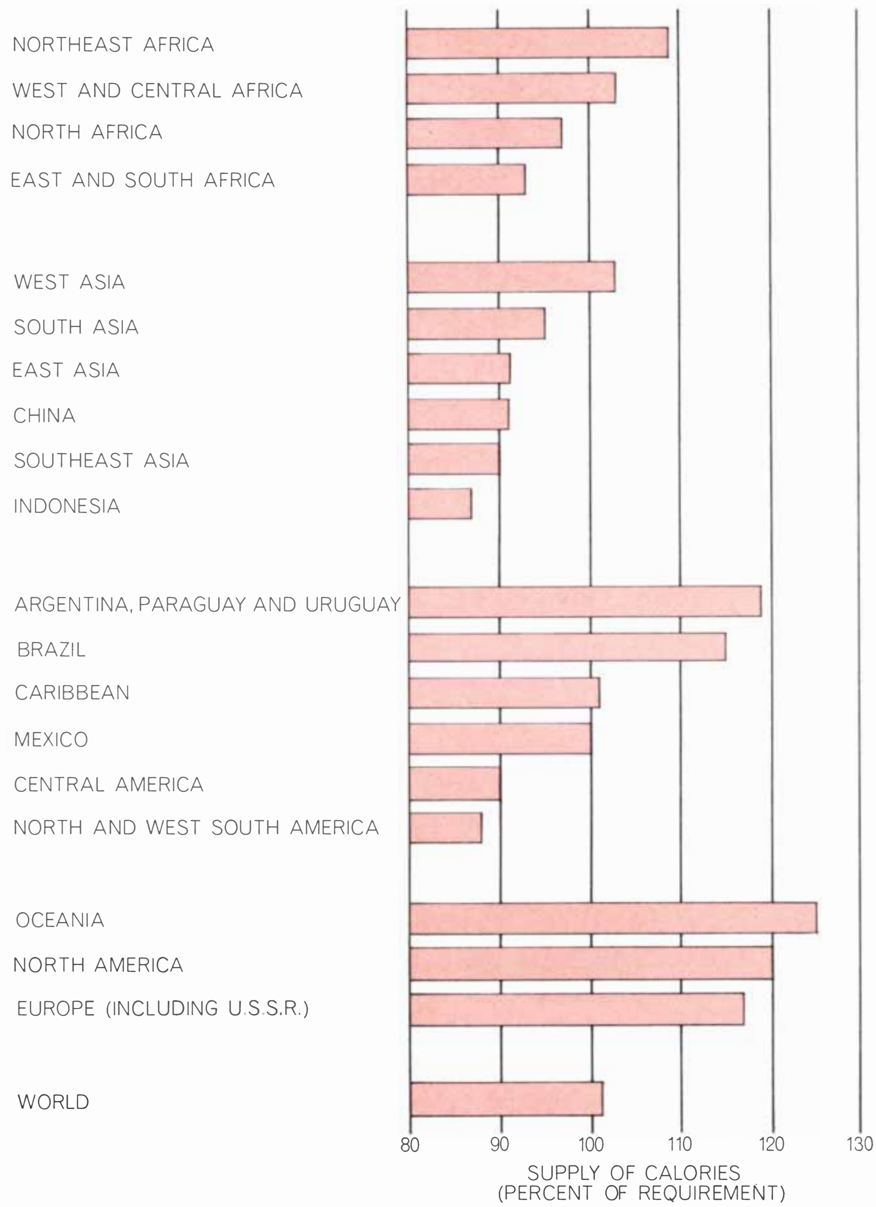
Nor do official plans usually provide for any change in the present distribution pattern of food supplies. Yet in the absence of any deliberate policy of redistribution it is clear that still larger total supplies would be necessary to ensure nutritionally adequate diets to major sections of the population. V. M. Dandekar goes so far as to suggest that in India the average daily intake of calories would have to be 3,000 or more if "the usual inequalities in the distribution of essential food supplies among individuals are to be allowed for." For most of the low-calorie countries the achievement of such an average level of calorie intake is much more than 20 years away.

Thus according to current development plans there appears to be no prospect of a solution to the problem of hunger for 20 years at the very least. Given the resources that are at the disposal of the rich countries, it seems quite unreasonable to condemn at least 300 million people to wait 20 years for their hunger to be satisfied. What is required to complement the long-run development strategy is a short-term program to alleviate the most extreme cases of hunger and other forms of poverty. Such a program might include three features: first, surveys of the health and nutritional status of the populations in the poorest areas of the world to establish priorities and requirements; second, food given to women and children either at schools or clinics (or both) in exchange for their attendance at instruction on elementary points of nutrition and hygiene; third, food given to men in exchange for work on projects yielding some immediate and visible return, such as improving the supply and distribution of water.

Such a program could not be more than a holding operation, but it would have two clear advantages. By feeding those who normally have the least food in relation to their needs (women and children), it would reduce the long-run food production requirement, because fewer calories would be needed to lift the lower end of the population distribution free from the level of undernutrition. Furthermore, a program of this kind would be less likely to encounter the current political resistance to transfer of resources from the rich countries to the poor ones. From the point of view of the donor country each unit of aid would have visible and immediate results; from the recipient country's point of view there would be no interference in its long-run development strategy.

There are of course many organizations, both official and voluntary, that already carry out functions such as those I have proposed. These activities are, however, only a drop in an ocean of need. The major objection to giving these proposals a systematic basis is the problem of administration: one recoils instinctively at the prospect of still another international-aid bureaucracy, yet some administration is essential to organize the transport and distribution of food and medicine. One possible solution might be to use the most effective organization already existing in each country; in many countries this might be the armed forces.

A further objection is that such a scheme would never work because of its low political priority: in the areas of serious poverty people are literally too weak to protest. Unless some such scheme is put into effect, however, there seems to be little prospect of making any reduction in the number of people suffering from serious poverty in the world during the next 20 years.



CALORIE PROVISIONS, in proportion to need, are another rough indicator of poverty (but one that does not tell how calories are distributed within a population). Almost 1.8 billion people live in calorie-deficient countries, 1.6 billion of these people in Asia. Oceania is chiefly Australia and New Zealand. Regions of Africa and Asia do not include rich countries.

STRONG AND DUCTILE STEELS

Traditionally the price paid for strength in steel alloys was brittleness. Deeper knowledge of the behavior of solids has led to a class of alloys much tougher than any previously known

by Earl R. Parker and Victor F. Zackay

Strong materials are normally brittle, and strong steels have been no exception. Commercial steels are strong when they are brittle and comparatively weak when they are ductile. Within the past few years, however, advances in the basic understanding of solids have led to the development of a new class of high-strength steel alloys that are unusually ductile. These alloys are the "trip" steels, "trip" standing for "transformation-induced plasticity."

The new steels are a tangible result of undertaking to answer the question: Can hard steels ever be made tough and ductile? Most earlier attempts to answer the question did not lead to encouraging results, perhaps because until recently too little was known about the basic phenomena that control strength and ductility. As knowledge of these phenomena has advanced during the past two decades, it has gradually become possible to apply quantitative theory to analyze the behavior of solids as their internal structure is varied in controlled ways.

One of the properties of materials that are of greatest concern to engineers and scientists concerned with materials is fracture. The scope of fracture problems is wide, ranging from catastrophic failures of bridges, tanks, pipelines and machine parts to basic considerations such as how atoms become separated when single crystals of a metal are broken. Both calculations and experiments have shown that the metals used by engineers should be about 10 times stronger than the engineer actually finds they are. The hope of achieving this strength in technically useful materials seemed remote, however, because experience had also shown that when materials are made stronger by alloying and processing treatments, they become more brittle and consequently less useful in engineering structures.

Several fundamental questions thus presented themselves: Why do materials become brittle when they become stronger? Can something be done to double or triple the load-carrying capacity of practical materials without their becoming too brittle for safe use in structures? Although questions of this kind have by no means been fully answered, advances are certain to be made by the application of the basic knowledge that has been accumulated on the flow and fracture of materials. The story of trip steels is an example of the kind of investigation that is helping to reveal and define the upper boundaries of strength and ductility that practical materials may reasonably be expected to reach within the next decade.

Steels were selected as a research material for a number of reasons. They are the cheapest and most commonly used metallic materials. Moreover, they are among the most versatile. Steels are iron alloys containing carbon and often other elements such as nickel, chromium and molybdenum. The crystal structure of iron can change within a convenient temperature range. At moderate temperatures the iron atoms are packed in a body-centered cubic array; at high temperatures they are rearranged into a face-centered cubic packing [*see top illustration on page 38*].

The atoms of carbon that harden steel are small enough to fit into the interstices between the iron atoms in the face-centered cubic structure but are much too big to fit into the spaces when the structure becomes body-centered cubic. As a result carbon dissolves in iron at high temperatures but precipitates out of the metal at low temperatures. As the carbon precipitates out of the iron during cooling or subsequent treatment, it does so not as elemental carbon but as a carbide of iron (Fe_3C). This compound is both hard and strong. When it precipitates, it prevents the planes of atoms in iron from sliding freely over one another as they normally do when the carbon is absent.

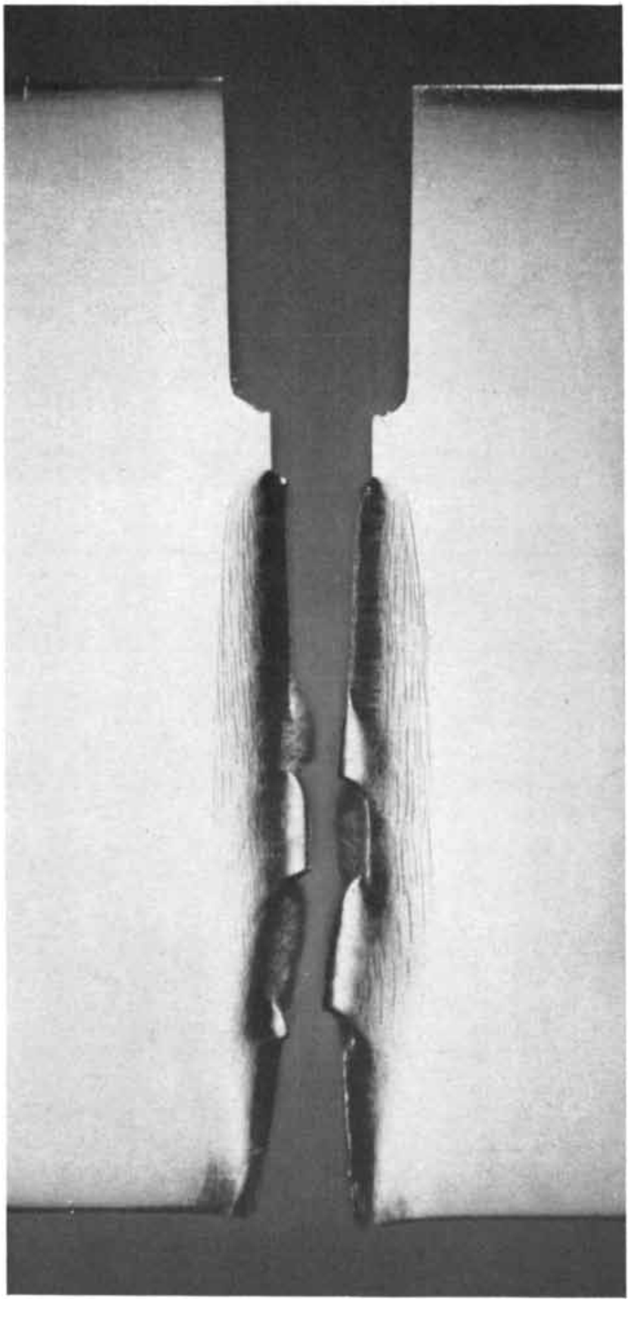
By adjusting the composition to control the amount of carbide in the steel, and by controlling heat treatment to produce the desired fineness of the precipitated particles, the hardness and strength of the steel can be varied by a factor of four or five. Increased strength, however, was always accompanied by a loss of ductility. The problem we set ourselves was to find out, if we could, why steels become less ductile as their strength is increased, and if this could be achieved, to discover what could be done to enhance the ductility of high-strength steels.

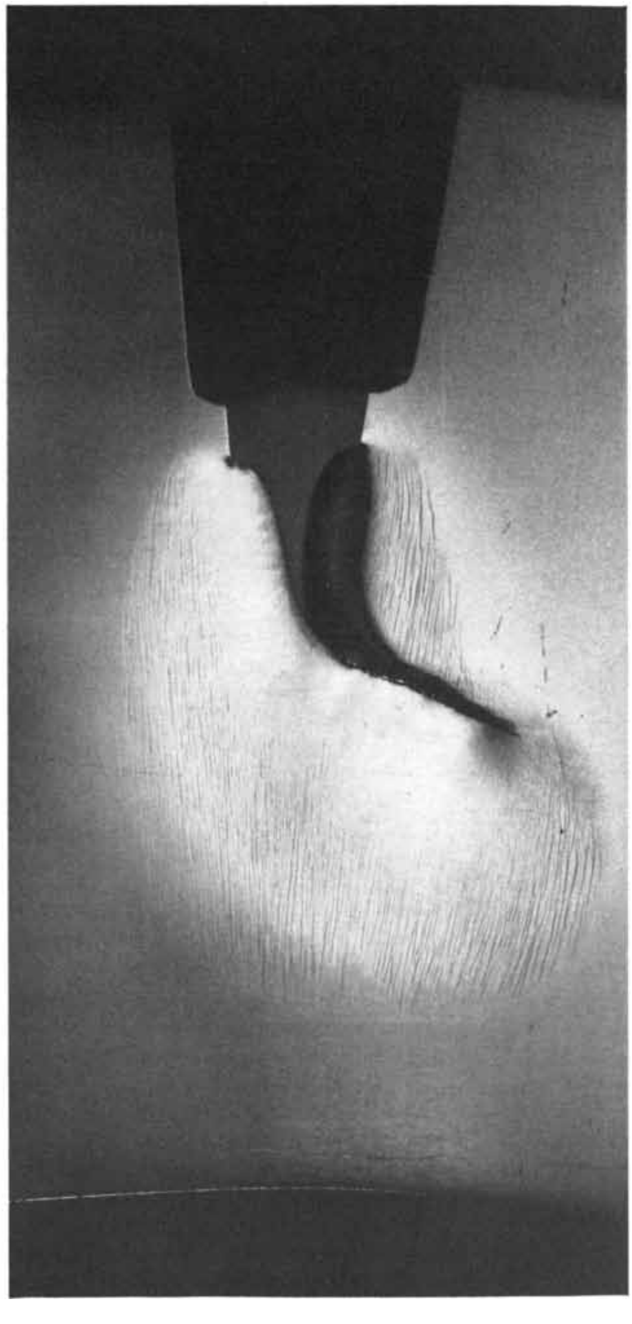
In evaluating the tensile strength and ductility of steels engineers commonly plot "yield strength" against the elongation of steel test bars that have been pulled apart [*see bottom illustrations on page 38*]. The yield strength is a measure of the useful load-carrying ability of the material. It is equal to the number of pounds of load that would be required to permanently stretch a bar with a cross-sectional area of one square inch by a small amount (usually .2 percent of its original length). The units of yield strength are pounds per square inch.

The elongation is a measure of ductility, in this case how much a bar can be stretched before it finally breaks. It is determined by actually breaking the bar by pulling it apart in a special testing machine and then measuring the separation that has occurred between two points located exactly two inches apart on the original bar. As the bar stretches the two points move apart. The amount by which they have moved, divided by the original distance between them, is the elongation (generally expressed as a percentage).

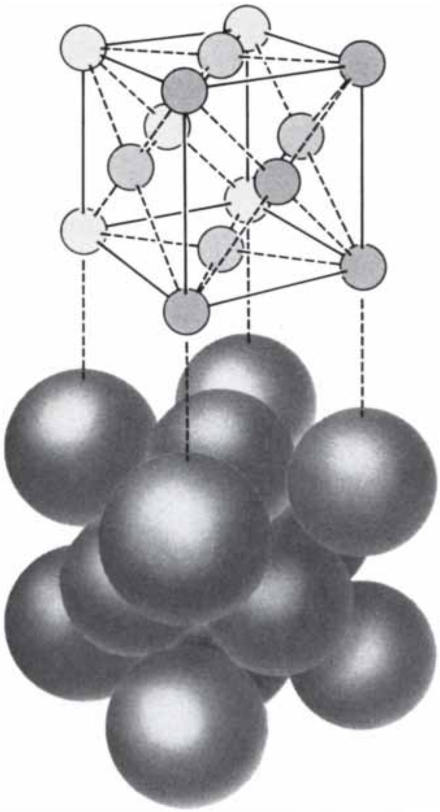
When the strength of steel is increased by alloying and heat treatment, the ductility decreases continuously with increasing strength. Conservative engineers are generally reluctant to use materials that have elongation values as low as 10 percent, because there have been a number of cases where such materials have failed in unexpected ways. Hence the practical upper limit of the yield strength of steels is some 200,000 pounds per square inch.

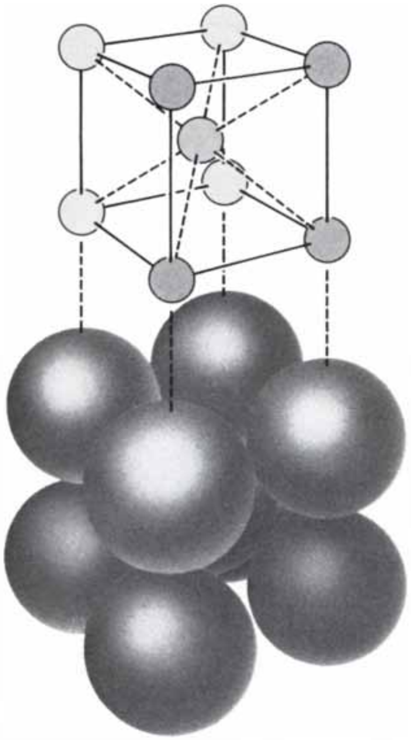
Metallurgists for a long time tried to estimate the upper limit of ductility, a property that is highly sensitive to changes in internal structure. It turns out that the mathematical theory known as continuum mechanics provides a more useful approach to the problem than a theory based on atomic bonding and crystal structure. Continuum mechanics, which can be applied to any homogeneous material whose properties are the same in all directions, can be used to predict the bulk behavior of steels and other metals. The ductile behavior of metals is determined primarily by microstructure rather than by structure at the atomic level. By microstructure is meant those internal structural features that can be seen with a light microscope at magnifications ranging from 100 diameters to a few thousand.



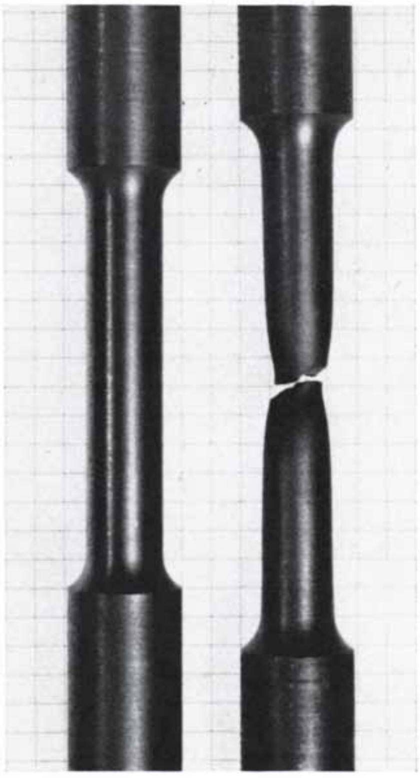


BRITTLE AND TOUGH STEELS, both of roughly the same yield strength, behave very differently when notched and placed under stress. A strong commercial steel yields very little, then breaks brittly (*left*). One of the tough new steels developed in the authors' laboratory tears under the same conditions (*right*). Toughness is produced by the plastic zone that forms ahead of the crack.

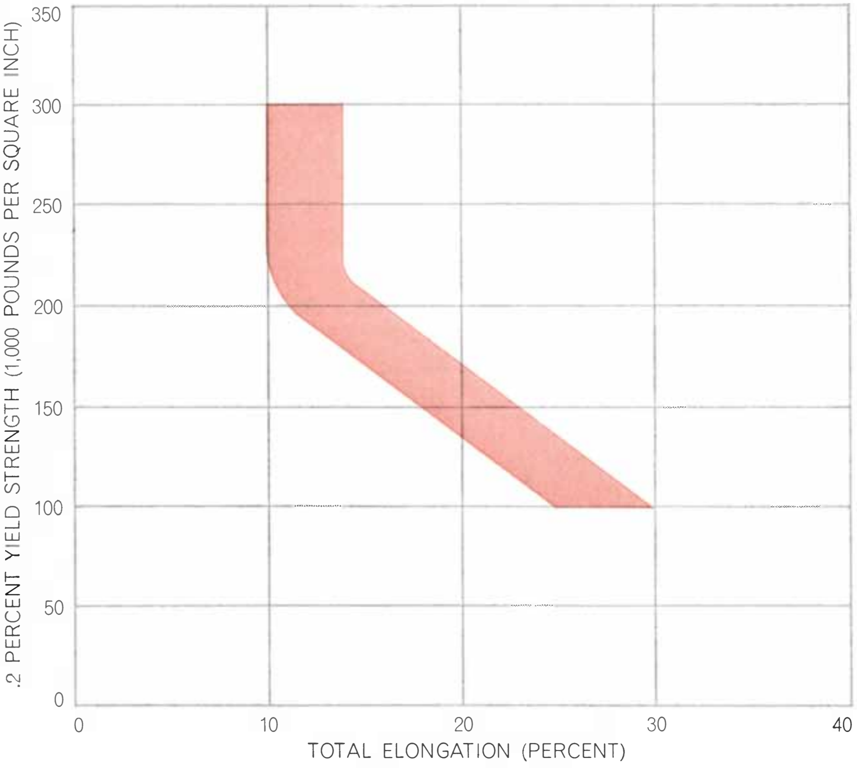




IRON ATOMS IN STEEL can exist in two possible arrangements. At temperatures in the red-heat range (910 to 1,400 degrees Celsius) the stable configuration is a face-centered cubic lattice (*left*). At room temperature the stable form is a body-centered cubic lattice (*right*). Carbon atoms can dissolve in iron at high temperatures because the face-centered packing is looser than the body-centered.



TEST BARS used to measure strength and ductility of steel specimens have been stretched by a large machine. A "neck" forms just before the final fracture occurs.



STRENGTH AND DUCTILITY of commercial high-strength steels fall within the colored band. Yield strength is the load needed to produce a permanent change of .2 percent in the length of a bar one inch in cross section. Elongation is a measure of ductility, usually expressed in percent. It is the amount that a two-inch length of bar stretches before it breaks.

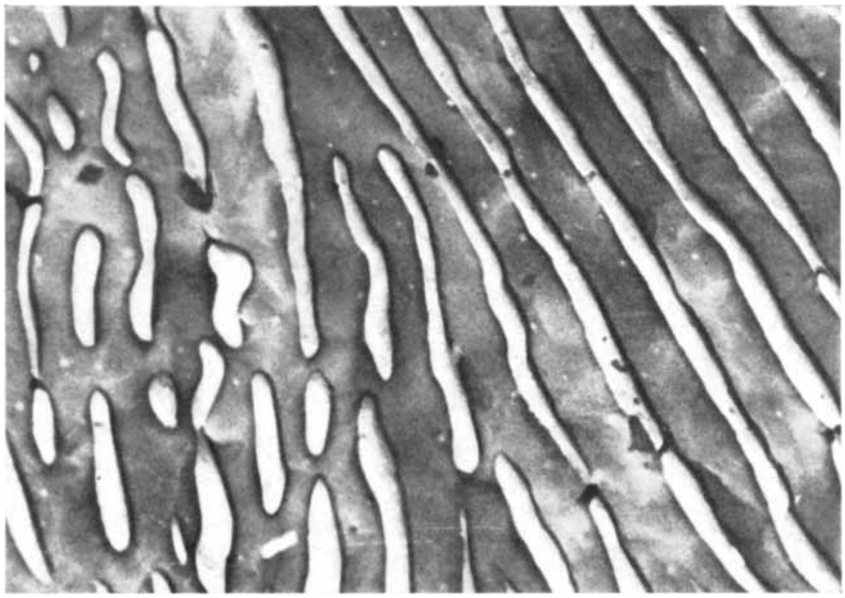
Examples of such microstructures are provided by the photomicrographs on this page, which show iron containing iron carbide particles. In one case the carbide is in the form of plates, which appear as lines in the micrograph. In the other case the carbide is in the form of spheroidal particles. The same steel can have either microstructure, depending on how it is heat-treated. Slow cooling from a high temperature produces the platelike structure. The spheres are produced by fast quenching followed by reheating.

Iron carbide is an intermetallic compound, and such compounds are characteristically strong but brittle. Therefore when steel containing carbide plates is stretched or bent, the plates crack. With continuous stretching the multitude of microscopic cracks causes the ductile iron between the carbide plates to tear in much the same way that perforated paper tears between the holes, and the metal breaks with limited ductility. The same material, however, can be made tough and ductile by changing the shape of the carbide particles into spheres. The shape of brittle particles has important effects, as one can sense by considering the behavior of glass. A small sphere of glass—a marble, say—can be dropped onto a concrete sidewalk from a height of several feet and it will rebound without breaking, whereas the same amount of glass in the form of a thin sheet would shatter.

Control of microstructure can thus be used to provide a partial answer to the control of ductility. This has been known for many years. All the high-strength steels with the properties plotted in the bottom illustration at the right on the opposite page were heat-treated to produce spheroidal carbide particles. The size of the particles and their total volume controlled the yield strength. The presence of other alloying elements such as nickel, chromium and molybdenum (added for other purposes) has essentially no effect on the curve of yield strength plotted against elongation. Accordingly all commercial steels that are heat-treated to produce the same microstructures have properties that fall within a narrow range.

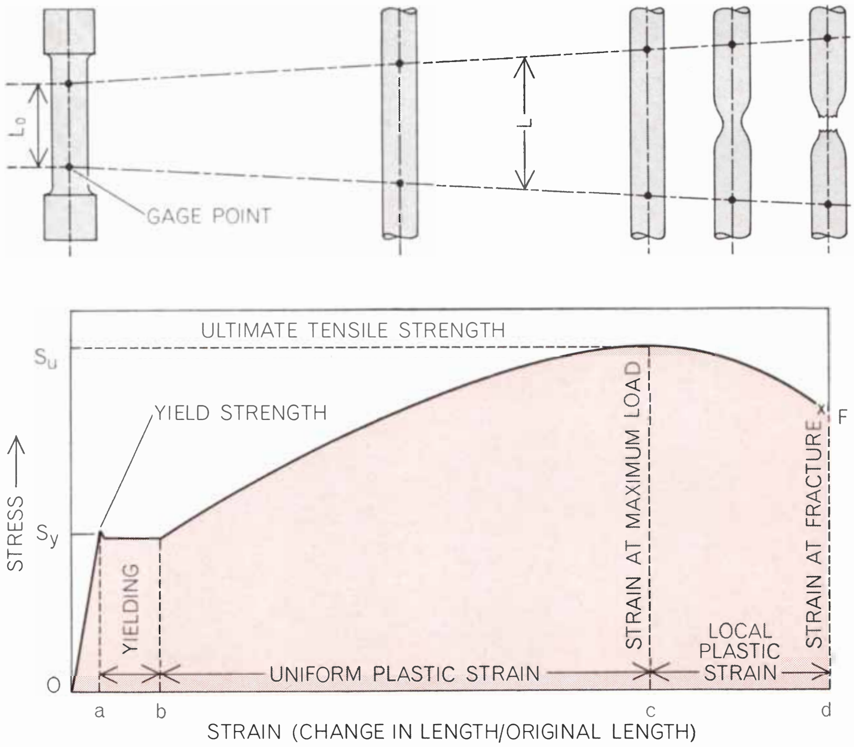
It might therefore seem that little could be done to change the relation between yield strength and elongation. Closer examination of the matter reveals, however, that ductility measured by elongation is somewhat misleading. When a test bar is stretched to the breaking point, it does not stretch uniformly throughout the two-inch length used for measuring elongation. In fact, the deformation is highly nonuniform. To analyze this nonuniform behavior one must again make use of continuum mechanics.

Let us take a closer look at the changing shape of a metal bar as it is gradually pulled apart [*see top illustration on next page*]. The shape of the bar changes as it is loaded; the corresponding stress-strain curve rises to a maximum and then turns down. The load level is given by the nominal stress, which is the load applied to the bar divided by the original cross-sectional area of the

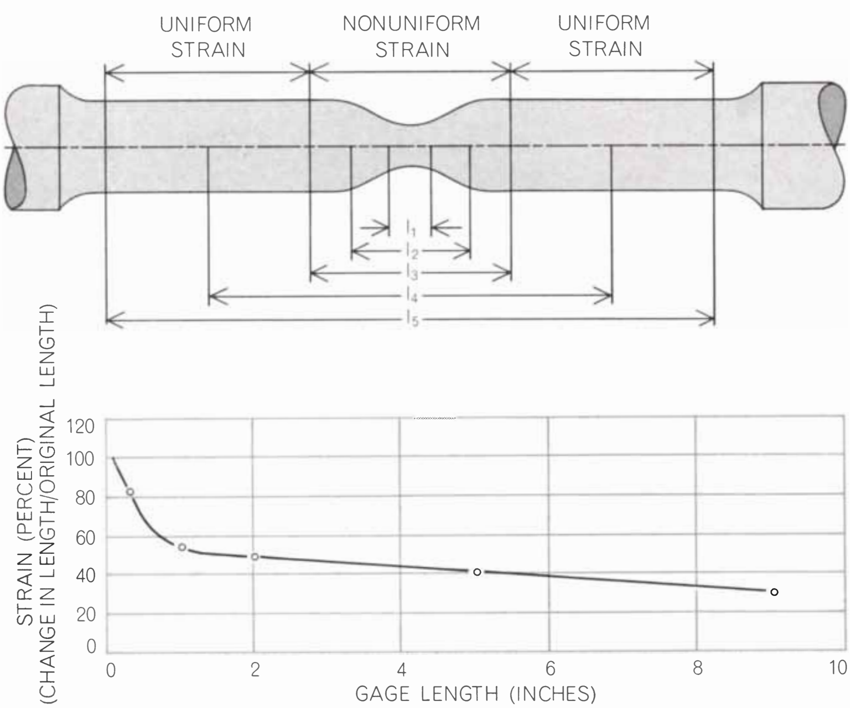


IRON CARBIDE PLATES appear as parallel rods in a micrograph of steel that has been cooled slowly from red heat. Slow cooling produces a platelike structure in which layers of iron (*darker areas*) alternate with layers of iron carbide (Fe_3C). Before cooling the carbon atoms were dissolved in the iron. Iron carbide is strong but brittle. Thus steels that contain plates of iron carbide tend to crack readily if the steel is bent. The polished surface of the specimen has been lightly etched with acid. The magnification is about 2,000 diameters.

SPHEROIDAL PARTICLES OF IRON CARBIDE appear in a sample of steel that has been quenched rapidly in cold water and then reheated to 300 to 400 degrees C. The carbon in solution at high temperatures does not have time to precipitate during quenching but remains in supersaturated solution. Reheating allows the carbon to migrate through the iron and to precipitate as rounded particles of iron carbide. Spheroidal particles of iron carbide resist cracking and produce a steel that is much tougher than one containing carbide plates.



STRESS-STRAIN CURVE summarizes important properties of steel. To obtain such a curve the load on a test bar (*top*) is gradually increased until it breaks. Stress is the applied load divided by the original cross-sectional area of the bar. Strain is the change in length divided by the original length between two gage points, commonly two inches. Initially the metal is elastic and there is a linear relation between stress and strain. At the yield point planes of atoms begin sliding past one another, so that the change in length becomes permanent. This plastic flow produces "strain-hardening," which continues until the maximum stress is reached. A neck then forms in the specimen and fracture occurs soon thereafter.



STRAIN AT FRACTURE depends on the initial gage length selected and so does not accurately reflect the plastic behavior of a steel specimen. The curve shows how the strain at fracture varies when the elongation is measured over different initial gage lengths. The shorter the gage length, the greater the elongation and the greater the strain at fracture.

bar. The strain is determined by dividing the increase in distance between the points that mark the two-inch gage length by the original two-inch length.

Several significant properties of the metal are revealed by the stress-strain curve. The first is the elasticity of the material, which is shown by the straight line rising steeply from the origin to the yield point. At this stage of loading the material is elastic, and if the load is removed, the bar will return to its original shape. Beyond the yield point, however, permanent stretching (called plastic strain) occurs. As the load is increased above the yield point, the material actually becomes stronger. The curve rises rapidly with increased strain until it has reached a maximum stress called the ultimate tensile strength.

The phenomenon of increasing strength with increasing strain is called strain-hardening. (We shall need to consider this phenomenon again, because the rate at which a metal strain hardens has a controlling influence on the elongation and toughness of high-strength steels.) Beyond the ultimate tensile strength the curve drops off rapidly, and soon the bar breaks. During this last stage of plastic flow the bar no longer stretches uniformly but forms a comparatively narrow neck. Plastic flow becomes localized in a small region of the bar where the cross-sectional area is becoming smaller. Fracture finally occurs across the section with the minimum area.

Why does uniform elongation cease and necking down begin? Continuum mechanics answers this question. As the load increases, the bar stretches and its cross-sectional area becomes smaller. Plastic flow does not, however, occur uniformly along the length of the bar. Some particular small element of length stretches first. The actual stress on this small element is therefore higher than it is on the unstretched areas. The bar would quickly fail in the first element that had stretched if it were not for the fact that, by virtue of stretching, this little element had become substantially stronger.

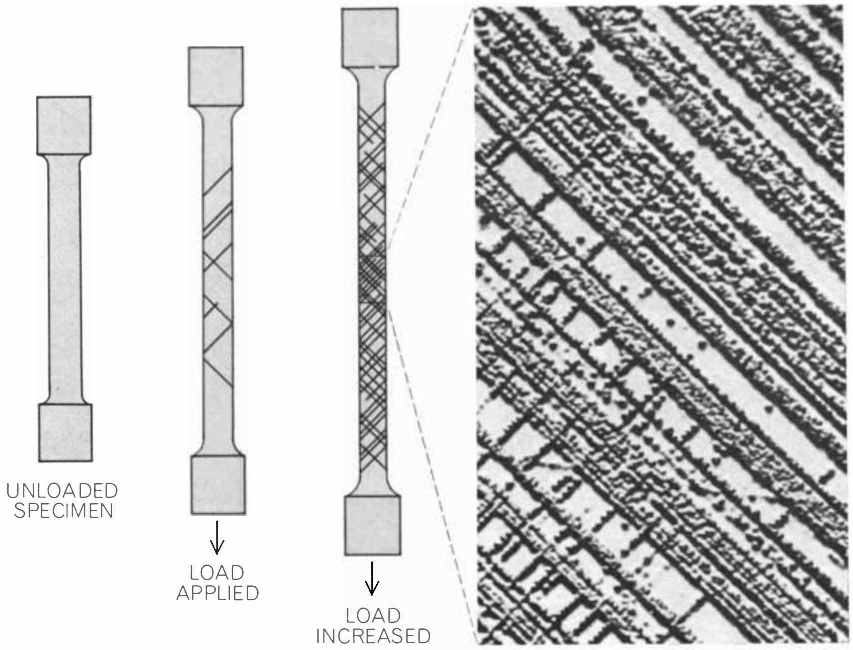
At stresses below the ultimate tensile strength the strain-hardening rate is so high that the elastic limit is raised in the stretched portions above the imposed stress level and plastic flow stops. Plastic flow will not start again in the deformed element until all elements along the length of the bar have been stretched an equal amount. When the load is raised, plastic flow will again occur in the original element, and the process is repeated. The bar will stretch uniformly throughout its length because of the high strain-hardening rate that holds during the early stages of straining. As loading continues, however, the strain-hardening rate decreases until finally, at the ultimate strength of the material, the rate becomes too low to produce an increase in strength sufficient to compensate for the reduction in cross-sectional area. Necking down then begins. The maximum stress has been reached and thereafter the stress decreases with increasing strain.

When we reexamine the term "elongation" as it is customarily used by engineers, we find that it has no basic physical meaning. It is not a material constant but an arbitrary figure used as an empirical relative measure of ductility. If the gage length had not been arbitrarily selected as two inches, a different value would have resulted for the measured elongation. For example, the bottom illustration at the left on the opposite page shows that a bar with an elongation of 47 percent in a two-inch gage length has an elongation of only 30 percent in an eight-inch gage length, or one of 80 percent in a half-inch gage length. We can conclude that the low elongation (about 10 percent) stated above as being typical of high-strength steels does not accurately reflect the potential of the material for plastic flow prior to fracture.

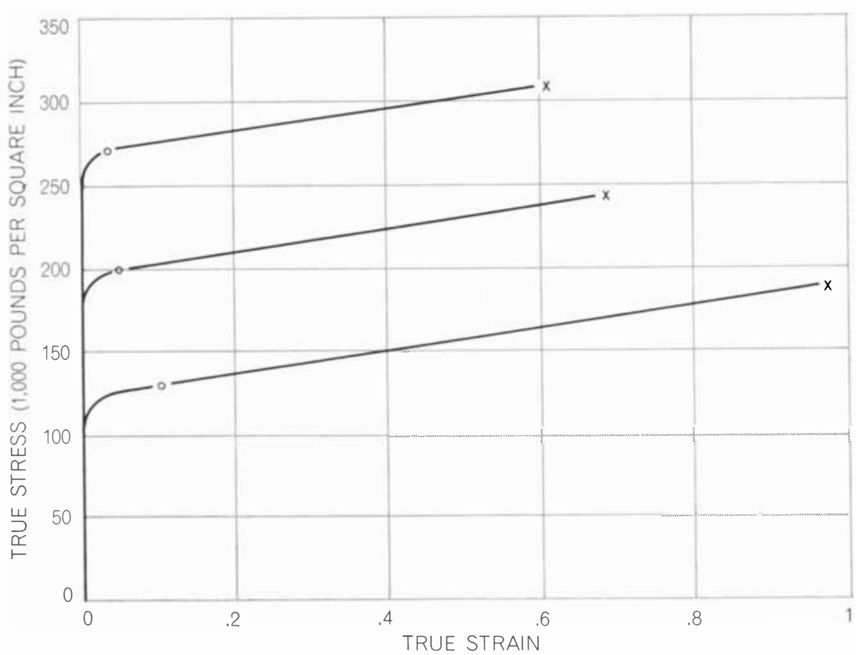
A far better indicator of the material's potential can be obtained from a measure of how much the cross-sectional area of a bar decreases during the necking-down process and before fracture occurs. An examination of published data for high-strength steels shows that a large majority of those steels with yield strengths between 200,000 and 300,000 pounds per square inch have a reduction in cross-sectional area of 50 percent at the point of fracture. This corresponds to a local elongation of 100 percent. When the final area is only half of the original area and the volume remains constant, a short local element must become twice as long.

Thus we see that high-strength steels are in reality not brittle at all. They undergo extremely high strains before they fail, but only locally. The problem, then, is not how to make high-strength steel more ductile, because such steels are inherently highly ductile, but how to make such materials stretch uniformly as much as they stretch locally.

As we have seen, local straining occurs when the strain-hardening rate be-



PLASTIC FLOW occurs in steel test bars when planes of iron atoms slide past one another. The sliding takes place along planes that make angles of about 45 degrees to the axis of loading. Traces of the slip planes can be observed in micrographs of polished surfaces (*right*). Slip does not occur uniformly throughout the metal. Bands of slip planes move while large blocks of crystal remain unchanged. Plastic strain destroys the perfection of the crystal lattice, making additional slip either within the bands or across them more difficult. As new slipbands grow across a crystal they tend to stop when they meet bands previously created.



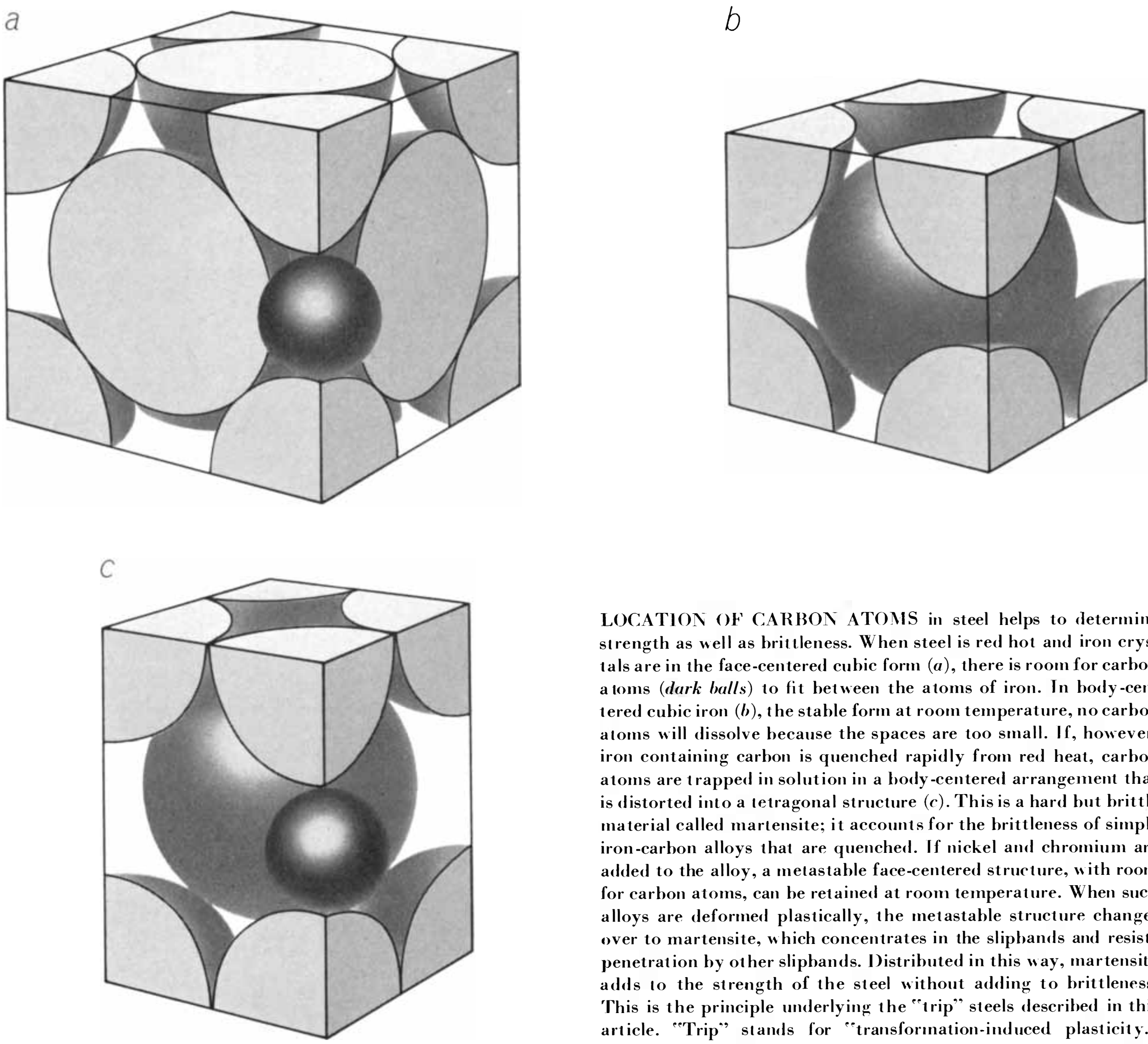
CURVES OF TRUE STRESS AND TRUE STRAIN provide a more accurate picture of steel performance than the engineering type of stress-strain curve (*see top illustration on opposite page*). The slope of a true-stress true-strain curve shows the strain-hardening rate. The true stress at any strain is the load divided by the actual minimum cross-sectional area; as the bar is stretched it becomes smaller in diameter. The corresponding true strain must take into account the elongation of the bar with strain. Thus the true strain is the integral of the incremental change in length divided by the length at each instant. The open circles show the onset of necking down; the X's signify fracture. In these curves slope does not reverse.

comes too low to strengthen the material at a rate greater than the rate at which the cross-sectional area is reduced by the plastic flow. To prevent necking down, and therefore to enhance ductility, we must discover how to increase the rate of strain-hardening above the rate provided by the natural processes that function within strained metal.

The normal strain-hardening processes that occur in metals are the result of defects that are introduced into the crystal lattice of the metal by plastic flow. To describe plastic flow briefly and in a somewhat simplified way, it is due to the fact that the flat planes of atoms in a crystal tend to slide over one another, much as the cards in a deck can be moved past one another. When a test bar of metal is stretched in tension, it becomes longer as the planes of atoms are forced to slide over one another. The sliding occurs along planes at 45 degrees to the loading axis, and since there are two 45-degree directions, two intersecting sets of slip planes come into play.

Plastic flow destroys the perfection of a crystal lattice, introducing local regions where there are either too many planes of atoms with respect to the surrounding lattice or too few. Planes of atoms slide over one another easily, however, only in highly perfect lattices. As plastic flow progresses the lattice in the slipped region becomes less perfect, until finally the slippage is so strongly resisted that it stops in that region. When the load is increased, plastic flow starts again, but only in regions of the crystal that had not previously slipped [*see top illustration on preceding page*]. When there are two or more sets of slipbands in a metal crystal, a newly formed slipband has difficulty crossing an existing one. Hence the metal is hardened by slip both along slipbands and across them. This is one of the more important phenomena contributing to strain-hardening.

The lattice defects generated by plastic flow effectively strengthen metals with low yield strength, but as the yield strength is enhanced by alloying and heat treatment these stratagems become less effective. High stresses can force blocked slipbands to break through the imperfect lattice in intersecting slipbands. Therefore in high-yield high-strength steels, although the normal strain-hardening processes function, they do not give rise to barriers with sufficient strength to prevent penetration by intersecting slipbands, and the strain-hardening rates are too low to prevent necking down at low strains. Expressed more



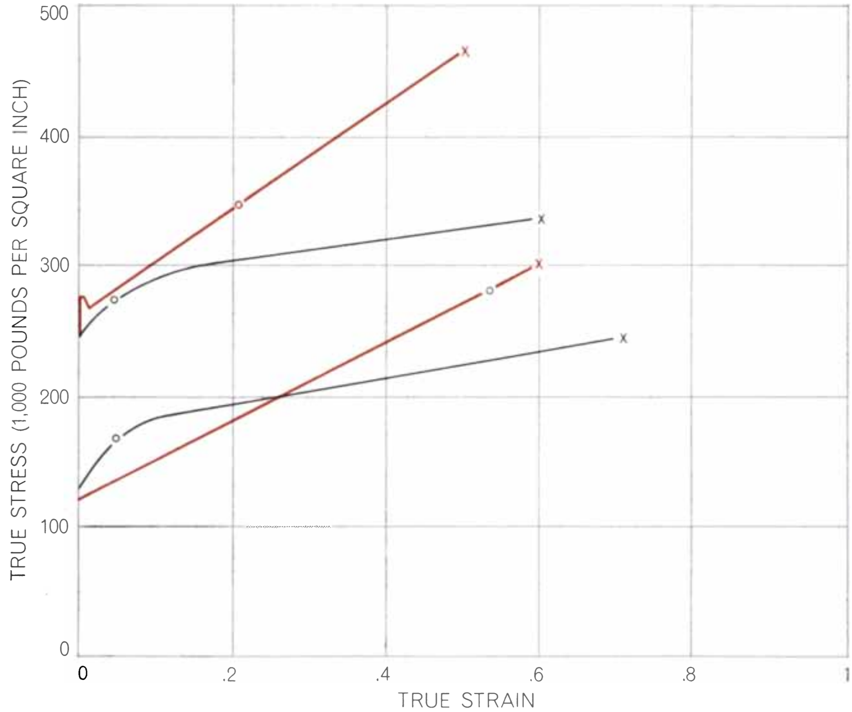
LOCATION OF CARBON ATOMS in steel helps to determine strength as well as brittleness. When steel is red hot and iron crystals are in the face-centered cubic form (*a*), there is room for carbon atoms (*dark balls*) to fit between the atoms of iron. In body-centered cubic iron (*b*), the stable form at room temperature, no carbon atoms will dissolve because the spaces are too small. If, however, iron containing carbon is quenched rapidly from red heat, carbon atoms are trapped in solution in a body-centered arrangement that is distorted into a tetragonal structure (*c*). This is a hard but brittle material called martensite; it accounts for the brittleness of simple iron-carbon alloys that are quenched. If nickel and chromium are added to the alloy, a metastable face-centered structure, with room for carbon atoms, can be retained at room temperature. When such alloys are deformed plastically, the metastable structure changes over to martensite, which concentrates in the slipbands and resists penetration by other slipbands. Distributed in this way, martensite adds to the strength of the steel without adding to brittleness. This is the principle underlying the "trip" steels described in this article. "Trip" stands for "transformation-induced plasticity."

quantitatively, the strain-hardening rate would have to increase in direct proportion to the yield strength if the uniform strain preceding necking down were to remain unchanged.

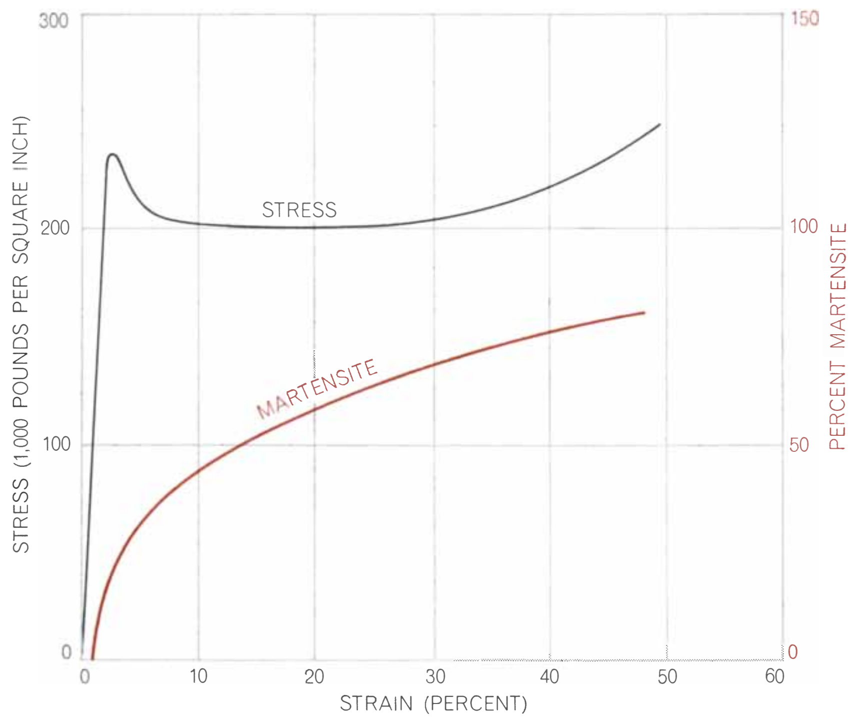
The best way to measure the strain-hardening rate is by means of the true-stress true-strain curve, which is similar to the stress-strain curve described above [*see top illustration on page 40*] except that here the stress is the load applied to the specimen divided by the actual cross-sectional area supporting that load (whereas in the conventional curve the stress value is obtained by dividing the load by the original cross-sectional area). The strain in the true-strain curve is equal to the integral of dl/l between the limits of l_0 and l, where dl is the instantaneous change in length, l_0 is the initial length and l is the final length.

When low-alloy steels are heat-treated to produce higher yield strengths, the true-stress true-strain curves are parallel [*see bottom illustration on page 41*]. The strain-hardening rate is the slope of the true-stress true-strain curve. It is evident that strain-hardening by the interaction of dislocations produces a strain-hardening rate that is substantially independent of the yield strength. As the circles on the plot show, however, necking down begins at lower strains the higher the yield strength of the material. It thus becomes evident that barriers that are stronger than dislocation arrays lodged in slipbands must be introduced during plastic straining if the onset of necking down is to be delayed so that the inherent ductility (as indicated by the reduction of area) can be utilized more effectively.

There are very few changes in internal structure other than those associated with dislocations that can be made to occur as a consequence of plastic flow. Nonetheless, there is one that could have a major effect on mechanical behavior, namely a transformation in crystal structure from the face-centered cubic form to the body-centered tetragonal one. In steel the latter structure is called martensite, and the changeover is called a martensitic transformation. This change can, in certain special alloys, be made to take place during straining. As we have said, iron can exist in two different crystal structures, the face-centered cubic structure at high temperatures and the body-centered cubic one at low temperatures. Carbon dissolves in the face-centered structure at high temperatures, but it is substantially insoluble in the body-centered form at room temperature. Fast



STRAIN-HARDENING, represented by the slopes of these curves, occurs at a higher rate in trip steels (*colored curves*) than in commercial steels of comparable strength (*black curves*). Because the martensite bands produced in trip steels by plastic deformation are not readily penetrated by intersecting slipbands, the applied load (reflected in true stress) increases more rapidly per increment of strain (reflected in true strain) than is the case when only normal slipbands are present. As a consequence, necking down (*open circles*) is postponed.



MARTENSITE CONTENT OF TRIP STEELS increases rapidly when a load is applied to a test bar. The body-centered tetragonal structure of martensite is ferromagnetic, whereas the metastable face-centered cubic structure is nonmagnetic. Thus by making magnetic measurements during a tension test the increase in martensite content can be determined.

quenching causes the carbon to become trapped in the body-centered lattice, distorting it from a cubic structure into the tetragonal martensitic structure [*see illustration on page 42*]. The change to the tetragonal structure cannot be suppressed in iron-carbon alloys, and they become brittle. If nickel and chromium are added to the alloy, however, a face-centered structure can be retained at room temperature. This structure can later be changed to martensite, and distributed in a more favorable way, if the material is deformed plastically.

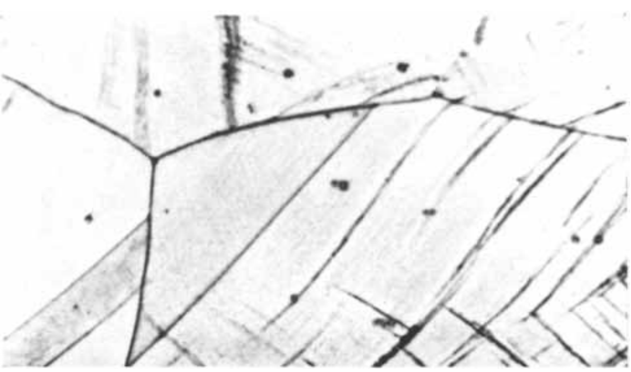
The tetragonal martensite that forms in the slipbands is stronger than its face-centered cubic counterpart; it is also significantly stronger than the defective slipbands that account for the normal kind of strain-hardening. Because the martensite bands cannot be as readily penetrated by intercepting slipbands, the applied load must be increased more rapidly with strain than is the case when only normal slipbands are present. In steels that form martensite during straining necking down is postponed, and the slope of the curve that is obtained by plotting true-stress true-strain curves is steeper than it is for conventional steel [*see top illustration on preceding page*]. The higher rate of strain-hardening associated with martensite formation enhances uniform plastic flow by delaying the onset of necking down. Steels that have high values of elongation because of a martensite transformation can be said to have a transformation-induced plasticity; they are the trip steels.

The transformation that occurs in trip steels has been known and studied for many years, but the earlier investigations were confined to materials whose yield strength was low. To make materials of high yield strength it is necessary to increase the carbon content so that enough tiny particles of iron carbide are precipitated during heat treatment to provide the high yield strength desired (more than 150,000 pounds per square inch). Attempts have been made to increase the yield strength of face-centered cubic steels by larger additions of carbon, as has been done successfully with body-centered cubic steels, but the face-centered materials invariably become brittle when the carbon content is increased significantly. Carbides tend to precipitate preferentially at the boundaries between crystals. The brittle networks thus formed lead to early failure when the material is strained.

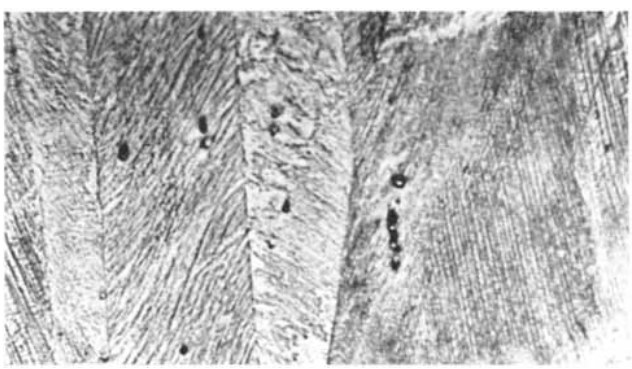
The tendency for carbides to precipitate at crystal boundaries is a natural one; in these regions the atomic architecture is less perfect. When two differently oriented crystals join as they grow from a liquid (or when two crystals join in a highly deformed solid that is heated enough for the atoms to move around and rearrange themselves in new crystals), between them there is a poorly fitted region where the atomic density is low. Such regions provide favorable nucleation sites for the precipitation of the brittle carbides.

We had to devise a means for overcoming this embrittling reaction in order to make strong steel alloys that would also exhibit high elongation and toughness. This was accomplished by providing nucleation sites throughout the volume of *all* the crystals in the metal. As we have seen, plastic flow produces internal defects in the lattices of the crystals. These defects are excellent nucleation sites where particles of precipitate can form as readily as they do at crystal boundaries. The trip alloys were deformed at an elevated temperature where the face-centered structure was stable. (The deformation was accomplished by passing hot bars of alloy repeatedly through a laboratory rolling mill.) The temperature was high enough (which means that atomic mobility was high enough) for spontaneous precipitation to occur. The resulting materials exhibited remarkably high yield strength when tested at room temperature. The photomicrograph at the left below shows how carbide has precipitated in the deformed face-centered material. The micrograph at the right below shows bands of martensite that appeared when a specimen of trip steel was placed under strain and fractured at room temperature.

The transformation process can be followed precisely but simply in the trip alloys because the body-centered tetragonal crystals of martensite that form during straining are ferromagnetic, whereas the face-centered cubic crystals are nonmagnetic. Therefore by making magnetic measurements one can readily plot the volume of martensite that forms during a tension test as a function of strain at room temperature [*see bottom illustration on preceding page*]. In addition one can actually see the solid-state transformation as it is taking place. The transformation is accompanied by a substantial amount of shear, so that if a sheet of material is pulled, it shears along planes at 45 degrees to the surface. The shearing produces an offset at the surface that



CARBIDES IN TRIP STEELS precipitate preferentially along slipbands (*dark lines*) produced when the steels are plastically deformed at an elevated temperature. The magnification is about 600 diameters. The carbide content must be high to produce an alloy with the desired strength. In an ordinary high-carbon alloy the carbides precipitate along grain boundaries, making the steel brittle. Trip steels are much less brittle because plastic deformation provides nucleation sites throughout the volume of all crystals.



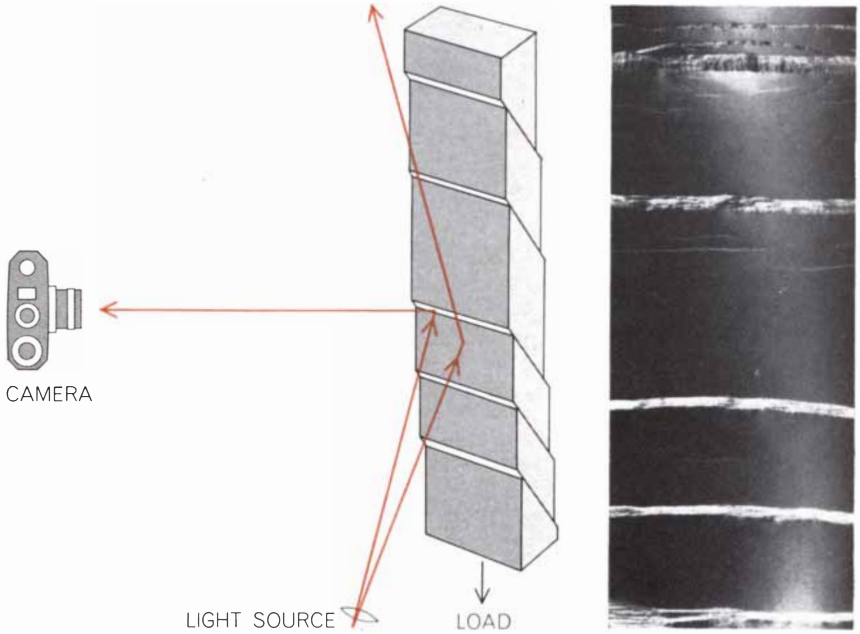
MARTENSITE BANDS IN TRIP STEELS show up as closely spaced parallel lines in this photomicrograph of a trip specimen that was stressed until it fractured. The magnification is the same as in the micrograph at the left. The slipbands show where plastic flow has changed the crystal structure from the metastable face-centered cubic form to the body-centered tetragonal form of martensite. Martensite bands not only are hard but also resist plastic deformation more effectively than ordinary slipbands do.

will scatter light from a beam shining upward from below. The scattered light can then be recorded by a camera located in front of the specimen [*see top illustration at right*]. The same technique can be used to reveal the zone of metal where plastic flow has occurred ahead of a sharp notch or crack.

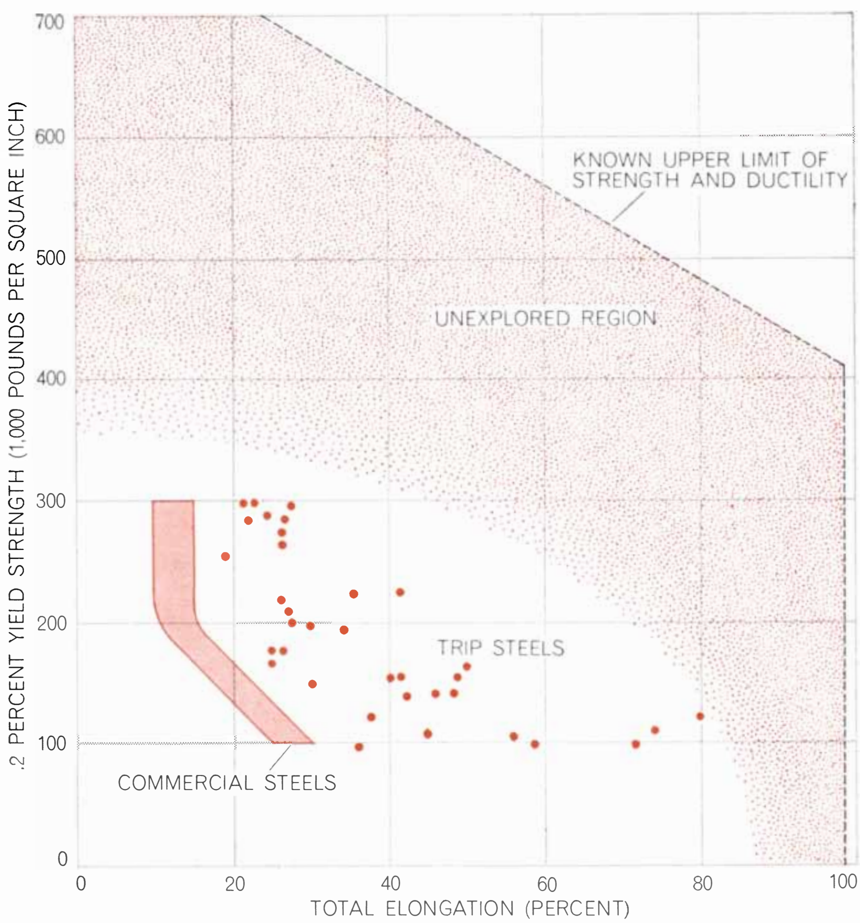
The behavior of high-strength steels when notches or cracks are present is quite significant. Defects of this kind weaken and embrittle strong steels, just as they do a piece of glass. Steels, however, are not as brittle as glass; moreover, there are big differences in the tendency of various steels to fracture in a brittle way when cracks are present. The trip steels perform unusually well under these adverse conditions. Whereas an alloy steel of high yield strength will break brittly, an equally strong trip steel, being much tougher, will tear apart [*see illustration on page 37*]. The higher strain-hardening rate of the trip steel helps to spread the deformation over a much greater volume than is the case in an ordinary steel, with its lower strain-hardening rate.

As we have noted, an elongation of 15 percent is on the high side for present steels with a yield strength in the range of 200,000 to 300,000 pounds per square inch. Trip steels of comparable yield strength show an elongation of 20 to 40 percent. And trip alloys of somewhat lower yield strength (100,000 pounds per square inch) can be stretched as much as 80 percent before fracturing [*see bottom illustration at right*]. Present commercial steels of this lower strength fracture at an elongation below 30 percent. (We remind the reader that these elongations are measured at the arbitrary two-inch gage points.)

It is evident that substantial progress has been made on the problem of enhancing the ductility and toughness of high-strength steels. A number of companies are interested in the possibility of using trip steels in special applications where high ductility must be combined with high strength. The objective of the investigation, however, was not to develop new steels. The work was undertaken to establish upper limits for strength and ductility, to set forth the principles that control the relations of strength to ductility in high-strength materials, and to apply these principles to the production of new materials with properties superior to those now exhibited by available steels. The trip steels are only the first step into this unexplored territory.



DEFORMATION BANDS on the surface of a polished specimen of trip steel can be photographed directly using the lighting and camera arrangement illustrated at the left. The slipbands produce offsets in the polished surface and scatter light into the camera lens, whereas the undeformed surface of the specimen reflects light away from the lens. Thus the deformed bands appear white against a dark background in the photograph at the right.



UPPER LIMITS OF STRENGTH AND DUCTILITY are now clearly defined. Over a wide range of yield strengths, trip steels (*dots*) exhibit significantly higher values of elongation than conventional steels. But they have barely penetrated the large unexplored region.

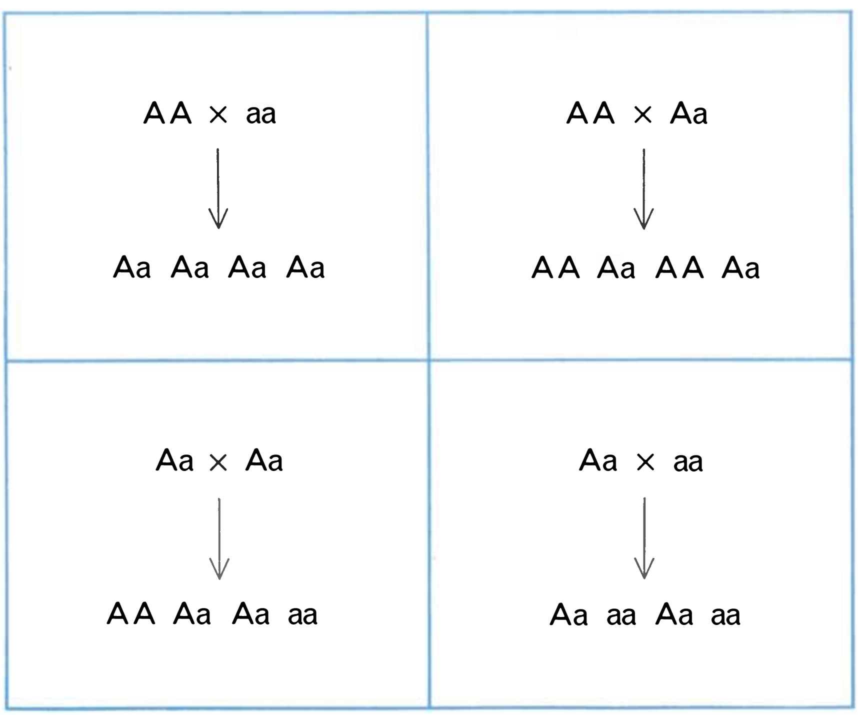
The Prevention of "Rhesus" Babies

The problem of Rh incompatibility can now be solved by giving an Rh-negative mother an anti-Rh antibody that inactivates any Rh-positive fetal blood cells that may pass into her circulation

by C. A. Clarke

As a child I was fascinated by butterflies, particularly a yellow swallowtail butterfly that flies in a marshy area of the east coast of England known as the Norfolk Broads. After World War II, I wanted to breed these insects but found it easier said than done. Swallowtails usually will not mate in a cage, as they need an elaborate courtship flight to stimulate pairing. My interest in the insect did not wane, and by persevering I learned a simple trick to make captive swallowtails mate. Holding the female in the left hand and the male in the right, one brings the pair close together, pries open the male's claspers with the nail of the left-hand middle finger and thereby induces the male to lock onto the female, after which mating follows naturally.

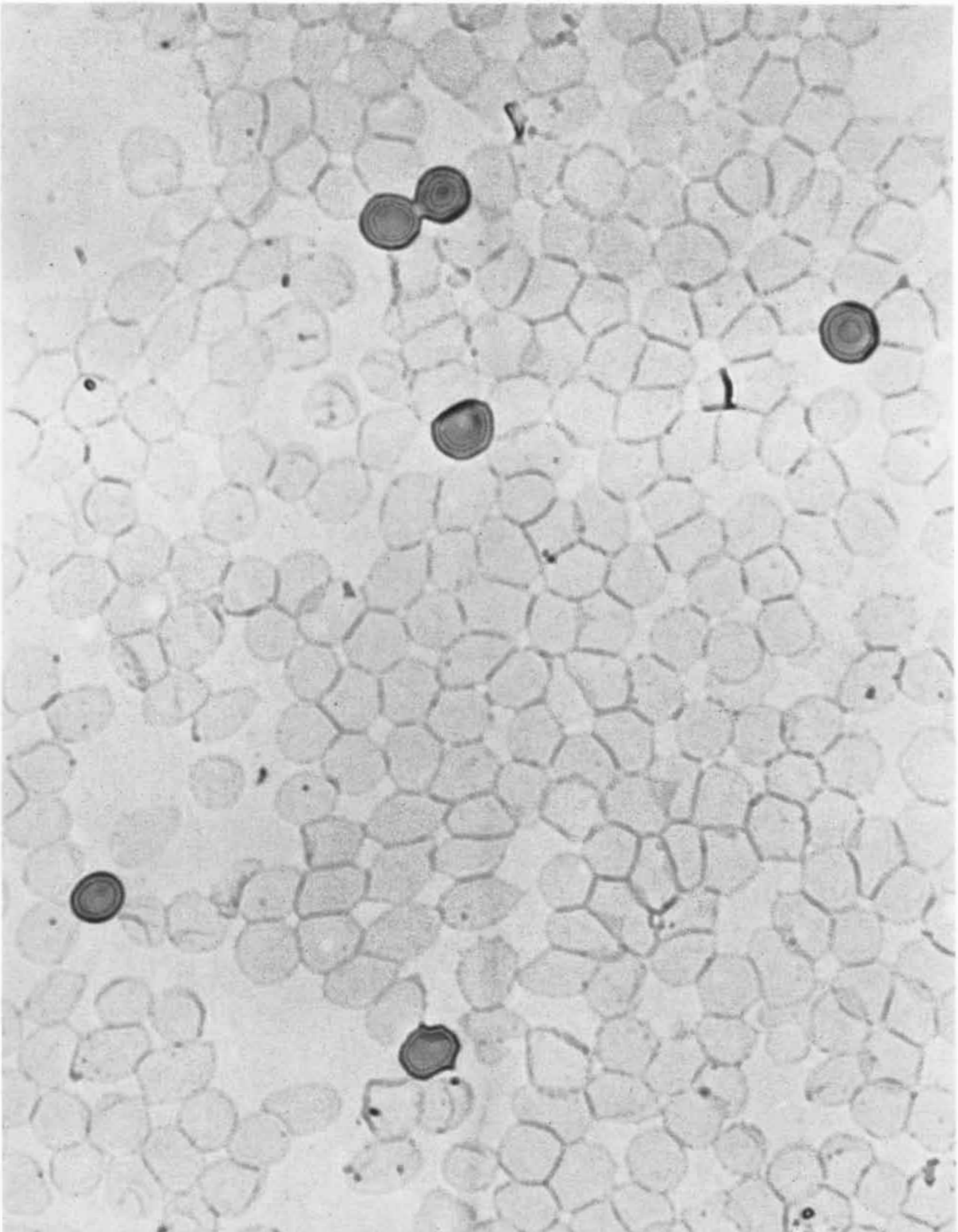
The happy acquisition of this technique in 1952 led me on to experiments in crossbreeding butterflies that turned up some surprising results and fruitful genetic findings. Thus, by the pleasant route of pursuing idle curiosity, my colleagues and I were led unexpectedly to a solution for the well-known medical problem having to do with the inheritance of the Rh factor in human blood! A clue suggested by the butterfly work has enabled us to develop a successful method of preventing the anemia hazard for babies born of an Rh-positive father and an Rh-negative mother. The method can best be explained by describing both the butterfly work and the blood-group investigation from the beginning.



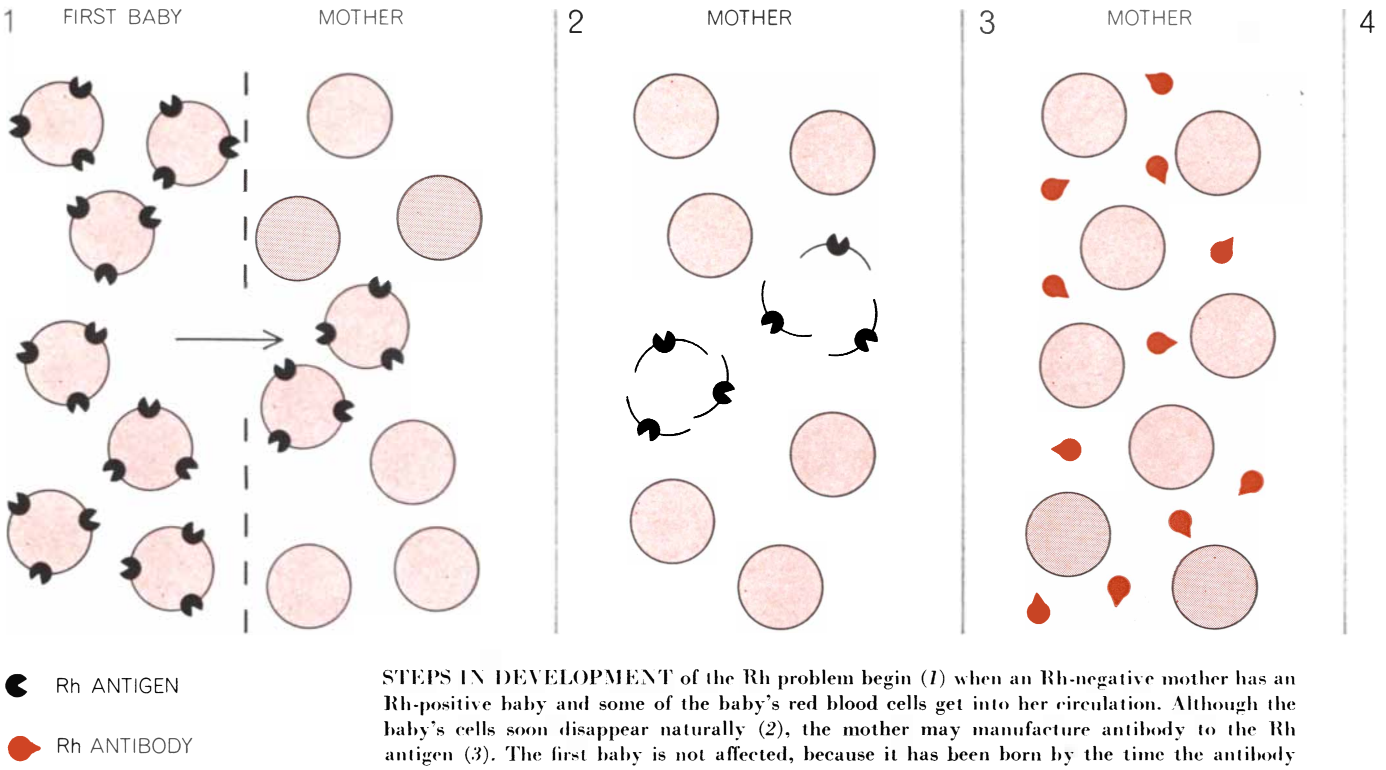
DOMINANT AND RECESSIVE GENES figure in the Rh problem. Each box shows in the top line a parental arrangement of dominant genes (*capital letters*) and recessive ones (*small letters*) and in bottom line the combination of genes to be expected in offspring.

In 1952 I happened to acquire a female butterfly of a black swallowtail species common in America (*Papilio asterias*), and in an idle moment one Sunday afternoon I hand-mated her to a male of the yellow British species (*Papilio machaon*). Since the two species are related, the mating was successful, and their first-generation offspring turned out to be like the American parent (showing that black and American were dominant to yellow and British!). When the hybrid was back-crossed to the recessive yellow parent species, however, the new (second) generation segregated for the ground color again: half of the offspring were black and half were yellow. Clearly, then, the ground color of the wings must be controlled by a single gene. A butterfly that inherited the dominant gene for black from either hybrid parent would have black wings, whereas an offspring that received yellow genes from both parents (each of which possessed the yellow as the recessive gene) would be yellow.

It was this experiment that aroused my interest in genetics. Soon afterward I met P. M. Sheppard, who is now a colleague of mine at the University of Liverpool but then was at the University of Oxford. We decided to use the mating technique to investigate the genetic aspects of mimicry in certain butterfly species. In wing coloring and form the mim-



BABY'S CELLS in the mother's circulation give rise to the Rh problem. In this photomicrograph, made by Flossie Cohen of the Child Research Center of Michigan, the red blood cells of the baby are darker than the mother's red blood cells because of a technique that has washed the hemoglobin out of the adult cells while leaving hemoglobin in the fetal cells that are more resistant to the technique. The steps whereby fetal cells in the maternal circulation can create an Rh problem are shown at top of next two pages.



STEPS IN DEVELOPMENT of the Rh problem begin (*1*) when an Rh-negative mother has an Rh-positive baby and some of the baby's red blood cells get into her circulation. Although the baby's cells soon disappear naturally (*2*), the mother may manufacture antibody to the Rh antigen (*3*). The first baby is not affected, because it has been born by the time the antibody

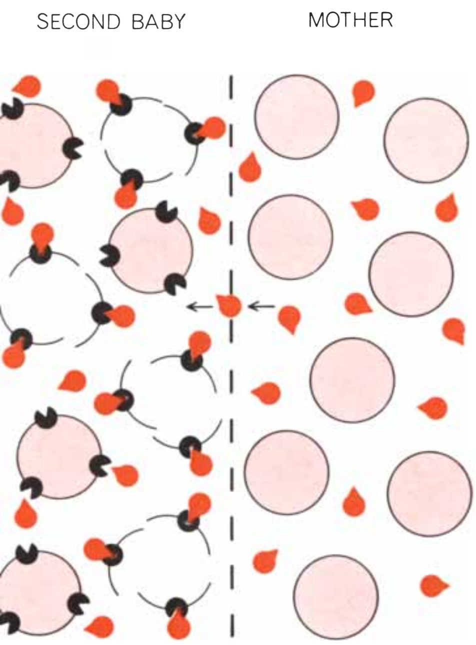
icking butterflies copy butterflies of different species or genera and even of different families. The "model" butterflies are nauseous to predators (particularly birds), and thus the mimics avoid attack although they are themselves edible. A single species of mimic may have several different forms, each imitating a different model; such a species is said to be polymorphic. In formal terms polymorphism refers to distinctly different types (such as blood types in human beings) that persist in an interbreeding population living in the same habitat, and that occur in frequencies such that the rarest form could not be maintained by recurrent mutation. In both mimic butterflies and their models the relative proportion of edible and inedible species in any one area is kept in balance by natural selection. For example, if the edible species mimicking a particular wing pattern comes to outnumber the inedible species, that pattern becomes attractive to predators. The pressure of natural selection is then unfavorable to the mimic species instead of being favorable to it.

How does the mimicry arise in the first place? Does it come about by the mutation of a single gene, causing a butterfly to acquire a mimetic pattern at one jump? This seemed to us a tall order, considering the complexity of colors and configurations in a butterfly's wings. For an answer to our question we investigated an African butterfly (*Papilio dardanus*) and one from southeast Asia (*Papilio memnon*). In both cases we found that the "gene" controlling the wing pattern is really a group of closely linked genes behaving as a single unit—what is known as a supergene. We found evidence for this in crossovers (exchanging of genes) within the genetic group. For example, in a southeast Asian butterfly we bred we were able to see a crossover in the chromosomal unit responsible for the change in wing pattern [*see illustration on page 51*].

There is another significant point about these two species of butterfly that is relevant to the blood-group work. In these species mimicry occurs only in the female; in both species the males do not show mimetic patterns although they carry the genes that are responsible for the patterns in the female. Evidently there is an interaction between sex and the mimetic supergene, so that the supergene is somehow switched off in the male.

By the time we had got this far in the genetic research on butterflies we could not help noticing certain striking parallels between the inheritance of their wing patterns and the inheritance of blood types in man. In man the blood-group differences between individuals —Rh-positive, Rh-negative, O, A, B, AB and so on—are genuine manifestations of polymorphism. The Rh genetic units are supergenes, composed of three closely linked genes, with alternative recessive forms in many different combinations. Moreover, as in the male butterfly, in man there is an interaction whereby another blood-group system can interfere with the formation of antibodies against the antigens controlled by the Rh supergene. To appreciate the significance of these facts we must take a fresh look at the particulars of the Rh problem.

About 85 percent of the population in Britain and in the U.S. are Rh-positive, which means their red blood corpuscles contain the "rhesus" factor or substance, so named because it was originally detected in rhesus monkeys. The Rh factor is an antigen; if Rh-positive blood gets into the bloodstream of an Rh-negative individual, the person may produce an antibody (called anti-Rh or anti-D) that destroys the Rh-positive red blood cells. Therein lies the hazard for babies of an Rh-negative mother. The hazard, when it arises, usually comes about in the following way. If an Rh-positive father and an Rh-negative mother produce an Rh-positive baby (inheriting the Rh factor from the father), and if some of the baby's Rh-positive red blood cells get into the mother's circulation at the time of delivery, the mother may subsequently manufacture the Rh antibody. The antibody does not harm the mother, and a first baby is not affected because the antibody is produced after the baby's birth. The antibody in the mother's blood remains as a threat, however, to



appears. If the mother has a subsequent Rh-positive baby, however, the antibody may attack the baby's red blood cells (*4*), thereby giving rise to a possibly fatal anemia.

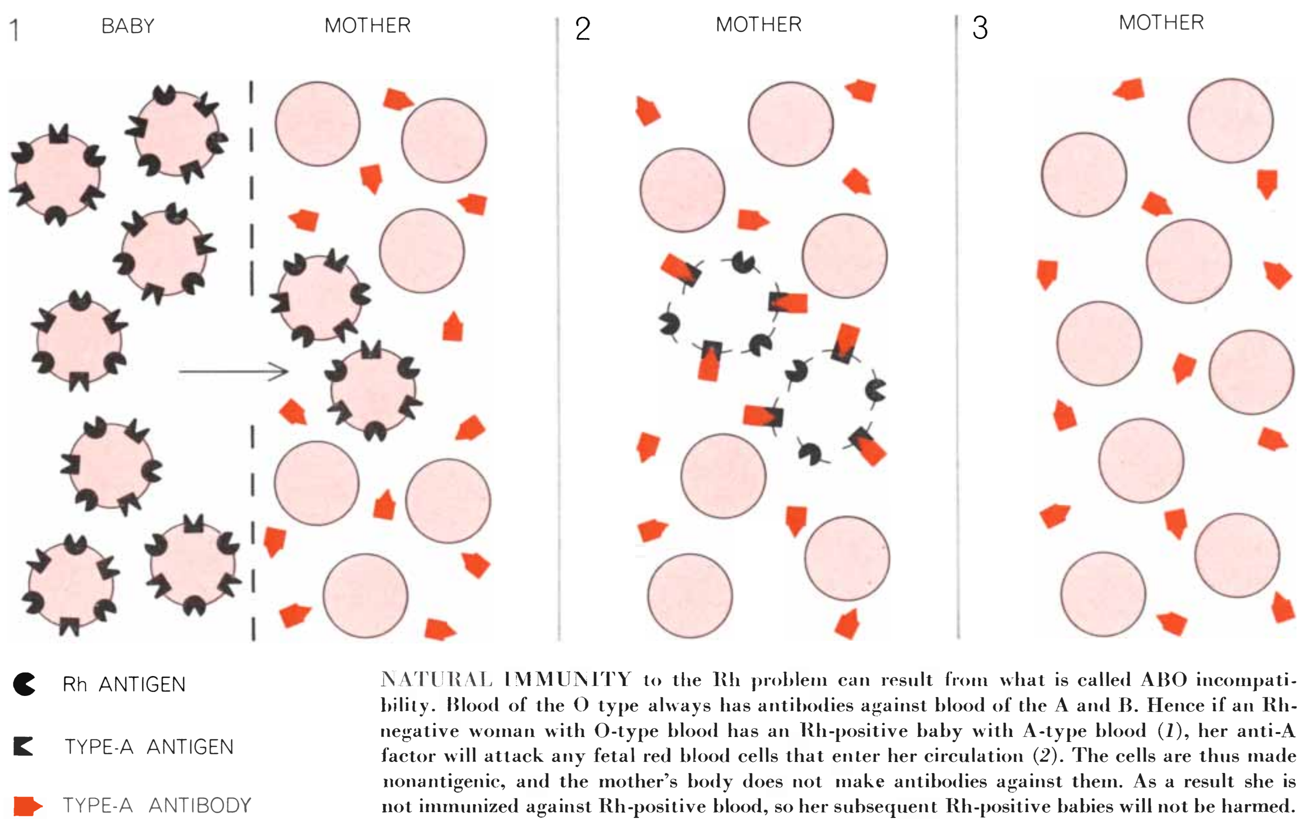
any subsequent Rh-positive baby, because it will enter the circulation of the fetus in the womb and destroy red blood cells, thereby causing possibly fatal anemia. The baby may be stillborn or be born with hemolytic disease.

The risk of this happening is not very high; although 15 percent of women are Rh-negative, among the 850,000 births each year in Britain, for instance, the number of "rhesus" babies is probably not more than about 5,000. Several factors operate to limit the risk. First, leakage of the baby's blood through the placenta into the mother's circulation in sufficient quantity to stimulate the production of Rh antibodies does not occur often. Second, some women do not produce antibodies even though there is leakage. Third, when the Rh-positive father is heterozygous (having received an Rh-negative gene from one of his parents), there is only a 50 percent chance that the baby will be Rh-positive. Fourth, and this is what particularly interested us, in about 20 percent of all the potential cases the formation of antibodies is prevented by the protective mechanism arising from interaction with other blood-group genes.

As an example, the mechanism operates in cases where the blood of the Rh-negative mother is of the type known as Group O. Blood of the O type always contains naturally occurring antibodies against A-type or B-type blood. The antibodies, called anti-A and anti-B, attack the red cells in blood of Group A or Group B. Thus if a Group O Rh-negative mother bears an Rh-positive baby whose blood is of the A type, her anti-A will rapidly get rid of any red cells that leak into her circulation from the baby at delivery, thereby removing the stimulus for the production of anti-Rh antibodies [*see illustration below*]. This situation, technically called ABO incompatibility between the mother and the fetus, is almost always effective in preventing immunization of an Rh-negative mother against an Rh-positive baby.

Here, then, was an intriguing analogy to our findings about butterflies. The mode of inheritance of the blood groups and the interaction of the Rh and ABO systems were remarkably similar to what we had observed in the insects, particularly the interaction of sex and the mimetic supergene that in male butterflies prevents wing mimicry. Could we somehow devise a protective system for unprotected Rh-negative mothers, that is, for cases where there is no ABO incompatibility between the mother and the fetus?

For months I puzzled over the problem with my colleagues Sheppard and Richard B. McConnell. One night my wife, who had taken a keen interest in our work, woke me from a sound sleep and said: "Give them anti-Rh." Now, nothing is more irritating to a physician than to be awakened in the middle of the night and told how to manage his medical affairs. In a huff I replied, "It is anti-Rh we are trying to *prevent* them from making," and turned over and went to sleep again. In the clear light of morn-



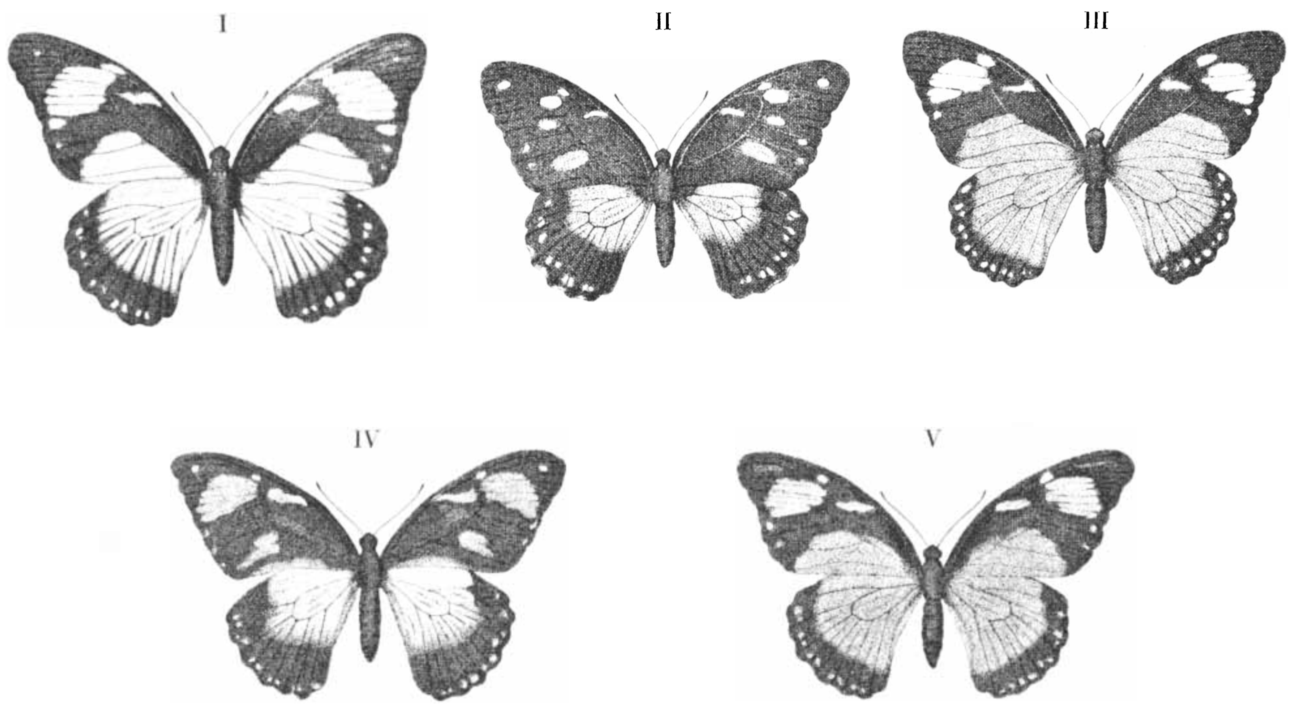
NATURAL IMMUNITY to the Rh problem can result from what is called ABO incompatibility. Blood of the O type always has antibodies against blood of the A and B. Hence if an Rh-negative woman with O-type blood has an Rh-positive baby with A-type blood (*1*), her anti-A factor will attack any fetal red blood cells that enter her circulation (*2*). The cells are thus made nonantigenic, and the mother's body does not make antibodies against them. As a result she is not immunized against Rh-positive blood, so her subsequent Rh-positive babies will not be harmed.

ing, infuriatingly, the idea began to make sense. Giving the mother antibody to get rid of incompatible Rh-positive cells before her own antibody machinery went into production was obviously similar to the way nature accomplished the same objective, for instance in Group O mothers with a Group A baby or Group B one. I discussed the proposal with my colleagues, and we decided to test it.

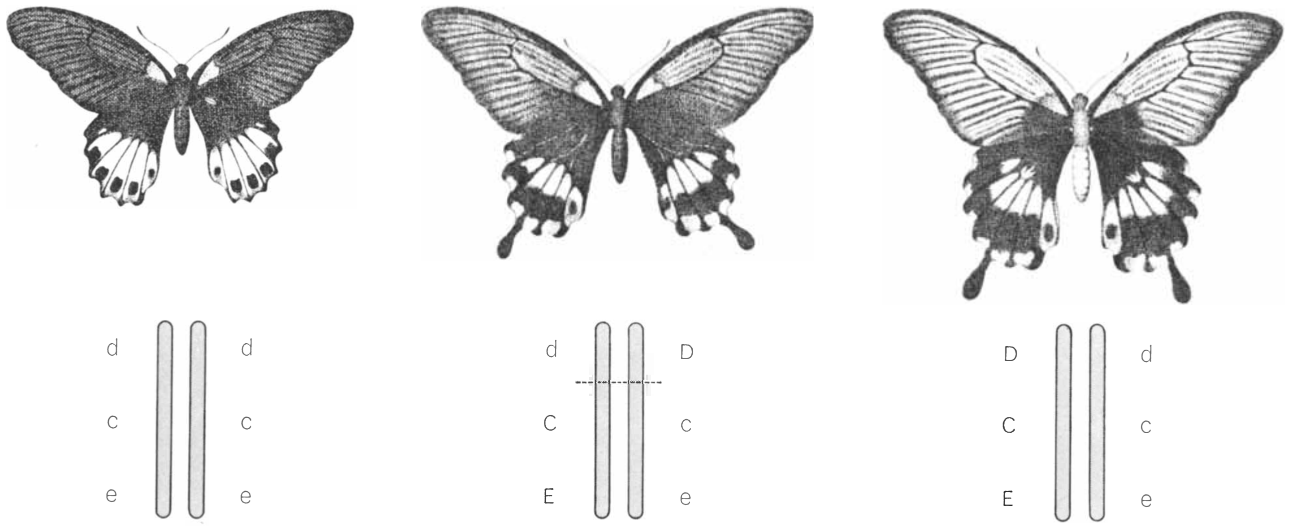
The first experiments consisted in injecting Rh-positive red blood cells, labeled with radioactive chromium atoms, into Rh-negative male volunteers and then giving anti-Rh to half of the subjects, the other half serving as controls. We put Ronald Finn in charge of the experiments, and Dermot Lehane, director of the Liverpool Blood Transfusion Service, provided and injected the radioactively labeled infusions. The immediate results were exciting: the injected anti-Rh did indeed knock down a high proportion of the Rh-positive cells. Alas, the initial effect did not stand up. After six months we found that instead of suppressing the formation of antibodies the treatment had actually enhanced it. Confident nonetheless that our reasoning was basically sound, we persisted and discovered that we had given the wrong type of anti-Rh: the "complete" form of the antibody (which acts in saline solution). This material, we found, destroys the Rh-positive cells but still leaves the residue antigenic. We therefore did a second series of experiments with "incomplete" anti-Rh, which coats the antigen so that it does not make contact with the antibody-forming cells. These injections were much more successful: they prevented the production of Rh antibody in most of the subjects.

We now proceeded to find out if the treatment would work in Rh-negative mothers who received the antibody injection after delivery of their first baby. First of all, Finn and Joseph C. Woodrow of our group determined that the likelihood of production of Rh antibody by mothers generally depended on the number of Rh-positive cells that had leaked into the maternal circulation from the fetus: the more such cells in the mother's blood just after delivery, the greater the risk she would produce antibody. On the strength of this information we felt justified in testing the preventive effect of antibody injection in Rh-negative mothers who, after delivery of their first baby, showed a fair number of fetal red cells in their blood (five or more per 50 fields in a low-power microscope). Our obstetrical liaison was with Shoma H. Towers of the department at Liverpool headed by T. N. A. Jeffcoate. In these clinical trials we used a new form of the antibody preparation that was similar to one that had been developed by a team at the Sloane Hospital for Women in New York: John G. Gorman, Vincent J. Freda and William Pollack, who had arrived independently at the anti-Rh concept. The preparation consists of anti-Rh gamma globulin instead of anti-Rh serum; its great advantage is that it avoids the risk of jaundice, which is always a potential danger in blood transfusions. Employing anti-Rh gamma globulin prepared for us from the serum of our immunized male volunteers by William d'A. Maycock and his colleagues at the Lister Institute in London, we gave the antibody to 131 selected first-baby mothers within 48 hours after delivery of the baby. Six months later W. T. A. Donohoe and his staff, who have carried out all our serological tests, assayed the mothers' blood for the presence of Rh antibody. Only one of the 131 mothers produced this antibody, whereas in a comparable control group of 136 first-baby mothers who had not received the anti-Rh injection 21 percent proved to be anti-Rh producers at the six-month examination.

This result, suggesting that the treatment gave almost complete protection, was far better than we had anticipated



WORK WITH BUTTERFLIES provided a lead to the solution of the Rh problem. The work involved an investigation of mimicry, in which a form of butterfly that is palatable to birds comes to resemble a form the birds find distasteful. Mimicry occurs only in females. A single difference in genes can turn one mimetic pattern into another. Here five female forms of the South African butterfly *Papilio dardanus* are arranged in order from the bottom recessive (*I*) to the two top dominants (*III and IV*), which form a recognizable heterozygote (*V*). The human blood types equivalent to these mimetic patterns are respectively O, B, A_2, A_1 and AB.



BREEDING EXPERIMENTS involving a nonmimetic (*left*) and a mimetic form (*right*) of the butterfly *Papilio memnon* of southeast Asia produced a crossover insect (*center*). At bottom are the respective chromosomal arrangements; *D* is yellow body color, *C* is small white wing window, *E* is long tails, *d* is black body color, *c* is large white wing window and *e* is absence of tails. The patterns are controlled by a group of closely linked genes called a supergene. There is interaction of sex and the mimetic supergene, reflected by the fact that mimicry does not occur in male butterflies. The Rh factor in human genetics is also controlled by a supergene.

on the basis of the anti-immunization results in our male subjects. Furthermore, clinical trials of essentially the same method in the U.S., Canada, West Germany, Australia and elsewhere produced similarly successful outcomes for first-baby mothers. Critics objected that the six-month test was not necessarily conclusive as to protection: the treated mothers might start to make anti-Rh antibody under the stimulus of a second pregnancy. This objection proved to be groundless: subsequent tests at various centers on treated women who had a second Rh-positive baby showed that these mothers very rarely produced anti-Rh antibody. Immunologically speaking, the treated mothers entered their second pregnancy as if it were their first. The possibility remains, of course, that a "bleed" from the baby across the placenta at the second delivery or any subsequent one may stimulate the mother to begin producing antibody. In such cases the mother will require a new injection of the protective treatment whenever her blood after the birth carries fetal Rh-positive cells.

We are currently conducting studies to settle on a standard, minimum effective dose of antibody for the treatment. Tentatively it appears that about 200 micrograms of anti-Rh (about a fifth of what we gave in the original trials) is effective in most cases.

We have, of course, given a great deal of study to the possible risks involved in the anti-Rh injection. Occasionally we have noted a local swelling afterward at the site of the injection (made intramuscularly), but this disappears within a day or two. Will the injected gamma globulin produce harmful effects later? It disappears from the blood after a few months, but some women (about 5 percent in our trials) do produce antibodies to the gamma globulin that perhaps might cause a reaction to an anti-Rh injection given after a later pregnancy. This, however, does not appear to be a substantial hazard, as is evidenced by the fact that after a person has received an ordinary blood transfusion (which can generate gamma globulin antibodies) it is not considered necessary as a general practice to test the person for sensitivity before giving him a second transfusion. All in all, it appears that the risks of giving anti-Rh gamma globulin to an Rh-negative mother after her first pregnancy are negligible.

On the other hand, there is some risk for the donors of the anti-Rh: the male Rh-negative volunteers who must be injected with whole Rh-positive blood to manufacture the antibody. This risk is the possibility of the virus of jaundice being present in the injected blood. It can be minimized by making sure that the blood is obtained only from donors whose contributions have never induced jaundice in recipients. We have used blood from a few carefully selected donors and so far have not had a case of transmitted jaundice. There is, of course, the possibility of using serum from Rh-negative women who have been naturally immunized by an Rh-positive pregnancy; the Canadian workers use this source exclusively. The number of volunteers can also be greatly reduced with the new technique called plasmapheresis, which makes it possible to bleed the donors of anti-Rh every few weeks; a liter of blood is taken, the plasma containing the anti-Rh is skimmed off, and the red blood cells are reinjected into the donor.

Some authorities feel that, because of the jaundice risk to the donors and possible long-term harm to the women who receive anti-Rh, it is unwise to administer the antibody on a wholesale basis to all Rh-negative mothers who conceivably might have "rhesus" babies. Considering the small proportion of cases in which this actually happens, they suggest that anti-Rh should be given only to mothers who show a high probability of producing Rh antibody. The trouble is that it is impossible to identify these "high risk" cases with precision. The number of red cells from the baby found in the mother's circulation after the birth is not always a reliable measure of the risk. Many women produce antibodies after receiving only a very tiny bleed from the baby, and the indications are that the cell-count basis for selection of women to be treated would catch only about a third of the risky cases. It seems to us that if proper precautions are taken, the hazards involved in the treatment are so small, for the donors as well as the mothers, that they are far outweighed by the benefits. All vaccination programs entail giving the injection to great numbers of people who do not necessarily need it but who take it nonetheless for safety's sake. In this case the inoculation would banish anxiety for Rh-negative women, who would no longer need to worry about the possibility of endangering their babies.

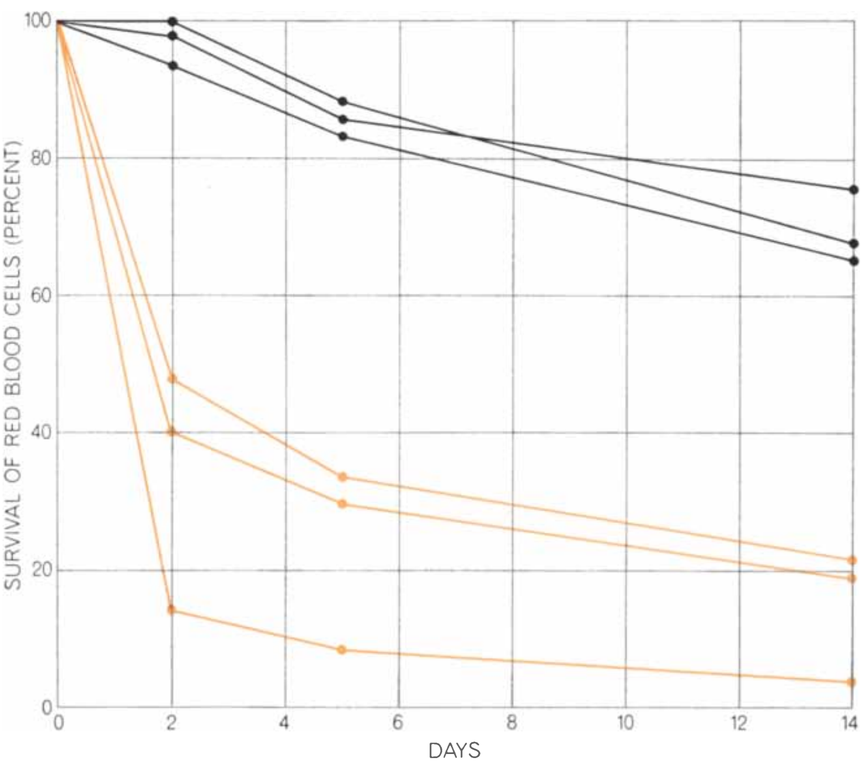
The discussion of the risks has, however, called attention to the fact that the need for anti-Rh treatment could be obviated in some cases by doing more than is now done to keep the baby from bleeding into the mother's circulation in the first place. It appears that the situations most likely to produce this untoward happening (called transplacental hemorrhage) are the following: peeling the placenta off the womb by hand when the afterbirth is delayed, attempts to turn around a poorly positioned baby in the womb before it is delivered, an excessive number of abdominal examinations of the pregnant mother, toxemia of pregnancy, Cesarean delivery and abortion. Therapeutic abortions are particularly likely to give rise to transplacental bleeding, and when this occurs in an Rh-negative mother with an Rh-positive fetus, all the Rh-positive children she may deliver subsequently are apt to be exposed to anti-Rh attack. It therefore seems prudent to give anti-Rh to all Rh-negative women who have had an abortion even if the husband is Rh-negative, as one cannot always be absolutely certain that the husband is the father.

Among the thousands of mothers who have received the anti-Rh treatment since the trials began in 1964, there have been a few failures—cases in which the mother produced antibody in spite of the treatment. Two interesting possible explanations suggest themselves. The general rule has been to select for the treatment only women who apparently are not immunized, that is, who do not show evidence of producing Rh antibodies. One can suppose, however, that the antibodies may be present in the blood but not detectable by the usual methods, and that they manifest their presence only by going into action against Rh-positive cells when the woman becomes pregnant with an Rh-positive child. This may happen in the case of a mother who had a previous Rh-positive pregnancy but showed no sign of immunization afterward. In short, she may have been "primed" by the earlier pregnancy. We have actually encountered a case of priming in an Rh-negative man who volunteered for one of our experiments. After testing his blood and finding no evidence of the presence of Rh antibodies, we injected five milliliters of Rh-positive fetal blood. Within 48 hours all the fetal cells disappeared from his circulation, and we found traces of Rh antibodies in his blood. Since they could not have been produced so soon after the injection of the Rh-positive blood, we had to assume that he had been primed earlier. We then learned that the subject, who was 70 years old, had received a blood transfusion in World War I, which evidently was the source of his immunization against Rh-positive red cells.

This clear case of unsuspected priming suggests the exciting possibility that the anti-Rh treatment may work even for some mothers who are immunized, that is, whose antibody-producing mechanism has already been set in motion. It may be that a number of the mothers who have been given anti-Rh in the trials had actually been primed by previous exposure to Rh-positive cells although they showed no sign of being immunized when they were accepted for the treatment. If that is the case, the nearly perfect success in eliminating immunization in the thousands of women who have received anti-Rh is all the more remarkable.

Undetected priming is one of the two interesting explanations that have been offered for the few failures. The other is that occasionally the Rh-positive fetus's red cells may get into the Rh-negative mother's circulation early in her pregnancy, in which case the mother may develop the antibody-producing capacity before the baby is delivered and treatment with anti-Rh at that time will be too late. We believe such cases must be very rare, because first babies are seldom exposed to antibody from the mother. Bruce Chown and his colleagues at the University of Manitoba have, however, found evidence of the presence of Rh antibodies in some mothers during the first pregnancy or immediately after delivery. They have therefore begun giving anti-Rh to the mother during pregnancy and find that in the doses they use it does no harm to the baby. In cases where a bleed is known to have occurred early in pregnancy this method may be extremely valuable.

So, starting with experiments in the breeding of butterflies, the research has grown into a project that has enlisted the enthusiastic interest of a large team at Liverpool, stimulated workers in other laboratories around the world and produced a helpful advance in medicine and that may be found to have still wider applications.



FIRST TEST of plan to attack the Rh problem by administering Rh antibody produced these results. Male volunteers were injected with Rh-positive cells and then half of them (*color*) were given anti-Rh. Technique produced the same result as natural ABO incompatibility.

In hope of doing each other some good

The burden and privilege of choice

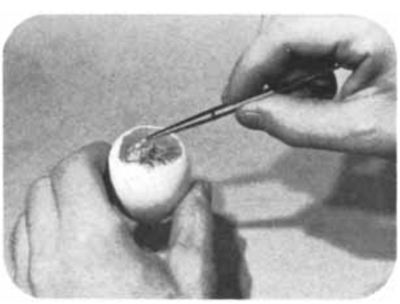
With KODACHROME-X Film widely available for 35mm color slides at 2½ times the speed of KODACHROME II Film and therefore capable of delivering good pictures under a wider range of conditions, why do we go on making KODACHROME II Film?

Because the two interpret colors a little differently, and enough people still prefer what they see on KODACHROME II Film. Any expert who knows better than the customer what constitutes a good picture is also a bit of a fool.

Movie camera as teacher's tool

An art teacher wants all her students to see exactly how an expert holds a bamboo brush for various Sumi brushstrokes. Even if she had been able to bring the expert to the classroom, the students in the back row would probably have missed out.

A primary-grades teacher wants to get across the idea that despite the differences there are certain similarities between a lion in the local zoo and a kitten at home.



A biology teacher wants to show how to open a chicken egg without destroying the embryo.

A social studies teacher wants his students to understand a little more about each other's religious feelings.

A chemistry teacher wants to show how analytical chemistry is done around town with atomic absorption equipment for which the school laboratory is not yet ready.

The actual filming of a single-concept movie may take the teacher no more than an hour, sometimes only minutes. If the students make the movie instead of the teacher, it will take longer but they will enjoy the lesson more and get much more out of it. But don't count on just picking up the egg or the kitten and the camera and starting to shoot point-blank. All you'll do is use up film, which might be advantageous for us, but not for you.

There is a grammar of movie-making. It is not hard to learn. And there is a system of cards one writes out to guide the shooting of each scene. While shooting, three cards are kept in sight at all times: one for the previous scene, one for the scene on camera, and one for the next scene to be taken.

It's all explained in "Movies with a Purpose," a pamphlet obtainable for the asking from R. D. Poey, Department 640, Eastman Kodak Company, Rochester, N.Y. 14650.

Rising tide of mesomorphics

Imaginative people get excited over liquid crystals. This category of people includes optical physicists, artists, analytical chemists, aerospace engineers, dermatologists, designers of integrated electronic circuits, contestants in science fairs, biophysicists, osmologists, welding engineers, and entrepreneurs who think it is still not too late to make a bundle by interesting the human female in body paint. Unimaginative people believe the word "fraught" is being overused. They may regret their attitude, or they may not.

Meanwhile, there must be almost as many laboratories either guarding or disclosing liquid crystal secrets as are working on holograms. With which the mesomorphic, or liquid crystal, state has no connection. Or does it?

A fraught statement enunciates the liquid crystal principle and why we bring it up: The liquid crystal state is the opposite of the glassy state in the sense that glass is rigid but unordered, while the following become highly ordered even when soft as an unguent:

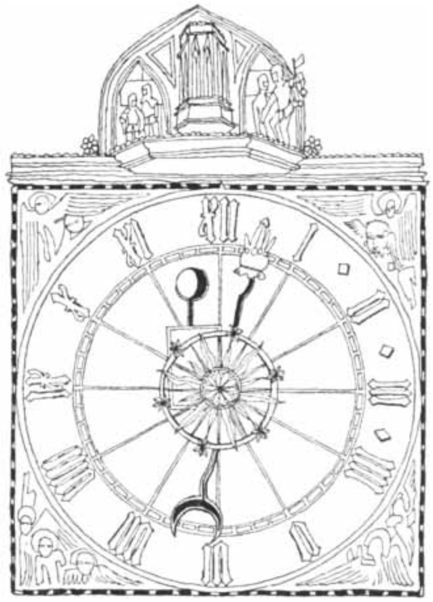
EASTMAN Cholesteric Mixture Solution No.	for temperature range
A10629	12-17 C
A10632	16-19
A10634	17-20
A10637	18-21
A10673	21-23
A10639	22-25
A10676	24-27
A10642	31-32
A10645	32-33
A10647	33-34
A10650	34-35
A9861	35-36
A10655	36-37
A10657	37-38
A10660	38-39
A10662	39-40
A10665	40-41
A10668	41-42
A10670	43-44

These believed of most immediate practical application for thermographic mapping of a surface within each range indicated. With No. A10650, for example, you get no information about areas cooler than 34 C or warmer than 35 C, but you ought to be able to spot variations within that one-degree span from an iridescent blue appearance at 35 through a gamut of color to a red at 34. *Order any of them at $25 for 100 ml from Distillation Products Industries, Rochester, N.Y. 14603 (Division of Eastman Kodak Company).* Blacken surface, spray on, let evaporate.

If no temperature range here listed fits proposed use, or if price seems discouraging for application from a big hose, inquire anyway. We pride ourselves on a practical outlook. Said outlook precludes offering (at least until this thing develops further commercially) much technical help beyond what is contained in new "Informational I22-868", which Distillation Products Industries glad to send with or without an order. Points way to further reading, lists our more numerous cholesteric mesomorphics offered as identified compounds, as well as many other EASTMAN Organic Chemicals that assume the progressively freer smectic and nematic mesomorphic states.

Price subject to change without notice.

SCIENCE AND



Deterrence and Defense

In a kind of farewell address after seven years in office, former Secretary of Defense McNamara has set forth what he believes should be the basic assumptions and general line of reasoning underlying the negotiating positions of both sides in the forthcoming talks between the U.S. and the U.S.S.R. on the prospects of limiting the arms race in the area of strategic nuclear weapons. McNamara's thoughts on the subject, which are essentially the same as those he expressed directly to Premier Kosygin at the Glassboro conference in June, 1967, are outlined in Chapter IV ("Mutual Deterrence") of his new book *The Essence of Security.*

In McNamara's view the cornerstone of a strategic policy based on the concept of mutual deterrence is the maintenance of an "assured-destruction capability," that is, "a highly reliable ability to inflict unacceptable damage upon any single aggressor or combination of aggressors at any time during the course of a strategic nuclear exchange, even after absorbing a surprise first strike." At present, he writes, both the U.S. and the U.S.S.R. have a strategic nuclear arsenal "greatly in excess of a credible assured-destruction capability." What neither nation has at present, he continues, and what neither side can acquire in the foreseeable future, is a "first-strike capability," that is, the ability of one nation to attack another nation with nuclear forces first and thereby eliminate the attacked nation's retaliatory second-strike forces.

It is in the context of this mutual capability for assured destruction, McNamara believes, that the U.S. should view the recent Russian decision to deploy a "light" antiballistic-missile system around Moscow. In his judgment such a system "does not impose a threat because we have already taken the steps necessary to assure that our land-based Minuteman missiles, our submarine-launched new Poseidon missiles and our strategic bomber forces have the necessary penetration aids."

It is in the same context, McNamara continues, that the U.S. should consider the question of "whether or not we should deploy an ABM system against the Soviet nuclear threat." Although technology in this area has advanced substantially in recent years, "it is important to understand that none of the systems at the present or foreseeable state of the art would provide an impenetrable shield over the United States."

Moreover, "were we to deploy a heavy ABM system throughout the United States, the Soviets would clearly be strongly motivated to so increase their offensive capability as to cancel out our defensive advantage." The inevitable conclusion to be drawn from this "nuclear action-reaction phenomenon" is that "it is futile for each of us to spend $4 billion, $40 billion or $400 billion—and, at the end of all the spending, at the end of all the deployment, at the end of all the effort, to be relatively at the same point of balance on the security scale that we are now."

In an appendix to his book McNamara draws a distinction between a "heavy" $40-billion ABM system designed to protect U.S. cities against a Russian attack—a system he continues to oppose—and the "light," China-oriented Sentinel ABM system decided on by President Johnson, approved by Congress and now under construction. Although he concedes that "there are *marginal* grounds for concluding that a light deployment of U.S. ABM's against this possibility is prudent," he cautions that such a decision contains two possible dangers. The first is that "we may lapse psychologically into the old oversimplification about the adequacy of nuclear power." The second is that "in deploying this relatively light and reliable Chinese-oriented ABM system . . . pressures will develop to expand it into a heavy Soviet-oriented ABM system. We must resist that temptation firmly."

As things stand at present, McNamara says, "we have already initiated offensive-weapons programs costing several billions in order to offset the small present Soviet ABM deployment, and the possibly more extensive future Soviet ABM deployments." We must at the same time "measure our own response in such a manner that it does not trigger a senseless spiral upward of nuclear arms.... Keeping in mind the careful clockwork of lead-time, we will be forced to continue that effort over the next few years if the evidence is that the Soviets intend to turn what is now a light and modest ABM deployment into a massive one.... We would prefer not to have to do that, however. It is a profitless waste of resources, provided we and the Soviets can come to a realistic strategic arms-limitation agreement."

Should the proposed talks fail and should the Russians decide to expand their ABM deployment, McNamara believes that "our response must be realistic." "There is no point whatever in our responding by going to a massive ABM deployment to protect our population when such a system would be ineffective against a sophisticated Soviet offense. Instead, realism dictates that we then must further expand our sophisticated offensive forces and thus preserve our overwhelming assured-destruction capability. The intractable fact is that both the Soviets and we would be forced to continue on a foolish and unproductive course. In the end it would provide neither the Soviets nor us with any greater relative nuclear capability. The time has come for us both to realize that and to act reasonably. It is clearly in our own mutual interest to do so."

Space Travel on the Ground

A special panel of the National Academy of Sciences has urged greater support for study of the planets using a variety of new and improved earth-based instruments. The report, titled *Planetary Astronomy: An Appraisal of Ground-Based Opportunities,* points out that continuing improvements in radar, radio telescopes, image-scanning devices, image reconstitution and Fourier interferometers now put within reach important new knowledge about the planets.

Included in the panel's recommendations are the construction of a 60-inch optical telescope, specifically for planetary study, in the mountains of northern Chile, where seeing conditions are superior to any found in the U.S. The panel urges that the instrument be completed by 1971 so that it can be used to observe Mars during its next close approach. For the observation of planetary atmospheres the panel recommends construction of a 120-inch infrared telescope at some desert site in this country where atmospheric water vapor, which absorbs infrared radiation, would be low. Because optical precision is not critical at infrared wavelengths, the instrument could have an inexpensive mirror, perhaps one made of metal or plastic. The report also endorses a plan to install a 36-inch infrared telescope in a jet aircraft, which could fly above 99 percent of the water vapor in the atmosphere. For spectrometry in the infrared, the panel recommends the use of new Fourier interferometers of the type that has been developed in France by Pierre Connes (see "How Light Is Analyzed," by Pierre Connes; SCIENTIFIC AMERICAN, September).

Other recommendations in the report include (1) construction of a large new dish-type facility for planetary radar astronomy, (2) construction of three large radio-telescope arrays for high-resolution observation of planetary radiation at wavelengths ranging from millimeters to decimeters and (3) worldwide photographic coverage of the planets from January 1, 1969, to January 1, 1974, using relatively small telescopes located at various longitudes.

Subversive DNA

One of the puzzles associated with virus-induced cancers of animal cells is that virus particles can usually no longer be found in cells after they have become cancerous. Renato Dulbecco and his colleagues at the Salk Institute for Biological Studies now publish evidence in *Proceedings of the National Academy of Sciences* that supports a favored hypothesis: a portion of the hereditary material of the virus—its DNA—becomes integrated with the DNA of the host cell and in effect disappears. The fragment of viral DNA attached to the cell's own DNA now becomes part of the genetic message that is replicated at each cell division. It is the information contained in this foreign fragment that subverts the cell's normal controls, converting it into a cancer cell.

Dulbecco and his co-workers contrived a series of experiments to follow what happened to the DNA of the animal virus SV40 after it had invaded and "transformed" a pure line of cultured mouse cells, a strain designated 3T3. These experiments established the following points: (1) the transformed cells contain the viral DNA not in its normal coiled form but in a linear form; (2) the transformed cells contain less free viral DNA than is present in the virus; (3) the viral DNA found in transformed cells is integrated with the cell's own DNA; (4) the fragment of viral DNA is sufficient to give rise to some 20 different proteins; (5) the viral DNA is bound to the cellular DNA by an enzyme manufactured according to the instructions contained in the viral DNA.

Dulbecco and his colleagues conclude: "The viral DNA may be linked to the cellular DNA as one large piece at a single site, or it may be connected at multiple sites after many individual insertions. This problem is currently under investigation." Dulbecco's co-workers were Joseph Sambrook, Heiner Westphal and P. R. Srinivasan, who is on leave from Columbia University.

Galactic Magnetism

The first accurate measurement of the strength of the magnetic field in the galaxy has been reported by Gerrit L. Verschuur of the National Radio Astronomy Observatory in Green Bank, W.Va. The measurement was made by a method first suggested in 1957 by two Australian radio astronomers, J. G. Bolton and J. P. Wild, and attempted many times since without success by radio astronomers at various observatories around the world. The method is based on a precise determination of the Zeeman splitting of the radio "line" emitted at a wavelength of 21 centimeters by clouds of hydrogen atoms in space. The amount of Zeeman splitting observed is proportional to the strength of the magnetic field in the vicinity of the emitting atoms.

Working with this method, Verschuur measured the magnetic field in two regions of the Milky Way. The two regions are in directions toward the strong radio-emitting sources Taurus A and Cassiopeia A. The target areas, which are respectively about 3,000 and 8,000 light-years away, were found to have a field strength of three and 20 microgauss respectively. (A microgauss is a millionth of a gauss, the unit of magnetic-field strength. The earth's magnetic field is about one gauss near the magnetic poles.)

Verschuur attributes his present success in part to the powerful 140-foot radio telescope at Green Bank and also to a new 400-channel receiver developed recently by his colleagues Sander Weinreb, A. M. Shalloway and R. Mauzy.

Smog for Sale

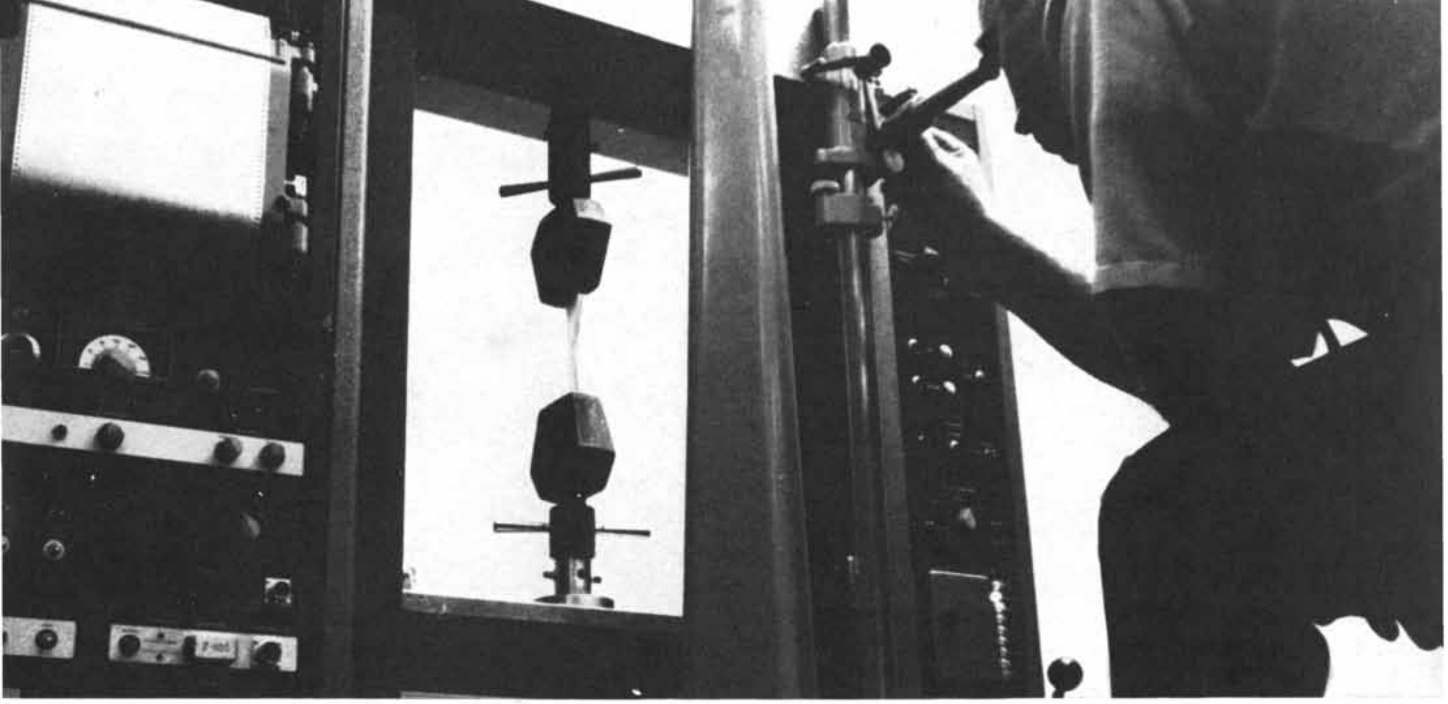
A successful means of removing the atmospheric pollutant sulfur dioxide from flue gas and converting it into salable sulfuric acid has been worked out by the Monsanto Company and the Metropolitan Edison Company. A prototype plant that employs a catalytic oxidation process has been in operation at Metropolitan Edison's generating station at Portland, Pa., for a year. Officials of the two companies assert that they have achieved "a demonstrated solution to the serious air-pollution problem of sulfur dioxide emissions."

The Portland station burns soft coal. Flue gases are taken directly from the boiler and passed first through an electrostatic precipitator, which removes more than 99 percent of the solids, such as fly ash. The gases next go through a converter, where the sulfur dioxide is catalytically oxidized to sulfur trioxide, which is combined with water to form sulfuric acid. The acid is of commercial quality and has been sold; Monsanto believes that in a full-scale operation the sales would cover the installation and operating costs of the purification system. At Portland the operation converts 90 percent of the sulfur dioxide.

Hybrid Ribosomes

The particles called ribosomes, the biological machines that assemble proteins inside the living cell, are complex structures consisting of a number of proteins associated with molecules of ribonucleic acid (RNA). Each ribosome consists of two subunits of unequal size, identified as 30S and 50S because of their sedimentation properties. Earlier this year Masayasu Nomura and his co-workers at the University of Wisconsin showed that if the 30S subunit was dissociated into an RNA fraction and a protein fraction, the two fractions would spontaneously reassemble, join with a 50S subunit and exhibit their normal functional activity.

Now Nomura, Peter Traub and Helga Bechmann report in *Nature* that they have reconstituted active 30S subunits



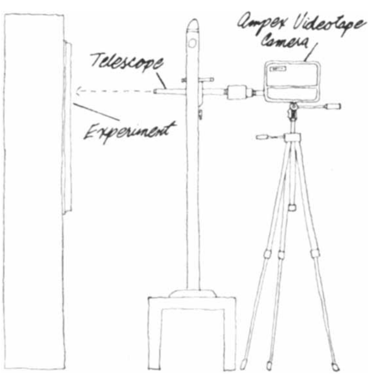
Isn't it about time you investigated Ampex Videotape?

One man. Observing the failure of a material being subjected to tensile loading. One man.

And when the critical point is reached where the material thins, necks, fractures and fails, one man will see it. One man to communicate his findings to his colleagues.

All that takes time.

Time has always been important in research and development. Today it's *critical.*



Let's take the same experiment captured on videotape. Mounting the camera to the telescope allows a roomful of colleagues to view it simultaneously.

And only videotape gives you instant playback that lets you stop and analyze a critical moment, just seconds after it happens. Or anytime afterwards, *anywhere.*

The Ampex VR-7800 videotape recorder has unique features which make it invaluable to science and technology.

It records and plays back in ultra fine detail, in black and white or color. It lets you *compare* separate tests or experiments as though they had occurred in succession, thanks to electronic editing. It replays experiments in *slow motion.* And it allows multiple dubbing and remote control operation. The timesaving benefits go on and on.

As a result, videotape makes for better researchers, better technicians, better results.

Ampex has the longest, most extensive experience in videotape. We introduced the first practical videotape system and we've been first with every major innovation since.

THE AMPEX VR-7800 VIDEOTAPE RECORDER

Video isn't something you can put off for the future. You, your work, and those who depend on your work, need it now.

Find out the facts from the people who know the most about video. Write for more information today.

Isn't it about time?

AMPEX

AMPEX CORPORATION
EDUCATIONAL AND INDUSTRIAL PRODUCTS DIVISION
205 WEST TOUHY AVENUE, PARK RIDGE, ILLINOIS 60068

Yes, it's about time
I investigated Ampex Videotape Systems.
Send me more information.

NAME

TITLE

ORGANIZATION

ADDRESS

CITY

STATE ZIP

SA-118

Ampex Video.
It's about time.

Powerful Computing Genie: $4900

READY, WILLING AND ABLE.

Ready—to relieve you of waiting to get on the big computer.
Constantly available. At your fingertips whenever you need it.
Ready to abolish tedium from scientific and engineering computation.
Ready to slash through long routines
and come up with answers in milliseconds.
The new Hewlett-Packard 9100A personal computer.

Willing—to perform log and trig functions,
even hyperbolics and coordinate transformations,
at the touch of a key. Willing to work
with extremely large and small numbers simultaneously.
Willing to take your programming commands
in mathematical language.
No computer language or programming specialist required.
Willing to communicate with you on *your* terms.
The new Hewlett-Packard 9100A computing marvel.

Able—to take on the most complex problems:
roots of a fifth-degree polynomial . . .
solutions to three simultaneous equations . . .
Bessel functions . . . Fourier analysis . . . elliptic integrals . . .
real and complex polynomial evaluation . . .
coordinate geometry . . . regression analysis . . .
numerical integration . . . vector analysis . . .
and many, many more!
Able to be your fast, responsive mathematical servant.
The new Hewlett-Packard 9100A electronic genie.

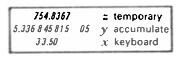
This major computing capability
is compressed into one 40 pound package.
Its only moving parts are the keys, the switches
and one decimal wheel.
No noise.

The 9100A computing genie is being delivered *NOW,*
with an extensive—and growing—program library
that puts you in control.

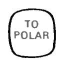
Examine the keyboard, question every key and switch.
Then decide to command the computing genie.
A telephone call or purchase order directed to any
HP Sales and Service Office
(in principal cities throughout the world)
will start the executive process.
If you are still skeptical, or of faint heart
ask for a demonstration.
It will affirm, assure
(and only slightly delay)
your entry into the solid-state
of personal computing power.
Be a Master.
Hewlett-Packard, Box 301,
Loveland, Colorado, 80537;
Europe: 54 Route des Acacias,
Geneva.

9100A puts answers just a touch away!

HEWLETT hp PACKARD



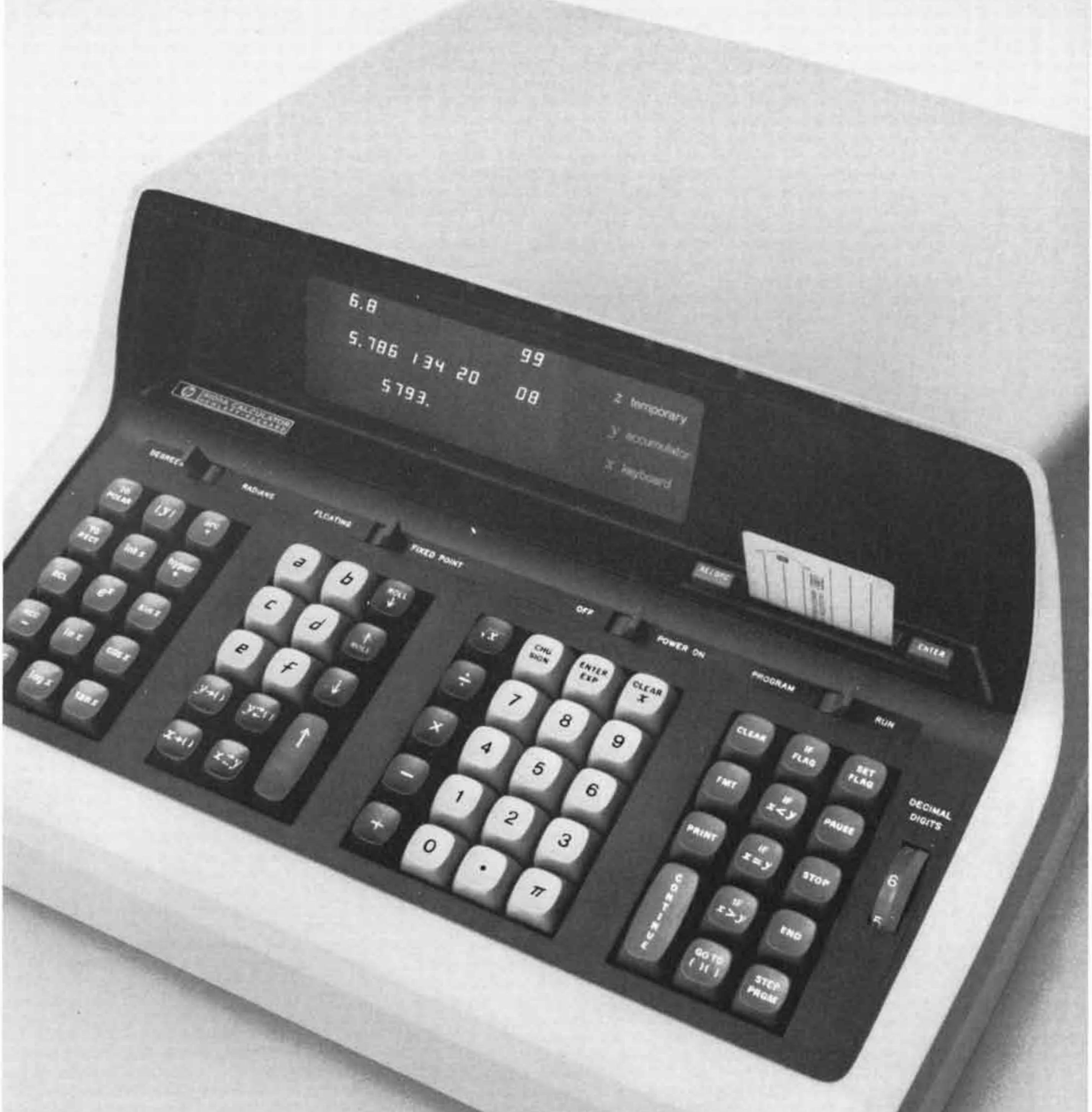
Dynamic range 10^{-98} to 10^{99}, nearly 200 decades. Observation of math operations on 3 displayed registers. Up to 16 more registers for data storage.



Complex and vector arithmetic simplified with coordinate transformation keys, rectangular-to-polar and vice-versa, in milliseconds.

Trig functions covering all quadrants and any size angle in degrees or radians.

098/21


6.8
5.786 134 20
99
5793.
08
z temporary
y accumulator
x keyboard
DEGREES
RADIANS
FLOATING
FIXED POINT
OFF
POWER ON
PROGRAM
RUN
DECIMAL DIGITS
CLEAR
PRINT
PAUSE
STOP
END
CONTINUE
ENTER

that are hybrids: the protein fraction is supplied by the bacterium *Escherichia coli* and the RNA fraction can be from any of three bacterial species that are only distantly related to *E. coli.* Less active but still successful hybrids were also produced by combining *E. coli* ribosomal RNA with ribosomal protein from two of the three species of bacteria.

These findings lead to a number of inferences about the RNA and protein fractions, whose structures are still not known. For a hybrid 30S subunit to be active there must be a rather good fit between the RNA from one species and the set of proteins (more than a dozen in all) from another species. Evidently as the species became separated in the course of evolution, a functional property of the ribosomal RNA was conserved—its ability to interact successfully with various sets of ribosomal proteins. It is known, however, that the sequence of bases (the chemical building blocks) in RNA varies considerably among different species of bacteria. "We conclude," say Nomura and his colleagues, "that the requirement for a specific base sequence in ribosomal RNA in the reconstitution is not absolute. We suggest that only certain small regions ('conserved' regions) of . . . RNA are directly involved in the specific interaction with ribosomal proteins in the assembly of ribosomal particles." They suggest that the proteins may also retain common structural features that have been conserved by evolution.

What Keeps the Earth Wobbling?

The force that sustains the earth's natural wobble on its axis of rotation appears to be the large-scale deformations produced by major earthquakes. This is the conclusion of L. Mansinha and D. E. Smylie of the University of Western Ontario. The wobble was first observed in the 1890's, when it was found that, among other motions, the earth's north pole of rotation describes an irregular counterclockwise circle some 40 feet in diameter every 14 months. Rigid-body dynamics allows an object such as the earth to have a natural wobble with a 10-month period. The origin of the force required to keep the earth wobbling in spite of strong natural damping tendencies, however, has continued to be a puzzle. Mansinha and Smylie note in *Science* that displacement of the pole of rotation with respect to the geographical pole produces variations in latitude measurements. As a result the movements of the pole of rotation have been observed since 1900, and 10-day mean positions have been published since 1957.

Recently the two investigators compared the dates of the 22 major earthquakes that have occurred since 1957 with the dates of unusual changes in the pole path. Over the 11-year period they found a correlation for 15 out of the 22 earthquakes, which is far greater than might be explained by chance. Moreover, they found that path changes had occurred from one to 18 days before five of the six most severe earthquakes and from eight to 15 days before three of the seven next most severe.

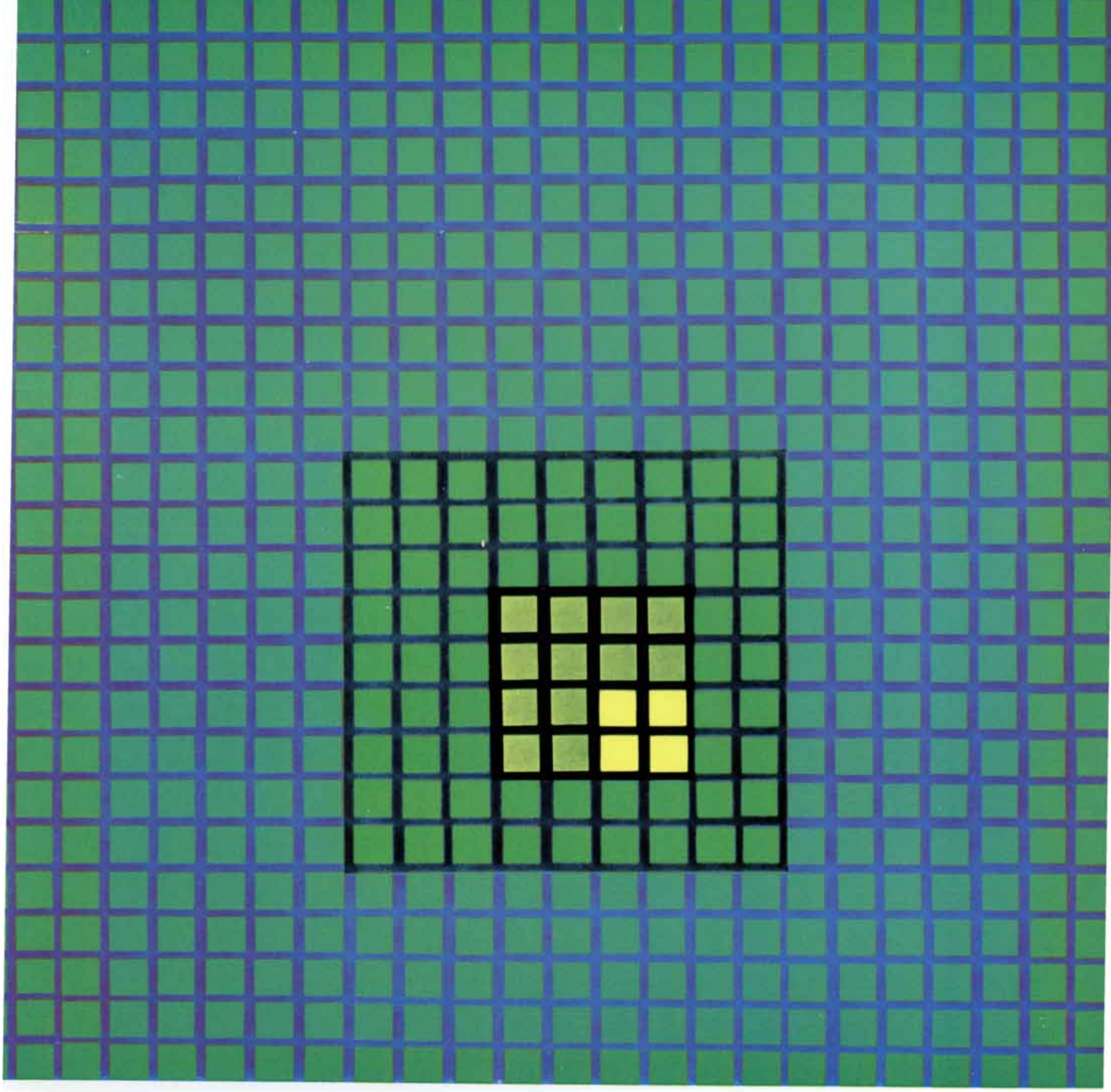
As long as the shift of mass within the earth produced by major earthquakes was thought to extend only a few hundred miles from their epicenter, such deformations fell short by several orders of magnitude of the force needed to sustain the wobble. Mansinha and Smylie had nonetheless speculated that the cumulative effect of large-scale deformations might be sufficient; in their report they point to recent studies implying that the mass shifts associated with major earthquakes actually extend for thousands of miles. They suggest that observation of the pole path, combined with a watch over active fault zones, could contribute to a solution of the problem of forecasting earthquakes.

Ionospheric Ion

A large negative ion of a type that may account for certain properties of the ionosphere has been isolated and studied at the National Bureau of Standards. It is the five-atom ion of hydroxyl monohydrate (H_3O_2). Workers at the bureau think it may be the most complex negative ion ever isolated with sufficient resolution for unambiguous identification.

The ionospheric phenomenon of interest takes place from time to time in the lowest region of the ionosphere. At such times the concentration of ions in the region increases at sunset and decreases at sunrise. Because the lowest region of the ionosphere is the one that reflects radio and radar waves back to the earth, the changed concentrations of ions affect radio and radar transmissions.

Presumably the changes arise from the presence in the ionosphere of ions from which electrons are detached during the day by the energy of solar radiation. Hence during the day the ions become electrically neutral molecules. At night the electrons reattach themselves to the molecules, reconstituting the negative ions. Investigators in several laboratories have been trying to identify



no ivory tower

The scientists who operate Celanese' 39 million dollar R & D effort work in a very real world. When they leave the laboratory, they are just as likely to be headed for a customer's plant as for a seminar on theory. The problems they seek to solve are cleanly stated. Who needs the problem solved, and why, and what the solution is worth, are also stated.

In the practical world of commercial chemistry, there is intellectual stimulation aplenty. The problems are no less complex for being commercial. But the scientist who functions best in this atmosphere takes pleasure in the pragmatic proof of profitable marketing to validate the success of his efforts.

CELANESE®

the negative ions responsible for the ionospheric effects and to determine the amount of energy the ions require for the detaching of electrons. Bruce Steiner and Stephen Golub of the Bureau of Standards were able to isolate and identify the H_3O_2 ion by means of a recently completed apparatus that consists of a source of ions, a double-focusing mass analyzer that focuses a narrow beam of ions for study, a collision chamber and a source of monochromatic light. In the collision chamber the ion beam interacts with light at various wavelengths, absorbing photons and emitting electrons in ways that can be accurately measured.

Ikhnaton and the Computer

A 3,300-year-old jigsaw puzzle, created when Egypt's traditional priesthood destroyed the great temple erected at Thebes by the ill-fated monotheistic reformer Ikhnaton, appears to be well on its way to solution through the use of computer matching techniques. Ikhnaton's temple for the sun god Aten was built out of uniform sandstone blocks 24 inches long and 10 inches high; its walls were then sculptured in relief and the scenes and inscriptions were decorated in a variety of colors. After the temple's destruction the blocks were all reused, either as fill or as foundation stone for later structures. For many decades Egyptologists digging through later ruins have recognized and set aside the characteristically uniform blocks with sculptured faces. Some 30,000 of them have now been recovered; preserved on some are portraits of Ikhnaton, his wife Nefertiti, their children, scenes of ritual and the chase, and numerous inscriptions.

Scholars have despaired of rearranging the scrambled blocks so as to restore the original appearance of the temple walls. Recently, however, the Egyptian Antiquities Service issued a permit to the University Museum of the University of Pennsylvania to develop a project in collaboration with the Cairo service center of the International Business Machines Corporation aimed at applying machine methods to the formidable task. Financed by counterpart funds, project workers have already photographed 25,000 of the blocks and coded their visual contents so that computer matching of block with block can be substituted for laborious handwork. Ray W. Smith, the director of the project, and his Egyptian colleagues expect that a photomontage restoration of the temple's decorated walls will be completed within a few months.

VISUAL ILLUSIONS

Why do simple figures sometimes appear distorted or ambiguous? Perhaps because the visual system has to make sense of a world in which everyday objects are normally distorted by perspective

by Richard L. Gregory

A satisfactory theory of visual perception must explain how the fleeting patterns of light reaching the retina of the eye convey knowledge of external objects. The problem of how the brain "reads" reality from the eye's images is an acute one because objects are so very different from images, which directly represent only a few of the important characteristics of objects. At any instant the retinal image represents the color of an object and its shape from a single position, but color and shape are in themselves trivial. Color is dependent on the quality of the illumination, and on the more subtle factors of contrast and retinal fatigue. Shape, as we all know, can be strongly distorted by various illusions. Since it is obviously not in the best interests of the possessor of an eye to be tricked by visual illusions, one would like to know how the illusions occur. Can it be that illusions arise from information-processing mechanisms that under normal circumstances make the visible world easier to comprehend? This is the main proposition I shall examine here.

Illusions of various kinds can occur in any of the senses, and they can cross over between the senses. For example, small objects feel considerably heavier than larger objects of exactly the same weight. This can be easily demonstrated by filling a small can with sand and then putting enough sand in a much larger can until the two cans are in balance. The smaller can will feel up to 50 percent heavier than the larger can of precisely the same weight. Evidently weight is perceived not only according to the pressure and muscle senses but also according to the expected weight of the object, as indicated by its visually judged size. When the density is unexpected, vision produces the illusion of weight. I believe all systematic-distortion illusions are essentially similar to this size-weight illusion.

Although several visual illusions were known to the ancient Greeks, they have been studied experimentally for only a little more than a century. The first scientific description in modern times is in a letter to the Scottish physicist Sir David Brewster from a Swiss naturalist, L. A. Necker, who wrote in 1832 that a drawing of a transparent rhomboid reverses in depth: sometimes one face appears to be in front and sometimes the other. Necker noted that although changes of eye fixation could induce this change in perception, it would also occur quite spontaneously. This celebrated effect is generally illustrated with an isometric cube rather than with Necker's original figure [*see top illustration on page 68*].

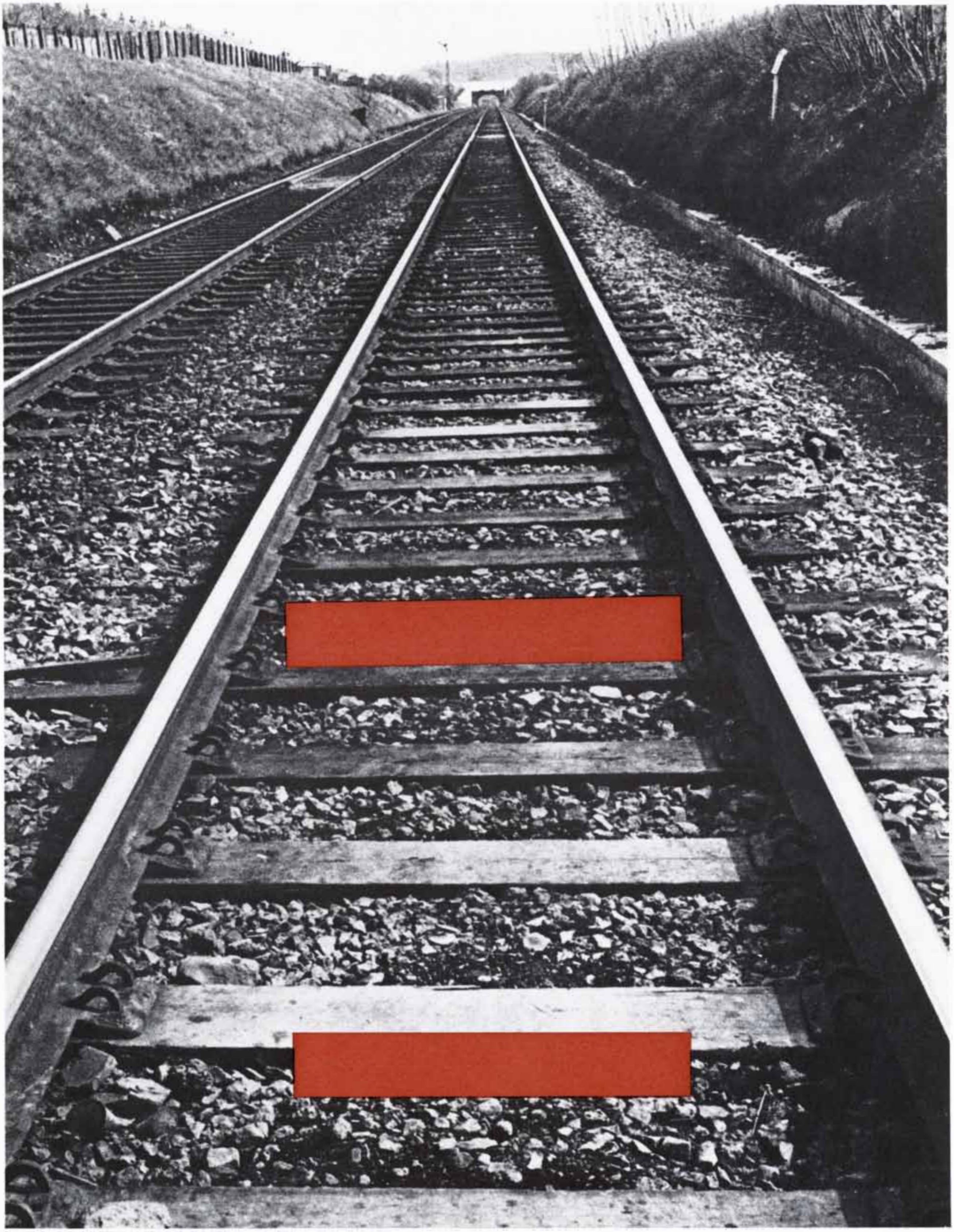
Somewhat later W. J. Sinsteden reported an equally striking effect that must have long been familiar to Netherlanders. If the rotating vanes of a windmill are viewed obliquely or directly from the side, they spontaneously reverse direction if there are no strong clues to the direction of rotation. This effect can be well demonstrated by projecting on a screen the shadow, seen in perspective, of a slowly rotating vane. In the absence of all clues to the direction of rotation the vane will seem to reverse direction spontaneously and the shadow will also at times appear to expand and contract on the plane of the screen. It is important to note that these effects are not perceptual distortions of the retinal image; they are alternative interpretations of the image in terms of possible objects. It is as though the brain entertains alternative hypotheses of what object the eye's image may be representing. When sensory data are inadequate, alternative hypotheses are entertained and the brain never "makes up its mind."

The most puzzling visual illusions are systematic distortions of size or shape. These distortions occur in many quite simple figures. The distortion takes the same direction and occurs to much the same extent in virtually all human observers and probably also in many animals. To psychologists such distortions present an important challenge because they must be explained by a satisfactory theory of normal perception and because they could be important clues to basic perceptual processes.

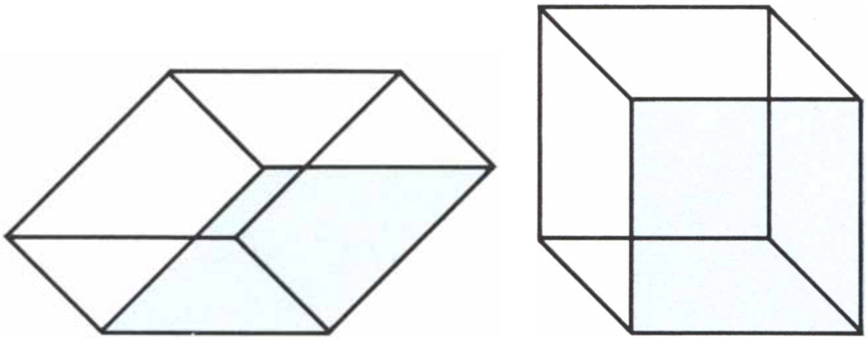
Distortion Illusions

The simplest distortion illusion was also the first to be studied. This is the horizontal-vertical illusion, which was described by Wilhelm Wundt, assistant to Hermann von Helmholtz at Heidelberg and regarded as the father of experimental psychology. The illusion is simply that a vertical line looks longer than a horizontal line of equal length. Wundt attributed the distortion to asymmetry in the system that moves the eye. Although this explanation has been invoked many times since then, it must be ruled out because the distortions occur in afterimages on the retina and also in normal images artificially stabilized so as to remain stationary on the retina. In addition, distortions can occur in several directions at the same time, which could hardly be owing to eye movements. It is also difficult to see how curvature distortions could be related to eye movements. All the evidence suggests that the distortions originate not in the eyes but in the brain.

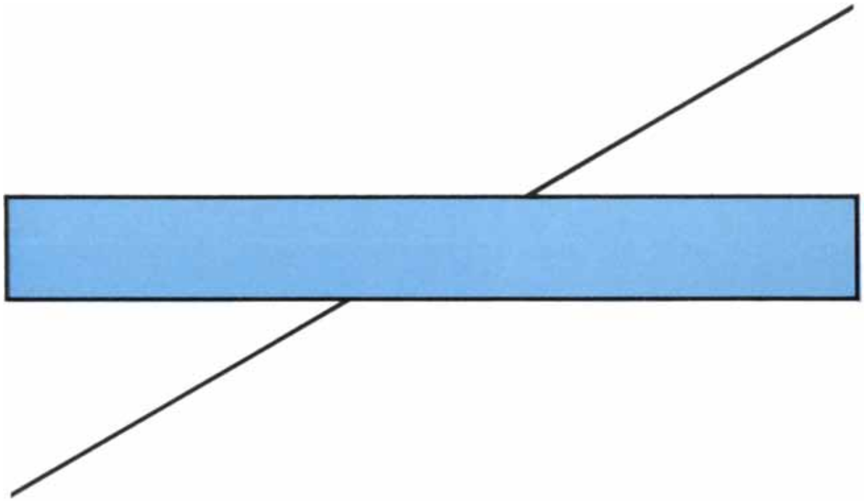
Interest in the illusions became general on the publication of several figures showing distortions that could produce errors in the use of optical instruments. These errors were an important concern to physicists and astronomers a centu-



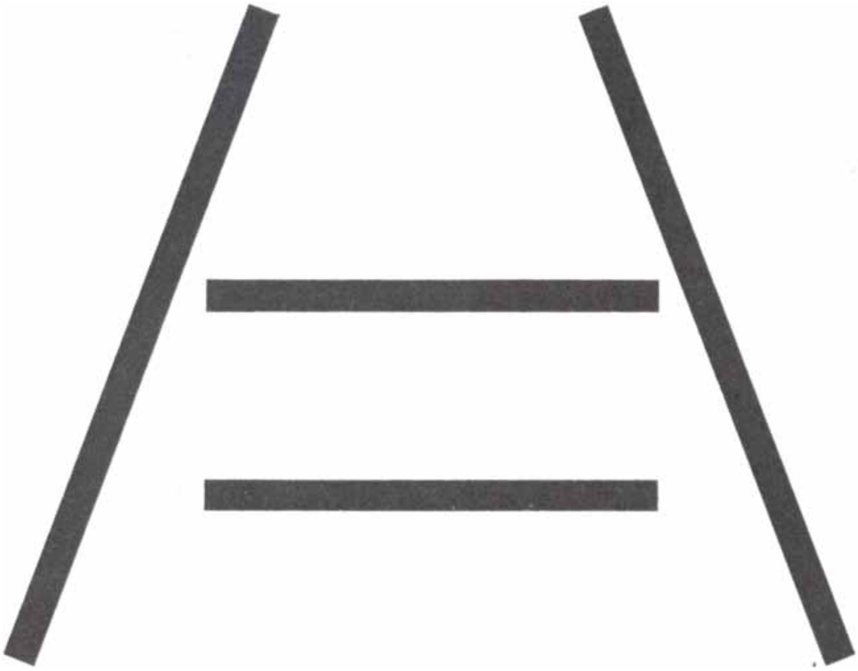
ILLUSION INVOLVING PERSPECTIVE is remarkably constant for all human observers. The two rectangles superposed on this photograph of railroad tracks are precisely the same size, yet the top rectangle looks distinctly larger. The author regards this illusion as the prototype of visual distortions in which the perceptual mechanism, involving the brain, attempts to maintain a rough size constancy for similar objects placed at different distances. Since we know that the distant railroad ties are as large as the nearest ones, any object lying between the rails in the middle distance (the upper rectangle) is unconsciously enlarged. Indeed, if the rectangles were real objects lying between the rails, we would know immediately that the more distant was larger.



NECKER ILLUSION was devised in 1832 by L. A. Necker, a Swiss naturalist. He noticed that a transparent rhomboid (*left*) spontaneously reverses in depth. The area lightly tinted in color can appear either as an outer surface or as an inner surface of a transparent box. The illusion is now more usually presented as a transparent cube (*right*), known as a Necker cube.



POGGENDORFF ILLUSION was proposed by Johann Poggendorff in 1860, the same year that Johann Zöllner proposed the figure shown on the cover of this issue of SCIENTIFIC AMERICAN. In Poggendorff's figure the two segments of the diagonal line seem to be offset.



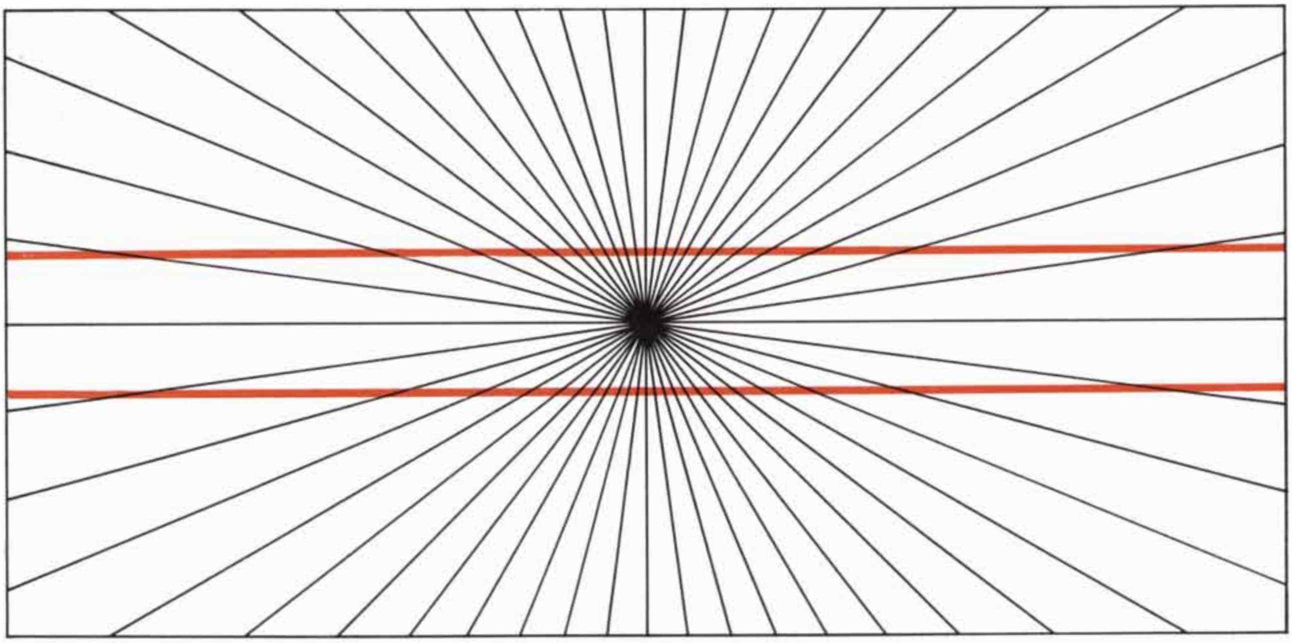
PONZO ILLUSION, also known as the railway lines illusion, was proposed by Mario Ponzo in 1913. It is the prototype of the illusion depicted in the photograph on the preceding page.

ry ago, when photographic and other means of avoiding visual errors were still uncommon. The first of the special distortion figures was the illusion published by Johann Zöllner in 1860 [*see cover of this issue*]. The same year Johann Poggendorff published his line-displacement illusion [*see middle illustration at left*]. A year later Ewald Hering presented the now familiar illusion in which parallel lines appear bowed; the converse illusion was conceived in 1896 by Wundt [*see illustrations on opposite page*].

Perhaps the most famous of all distortion illusions is the double-headed-arrow figure devised by Franz Müller-Lyer and presented in 15 variations in 1889 [*see illustration on page 70*]. This figure is so simple and the distortion is so compelling that it was immediately accepted as a primary target for theory and experiment. All kinds of theories were advanced. Wundt again invoked his eye-movement theory. It was also proposed that the "wings" of the arrowheads drew attention away from the ends of the central line, thus making it expand or contract; that the heads induced a state of empathy in the observer, making him feel as if the central line were being either stretched or compressed; that the distortion is a special case of a supposed general principle that acute angles tend to be overestimated and obtuse angles underestimated, although why this should be so was left unexplained.

All these theories had a common feature: they were attempts to explain the distortions in terms of the stimulus pattern, without reference to its significance in terms of the perception of objects. There was, however, one quite different suggestion. In 1896 A. Thiery proposed that the distortions are related to the way the eye and brain utilize perspective to judge distances or depths. Thiery regarded the Müller-Lyer arrows as drawings of an object such as a sawhorse, seen in three dimensions; the legs would be going away from the observer in the acute-angled figure and toward him in the obtuse-angled figure. Except for a brief discussion of the "perspective theory" by Robert S. Woodworth in 1938, Thiery's suggestion has seldom been considered until recently.

Woodworth wrote: "In the Müller-Lyer figure the obliques readily suggest perspective and if this is followed one of the vertical lines appears farther away and therefore objectively longer than the other." This quotation brings out the immediate difficulties of developing an adequate theory along such lines. The distortion occurs even when the

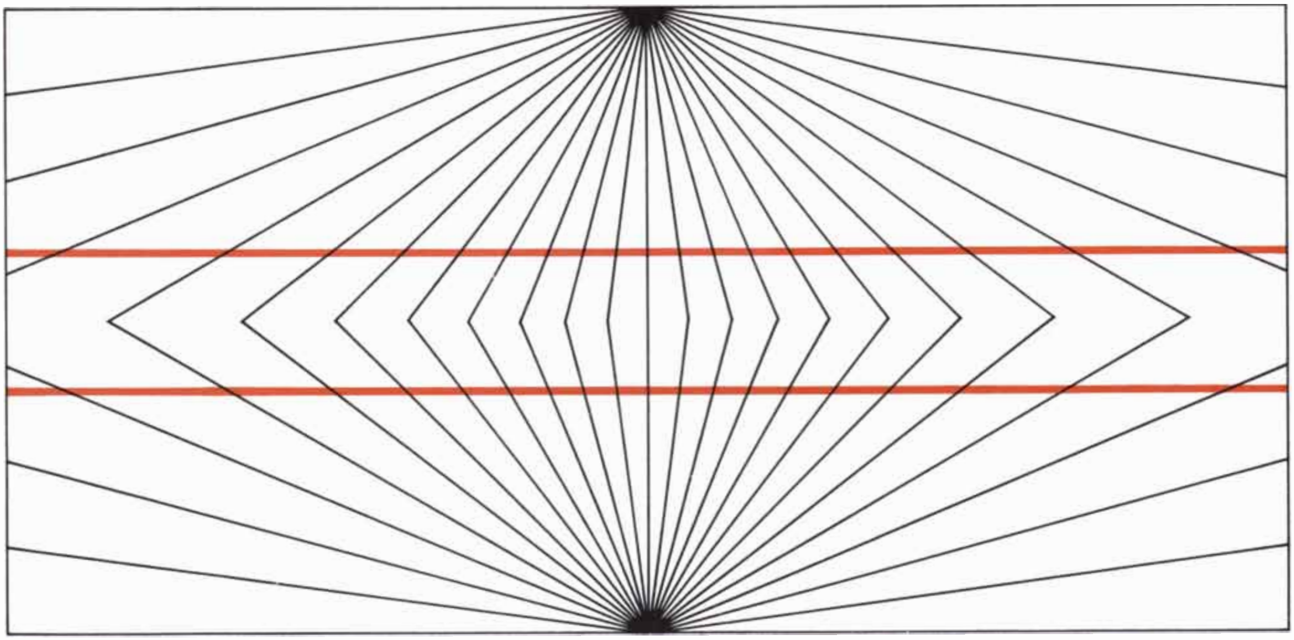


HERING ILLUSION was published in 1861 by Ewald Hering. The horizontal lines are of course straight. Physicists and astronomers of that period took a lively interest in illusions, being concerned that visual observations might sometimes prove unreliable.

perspective suggestion is not followed up, because the arrows generally appear flat and yet are still distorted. Moreover, no hint is given of a mechanism responsible for the size changes. An adequate theory based on Thiery's suggestion must show how distortion occurs even though the figures appear flat. It should also indicate the kind of brain mechanisms responsible.

The notion that geometric perspective—the apparent convergence of parallel lines with distance—has a bearing on the problem is borne out by the occurrence of these distortions in photographs of actual scenes in which perspective is pronounced. Two rectangles of equal size look markedly unequal if they are superposed on a photograph of converging railroad tracks [*see illustration on page 67*]. The upper rectangle in the illustration, which would be the more distant if it were a real object lying between the tracks, looks larger than the lower (and apparently nearer) one. This corresponds to the Ponzo illusion [*see bottom illustration on opposite page*].

Similarly, the eye tends to expand the inside corner of a room, as it is seen in a photograph, and to shrink the outside corners of structures [*see illustration on page 71*]. The effect is just the same as the one in the Müller-Lyer figures, which in fact resemble outline drawings of corners seen in perspective. In both cases the regions indicated by perspec-



CONVERSE OF HERING ILLUSION was conceived in 1896 by Wilhelm Wundt, who introduced experimentation into psychology. Wundt earlier described the simplest of the visual illusions: that a vertical line looks longer than a horizontal line of equal length.

tive as being distant are expanded, whereas those indicated as being closer are shrunk. The distortions are opposite to the normal shrinking of the retinal image when the distance to an object is increased. Is this effect merely fortuitous, or is it a clue to the origin of the illusions?

Paradoxical Pictures

Before we come to grips with the problem of trying to develop an adequate theory of perspective it will be helpful to consider some curious features of ordinary pictures. Pictures are the traditional material of perceptual research, but all pictures are highly artificial and present special problems to the perceiving brain. In a sense all pictures are impossible because they have a dual reality. They are seen both as patterns of lines lying on a flat background and as objects depicted in a quite different three-dimensional space. No actual object can be both two-dimensional and three-dimensional, yet pictures come close to it. Viewed as patterns they are seen as being two-dimensional; viewed as representing other objects they are seen in a quasi-three-dimensional space. Pictures therefore provide a paradoxical visual input. They are also ambiguous, because the third dimension is never precisely defined.

The Necker cube is an example of a picture in which the depth ambiguity is so great that the brain never settles for a single answer. The fact is, however, that any perspective projection could represent an infinity of three-dimensional shapes. One would think that the perceptual system has an impossible task! Fortunately for us the world of objects does not have infinite variety; there is usually a best bet, and we generally interpret our flat images more or less correctly in terms of the world of objects.

The difficulty of the problem of seeing the third dimension from the two dimensions of a picture, or from the retinal images of normal objects, is ingeniously brought out by special "impossible pictures" and "impossible objects." They show what happens when clearly incompatible distance information is presented to the eye. The impossible triangle devised by Lionel S. Penrose and R. Penrose cannot be perceptually interpreted as an object in normal three-dimensional space [*see illustration on page 72*]. It is, however, perfectly possible to make actual three-dimensional objects, not mere pictures, that give rise to the same perceptual confusion—provided that they are viewed with only one eye. For example, the Penrose triangle can be built as an open three-dimensional structure [*see top illustration on page 73*] that looks like an impossible closed structure when it is viewed with one eye (or photographed) from exactly the right position [*see bottom illustration on page 73*].

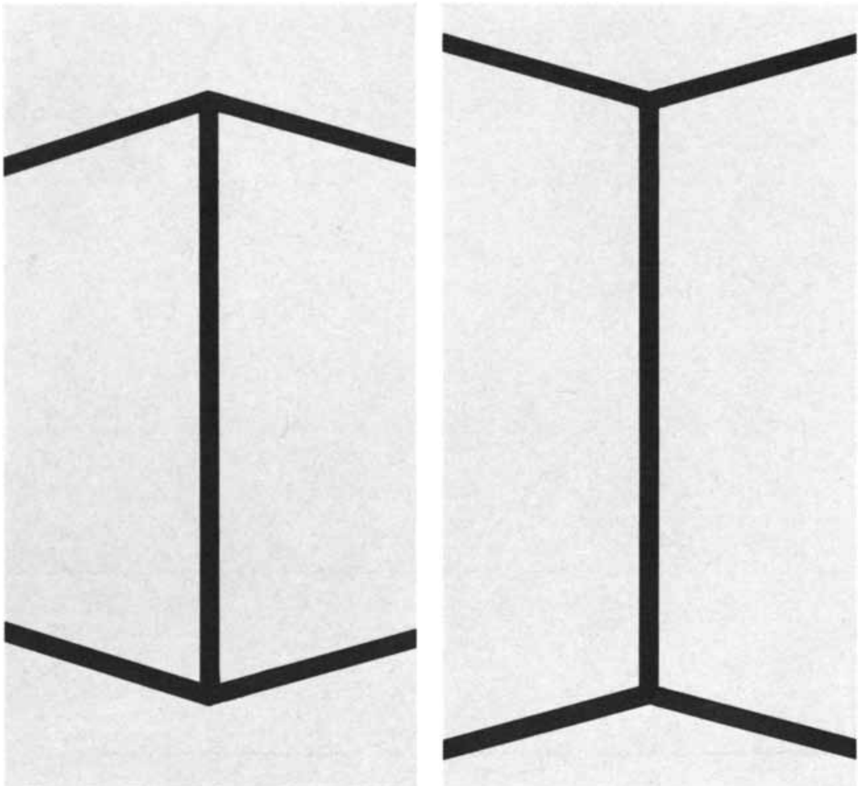
Ordinary pictures are not so very different from obviously impossible pictures. All pictures showing depth are paradoxical: we see them both as being flat (which they really are) and as having a kind of artificial depth that is not quite right. We are not tempted to touch objects shown in a picture through the surface of the picture or in front of it. What happens, however, if we remove the surface? Does the depth paradox of pictures remain?

The Removal of Background

To remove the background for laboratory experiments we make the pictures luminous so that they glow in the dark. In order to deprive the brain of stereoscopic information that would reveal that the pictures are actually flat the pictures are viewed with one eye. They may be wire figures coated with luminous paint or photographic transparencies back-illuminated with an electroluminescent panel. In either case there is no visible background, so that we can discover how much the background is responsible for the depth paradox of pictures, including the illusion figures.

Under these conditions the Müller-Lyer arrows usually look like true corners according to their perspective. They may even be indistinguishable from actual luminous corners. The figures are not entirely stable: they sometimes reverse spontaneously in depth. Nonetheless, they usually appear according to their perspective and without the paradoxical depth of pictures with a background. The distortions are still present. The figure that resembles a double-headed arrow looks like an outside corner and seems shrunk, whereas the figure with the arrowheads pointing the wrong way looks like an inside corner and is expanded. Now, however, the paradox has disappeared and the figures look like true corners. With a suitable apparatus one can point out their depth as if they were normal three-dimensional objects.

Having removed the paradox, it is possible to measure, by quite direct means, the apparent distance of any selected part of the figures. This we do by using the two eyes to serve as a range finder for indicating the apparent depth



MÜLLER-LYER ILLUSION was devised by Franz Müller-Lyer in 1889. Many theories were subsequently invoked in an attempt to explain why reversed arrowheads (*right*) seem to lengthen a connecting shaft whereas normal arrowheads seem to shrink the shaft (*left*).

of the figure, which is visible to only one eye. The back-illuminated picture is placed behind a polarizing filter so that one eye is prevented from seeing the picture by a second polarizing filter oriented at right angles to the first. Both eyes, however, are allowed to see one or more small movable reference lights that are optically introduced into the picture by means of a half-silvered mirror set at 45 degrees to the line of sight. The distance of these lights is given by stereoscopic vision, that is, by the convergence angle of the eyes; by moving the lights so that they seem to coincide with the apparent distance of selected parts of the picture we can plot the visual space of the observer in three dimensions [*see top illustration on page 74*].

When this plotting is done for various angles of the "fin," or arrowhead line, in the Müller-Lyer illusion figure, it becomes clear that the figures are perceived as inside and outside corners. The illusion of depth conforms closely to the results obtained when the magnitude of the illusion is independently measured by asking subjects to select comparison lines that match the apparent length of the central line between two kinds of arrowhead [*see bottom illustration on page 74*]. In the latter experiment the figures are drawn on a normally textured background, so that they appear flat.

The two experiments show that when the background is removed, depth very closely follows the illusion for the various fin angles. The similarity of the plotted results provides evidence of a remarkably close connection between the illusion as it occurs when depth is not seen and the depth that is seen when the background is removed. This suggests that Thiery was essentially correct: perspective can somehow create distortions. What is odd is that perspective produces the distortions according to *indicated* perspective depth even when depth is *not* consciously seen.

Size Constancy

The next step is to look for some perceptual mechanism that could produce this relation between perspective and apparent size. A candidate that should have been obvious many years ago is size constancy. This phenomenon was clearly described in 1637 by René Descartes in his *Dioptrics*. "It is not the absolute size of images [in the eyes] that counts," he wrote. "Clearly they are 100 times bigger [in area] when objects are very close than when they are 10 times farther away, but they do not make us see the objects 100 times bigger. On the contrary, they seem almost the same size, at any rate as we are not deceived by too great a distance."

We know from many experiments that Descartes is quite right. What happens, however, when distance information, such as perspective, is presented to the eye but two components of the scene, one of which should be shrunk by distance, are the same size? Could it be that perspective presented on a flat plane triggers the brain to compensate for the expected shrinking of the images with distance even though there is no shrinking for which to compensate? If some such thing happens, it is easy to see why figures that suggest perspective can give rise to distortions. This would provide the start of a reasonable theory of illusions. Features indicated as being distant would be expanded, which is just what we find, at least for the Müller-Lyer and the Ponzo figures.

It is likely that this approach to the problem was not developed until recently because, although size constancy was quite well known, it has always been assumed that it simply follows apparent distance in all circumstances. Moreover, it has not been sufficiently realized how very odd pictures are as visual inputs. They are highly atypical and should be

THEORY OF MÜLLER-LYER ILLUSION favored by the author suggests that the eye unconsciously interprets the arrow-like figures as three-dimensional skeleton structures, resembling either an outside (*left*) or inside corner (*right*) of a physical structure. A perceptual mechanism evidently shrinks the former and enlarges the latter to compensate for distortion caused by perspective.

studied as a special case, being both paradoxical and ambiguous.

Size constancy is traditionally identified with an effect known as Emmert's law. This effect can be explained by a simple experiment involving the apparent size of afterimages in vision. If one can obtain a good afterimage (preferably by briefly illuminating a test figure with an electronic flash lamp), one can "project" it on screens or walls located at various distances. The afterimage will appear almost twice as large with each doubling of distance, even though the size of the image from the flash remains constant. It is important to note, however, that there *is* a change in retinal stimulation for each screen or wall lying at a different distance; their images *do* vary. It is possible that the size change of the afterimage is due not so much to a brain mechanism that changes its scale as to its size on the retina with respect to the size of the screen on which it appears to lie. Before we go any further, it is essential to discover whether Emmert's law is due merely to the relation between the areas covered by the afterimage and the screen, or whether the visual information of distance changes the size of the afterimage by some kind of internal scaling. This presents us with a tricky experimental problem.

As it turns out, there is a simple solution. We can use the ambiguous depth phenomenon of the Necker cube to establish whether Emmert's law is due to a central scaling by the brain or is merely an effect of relative areas of stimulation of the retina. When we see a Necker cube that is drawn on paper reverse in depth, there is no appreciable size change. When the cube is presented on a textured background, it occupies the paradoxical depth of all pictures with visible backgrounds; it does not change in size when it reverses in pseudo-depth.

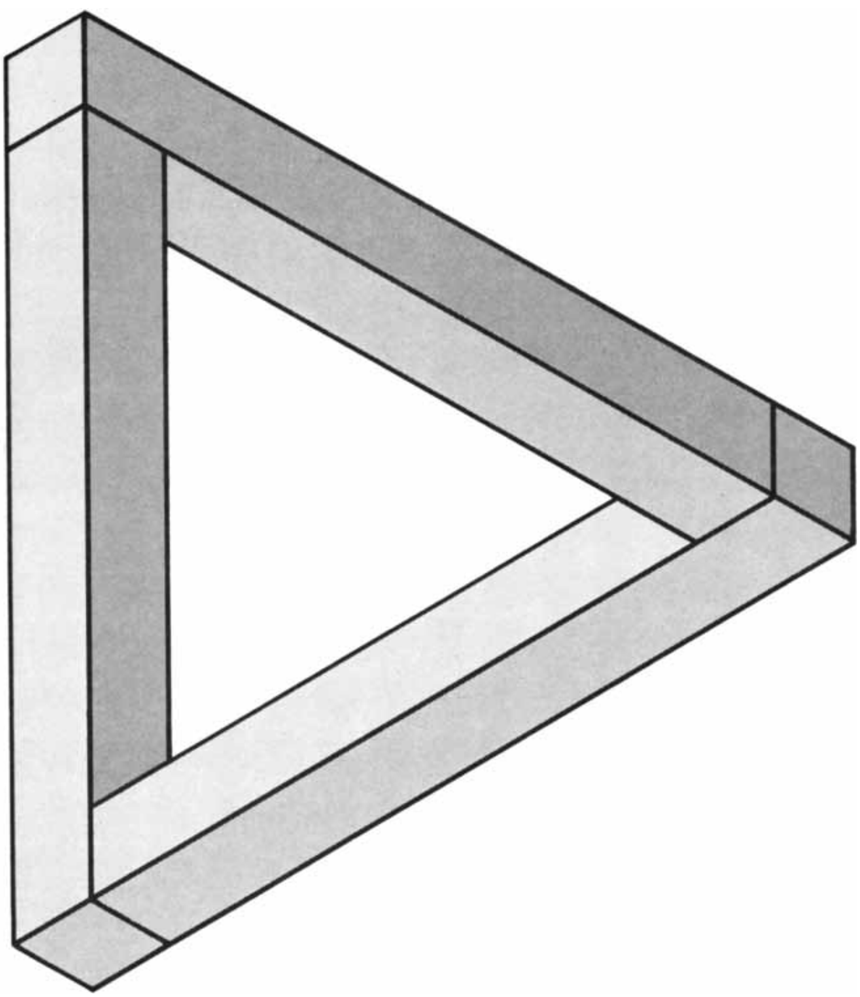
What happens, however, if we remove the cube's background? The effect is dramatic and entirely repeatable: with each reversal in depth the cube changes its apparent shape, even though there is no change in the retinal image. Whichever face appears to be more distant always appears to be the larger. The use of depth-ambiguous figures in this way makes it possible to separate what happens when the pattern of stimulation of the retina is changed. The answer is that at least part of size constancy, and of Emmert's law, is due to a central size-scaling mechanism in the brain that responds to changes in apparent distance although the retinal stimulation is unchanged.

Apparent size, then, is evidently established in two ways. It can be established purely by apparent distance. It can also be established directly by visual depth features, such as perspective in two-dimensional pictures, even though depth is not seen because it is countermanded by competing depth information such as a visible background. When atypical depth features are present, size scaling is established inappropriately and we have a corresponding distortion illusion.

The size scaling established directly by depth features (giving systematic distortions when it is established inappropriately) we may call "depth-cue scaling." It is remarkably consistent and independent of the observer's perceptual "set." The other system is quite different and more subtle, being only indirectly related to the prevailing retinal information. It is evidently linked to the interpretation of the retinal image in terms of what object it represents. When it appears as a different object, the scaling changes at once to suit the alternative object. If we regard the seeing of an object as a hypothesis, suggested (but never strictly proved) by the image, we may call the system "depth-hypothesis scaling," because it changes with each change of the hypothesis of what object is represented by the image. When the hypothesis is wrong, we have an illusion that may be dramatic. Such alternations in hypotheses underlie the changes in direction, and even size, that occur when one watches the shadow of a rotating vane.

Observers in Motion

The traditional distortion illusions can be attributed to errors in the setting of the depth-cue scaling system, which arise when figures or objects have misleading depth cues, particularly perspective on a flat plane. Although these illusions might occasionally bother in-



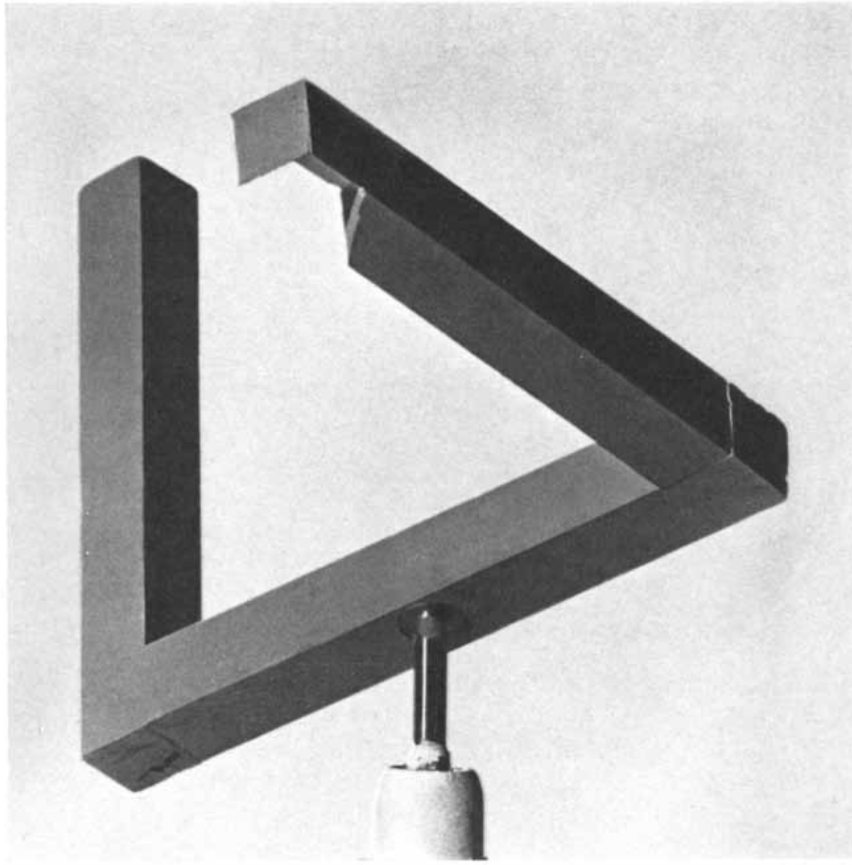
IMPOSSIBLE TRIANGLE was devised by Lionel S. Penrose and R. Penrose of University College London. It is logically consistent over restricted regions but is nonsensical overall. The author sees a certain similarity between such impossible figures and ordinary photographs, which provide the illusion of a third dimension even though they are flat.

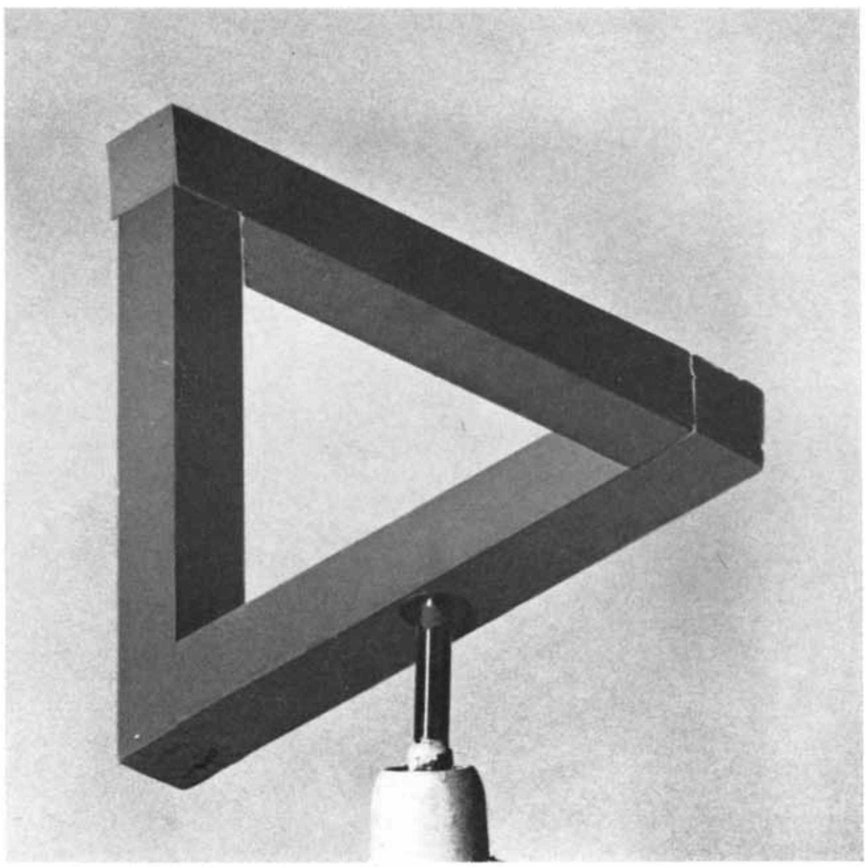
vestigators making visual measurements, they are seldom a serious hazard. The other kind of illusion—incorrect size-scaling due to an error in the prevailing perceptual hypothesis—can be serious in unfamiliar conditions or when there is little visual information available, as in space flight. It can also be important in driving a car at night or in landing an airplane under conditions of poor visibility. Illusions are most hazardous when the observer is in rapid motion, because then even a momentary error may lead to disaster.

So far little work has been done on the measurement of illusions experienced by observers who are in motion with respect to their surroundings. The experimental difficulties involved in making such measurements are severe; nevertheless, we have been tackling the problem with support from the U.S. Air Force. The equipment, which is fairly elaborate, can move the observer with controlled velocity and acceleration through various visual environments, including the blackness of space (with or without artificial stars presented optically at infinite distance).

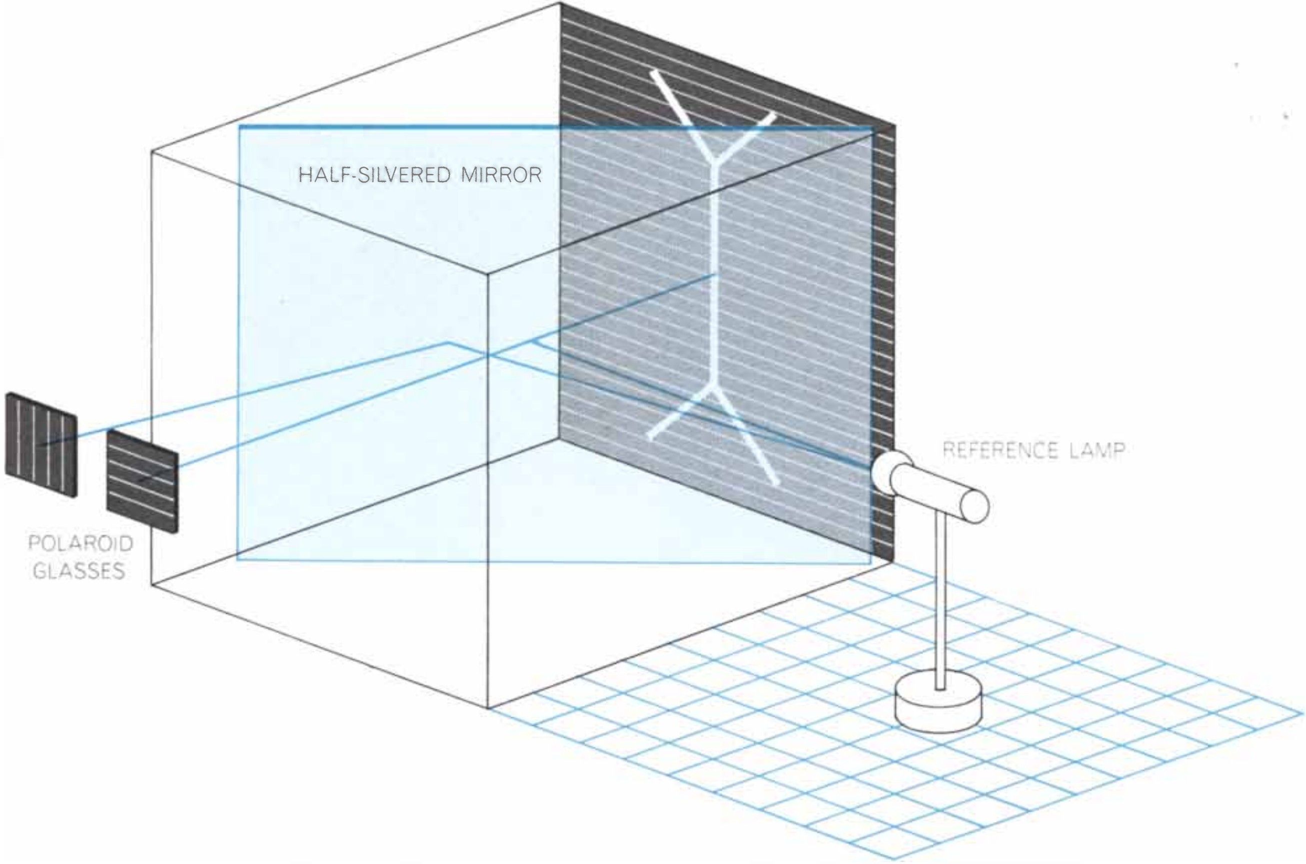
We measure the observer's visual sense of size constancy as he is moving by having him look at a projected display that changes size as he approaches or recedes from it. As he moves away from it, the display is made to expand in size; as he approaches it, the display is made to shrink. The change in size is adjusted until, to the moving observer, the display appears fixed in size. If there were no perceptual mechanism for constancy scaling, the size of the display would have to be adjusted so that its image on the observer's retina would be the same size regardless of his distance from it. If, at the other extreme, the size-constancy effect were complete, we could leave the display unchanged and it would still appear to be the same size regardless of its actual distance from the observer. In practice some size change between these limits provides the illusion of an unchanging display, and this gives us a measure of the size-constancy effect as the observer is moved about.

We find that when the observer is in complete darkness, watching a display that is projected from the back onto a large screen, there is no measurable size constancy when the observer is moving at a fixed speed. When he is accelerated, size constancy does appear but it may be wildly wrong. In particular, if he interprets his movement incorrectly, either in direction or in amount, size constancy usually fails and can even work in reverse. This is rather similar to the

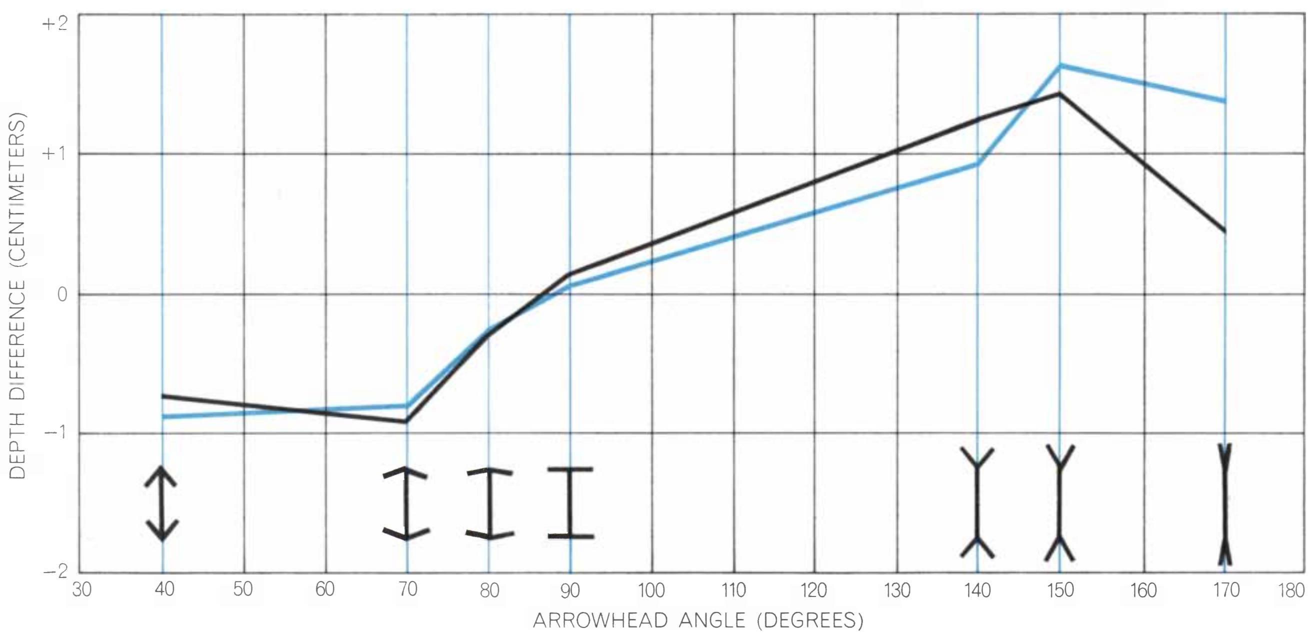




ACTUAL IMPOSSIBLE TRIANGLE was constructed by the author and his colleagues. The only requirement is that it be viewed with one eye (or photographed) from exactly the right position. The top photograph shows that two arms do not actually meet. When viewed in a certain way (*bottom*), they seem to come together and the illusion is complete.



APPARATUS FOR STUDYING ILLUSIONS was devised by the author. The objective is to present figures such as the Müller-Lyer arrows with the background removed so that the figures seem suspended in space. Under these conditions the Müller-Lyer arrows generally look like true corners. The subject can adjust a small light so that it appears to lie at the same depth as any part of the figure. The light, which the subject sees in three-dimensional space with both eyes, is superposed on the illuminated figure by means of a half-silvered mirror. A polarizing filter is placed over the figure and the subject wears polarizing glasses that allow him to see the figure with only one eye. Thus he has no way of telling whether the figure is really two-dimensional or three-dimensional.



QUANTITATIVE MEASUREMENT OF ILLUSION produced the results plotted here for Müller-Lyer arrows. The black curve shows the average results for 20 subjects who were asked to select a comparison line that matched the length of a central shaft to which were attached arrowheads set at the angles indicated. When arrowheads were set at less than 90 degrees, the comparison lines were as much as one centimeter shorter. When the arrowhead was set at 150 degrees, the comparison line was more than 1.5 centimeters longer. The colored curve shows the maximum depth difference perceived for the same set of arrows when displayed, with the background removed, in the apparatus shown in the illustration at the top of the page. The two curves match quite closely except at the extreme setting of 170 degrees, when the figure no longer resembles a true corner when presented in the light box.

reversal of size constancy with reversal of the depth of the luminous Necker cube. In the conditions of space, perception may be dominated by the prevailing hypothesis of distance and velocity. If either is wrong, as it may well be for lack of reliable visual information, the astronaut may suffer visual illusions that could be serious.

The Nonvisual in Vision

Visual perception involves "reading" from retinal images a host of characteristics of objects that are not represented directly by the images in the eyes. The image does not convey directly many important characteristics of objects: whether they are hard or soft, heavy or light, hot or cold. Nonvisual characteristics must somehow be associated with the visual image, by individual learning or conceivably through heredity, for objects to be recognized from their images. Psychologists now believe individual perceptual learning is very important for associating the nonoptical properties of objects with their retinal images. Such learning is essential for perception; without it one would have mere stimulus-response behavior.

Perception seems to be a matter of looking up information that has been stored about objects and how they behave in various situations. The retinal image does little more than select the relevant stored data. This selection is rather like looking up entries in an encyclopedia: behavior is determined by the contents of the entry rather than by the stimulus that provoked the search. We can think of perception as being essentially the selection of the most appropriate stored hypothesis according to current sensory data.

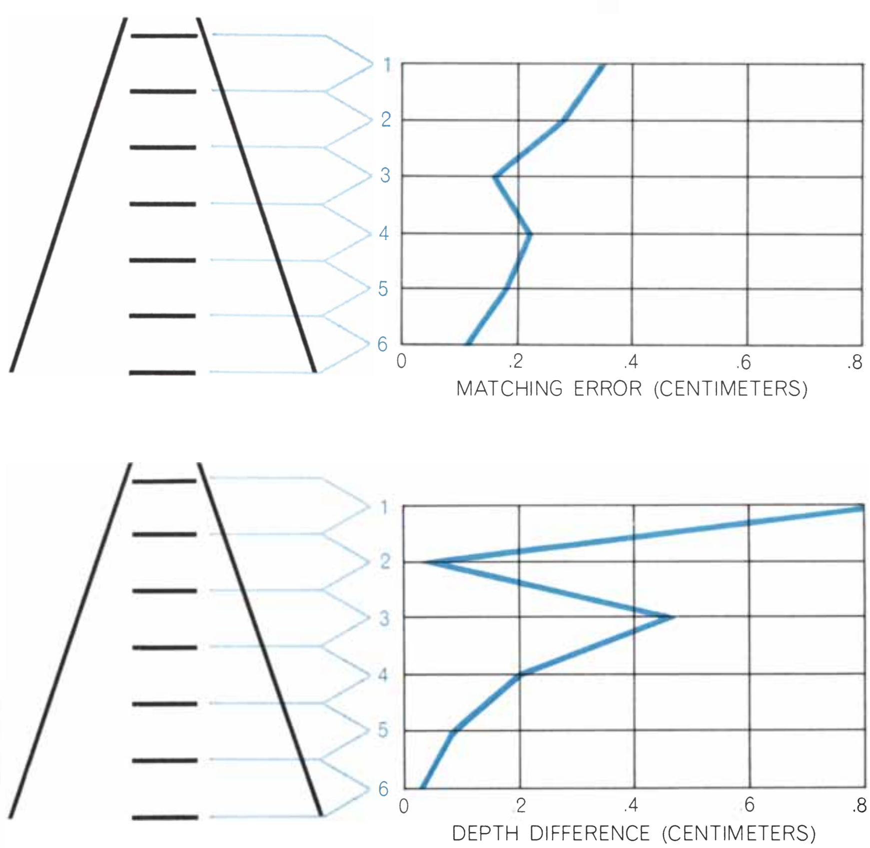
Now, a look-up system of this kind has great advantages over a control system that responds simply to current input. If stored information is used, behavior can continue in the temporary absence of relevant information, or when there is inadequate information to provide precise control of behavior directly. This advantage has important implications for any possible perceptual system, including any future "seeing machine": a robot equipped with artificial eyes and a computer and designed to control vehicles or handle objects by means of artificial limbs. Even when enough direct sensory information is available for determining the important characteristics of surrounding objects (which is seldom the case), it would require a rate of data transmission in excess of that provided by the human

nervous system (or current computers) to enable a robot to behave appropriately. Hence there are strong general design reasons for supposing that any effective seeing system—whether biological or man-made—should use current sensory information for selecting preformed hypotheses, or models, representing important features of the external world of objects as opposed to controlling behavior directly from sensory inputs.

If we consider the problems of storing information about objects, it soon becomes clear that it would be most uneconomical to store an independent model of each object for every distance and orientation it might occupy in surrounding space. It would be far more economical to store only typical characteristics of objects and to use current sensory information to adjust the selected model to fit the prevailing situation. The model must be continually scaled for distance and orientation if the owner of the perceptual system is to interact with the object.

We might guess that depth-cue scaling represents this adjustment of the selected model in the light of the available depth information. When the available information is inappropriate (as in the case of perspective features on a flat plane), it will scale the perceptual model wrongly. There will be a systematic error: a distortion illusion due to inappropriate depth-cue scaling. There will also be errors—possibly very large ones—whenever a wrong model is selected. We see this happening in a repeatable way in the ambiguous figures, such as the luminous Necker cube, that change shape with each depth reversal even though the sensory input is unchanged.

If this general account of perception as essentially a look-up system is correct, we should expect illusions similar to our own to arise in any effective perceptual system, including future robots. Illusions are not caused by any limitation of our brain. They are the result of the imperfect solutions available to any data-handling system faced with the problem of establishing the reality of objects from ambiguous images.



RAILWAY LINES ILLUSION can also be studied quantitatively. The methods are the same as those described in the bottom illustration on page 74. Subjects were presented with a horizontal line at one of the indicated positions and asked to select a second line that seemed to match it in length. The matching error for different pairs is plotted in the top curve. Pairs of lines were then presented in the apparatus shown at the top of page 74 and the subjects adjusted the light to match the apparent depth of each line. Under these conditions (*bottom curve*) the illusion of depth is much more dependent on where a given pair of lines is located with respect to the "rails," but the trend of the top curve is preserved.

monorails and rockets to the moon get all the publicity.

Railroads seem to go about their business more quietly. Yet they're keeping abreast of a fast moving world with the most advanced industrial design and engineering.

And the most modern computer technology. Like the UNIVAC® Real-Time System.

Take, for example, the Japanese National Railways, one of Asia's largest enterprises.

If it weren't for the JNR, Japan wouldn't be able to move the 100 million people that are crammed into an area

100 million people. And most of them depend on railroad transportation.

That's why passenger and freight volume are forever on the rise and have to be run on incredibly tight schedules.

This isn't easy when you're handling 16.5 million people and 563,000 tons of freight every day.

But the JNR does it. And with the help of the UNIVAC 490 manages to provide some of the fastest and safest train rides in the world. And some of the most comfortable and punctual.

The UNIVAC 490 serves as a nucleus for integrated work in cost accounting, settlements, assets, payroll, purchase and

personnel and health programs.

Univac is working for a number of railroad systems—from the newly formed Penn Central; the French National; C&O/B&O; Great Northern—to the Boston and Maine; Spokane, Portland and Seattle; Bessemer and Lake Erie.

Univac systems are working around the clock and around the world for industry, education and government, to help people go where they want to go faster.

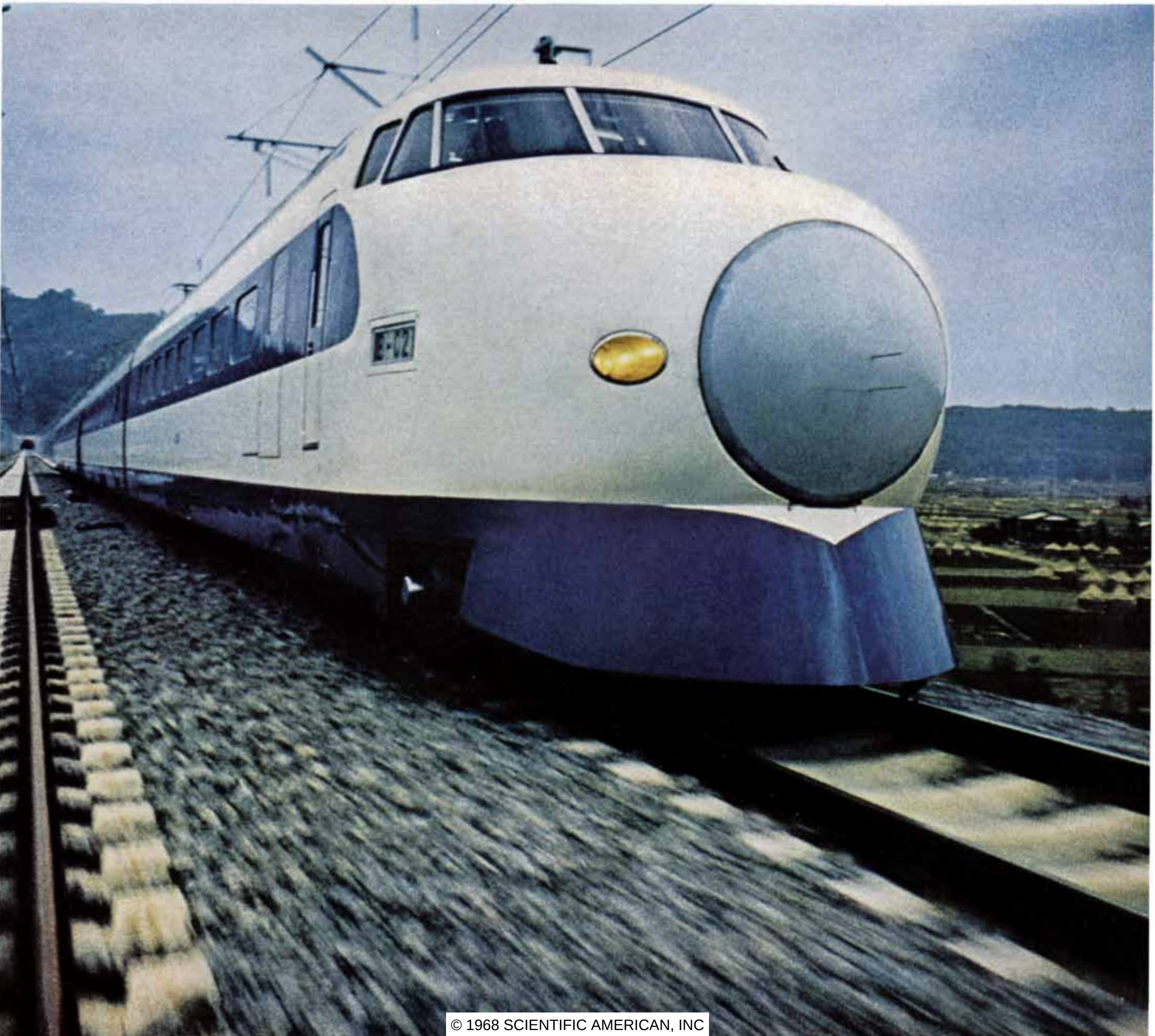
UNIVAC

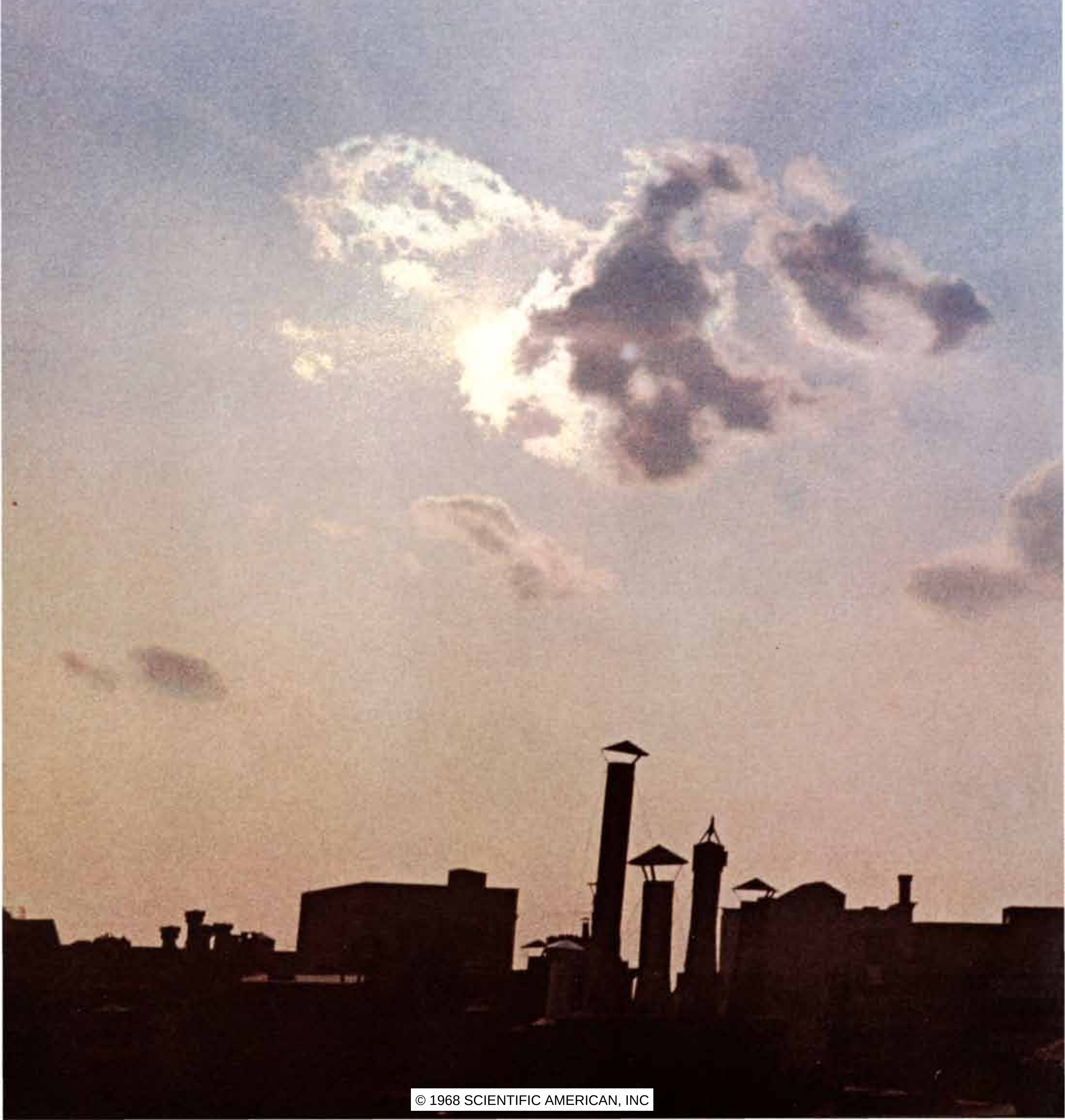
Univac is saving a lot of people a lot of time.

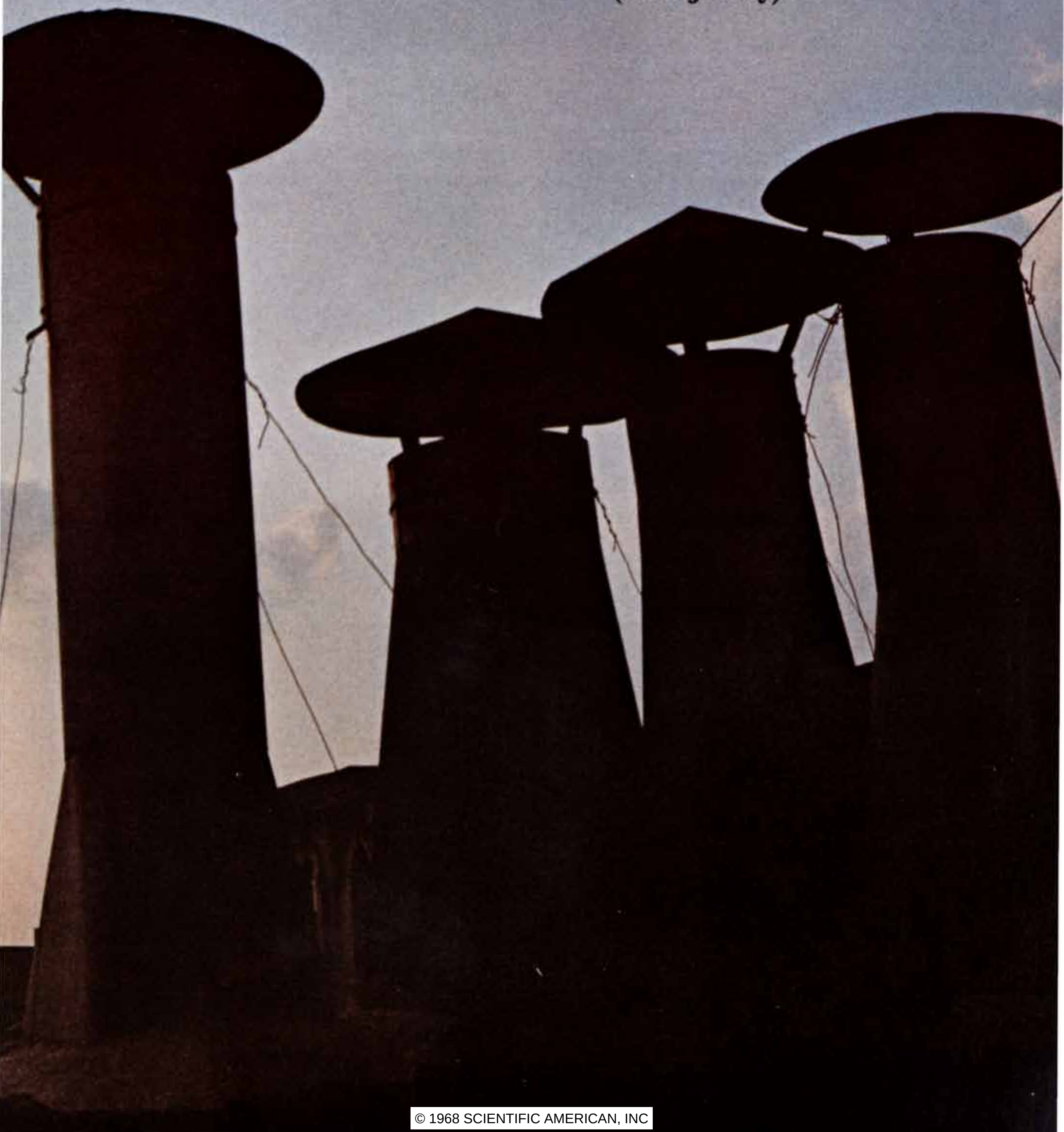
SPERRY RAND

This isn't exactly the Chattanooga Choo-Choo.

The Bullet Train is the world's fastest. It speeds by Mount Fuji every day at 125 mph.







BARIUM CLOUD changes in color and shape as its atoms undergo ionization from solar radiation. At first (*left*) the cloud is multicolored and spherical, but soon (*right*) the ionized atoms separate along the earth's lines of magnetic force. Ionized cloud is purple.

HIGH-ALTITUDE RELEASE of a barium cloud was made about 590 miles above the U.S. East Coast. At left the nonionized part is spherical and the ionized part is following lines of force that go through point of origin. Ions later fall to lower altitude (*right*).

TWO CLOUDS were created in the auroral zone over Canada in August, 1967. At left the first cloud has grown to a length of more than 60 miles when the second cloud is released. At right an elongated cloud shows striations aligned with earth's magnetic field.

Artificial Plasma Clouds in Space

In which clouds of barium atoms are released by rockets at high altitudes and ionized by solar radiation. These clouds of plasma then interact with electric and magnetic fields around the earth

by Gerhard Haerendel and Reimar Lüst

The early observation that the tails of certain comets always point away from the sun provided a hint of the vast movements and interactions of plasmas in the universe. A plasma is a gas with distinctive electrical properties. The tails of many comets consist of a plasma, and the fact that they are directed away from the sun led the German astrophysicist Ludwig Biermann to the recognition of another cosmic plasma: the solar "wind," a thin, hot gas expelled by the sun. The plasma tail of a comet points away from the sun for the same reason that a wind sock at an airport shows the direction of an earthly wind.

Comets, of course, are not under earthly control. It has seemed to a number of investigators that a useful purpose would be served by artificially creating visible clouds of plasma in space. Such clouds could be expected to lead to a better understanding of the behavior of comet tails. Another important interest was the likelihood that the artificial plasma clouds would help in the study of the magnetosphere, the region in which the earth's magnetic field influences the behavior of plasmas. Moreover, the interaction of plasmas and magnetic fields is of much interest in such diverse areas as space travel, high-temperature technology and the production of electric power from nuclear fusion.

It was with these aims in view that our group at the Max Planck Institute for Physics and Astrophysics near Munich began in 1962 to develop a technique for releasing visible plasma clouds from rockets fired into space. Our first shot, in 1963, was only partly successful, but since then we have produced and observed a number of clouds. The results have been spectacular, as can be seen in the photographs on the opposite page. The experiments are also fulfilling our hopes of acquiring information about plasmas and their interaction with electromagnetic forces.

A plasma in the sense we are using the word is a gas composed both of positively charged ions, which are atoms or molecules that have lost one or more electrons as a result of an outside influence such as the ultraviolet radiation of the sun, and of free electrons, which are negatively charged. These electrical properties make a plasma behave quite differently from an ordinary gas, which is electrically neutral because it consists of neutral atoms and molecules. The most significant behavioral difference is that a plasma responds to the forces of electric and magnetic fields.

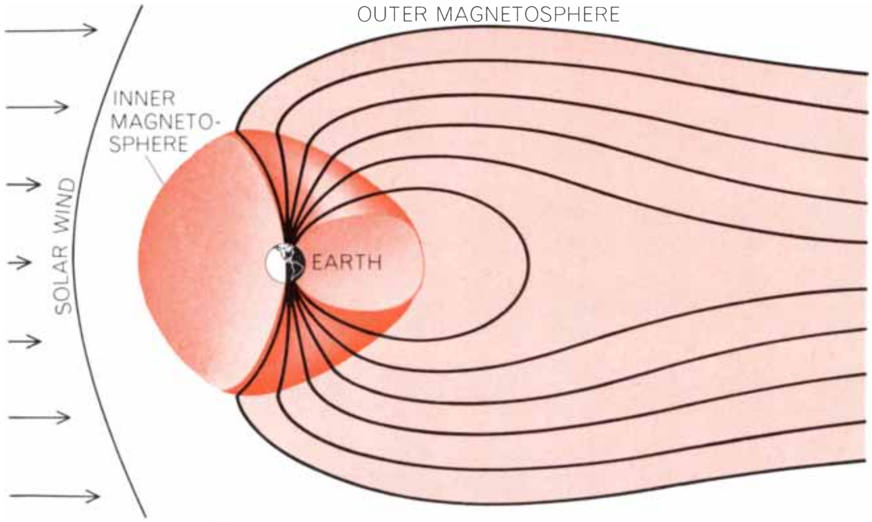
These responses are not easily observable in the cosmos. Part of the reason is that the cosmic plasma, although it accounts for more than 90 percent of the mass of the universe, is very dilute except where it is concentrated in stars. Moreover, the cosmic plasma consists mainly of ionized hydrogen and helium (protons and alpha particles), which have an extremely small cross section for light-scattering and so, like the even smaller electrons, do not scatter enough light to make their presence visible.

Two kinds of dilute plasma can occasionally be seen in the solar system. One of them is the corona of the sun. The corona can be seen during solar eclipses because it is somewhat denser than most of the plasma in the cosmos and becomes visible when the brighter disk of the sun is obscured. The second kind of visible dilute plasma is the plasma in comet tails. Its visibility arises from the comparatively large cross section for light-scattering of the ionized molecules (such as carbon monoxide) in the tails.

One might think that we would have used such molecules in creating our artificial clouds, since we were interested in learning more about the behavior of comet tails. We concluded, however, that it would be easier and more economical to work with the ions of a heavy element such as barium. One reason is that the ions of barium have a light-scattering cross section three orders of magnitude larger than the cross section of the molecular ions in comet tails and so are more effective in scattering light.

Underlying our expectation that experiments with artificial plasma clouds would yield valuable information were certain considerations about the behavior of charged particles in electric and magnetic fields. To the extent that a positively charged ion or a negatively charged electron entering a magnetic field has a component of velocity perpendicular to the field, the particle will be deflected by the field and so will gyrate in circles around the magnetic lines of force. To the extent that the particle has a component of velocity parallel to the field, it is unaffected by the field and so can proceed in the direction of the field. The combined forces cause the particle to move in a helical path along the lines of magnetic force [*see top illustration on page 83*].

It is possible for the particle to encounter two kinds of disturbing force that will deflect it from its helical path around a certain line of magnetic force. It can collide with another particle. In a cosmic plasma, however, the frequency of such collisions is very low compared with the frequency of gyration. As a result the predominant disturbing force is an encounter with an electric field. In an electric field that is at right angles to the magnetic field the charged particles of a plasma tend to drift in the direction that is perpendicular to both fields. The com-



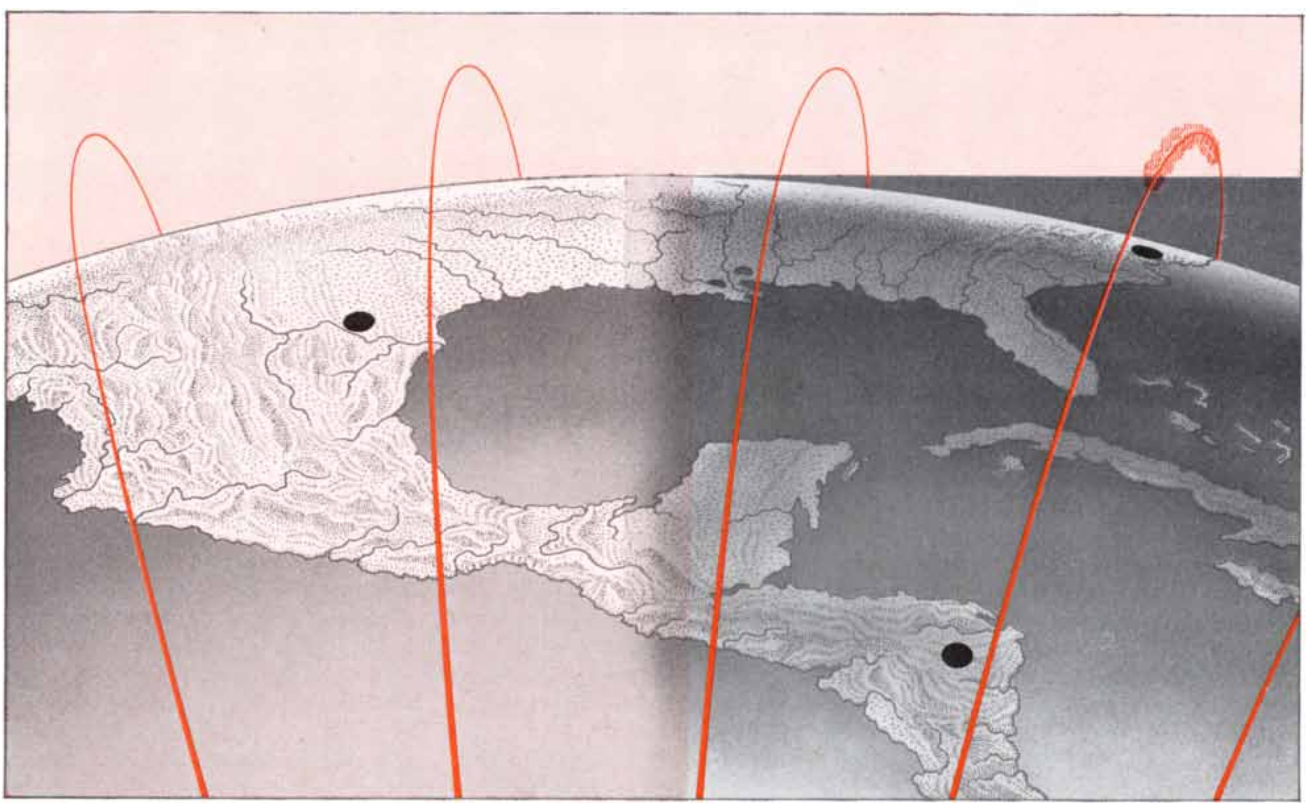
EARTH'S MAGNETOSPHERE is largely shaped by the solar wind. On the side of the earth toward the sun the magnetosphere is flattened by the pressure of the solar wind; on the other side of the earth the solar wind blows the magnetosphere into a long tail. Barium clouds help to show interactions of such plasmas with one another and with magnetic fields.

ponent of the electric field in the direction parallel to the magnetic lines of force is normally very small in a plasma. It affects predominantly the light electrons, giving rise to the conventional electric current. Such a current has very little effect on the behavior of an ion cloud.

An observer moving with the plasma-drift velocity will see only the spiraling of the particles around magnetic lines of force. In other words, in this moving frame of reference the electric field no longer exists. The Swedish physicist Hannes Alfvén describes such a case as one in which the lines of force are "frozen in the material." His description is the same as saying that the plasma and the lines of force move together as far as motions at right angles to the magnetic field are concerned. Electric fields and motions of field lines perpendicular to the direction of the magnetic field are consequently interchangeable notions in many situations.

Thus it follows that from the drift of a plasma cloud perpendicular to a known magnetic field, such as the earth's, one can determine the transverse component of an electric field that is affecting the particles. Information about this electric field is important to an understanding of the earth's magnetosphere and the ionosphere: the region of ionized atoms and molecules in the atmosphere. A cloud of artificial plasma makes the lines of force and motion of a magnetic field immediately apparent. Before the development of the artificial-cloud technique no other reliable measurements of electric fields in space were available.

It was clear from the outset of our program that the cheapest source of energy for ionizing and exciting the atoms in an artificial cloud was solar radiation. If we were to use that source, we would have to meet two requirements. The first was that the neutral atoms should have a high probability of being ionized



CLOUD EXPERIMENTS had to be conducted in early morning or evening, when the cloud at an altitude between 90 and 150 miles would be in sunlight but the observers on the ground would be in the shadow of the earth. At other times artificial clouds would have been difficult to see because they are rather dim. Ground stations (*dots*) had to be well separated for location of clouds by triangulation.

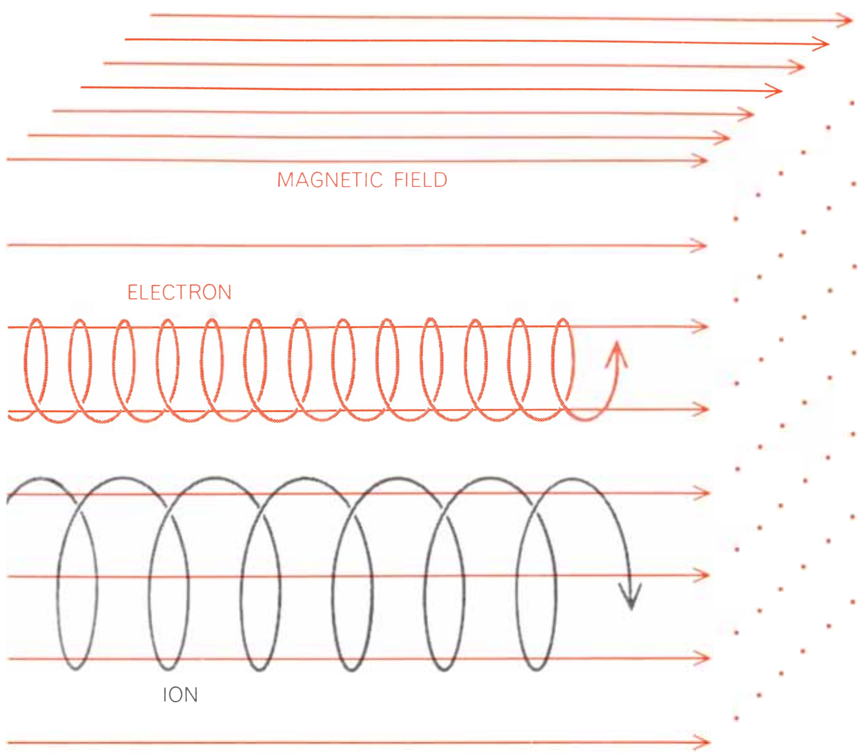
by the ultraviolet radiation of the sun. Second, the ions so generated should have resonance lines in the optical range—that is, they should absorb solar energy and reemit it at the wavelengths of visible light—so that sunlight scattered by them could penetrate the earth's atmosphere and be visible to observers on the ground.

The second requirement placed a severe limitation on the choice of a suitable element for ionization. Most singly ionized atoms either have [illegible] lines in the ultraviolet spectral region, so that they would not be visible, or have too low a probability of undergoing a transition from one energy level to a lower one and emitting a photon of light in the process. The elements that gave the most promise of meeting our requirements were the alkaline-earth metals strontium and barium and the rare earths ytterbium and europium.

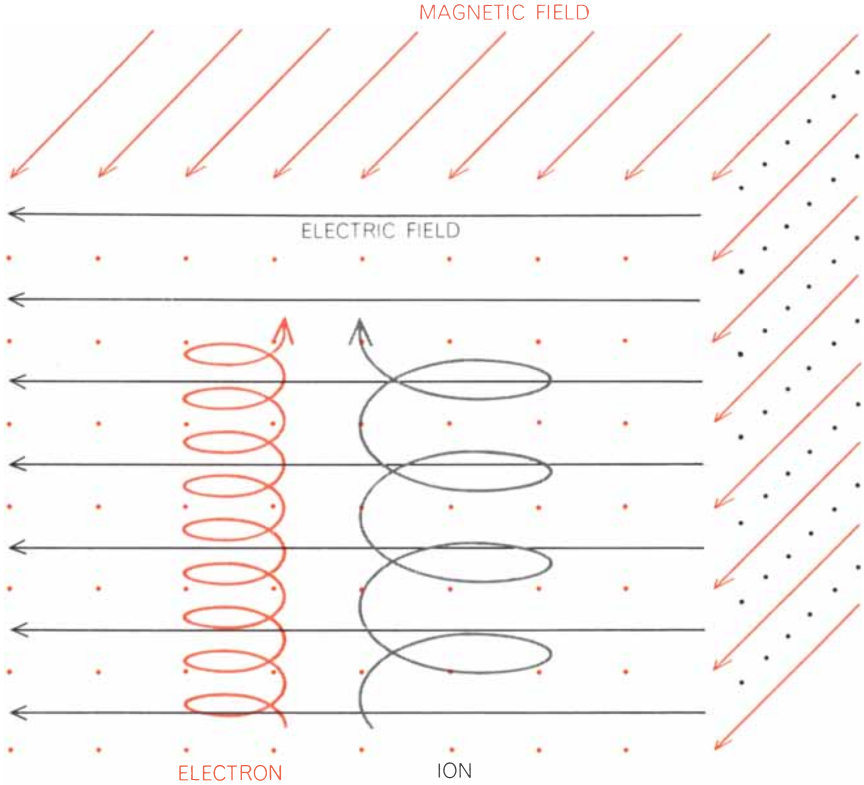
Since free atoms and ions absorb and reemit sunlight only at a few spectral lines, the brightness of even a dense artificial cloud is rather low. In order to make the cloud distinguishable from the background radiation of the sky the experiment must be carried out at twilight, when the cloud is illuminated by the sun but the observers on the ground are in the shadow of the earth. The cloud is observed from two or more stations, which must be well separated so that the position of the cloud can be determined by triangulation. The stations are equipped with a variety of cameras, spectrographs and other instruments.

During our first experiments in the upper atmosphere in 1963 a few kilograms of strontium in each of several rockets were shot to altitudes between 90 and 120 miles, vaporized by means of a chemical reaction and ejected into the atmosphere. On these occasions nonionized strontium clouds appeared, but to our disappointment no ionized strontium was detectable. Therefore we began developing new methods for vaporizing the heavier alkaline-earth element barium. During the development program we learned from detailed spectroscopic investigations that barium has a much higher probability of ionization by solar photons than strontium does because of differences in the energy levels of barium and strontium atoms.

By November, 1964, we were ready for a series of experiments using barium. To our delight we found that within 10 seconds after the release of vaporized barium a plasma cloud of ionized barium atoms could be seen from the ground with the unaided eye. Indeed, the transi-



BEHAVIOR OF PARTICLES in a magnetic field is to spiral around the magnetic lines of force if the particles are responsive to electromagnetic forces, as in the case of the ions and electrons in a plasma. To the extent that a particle has a component of velocity perpendicular to the field, it tends to move in a circle around a line of magnetic force. To the extent that the particle has a component of velocity parallel to the field, it tends to move in the direction of the magnetic field. The combination of the two effects puts the particle into a helical path.



ELECTRIC FIELD superposed on a magnetic field changes the direction of movement of charged particles. If the electric field is at right angles to the magnetic field, the particles tend to drift in a direction that is at right angles to both fields. The observed movement of a cloud of charged particles in a known magnetic field reveals the characteristics of an electric field.

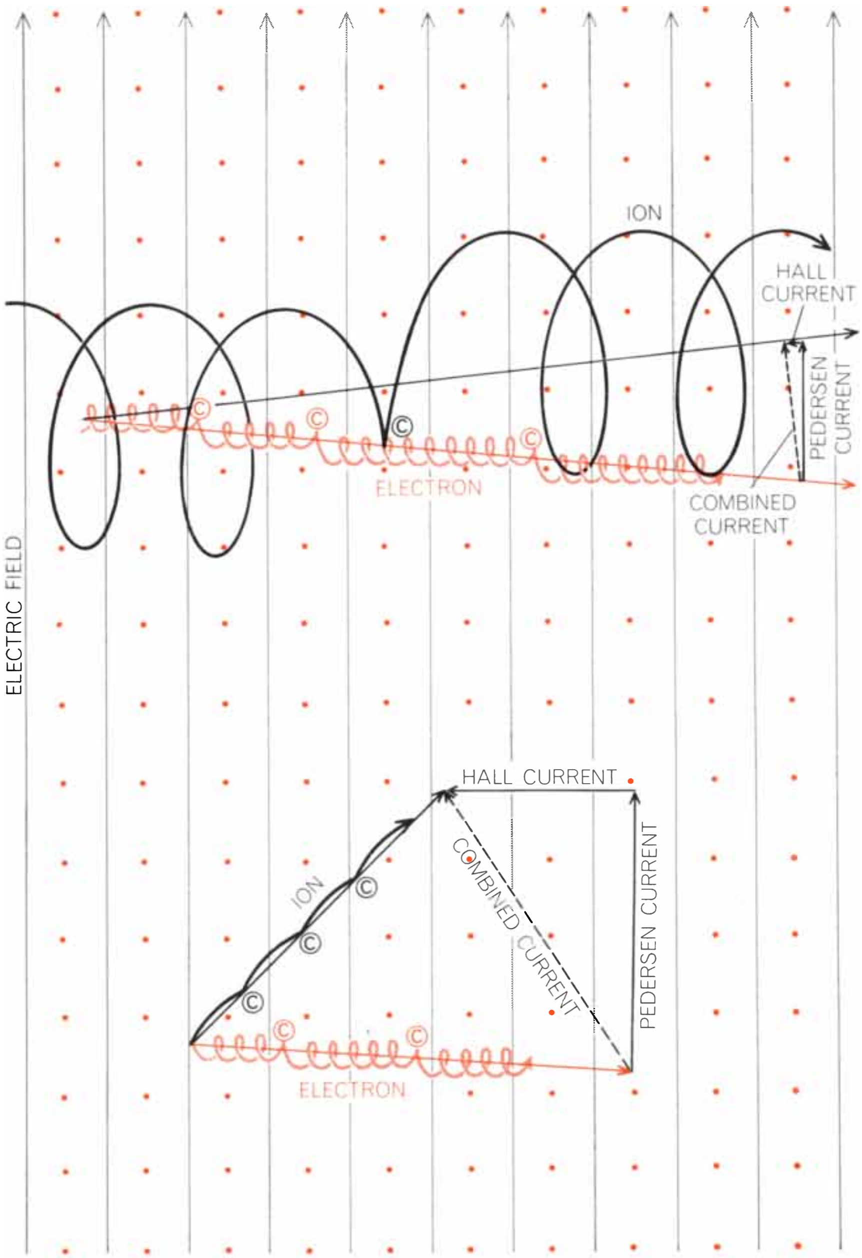
tion from the nonionized state to the ionized state could be watched without instruments, because the barium cloud changes in both color and shape during the transition.

The nonionized cloud is essentially green. In actuality it radiates in several green, yellow and red lines of the visible spectrum. The radiations in the green region are the strongest, and therefore green is the color that is seen the longest as the cloud becomes fainter. The ionized barium atoms radiate in the violet, blue and red regions of the spectrum, thus producing a purple color. Hence an ionized cloud can be distinguished easily from a nonionized one because the ionized cloud is purple and the nonionized one is green.

The change of shape takes place in the following way. The neutral cloud is spherical and increases in diameter rather rapidly. The expansion is eventually slowed by collision of the barium atoms with other atoms and molecules in the earth's atmosphere. Thereafter the neutral cloud increases in size at a much slower rate.

Meanwhile the ionized part of the barium cloud undergoes quite different changes. The positively charged ions and the negatively charged electrons are trapped by the earth's magnetic field, and they begin spiraling around the lines of magnetic force. For this reason the plasma cloud will continue to grow only along the lines of force. The cloud thus becomes cigar-shaped and so can be distinguished readily from the spherical nonionized cloud. Later, however, considerable distortion of this typical shape can be caused by inhomogeneous electric fields.

One further effect is visible. The barium used in the experiments always contains a small amount (less than 1 percent) of strontium as an impurity. The strontium does not become ionized, and therefore a neutral cloud of strontium, emitting blue light, remains visible even after all the barium atoms have become ionized.

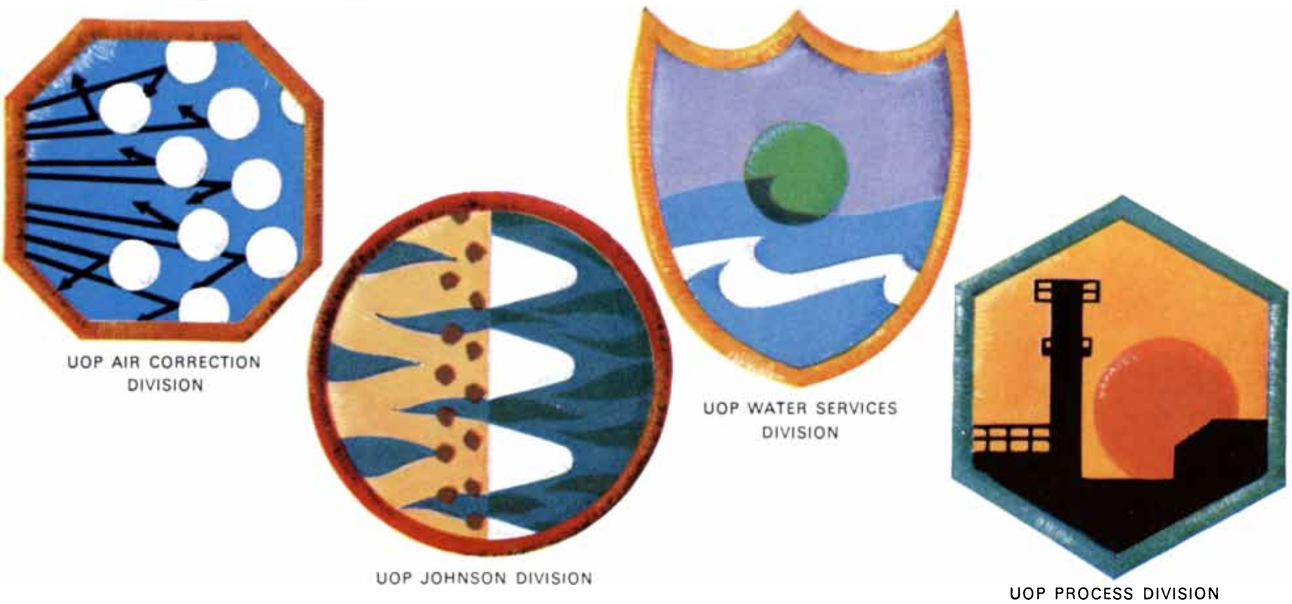


ELECTRIC CURRENTS in the ionosphere are mainly the Pedersen and Hall currents, which arise from collisions (C) of ions and electrons with neutral particles. Here the magnetic field (*colored dots*) is perpendicular to the electric field and projecting upward from the page. At higher altitudes (*top*) the ions, being of greater mass, collide more frequently during one period of gyration than the electrons do. If a collision occurs, the center of gyration of an ion is displaced an average of one radius of gyration in the direction of the electric field; an electron is displaced the opposite way. At lower altitudes (*bottom*) an ion cannot complete even one gyration. The influence of the magnetic field on the ions is therefore reduced, and they drift in direction of electric field; electrons still drift as at higher altitudes.

Most of our experiments to date have been carried out in the ionosphere at altitudes between 90 and 150 miles. We had two principal reasons for choosing this range of altitudes. The first was that these heights can be reached with small and relatively inexpensive rockets. Second, the motion of the plasma clouds yields information not only about the region of the ionosphere where the clouds are released but also about much higher regions in the magnetosphere.

The ionosphere extends from about 40 miles above the surface of the earth to about 600 miles. It can be regarded as the lowest layer of the magnetosphere, which forms a cavity with a long tail that is embedded in the streaming solar wind [*see top illustration on page 82*]. In the lower parts of the magnetosphere, out to perhaps five earth radii, the magnetic field is governed almost entirely by the earth. Therefore any motions of plasma in this region must leave the magnetic field unchanged. Hence the conducting matter distributed along a field line must move in such a way that the field line is transformed as a whole into a neighboring one. This class of motions was first discussed by Thomas Gold of Cornell University. They are possible only because the magnetic lines of force in the magnetosphere are not fixed to the

THE UOP CORPS OF ENVIRONMENTAL ENGINEERS IS WINNING THE WAR ON POLLUTION



UOP has four divisions marshalled to attack pollution on several fronts.

In air correction, this is the one company offering the broadest selection of systems and equipment, in world-wide use. **UOP Air Correction Division** relieves you of the technical burdens of air pollution control, and provides you with the best equipment at the most economical cost. It offers eight basic types of control equipment, plus a complete range of services, from stack gas analysis to field start-up.

To deal with water management problems, **UOP Johnson Division** manufactures screens and filtering equipment. These are widely used in water treating, water conditioning, slurry screening, water filtration, de-watering, odor, color and suspended solids removal. There are many other anti-water pollutant uses for Johnson-brand screens, including disposal well applications.

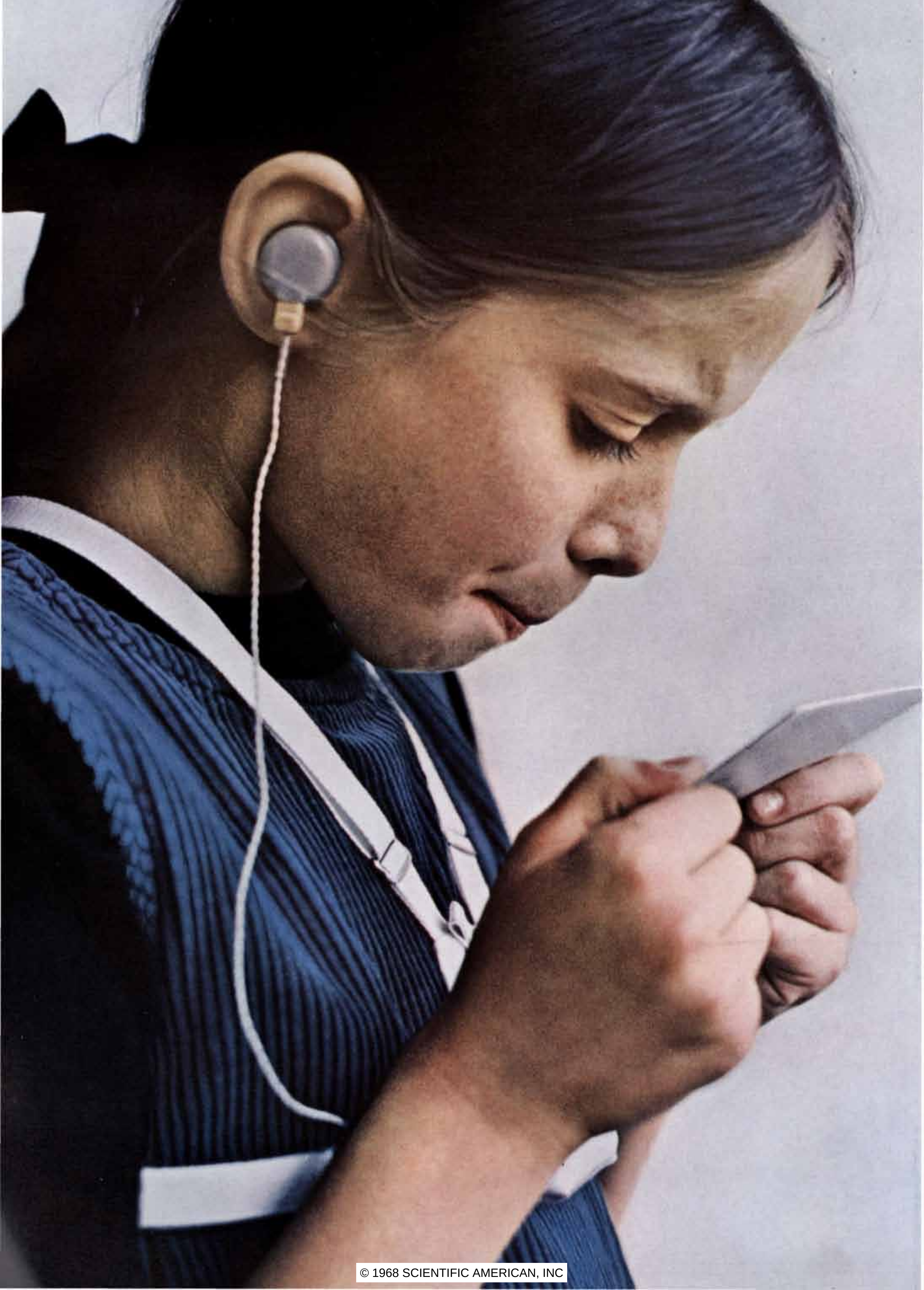
A variety of water treating chemicals, for both process and make-up, are offered by **UOP Water Services Division.** They are used for treating algae and slime, preventing scale and corrosion, providing oxygen scavenging, sludge conditioning, and foam suspension.

UOP works to alleviate pollution in many ways. One new UOP refining process is an efficient and economical method of desulfurizing heavy fuel oil, so that fuel oils burn cleaner. Another new development from **UOP Process Division** is an effective counter-measure against water contamination. It eliminates problems caused by detergents that do not break down by bacterial action, by improving biodegradable detergents.

It is easy to see how UOP's environmental engineering competence can help you with your air and water pollution problems. And new concepts are on the way. Universal Oil Products Company, 30 Algonquin Road, Des Plaines, Illinois 60016, U.S.A.

better ideas from UOP

Petroleum Processes · Transportation Equipment · Metals & Alloys · Plant Construction · Forest Products · Chemicals & Plastics · Fragrances · Air & Water Management



Julie's other hearing aid.

When you're trying to give language to a child who's never heard any, even the most powerful hearing aid may not help much. So you use every tool there is.

At St. Francis de Sales School for the Deaf in Brooklyn, N. Y., where children like Julie rely on their eyes to read lips, and their fingertips to feel sounds, the Polaroid Land camera has become such a tool.

Seeing a picture, seconds after it's taken, is fun for normal people. And that's nice.

It's just as much fun for profoundly deaf children. And *that's* a key to the enlargement of their entire education.

Before Julie begins the painstaking process of learning to lip-read and pronounce the word *parrot,* she must have a concept of what parrot means.

Field trips are often made for the purpose of obtaining new concepts. But the teachers at St. Francis de Sales find that, in the absence of language to keep them fresh, the concepts may lose their power to motivate by the time the children return to the classroom.

If conventional photographs of the trip are brought to class just a few days later, the children have little interest in them. "Finished," they say. (It's done with.) That's one of their most frequently used words. And that's why a Polaroid camera goes along on every field trip.

Because, with Polaroid photography, the children see picture and subject at the same time. So the picture is intimately tied to the event. This immediacy fixes the concept in the children's minds and language learning can begin again in the classroom.

By the time the learning program is finished, over half of these children can be expected to lip-read and speak well enough to go to college.

Perhaps one picture is worth a thousand words. But for us it's enough to know that, to Julie, one Polaroid picture is worth *one* word.

Polaroid Corporation

Zinc.
Make something of it. Something that lasts.

Like die-cast zinc functional and decorative parts for the deluxe model Maytag washer.

A beautiful one-piece bezel to surround the who's who and to house the what's what. Pump insert and pump pulley to keep things going, and zinc-plated fasteners to keep things tight.

Or a sturdy wringer washer with more than a dozen critical parts made of zinc; parts that will last for just as long as the washing keeps coming.

Or a dryer trimmed in chrome-plated zinc, with a zinc motor pulley to keep everything going.

Every major appliance manufacturer in the country makes decorative trim and many functional parts of die-cast zinc.

Why zinc?

Because he can make something of it that lasts.

ZINC INSTITUTE INC. • AMERICAN METAL CLIMAX • AMERICAN SMELTING AND REFINING • ASARCO MEXICANA • AMERICAN ZINC • ANACONDA • BALL BROTHERS • BUNKER HILL • CERRO SALES • COMINCO • DAY MINES • EAGLE PICHER • ELECTROLYTIC ZINC (AUSTRALASIA) • GENERAL SMELTING • HUDSON BAY MINING & SMELTING • IMPERIAL TYPE METAL • MATTHIESSEN & HEGELER ZINC • NATIONAL ZINC • NEW MARKET ZINC • NEW JERSEY ZINC • NORANDA SALES • OZARK-MAHONING • PEND OREILLE MINES & METALS • PLATT BROTHERS • ST. JOSEPH LEAD • SOCIETE METALLURGIQUE DU KATANGA (AFRICA) • SUPERIOR ZINC • U. S. SMELTING REFINING & MINING earth. The reason is that the highly conducting magnetosphere is shielded from the conducting body of the earth by the insulating atmosphere (in particular the troposphere), which need not participate in the motion. There is strong friction between the nonionized gas of the lower atmosphere and the plasma of the magnetosphere, so that the inner part of the magnetosphere is forced to rotate with the earth. (Some slipping of the magnetospheric plasma with respect to the surface of the earth is possible.)

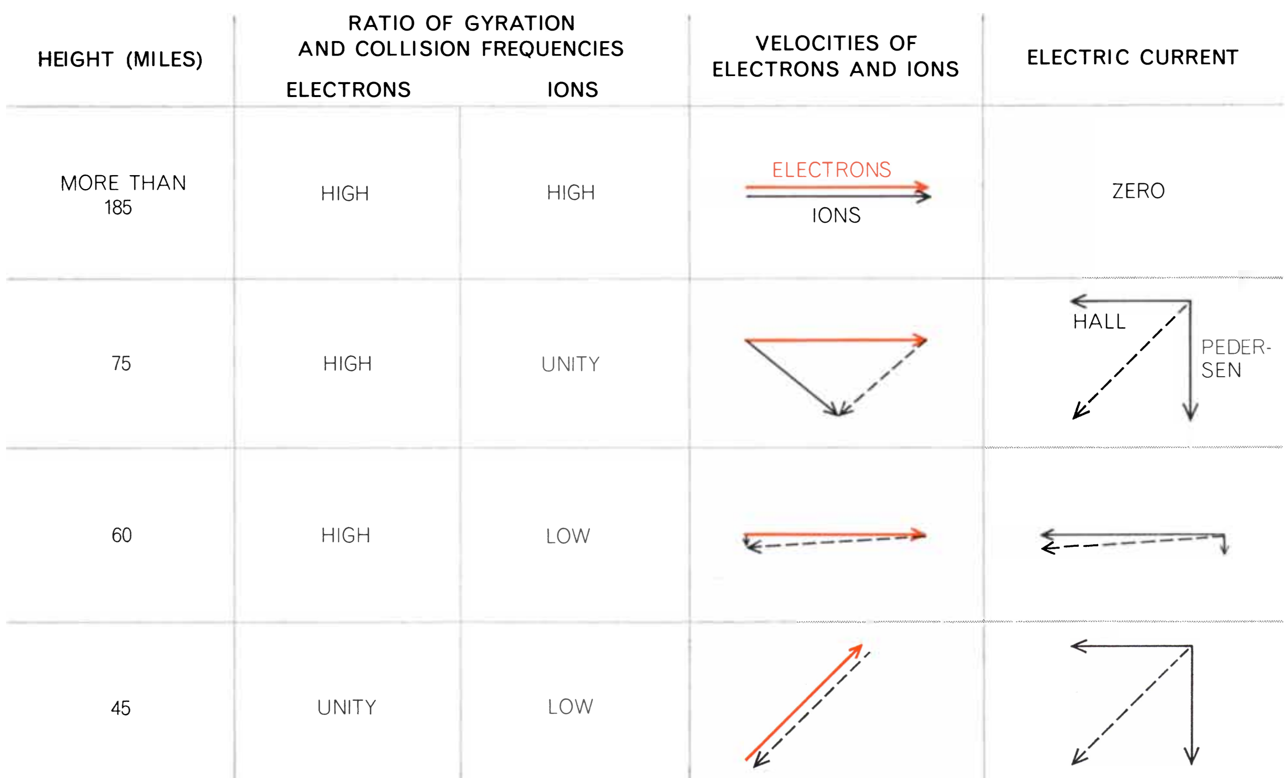
The frictional forces on the outside of the magnetosphere, which are caused by the solar wind, lead to motions of the magnetic-field lines inside the magnetosphere down to the insulating lower atmosphere. Thus it is that when a plasma cloud at a rather low level indicates motion of a line of magnetic force in that region, it may be giving information about the state of motion at much higher levels. The observed velocity of a plasma cloud can be expressed in terms of the strength of an electric field: a velocity of 100 meters per second perpendicular to a magnetic field of .5 gauss (a typical strength for low altitudes) corresponds to an electric-field strength of about five volts per kilometer.

The electric fields connected with these motions of the magnetic lines of force will give rise to electric currents in the ionosphere. There one encounters two particular kinds of electric current: the Pedersen current, which is essentially carried by positive ions, and the Hall current, which is carried by electrons. (The Pedersen current is named for the Danish physicist P. O. Pedersen, who introduced the concept in 1927, and the Hall current for the American physicist E. H. Hall, who first described the effect in metals in 1879.) Both currents are related to the fact that the transition from the highly conducting magnetosphere to the insulating lower atmosphere is not abrupt.

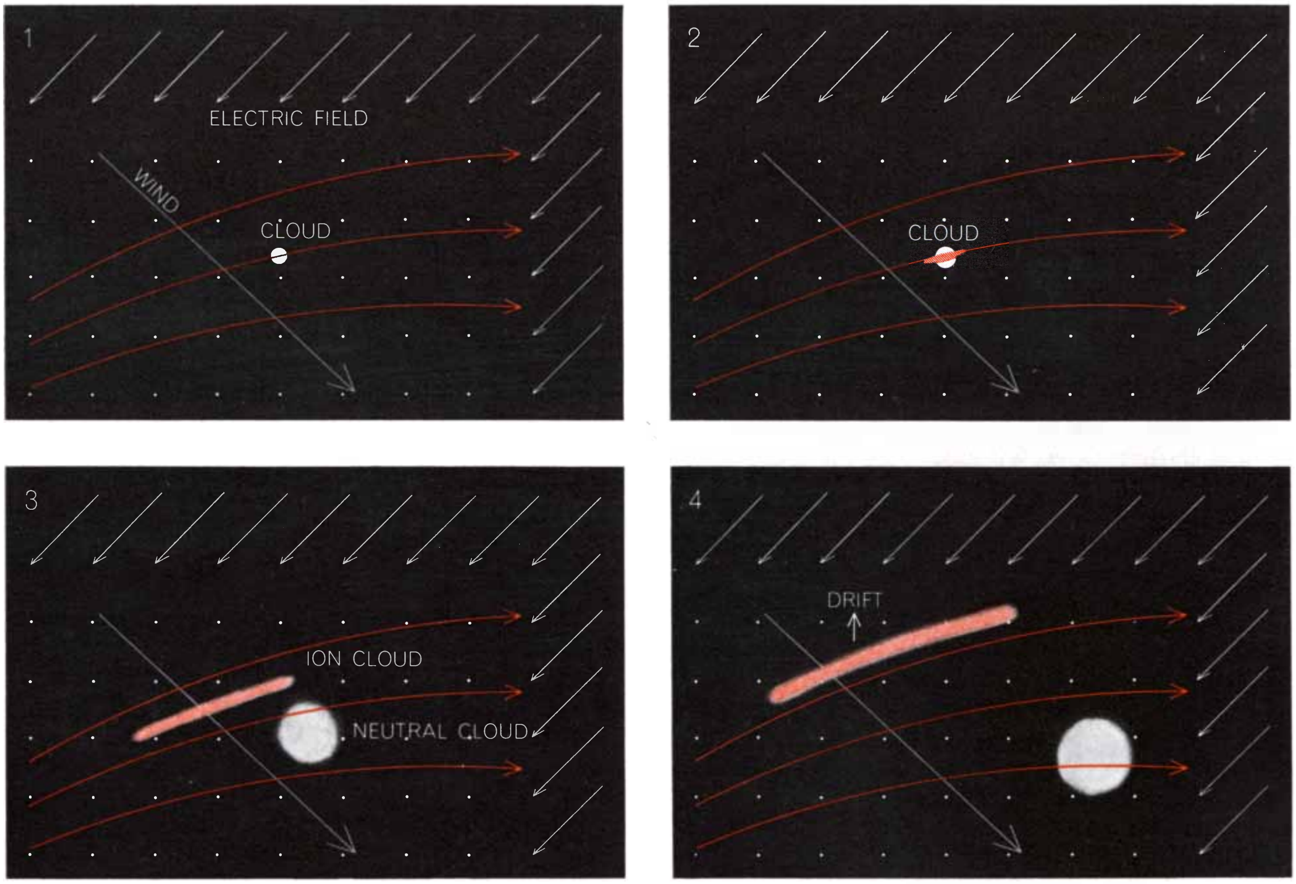
The transitional region is in the lower parts of the ionosphere, where collisions between the gyrating particles of the ionospheric plasma (consisting mainly of free electrons and of such positive ions as nitric oxide, molecular oxygen and atomic oxygen) and the neutral molecules of the air become frequent. When the gyration frequency is about equal to the collision frequency, the effect of the magnetic field on the particles is reduced. The electrons and positive ions begin to move in the direction of any electric field they encounter—as they would in the absence of a magnetic field. Since electrons and positive ions have opposite charge, their velocity components in the direction of the electric field are opposite to each other, which is another way of saying that they are carrying a current.

Electrons gyrate many times more around magnetic lines of force before hitting neutral atoms or molecules because the mass of an electron is far less than the mass of a positive ion. Hence there is a range of altitudes from about 50 to 90 miles where the electrons are still drifting as they would in free space, whereas the ions are already strongly affected by collisions with the neutral molecules. The resulting gain of ion mobility in the direction of the transverse electric field gives rise to the Pedersen current. At the same time the reduction of the drift of the ions at right angles to the electric field causes an electric current—the Hall current. The former effect predominates in the upper half of the altitude range between 50 and 90 miles, and the latter one predominates in the lower half.

When plasma clouds are created in the upper atmosphere for studying the electric field, it is important that the



HALL AND PEDERSEN CURRENTS are found in the ionosphere, which is the lowest part of the magnetosphere. The currents shown assume a magnetic field perpendicular to the plane of the paper and pointing downward and an electric field within the plane of the paper and pointing toward bottom of page. Length of the arrows indicates the magnitude of the phenomenon described. Ratio of gyration and collision frequencies indicates how long a particle will gyrate around lines of force before colliding with another particle.



MOVEMENT OF ARTIFICIAL CLOUDS is shown for a period of 1,000 seconds, or about 17 minutes. At *1* the cloud has just been ejected from a rocket. Ten seconds later (*2*) the cloud is in an expansion phase. About 100 seconds after the starting time (*3*) two distinct clouds are evident. The spherical neutral cloud, consisting of nonionized particles, is moved by the wind; the ionized cloud responds mainly to the electric field. Situation at end of period (*4*) shows large separation of clouds due to respective drift motions.

coupling to the neutral atmosphere be fairly weak, that is, that the frequency of gyration of the barium atoms be rather high compared with their frequency of collision with the neutral particles of the atmosphere. At a height of 120 miles the ratio of the two frequencies is about 100 to one; at 145 miles it is about 500 to one. Here is another reason for concentrating most of our experiments in this range of altitudes. For the study of ionospheric effects it is not economical to generate the clouds at higher levels; the ions are no longer supported by the atmosphere, and so they fall along lines of magnetic force to levels below 200 miles within a few minutes. The height gained by launching a bigger rocket is therefore of little value.

On the other hand, certain important effects can be examined only if the particles are high enough to travel for several minutes without colliding. In April, 1966, we were able to carry out two experiments at an altitude of 1,200 miles, using French rockets launched from a site in the Sahara Desert. The two ionized barium clouds, each of which consisted of about 50 grams of barium ions, marked the lines of force of the earth's magnetic field over a length of 1,200 miles. They were observed from the middle of Africa to central Germany.

Five months later we released a cloud some 570 miles above the East Coast of the U.S. The ion cloud could be watched for about 50 minutes as it expanded along the lines of magnetic force while falling into the lower atmosphere. It was visible as far away as North Dakota.

Our group has now conducted enough plasma-cloud experiments in enough places to make it possible to attack a few of the more general problems that can be approached through an analysis of the electric field in the magnetosphere. One such problem concerns the maintenance of the worldwide ionospheric electric-current system [*see upper illustration on opposite page*]. This current, which is strongest on the earth's sunlit hemisphere, consists of two systems meeting at the geomagnetic equator. There, for reasons connected with the horizontal direction of the magnetic field, the conductivity is high and the current is strong. These patterns of flow have been derived from the continuous recordings made by magnetic observatories throughout the world. Many features of the current were well known long before the era of space research; among its outstanding students have been Sydney Chapman of Britain (who is now at the Geophysical Institute of the University of Alaska) and Julius Bartels of Germany.

As early as 1882 the British physicist Balfour Stewart suggested that electric currents in the upper atmosphere could be generated by the motion of the neutral atmosphere across the magnetic field. The situation is analogous to the "dynamo effect" in a typical electromagnetic generator, where an electric current is generated when conductors are moved through a magnetic field. The entire atmospheric current system would be similar to an electric circuit consisting of a generator and an external resistance. There is an essential difference in the relative orientations of current and electric field in both parts of the circuit.

In the external resistance they are pointing in the same direction, whereas inside the dynamo they are opposite to each other.

Observation of the motion of the artificial plasma clouds demonstrated the existence of such electric fields in the atmosphere. They showed also that in the twilight zones at middle magnetic latitudes the direction of the electric fields corresponds to the situation inside a dynamo. The clouds have therefore provided what is apparently the first direct experimental verification of the Stewart hypothesis. The observed electric fields have a strength of between one and three volts per kilometer at middle magnetic latitudes.

Another interesting feature of the barium-cloud experiments is the appearance in the clouds of striations aligned with the magnetic fields. The striations range in width from a half-mile to about six miles. They seem to indicate that the density distribution of the ionized matter in the ionosphere (and probably also in the higher magnetosphere) is not smooth but rather like a bundle of fibers. The fibers are not constant in space but change within a few minutes. The mechanisms of their generation and decay are not well understood.

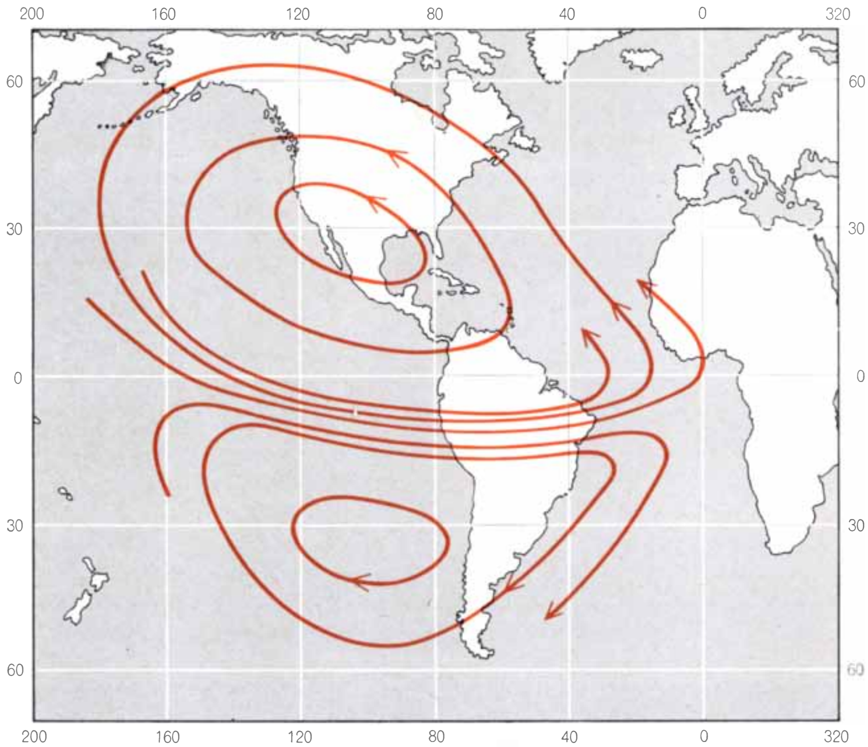
A fascinating region for experiments with ion clouds is the zone where auroras are regularly observed. In the auroral zone the magnetic lines of force that are linked to the distant part of the magnetosphere (particularly to the tail region) meet the surface of the earth. The motions set up in the outer magnetosphere by interactions with the solar wind are transferred by means of electric fields to lower altitudes.

For periods of a few hours strong currents can flow in the ionosphere. The maximum current, called the polar electrojet, flows westward along the oval track in which most auroras are seen. Such currents are normally accompanied by auroral displays.

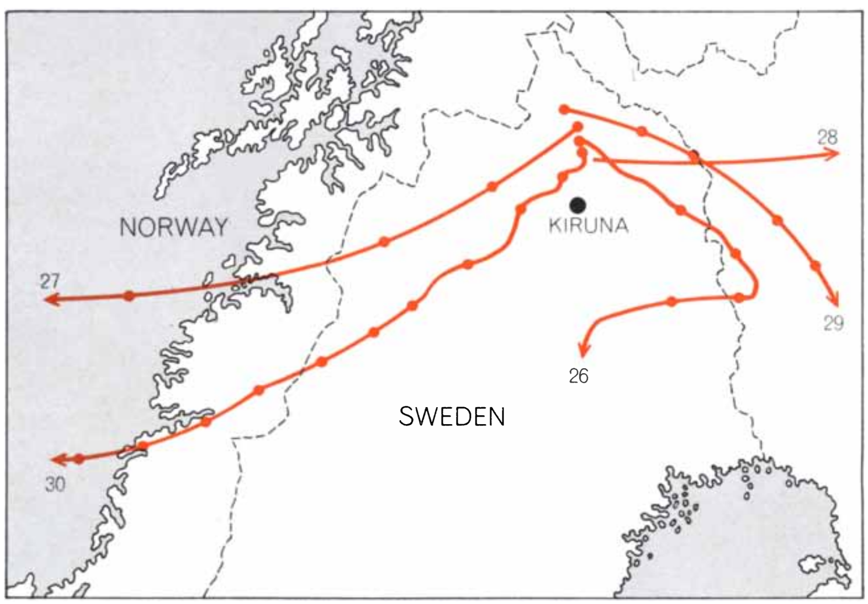
Since inside an aurora the density of ionization is higher than it is outside, the conductivity is also enhanced in that region. The maximum conductivity is normally located at an altitude of about 65 miles, which is the region of strong Hall current. Inasmuch as the Hall current consists of electrons, it is regarded as being positive in a direction opposite to the flow of electrons. In other words, a Hall current measured as moving westward consists of electrons drifting eastward.

At higher altitudes electrons and positive ions drift with the same velocity. Therefore one would expect to see an artificial ion cloud traveling eastward whenever a magnetometer on the ground records a Hall current in the ionosphere as flowing westward, and vice versa. This expectation was fully confirmed by the experiments.

The first experiments of this kind were carried out in April, 1967, in northern Sweden. On each of five consecutive nights an ion cloud was released at an altitude of about 140 miles. The development and motion of a cloud could be watched for as long as two and a half hours [*see lower illustration below*]. The changes in the value and direction



CURRENT SYSTEM in the ionosphere was plotted on the basis of magnetic perturbations recorded on the ground. The electric currents shown are on the sunlit side of the earth. The highest current density, at the geomagnetic equator, is called the equatorial electrojet.



PATHS OF CLOUDS released over Sweden on five days in April, 1967, are plotted. The clouds were released in the ionosphere over Kiruna in the late evening or early morning of the dates shown. The consecutive dots on each path represent intervals of 10 minutes.

of the velocity of the barium clouds showed that the electric field is quite variable.

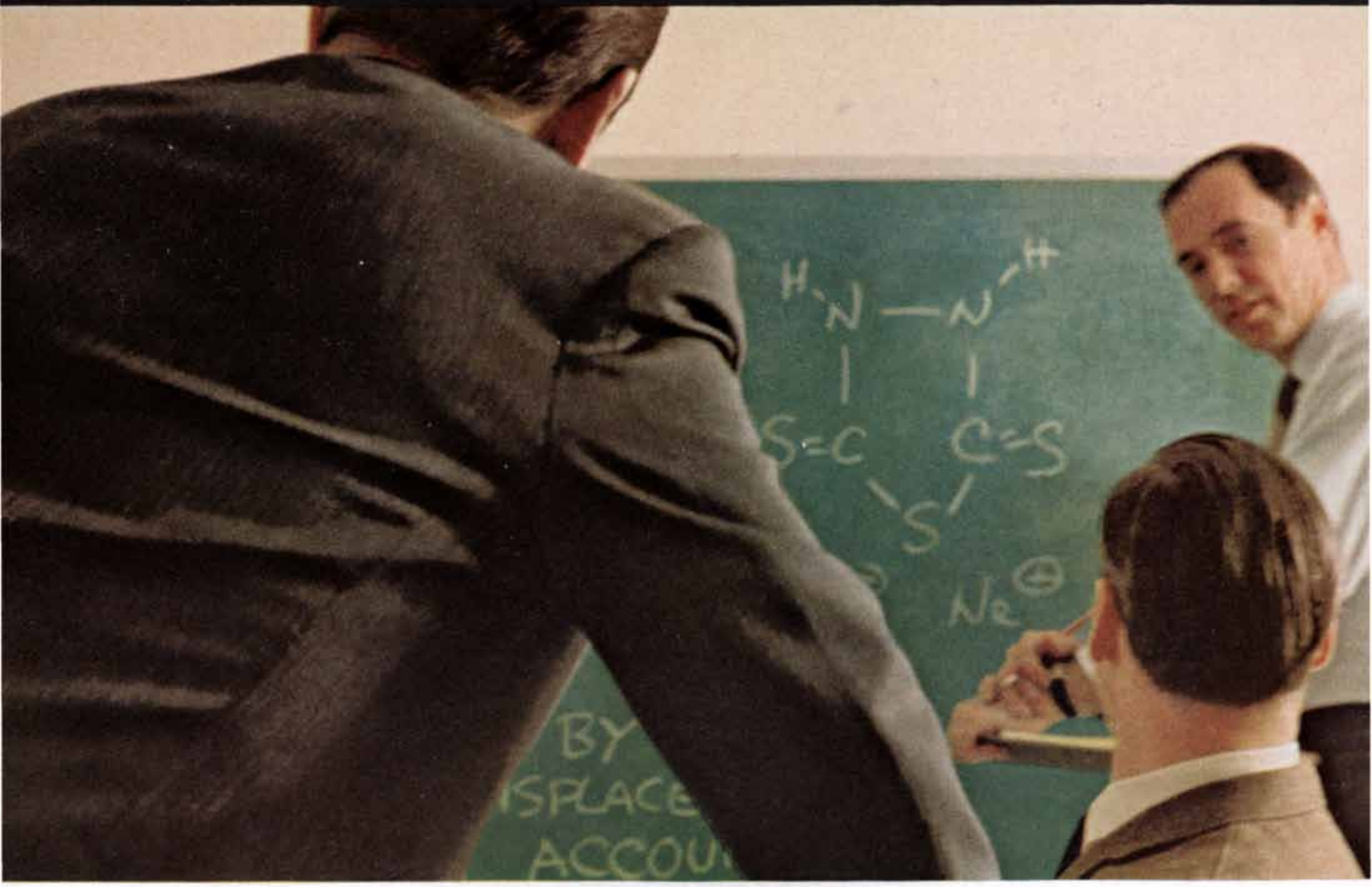
The variability of the electric field was also demonstrated in another way. During our experiments in the auroral zone a few artificial plasma clouds quickly assumed an elongated bandlike form that closely resembled an auroral arc. The length of such a cloud perpendicular to the magnetic field sometimes reached 120 miles and more. This elongation showed that the electric field varied considerably over the original width of the cloud and therefore imparted different velocities to different parts of the cloud.

The experiments in Sweden were carried out near midnight, meaning that we were creating clouds in the side of the magnetosphere away from the sun. The movements of the ion clouds showed that the magnetospheric matter on that side is drifting around the earth, sometimes westerly and sometimes easterly. There is also a southerly component of velocity, which corresponds to an inward motion of the plasma at the geomagnetic equator. If one can apply along the entire length of lines of force the concept that movements of lines in the distant regions of the magnetosphere lead to motions in the ionosphere, the observed movements of the ion clouds can be interpreted in terms of a convection in the magnetospheric plasma.

The young technique of producing artificial plasma clouds in the upper atmosphere is now being employed by several groups of investigators. It has started to provide geophysicists with new kinds of information about the magnetosphere, and in particular about its electric field. The experiments are also of interest to the plasma physicist, particularly when they are conducted far out in the magnetosphere. There the strength of the magnetic field is so low that the plasma can affect the field, which is the situation that obtains in most experiments with plasmas in the laboratory.

Experiments in the outer magnetosphere are now planned for the HEOS (highly eccentric orbital satellite) satellite being prepared by the European Space Research Organization and also for an undertaking that we shall conduct jointly with the U.S. National Aeronautics and Space Administration. If these experiments are successful, we may try as the next step to create visible plasma clouds outside the magnetosphere, in the solar wind. We would thus be making an artificial comet tail.

The 1975 cars are on the Amoco drawing boards.



If authorities are right, by 1975 smog-free gasoline-powered automobiles will be rolling off the assembly lines.

That's the objective of massive research programs underway currently by automotive and petroleum companies.

To aid these programs, Amoco petroleum additive specialists will be working on ways to keep the automobiles of the future running smoothly.

Anti-smog hardware began appearing on cars in 1966 with PCV (Positive Crankcase Ventilation) devices. As more complicated devices are developed, more sophisticated additive packages for gasolines and motor oils will very likely be needed.

So Amoco is putting its experience in dispersants, inhibitors, detergent-inhibitor blends, viscosity-index improvers, and pour point depressants to work developing these approaches. Right now.

Amoco Chemicals Corporation, 130 East Randolph Drive, Department 9693, Chicago, Illinois 60601.

AMOCO CHEMICALS

Where what's happening gets its start.

Protecting life in hostile environments.

For vehicles that move in hostile environmental worlds, Lockheed has devised some unique features and systems to help support human life over extended missions—like long-sustained flight at a searing Mach 3+, or days in the ocean deeps, or an entire year in outer space.

Guarding the Deep Divers. To work at great depths, new special undersea craft must contain life-support systems no less critical than those used in outer space. Such systems must be self-contained, since these deep-diving vessels can neither snorkel nor carry bulky equipment loads.

Deep Quest life-support system functions as specified in dive to 8,310 feet.

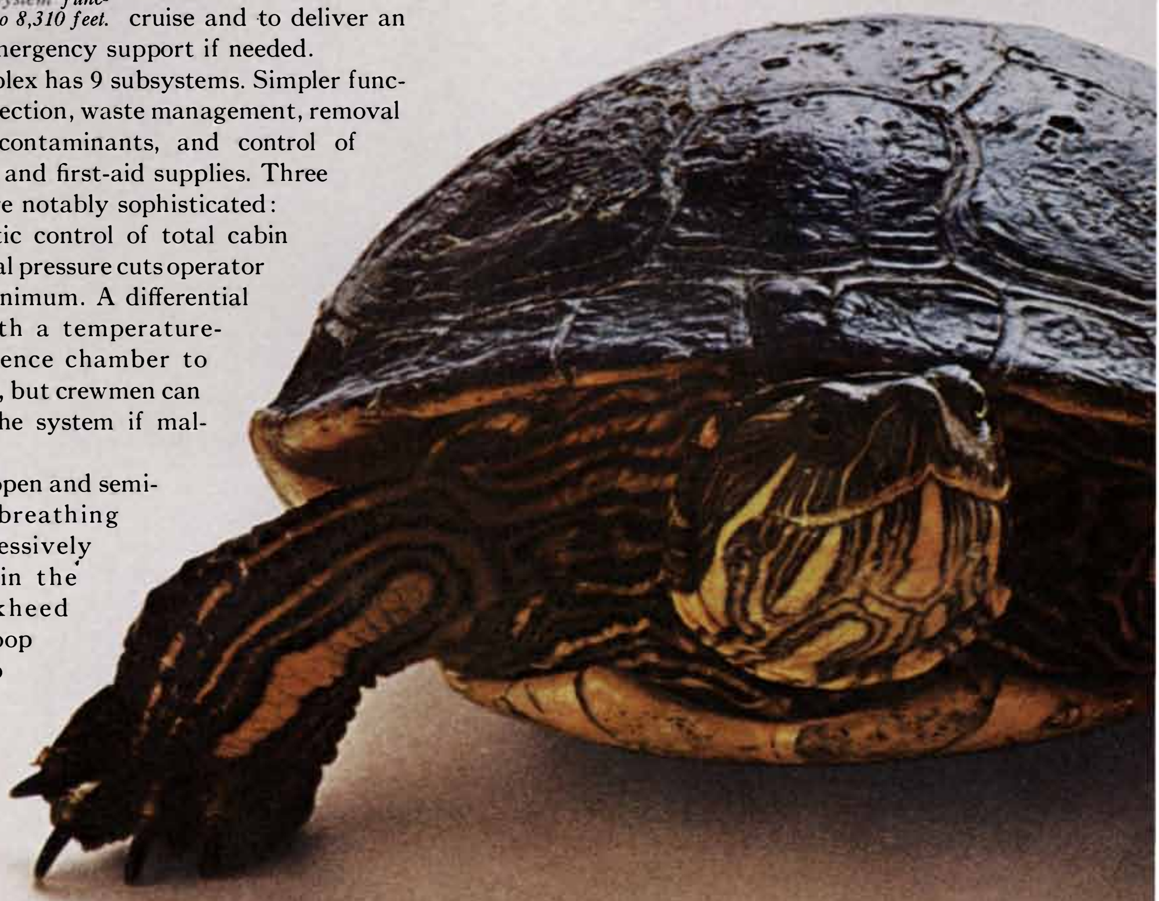
For Deep Quest, the Lockheed-funded submersible designed for missions down to 8,000 feet, a system was devised to sustain 4 men for a normal 12-hour cruise and to deliver an added 36 hours of emergency support if needed.

Deep Quest's complex has 9 subsystems. Simpler functions include fire protection, waste management, removal of CO_2 and trace contaminants, and control of carry-on food, water and first-aid supplies. Three features, however, are notably sophisticated:

(1) Fully automatic control of total cabin pressure and O_2 partial pressure cuts operator involvement to a minimum. A differential regulator works with a temperature-compensation reference chamber to maintain this control, but crewmen can manually override the system if malfunction occurs.

(2) Since existing open and semi-closed emergency breathing systems would excessively increase pressure in the small cabin, Lockheed developed a closed-loop system that works up to 3 hours without noticeably affecting pressure. Full face-masks and breathing bags assure complete personnel protection, easy gas circulation, and minimum breathing resistance. Activated charcoal and LiOH remove CO_2 and contaminants, and a differential pressure regulator automatically admits a fresh O_2 supply.

(3) A third subsystem exercises discriminating control

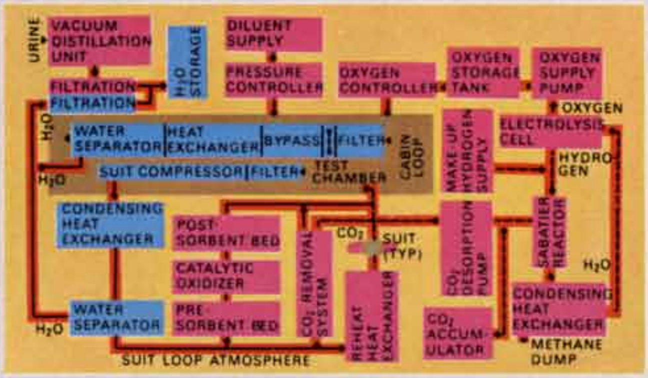


LOCKHEED

LOCKHEED AIRCRAFT CORPORATION

over temperature and humidity. By design, critical electronic gear is separated from the crew compartment. Since the equipment operates best at temperatures higher than comfortable for human beings, cooling is directed mainly to the "people space." This saves power, lessens atmosphere contamination, and improves effectiveness of fire prevention and extinguishing systems.

Following successful check-outs and manned tests, Deep Quest recently dived to an 8,310-foot depth. In all respects, the life-support system performed within tolerances.



Block diagram of TGRLSS, designed to help support 4 crewmen for up to year's duration in outer space.

Two-Gas Regenerative Life Support System (TGRLSS). Complications of sustaining human life grow by orders-of-magnitude as outer-space missions are planned to stretch over many weeks or months. Each facet of environment must be calculated and controlled to a point of fail-safe precision that has no precedent.

Anticipating long stays in space, Lockheed has developed the TGRLSS to help support a 4-man crew for up to a year. Embodying several unique Lockheed subsystems, the TGRLSS controls pressure, temperature, humidity, and O_2 partial pressure; removes CO_2 and toxic trace contaminants; processes CO_2 and H_2 to regenerate fresh O_2 stores; and, by filtering atmospheric condensate and vacuum-distilling urine, it supplies the crew with pure drinking water.

That last function involves a unique method for separating liquid from gas and reclaiming moisture under zero-gravity conditions.

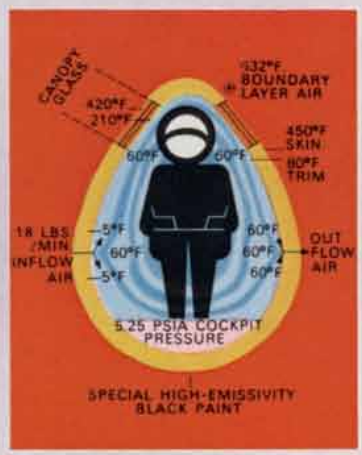
Initially, atmosphere is fan-drawn from both the cabin and the crewmen's suits and is circulated into a humidity control system. A condensing heat exchanger, governed by preset limiting devices, extracts excess moisture from the gas stream and passes both gas and water downstream to a water separator. There the condensed moisture is formed into droplets, and these, along with the "dried" atmosphere, are passed to a final separation stage: a system of 2 screens and sumps, one hydrophobic and the other hydrophilic, that perform an effective "go and no-go" function. Cabin atmosphere is blocked by the hydrophilic system but allowed to flow freely through the hydrophobic screen and be routed back to the cabin. Water, restricted by the hydrophobic screen, passes through the hydrophilic screen and is withdrawn for filtration and storage.

During a recent 5-day manned test, the full TGRLSS functioned exactly as designed, keeping a constant pressure of 7.5 psia in a cabin atmosphere of 42% oxygen and 58% nitrogen.

Cooling Off Fiery Flight. Hurtling through the atmosphere 80,000 feet up at Mach 3+, the SR-71 must endure extreme heat. To protect this U.S. Air Force special-purpose plane, which maintains its speed for long periods of flight producing stabilized high-temperature oven-like conditions, Lockheed had to evolve new thermodynamic approaches.

The airframe itself and every internal component were vulnerable to heat. (Pumps, valves, switches, wires, sealants and others were designed to tolerate more than 600°F.) Of chief concern, however, was the assurance of a tenable cockpit environment just inches away from lethal heat.

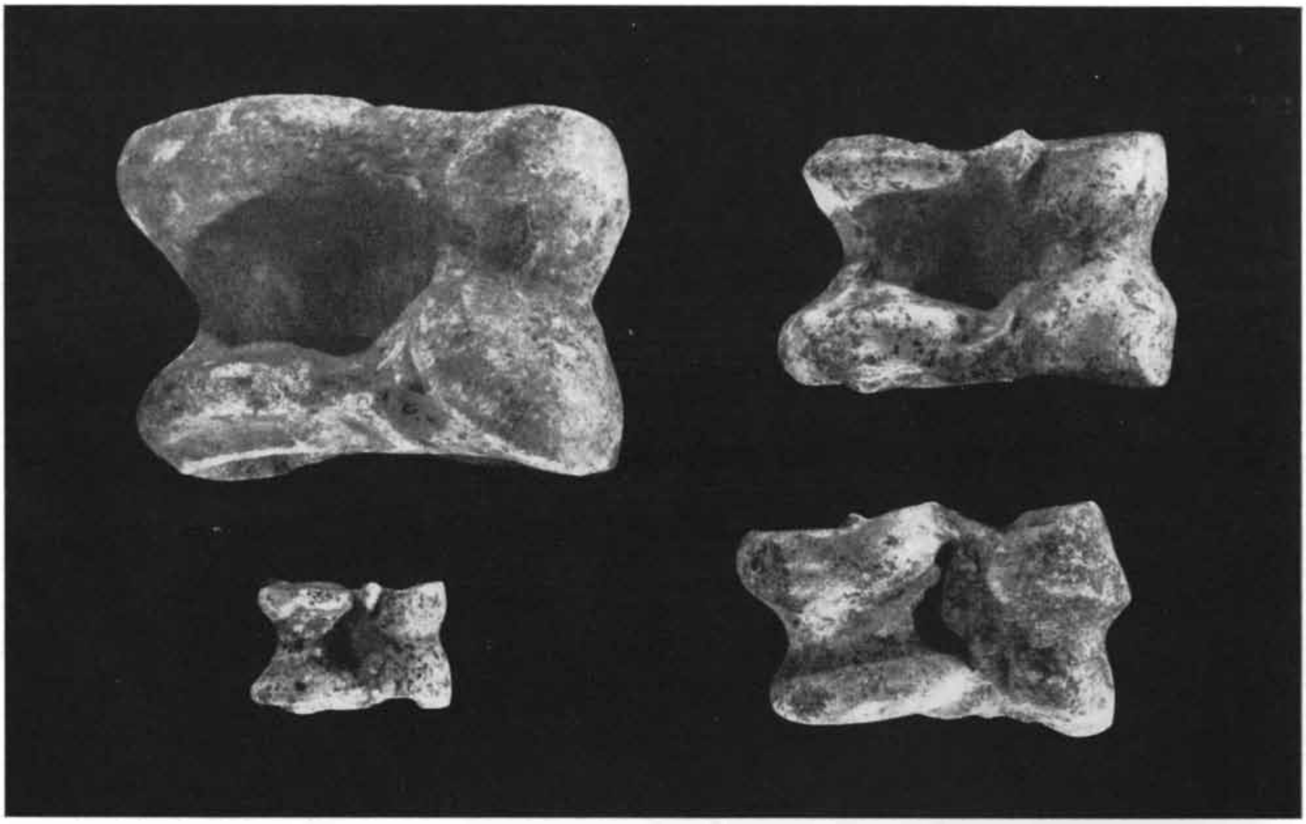
New criteria were set for all materials and functions. A high-grade titanium formed both structure and skin, and a high-emissivity external black paint increased external radiative heat losses and reduced the skin temperature. New techniques were developed to block or limit each heat leak path. But the major problem was finding a downstream heat sink for the super hot engine bleed air—primary cooling alone by ram air at over 700°F was far from adequate.



Schematic environmental diagram of SR-71 cockpit in flight conditions of Mach 3 speed at 80,000-foot altitude.

Expendable evaporants were out; the SR-71 could not take their extra volume and weight and still perform at top capability. The solution was a bold step taken for the first known time in aircraft: a direct air-to-fuel heat exchange through a specially designed fail-safe system. Graphic proof of its success is that the SR-71 crew operates in a 60°F environment despite the searing, oven-like external conditions.

The activities described here are only a few of Lockheed's R&D projects in environmental controls. If you are an engineer or scientist interested in this field of work, Lockheed invites your inquiry. Write K. R. Kiddoo, Lockheed Aircraft Corporation, Burbank, California 91503. An equal opportunity employer.



KNUCKLEBONES from the feet of four animals of the species that supplied most of Suberde's meat vary in size. They come from an ox (*top left*), a red deer (*top right*), a sheep or goat (*bottom left*) and a pig (*bottom right*). Each is a load-bearing bone, the astragalus. The size variations reflect the weight of the animals. Oxen weighed about 2,000 pounds, sheep only some 150 pounds.

METAPODIAL BONES of the same animals vary in size and also in number. Seen here is the end and part of the shaft of the single metapodial bone in the foot of a red deer (*top left*), an ox (*top right*) and a sheep (*bottom right*). Pigs have four per foot; two of them are visible here. They come from a modern boar killed at Suberde; only fragments of Neolithic pig metapodials were found.

A Hunters' Village in Neolithic Turkey

Were the inhabitants of Suberde herdsmen or hunters? The analysis of animal bones at the site shows not only that they were hunters but also that they probably "schlepped" meat home in animal skins

by Dexter Perkins, Jr., and Patricia Daly

Until quite recently most prehistorians believed that the first villages, which date back to early Neolithic times, arose in response to the settled way of life made possible by man's discovery of agriculture and animal husbandry. Within the past few years, however, a number of Neolithic villages have been excavated whose inhabitants clearly depended for their livelihood on collecting wild plants or killing wild game. This is one reason why there is currently much interest in Neolithic sites in western Asia, where the oldest known remains of villages have been found. The excavator seeks to know, among other things, whether the villagers were hunters and/or gatherers or farmers and/or herdsmen.

One aspect of this general question can be approached by means of a comparatively new technique: faunal analysis, or the analysis of the animal bones unearthed at an archaeological site. Faunal analysis can demonstrate whether the occupants of the site were hunters or herdsmen, and it can provide more detailed information on their way of life. For example, if the villagers were hunters, it can indicate what hunting techniques they used.

We have recently completed the faunal analysis of an early village site in southwestern Turkey. Some 300,000 pieces of bone, the largest number yet recovered from any site in western Asia, were unearthed there in 1964 and 1965 by archaeologists from New York University working under the direction of Jacques Bordaz and the auspices of the National Science Foundation. The site, a small community of the early Neolithic period, was first located by Ralph S. Solecki of Columbia University. It occupies the top of a hill some 3,000 feet above sea level in the region where the Konya plain borders the Taurus Mountains near the modern village of Suberde [*see map on next page*]. Until recently the hill was almost entirely surrounded by the waters of a lake, and at the time the Neolithic settlement was inhabited, in the middle of the seventh millennium B.C., the lake intermittently covered a large part of the adjacent plain. Today there are still wild boars in a marshy area to the southwest of the site, and wild goats roam the nearby foothills of the Taurus. Once the region also abounded with herds of wild sheep, but they were hunted to extinction less than a century ago.

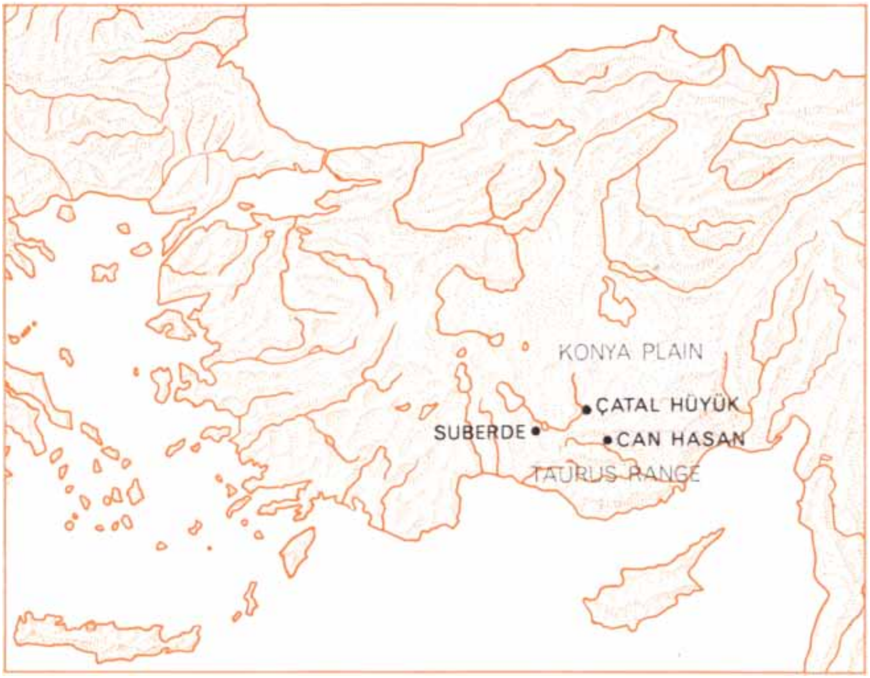
The digging of test trenches at Suberde in 1964 revealed levels of prehistoric occupation in an area half an acre in extent at the northern edge of the hill. The work of two seasons removed more than 230 cubic yards of material from the area. Below a disturbed surface layer the uppermost of two Neolithic levels was represented by a two-foot thickness of red-brown loam. In addition to tools, ornaments and bones, the upper level contained poorly preserved remains of houses with plastered floors and mud-brick walls. Underlying the red-brown loam was a second level, in places as much as six feet thick. In its light brown loam were hearths, deposits of ash and charcoal, a few unplastered floors, walls and benches, and some circular basins that had been scooped in the earth, lined with clay and then baked hard on the spot. Charcoal samples from the second level yielded carbon-14 dates that average around 6500 B.C. for the early occupation of Suberde.

By the end of the second season the excavators had collected about a ton and a half of animal bones. Our first step in dealing with this enormous accumulation was to cull out all the scraps of bone that were unidentifiable. The preliminary sorting took place at the site and reduced the collection from 3,000 pounds to 650 and from 300,000 specimens to 25,000. Although fewer than 10 percent of the potential specimens had survived the sorting, there were still plenty of bone fragments to work with.

We next sorted the bones according to the species of animal they represented. In many cases, however, it was not possible to tell what species was represented by a bone. Sheep and goat vertebrae, for example, look much alike. Worse still, the vertebrae of roe deer and fallow deer and even some pig vertebrae look enough like sheep and goat vertebrae to be confusing. Nonetheless, vertebrae are unmistakably vertebrae and are therefore not culled out when the unidentifiable scrap in a collection is eliminated. The same is true of rib bones: although they are easily identifiable as ribs, the species they represent is rarely certain. We put such bones aside and worked only with the specimens that could be identified by species.

By the time we had identified a total of 20 species, we had discarded as useless for identification nearly half of our 25,000 specimens, reducing the study collection to about 14,000 pieces of bone. The large majority of them—more than 9,000 specimens—were the bones of sheep (the Anatolian mouflon, *Ovis orientalis anatolica*) or goats (the Asian bezoar, *Capra hircus aegagrus*). Sheep and goats are lumped together in the statistics because, except for skulls, horns and a few other bones, their remains are not easily distinguished. Of the more than 9,000 specimens only 700—fewer than 10 percent of the sample--were identifiable as to species. The proportion was 85 percent sheep to 15 percent goats.

Considering Suberde's waterside location, it is curious that neither fish, shell-



SITE OF SUBERDE is located in southwestern Turkey, some 3,000 feet above sea level on the Konya plain. Two other Neolithic sites, Can Hasan and Çatal Hüyük, are its neighbors.

fish nor waterfowl seem to have played any significant role in the diet of the Neolithic villagers. Among our specimens were only a very small number of fishbones, freshwater-clam shells and bird bones (which seem to belong to a species of pelican). Better represented than any of these aquatic animals was the land tortoise, a slow-moving prey of the kind commonly collected by women and children in primitive societies even today.

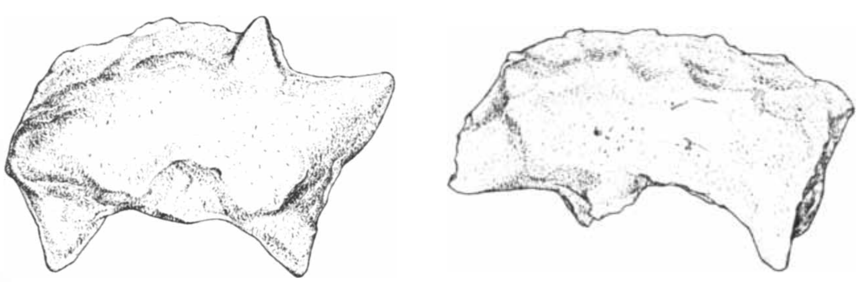
The inventory of mammals other than sheep and goats at Suberde is extensive. The domestic dog was present, and the countryside supported such wildlife as jackal, fox, bear, wildcat, marten, badger, hedgehog, hare, roe deer and fallow deer. The bones of three additional mammals were found in sufficient abundance to indicate that they had shared the role of meat animals with the sheep and goats. These were the pig (*Sus scrofa*), represented by more than 1,400 bones; the red deer (*Cervus elaphus*), represented by some 340 bones, and a now extinct ox (*Bos primigenius*), represented by nearly 300 bones.

Having determined that five animal species furnished most of Suberde's meat, our next task was to find out if the relative importance of the species in each of the site's various strata indicated any change over the centuries either in the villagers' dietary preferences, in the availability of particular animals, or both. Bordaz was able to distinguish a number of stratigraphic subdivisions within the two main levels at the site, but he found that the evidence for cultural change from stratum to stratum was slight. The major innovations in the upper strata were the use of polished stone in addition to the previously favored tool material, chipped obsidian, and the plastering of floors. The tools found at Suberde changed somewhat in style with the passage of time but not greatly in function. With such a record of cultural continuity, we did not expect to find much change in the villagers' diet.

The preponderance of sheep and goat bones indicates that these animals were the most important ones at Suberde. What about the other animals? The relative frequency of their bones in each stratum should provide at least part of the answer. One way to determine this relative frequency is simply to let the total number of all identifiable bone specimens represent 100 percent and then to conclude that the percentage of bones belonging to each species reflects its abundance among the animals killed. There are, however, several questionable assumptions inherent in this approach. It assumes that the survival of specimens has the same pattern for all species, and that the relative number of identifiable specimens is the same for each species. It further assumes that each of the animals was butchered in the same way.

A second approach is to determine the minimum number of individuals of each species present (based on a count of some particular bone or bones) and then to express these minimum numbers as percentages. This method largely avoids the pitfalls of the first, but it has its own drawbacks. The bone one selects as representative of a single animal may in fact prove to be so rare in a particular stratum that accidents of preservation (for example the lucky survival of two bones rather than one) could seriously distort the percentages.

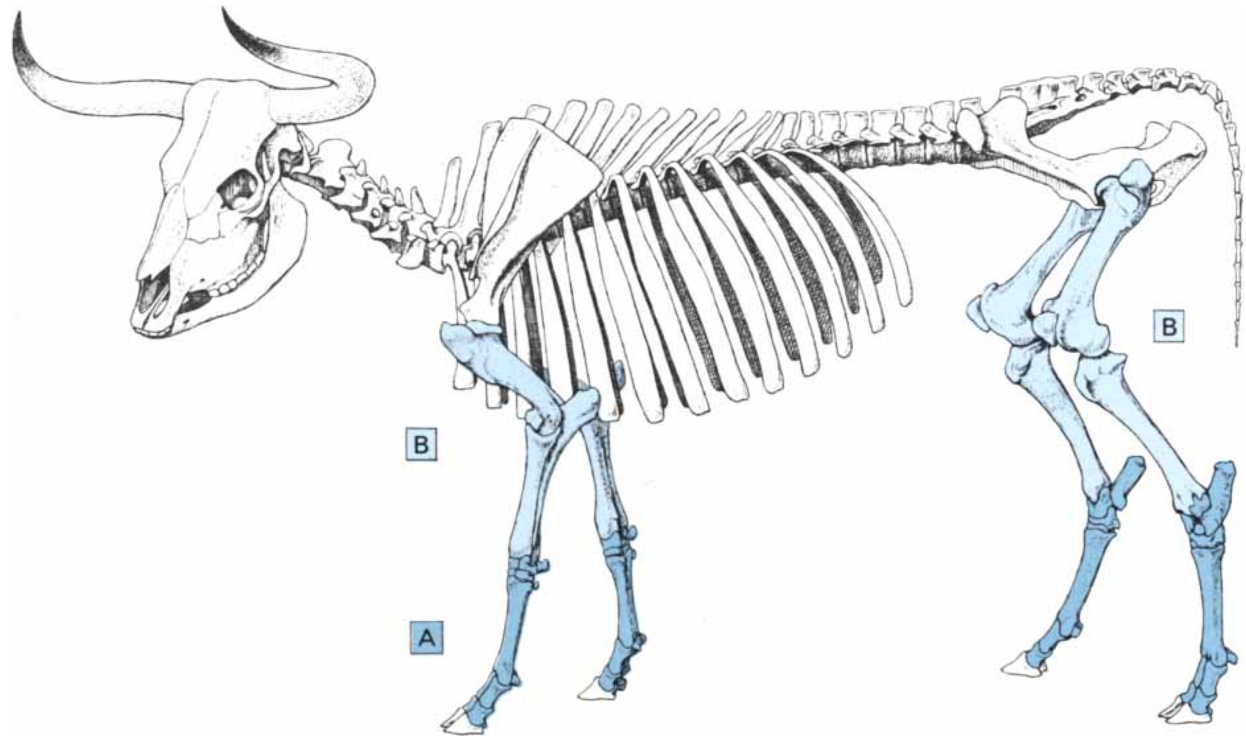
The method we used avoids both difficulties. We first eliminated from our calculations the bones of the five meat animals that, for one reason or another, had not survived in approximately equal numbers among all the species. This reduced the collection from some 11,000 specimens to about 3,800. At the same time we allowed for the fact that different animals have a different number of bones in their skeleton. In the Suberde collection the bones that survived equally well among all the species were certain of the foot bones. Pigs, however, have more than twice as many foot bones than the other meat animals at the site



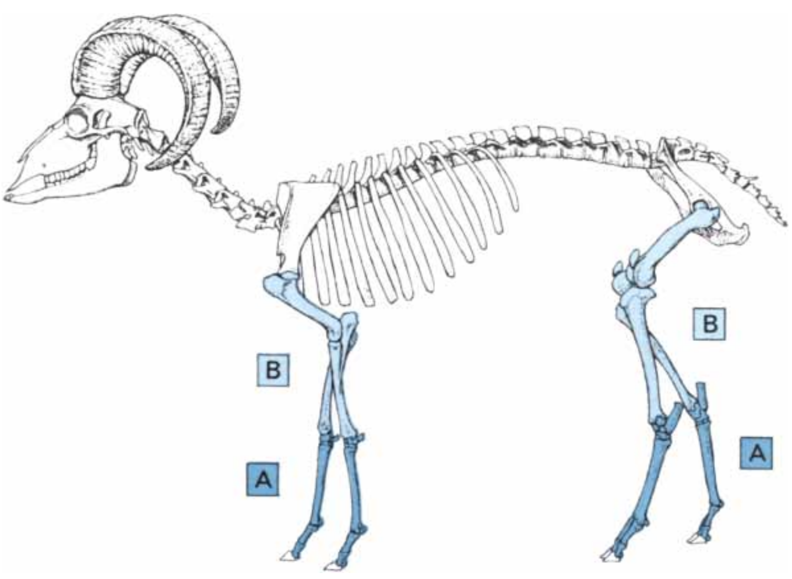
CLAY FIGURINES of pigs are among the few examples of art unearthed at Suberde. Pork was a consistently popular foodstuff throughout the site's occupation and boars' tusks were used as ornaments. Why the pig was represented in sculpture, however, remains unknown.

do: a pig's four extremities consist of 52 bones, whereas the extremities of the other animals consist of 24. A stratum that contains 100 sheep foot bones and 100 pig foot bones does not indicate, therefore, that sheep and pigs were present in a one-to-one ratio. The ratio is closer to two sheep for every pig. An example is provided by the number of identifiable pig bones in the lowest stratum of the site, designated by Bordaz as Level III–IV. They made up nearly 14 percent of all bones in the level. Moreover, the minimum proportion of pigs indicated by the pig foot bones in that level was 15 percent of all the animals. When we eliminated the bias due to the pig's characteristic skeleton, however, we found that the pig accounted for less than 7 percent of the population [*see bottom illustration on next two pages*].

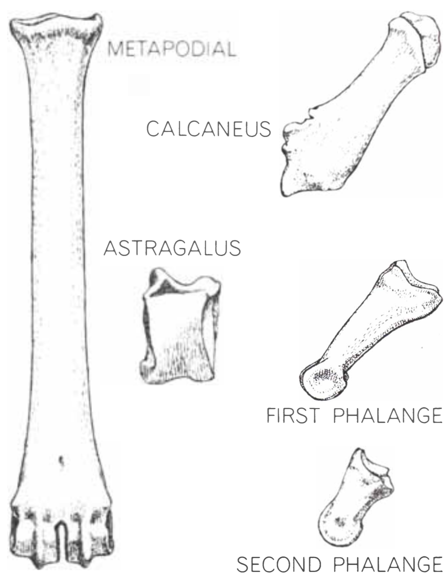
Determining the relative frequency of each species in each level did not by itself indicate its economic impor-



ANCESTRAL OX *Bos primigenius* became an increasingly important source of meat at Suberde over the centuries. The skeleton is shown divided into the *A* and *B* components. The *A* skeleton comprises bones of the feet, the *B* skeleton those of the legs. Many more ox foot bones than leg bones were unearthed at Suberde. This puzzle led to the authors' discovery of the "schlepp effect."



ANATOLIAN MOUFLON, a sheep of the species *Ovis orientalis*, together with lesser numbers of goats, was the primary meat animal at Suberde. The remains of sheep and goat *A* skeletons were found to be in proportion to the remains of their *B* skeletons, demonstrating that schlepp factors were inoperative in the inhabitants' treatment of smaller mammals.

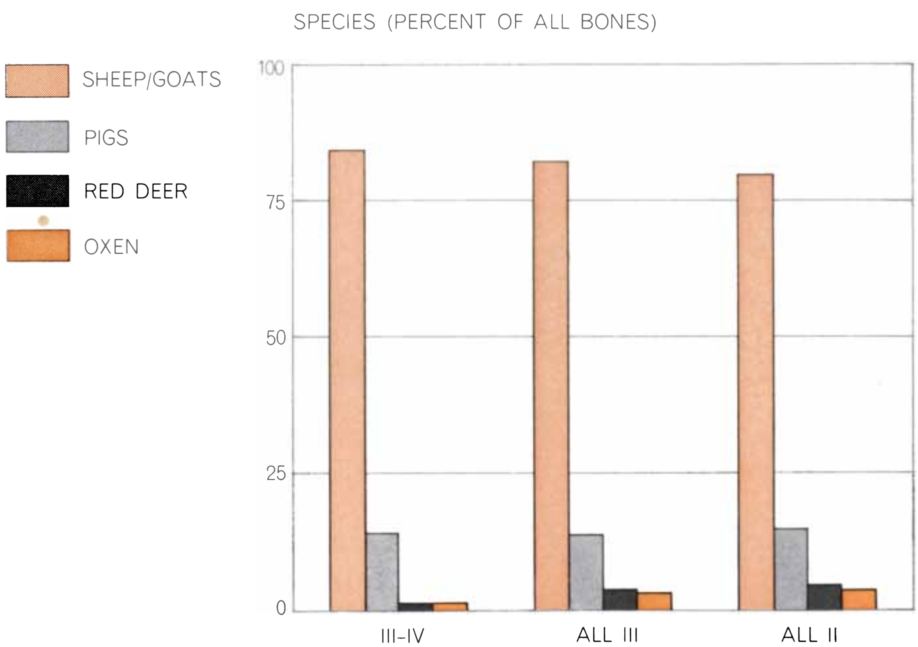


BONES OF THE FEET were used by the authors to calculate how many of each meat animal had been present at Suberde because most foot bones were usually well preserved.

DIGGERS AT SUBERDE had to cut away a disturbed surface layer before reaching the underlying Neolithic remains on a hill bordering a dry lake (*background*). The countryside is ideal pasture for sheep; wild goats still roam the Taurus foothills beyond.

tance in terms of meat. An additional calculation was required. Sheep and goats are much the same size, but an ox yields more meat than a deer and much more meat than a sheep. Because the pig has short legs with more meat on the shank than there is on the legs of other animals, a pig yields about 20 percent more edible meat per pound of live weight. To estimate the proportion of meat in the Suberde diet supplied by each of the five species we assumed that sheep and goats yielded about 77 pounds of edible protein each (half the live weight), that a red deer yielded about 220 pounds and an ox about 1,000 pounds (also half the live weight). Pigs provided the same amount of edible meat as red deer because 70 percent of their live weight is edible meat. We were now in a position to calculate if the composition of the Suberde meat supply had altered over the centuries.

The excavators at Suberde had of course catalogued the animal bones according to the strata in which they were found. It was our assumption at first that, regardless of which level contained which bones, the collection as a whole would probably form a homogeneous sample. When we tested the collections from different levels for homogeneity, however, we found the statistical probability that the whole collection was homogeneous was less than .02 percent. Working further with bones from various stratigraphic subdivisions, we found that the oldest ones (from the lowest stratum, where a particularly large quantity of animal remains extended down to bedrock) showed a better than 90 percent probability of homogeneity. The same was true of the bones from the higher strata in the older deposit, called the III levels by the excavators, and of the bones from the lower strata in the younger deposit above, known as the II levels. The bones from all the III and II



RELATIVE IMPORTANCE of the five meat animals during three time intervals at Suberde is not reflected accurately by a simple count of the number of bones of each species levels, when taken together, also showed a better than 90 percent probability of being homogeneous. Because the site's few cultural innovations appear only in the II levels, however, we have continued to deal with the animal remains from each of these deposits as separate entities.

Applying our calculated yields of meat per species to the estimated number of animals in the earliest levels and the later ones, we found a significant difference in proportions. The amount of pork in the Suberde diet remained about the same—14 percent of all meat—from Level III–IV at the bottom up through the II levels at the top. In contrast, the amount of sheep and goat meat showed a sharp decline: from nearly 70 percent in Level III–IV to barely 50 percent in the II levels. As sheep and goats declined in dietary importance, oxen and red deer increased. Deer meat, however, seems to have been a relatively marginal item: the supply in the II levels was twice that in Level III–IV but still represented less than 7 percent of all meat. The supply of ox meat showed a notable rise: from about the same percentage as pork in Level III–IV it grew to an average of 30 percent of all meat in the III and II levels.

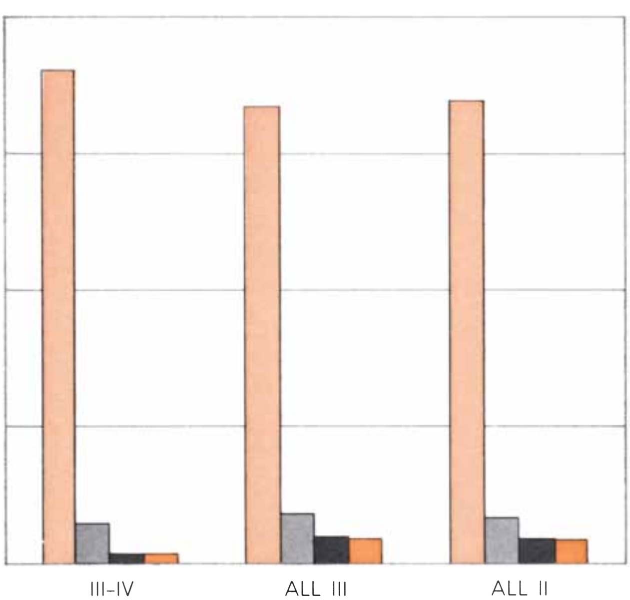
Do the animal bones at Suberde represent domesticated flocks or hunters' prey? There is no known instance of red deer being domesticated, but Suberde is not far from another Turkish Neolithic site, Çatal Hüyük, where domesticated cattle were known during roughly the same period. Moreover, domesticated sheep and goats were kept at the valley settlement of Zawi Chemi Shanidar in neighboring Iraq nearly 3,000 years before Suberde came into existence.

Evidence for domestication can be of several kinds. The plainest is the presence of an animal in a region outside its natural range; the pig in the New World is a recent example. In instances of this kind the suggestion is strong that the animal left its ancestral habitat under the guidance and control of man. A second kind of evidence is a change in the form of the animal, either because of the crowding that is a significant functional aspect of domestication or because of man's selective preservation of variant forms that would not survive in the wild. A third kind is a sudden rise in the proportion of one particular species for which no natural cause is apparent; the animal has obviously become a more reliable food source, possibly as a result of human control. A similar kind of evidence is the discovery that the remains of certain species all fall within certain age classes; the finding suggests either a seasonal pattern of hunting or selective culling of a domesticated herd, for example to cut down the number of animals that must be fed through the winter.

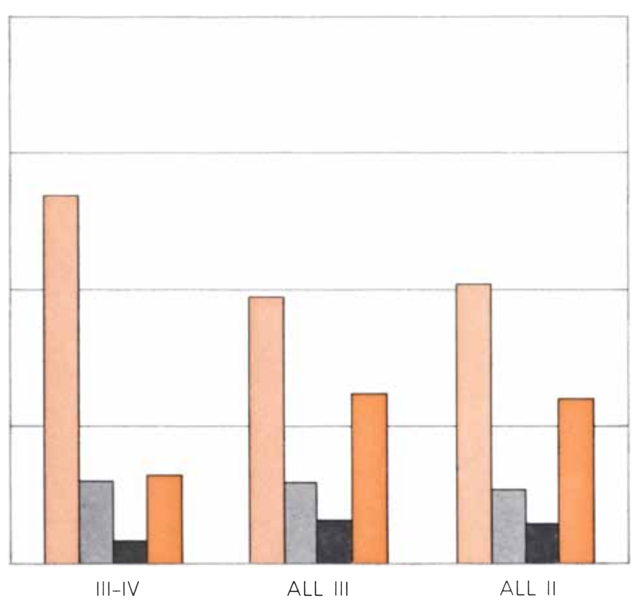
At Suberde no evidence of the first kind was available; the site is located well within the former natural range of all five of the meat animals, and two of them survive in the area today. As for any change in the form of the animals, we encountered some negative indications but only one doubtful piece of positive evidence. The evidence for and against domestication at Suberde is best described species by species.

To begin with the most numerous group, out of the more than 9,000 specimens of sheep and goat bone we found one skull fragment that seemed to be from a hornless sheep. Although the loss of horns is a change characteristic of domesticated ewes, one skull fragment is not an adequate basis for stating that the sheep at Suberde had been domesticated. Hornless females are known among some wild populations of the Asiatic mouflon, the species of sheep at Suberde. Moreover, instead of increasing in numbers and importance as time passed (an indication of possible human control) Suberde's sheep and goats declined. In order to determine if the last remaining kind of evidence—the evidence of age classes—was positive or negative, we compared the proportion of juvenile sheep to mature sheep in the Suberde sample with the proportion among the domesticated sheep in an Iron Age settlement in Europe (as reported by E. S. Higgs of the University of Cambridge) and the proportion in a population of living wild sheep (as reported by Adolph Murie of the U.S. National Park Service). The proportion in the Suberde

RELATIVE FREQUENCY OF SPECIES (PERCENT)



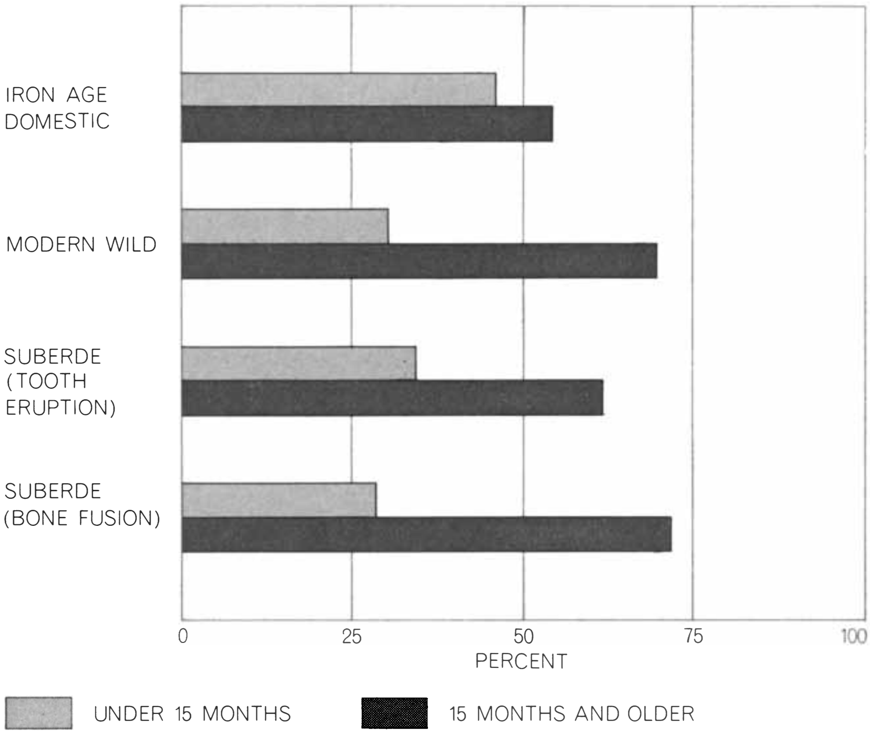
MEAT SUPPLY PER SPECIES (PERCENT)



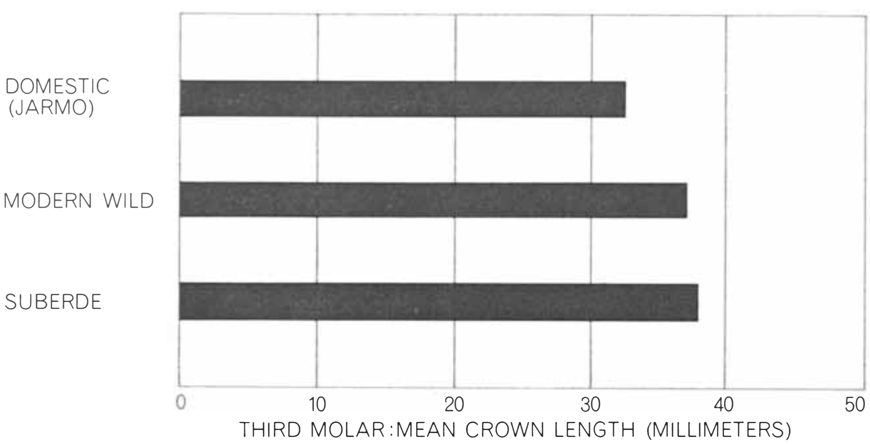
(*left*). The schlepp factors remain undetected and the pig, which has twice as many foot bones as the other animals, is disproportionately represented. Once the relative number of each species is known (*center*) one can show the percentage of meat that each provided (*right*).

sample was almost identical with the one found by Murie in wild sheep [*see upper illustration below*].

Subdividing our sample even further by age, we found that no sheep specimens represented animals younger than three months or older than three years, although the sample was in general evenly distributed between these two extremes. According to Murie, the old animals and the very young animals are precisely the ones that are taken by wild predators. We were therefore brought to two conclusions. First, the sheep and goats at Suberde had been wild. Second, the randomness of the sample with respect to age suggests that the Suberde villagers were not solitary hunters but rather were engaged in cooperative drives, slaughtering whole flocks at a time.



SUBERDE SHEEP were evidently wild rather than domesticated. Whether estimated on the basis of tooth eruption or on the basis of bone fusion, the age of most Suberde sheep was over 15 months. The proportion of mature to immature animals was close to that among living wild sheep and was quite unlike that among the domesticated sheep of the Iron Age.



SUBERDE PIGS were also evidently wild. The crown length of the rearmost molar teeth is soon reduced in domesticated pigs because the animals' jaws grow shorter; an example is the mean crown length of the third molar teeth in domesticated pigs from Jarmo, an Iraqi site of the seventh millennium B.C. The Suberde pigs' teeth are nearer to modern wild pigs' teeth in size. Kent V. Flannery of the University of Michigan measured Jarmo and modern teeth.

The status of the pigs at Suberde was also uncertain. They had neither declined nor increased in importance as time passed, and thus their numbers provided no evidence for or against possible domestication. Unfortunately reliable age-class information is not available for the pig. Age is commonly determined by the fusion of the ends of the long bones to the bones' main shaft. There is no information on the rate of fusion in wild pigs, and the information on domesticated pigs merely suggests that the process is too delayed to allow accurate identification of young age classes. One piece of negative evidence, however, was at our disposal. Ancient domestication might be defined as a combination of malnutrition and overcrowding. In pigs a change that soon results is a foreshortening of the jaw and face, with a consequent crowding of late-erupting tooth buds and a reduction in the length of the molar crowns. We compared the crown length of the Suberde pigs' upper third molars with the crown length of domesticated pigs from the site of Jarmo in Iraq and with the crown length of modern wild pigs. We found that the Jarmo crown length was substantially reduced but that the Suberde and wild-pig crown lengths were almost identical [*see lower illustration at left*]. We concluded that the Suberde pigs had not been domesticated.

This brought us to the oxen. Unlike the sheep and goats (whose numbers had declined) and the pigs (whose numbers had remained the same), the oxen had increased in number as time passed. Could the increase be taken as evidence for domestication? Two anomalies apparent in the bone collection argued against such a conclusion. The first is that none of the cattle specimens is from an immature animal. The same is true of the red deer specimens, which is attributable to the structure of deer herds: females and young comprise one herd and the males another. If hunters selectively stalk only the herd of males, which are notably easier prey than the alert and timid females, they will kill no juvenile deer. Perhaps the herds of ancient oxen had a similar composition. Since they are now extinct, we shall never know the answer. The total absence of juvenile cattle bones at Suberde, however, is only part of the evidence suggesting that the villagers hunted wild oxen.

Quite early in our analysis we noticed

This man keeps his kidney in the bedroom closet

He's living today thanks to an artificial kidney machine developed by doctors and technicians at the University of Washington. Here's the story:

Eight years ago, this man was dying of chronic kidney malfunction. Today, he and hundreds of other victims of otherwise fatal kidney disease lead productive, normal lives, distinguishable from others chiefly by their twice weekly trysts with a lifegiving, mechanical bedpartner.

To accommodate the mechanized kidney, an ingenious tube or cannula is permanently implanted in the patient's arm. Arterial blood is drawn out, filtered through the machine and returned intravenously. Harmful wastes filter through a porous membrane of the artificial kidney, leaving only the cleansed blood to circulate back through the body.

In 1960, the mechanical kidney and all its components filled a good-sized room. The kidney itself was about a yard long and the huge metal container of electrolytic dialysate solution looked like a small water tank. That was eight years ago. Today, the ingenuity of researchers and the specialized production capabilities of a local Washington State manufacturer have developed a safer and more efficient kidney which occupies only a modest corner—not of a hospital room—but of the patient's own bedroom at home.

Because of these new compact machines, the University was able to initiate the now widespread home dialysis program. Home dialysis cuts costs to the patient in half, provides opportunity for more frequent dialysis, and relieves crowding of hospital facilities. The compact home machines work on the same principle as the hospital models. Patients undergo an intensive training program prior to going home to eliminate their dependency on trained personnel.

The marriage of engineers, physicists and physicians that produced the improved artificial kidney is a harmonious one. In the near future this group plans to introduce an ultra-compact kidney unit the size of a telephone book. The next step, a portable kidney is in early developmental stages. Ultimately, the research team envisions an inexpensive, wearable kidney unit that can be connected inconspicuously at work or at home.

The State of Washington is a fertile field for the exciting new breakthrough industries of the future. In bio-engineering, aerospace, agriculture, fisheries, oceanography, atomic energy and many other areas, the smart money is betting on Washington State.

Daniel J Evans
Governor
STATE OF WASHINGTON

For information, write: Daniel B. Ward, Director, Department of Commerce and Economic Development, Olympia, Washington 98502.

that the leg bones of oxen were curiously scarce. When we compared the number of what we characterized as "*A* skeleton," or foot, bones with the number of "*B* skeleton," or leg, bones, for example, we discovered that the proportion was quite different for oxen from what it was for sheep and goats. The foot bones of sheep and goats comprised about 55 percent of the combined total; the leg bones made up the remaining 45 percent. With the oxen 83 percent of the bones were foot bones and only 17 percent were leg bones [*see lower illustration below*]. This distribution puzzled us until we remembered the various ways the bison hunters of the American Great Plains had dealt with their prey and realized that the villagers of Suberde must have faced a quite similar problem.

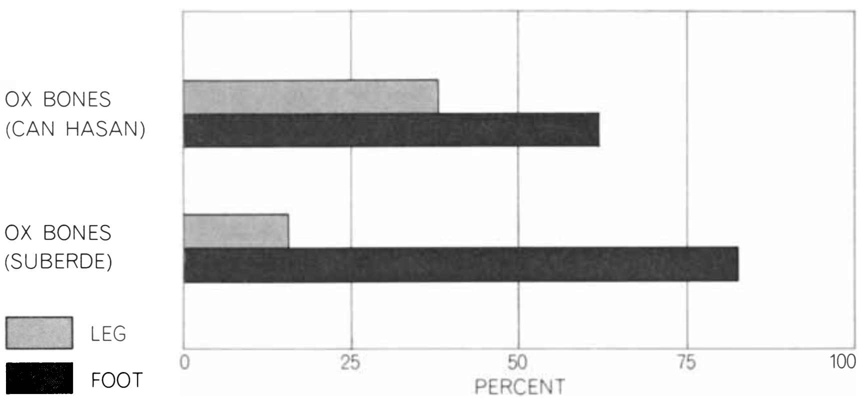
If the cattle at Suberde had been domesticated, we reasoned, they would have been slaughtered conveniently near home. How, then, could one explain the absence of the leg bones? Some bones are more likely to disappear after burial than others, for various reasons. Some decay rapidly, the way hooves do. Rodents may dig into the soil and carry away small bones, and larger carnivores such as wolves and jackals may do the same. The leg bones of oxen, however, are not more susceptible to decay than ox foot bones, and they are more difficult to carry away. Moreover, the foothills near Suberde are typical sheep terrain, but the nearest cattle country is a few miles away. The missing leg bones indicate that the cattle were not slaughtered near the village. At the same time the nature of the countryside makes it improbable that wild cattle would have been encountered near the village.

Archaeologists working at Paleo-Indian sites in the New World have shown that, if only a few parts of a bison skeleton are found, the site is probably a more or less permanent camp to which the hunters brought back meat from animals they had killed and butchered elsewhere. If, on the contrary, most of the bisons' bones are present, the site is probably a "kill" site to which the successful hunters summoned their families. Suberde was a permanent settlement, and most cattle long bones were missing from its faunal inventory. We concluded that the oxen were indeed wild and had been killed away from home.

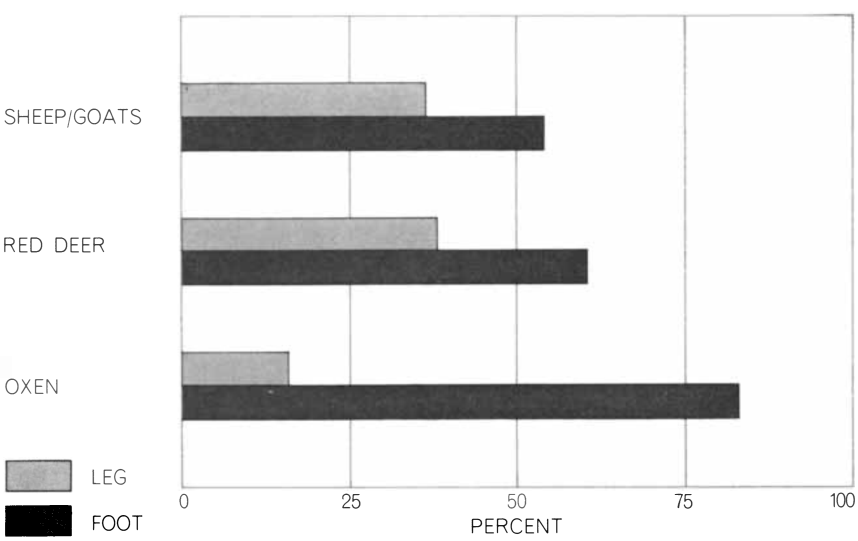
When a Suberde hunting party killed a wild ox, they apparently butchered it on the spot and used the animal's own hide as a container for carrying the meat home. They evidently stripped the forequarters and hindquarters of meat and threw the leg bones away. They apparently left the feet attached to the hide, perhaps because the feet made convenient handles for dragging the meat-filled hide. Perhaps they also valued the feet: this part of the animal contains useful sinews and has been called "the hunter's sewing kit." We have named the disparity between the number of cattle foot bones and leg bones that resulted from this treatment of the prey the "schlepp effect," after the German verb meaning "to drag." It combines a factor related to the size of the game animal with one related to the distance between kill site and home settlement. Sheep and goats, for example, were small enough, and were killed close enough to Suberde, to be immune from the schlepp effect. The wild oxen were not.

One further consideration supports our conclusion: the proportion of ox leg bones to ox foot bones at Can Hasan, a nearby Neolithic site where cattle were domesticated. The proportion is 38 percent leg bones to 62 percent foot bones, sharply different from the Suberde proportion [*see upper illustration at left*].

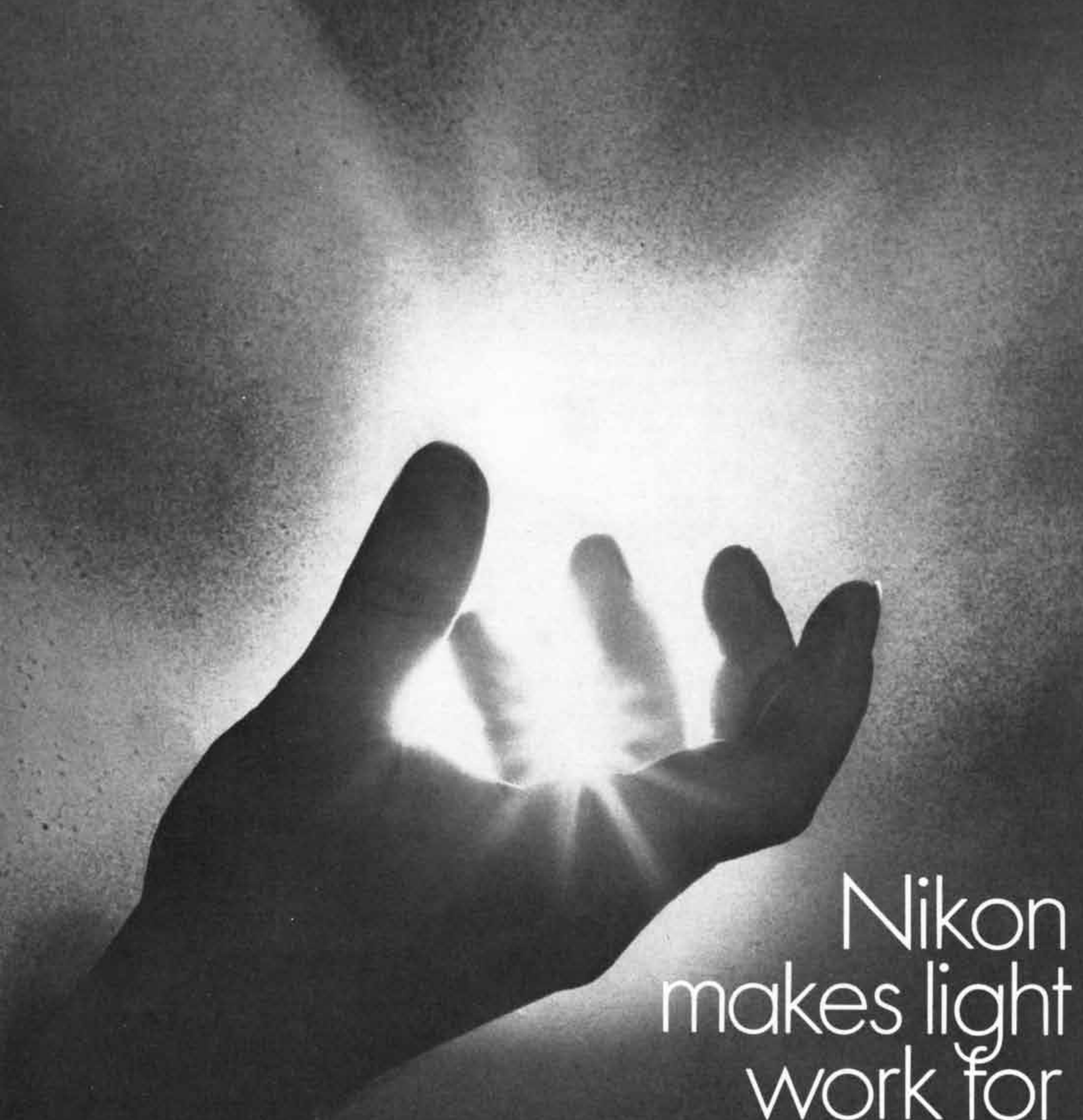
All in all, what have the bones at Suberde told us about the lives of its Neolithic inhabitants? Suberde was a



SUBERDE OXEN were also evidently wild. At Can Hasan, where cattle were domesticated, the proportion of bones from ox *B* skeletons and *A* skeletons was roughly three to two. The proportion at Suberde was closer to six to one. The authors attribute the discrepancy to the schlepp effect: the Can Hasan oxen, being domesticated, could be slaughtered close to home without leaving any bones. The Suberde oxen, in contrast, must have been butchered far from home, leaving some bones behind. Such a system suits hunters, not herdsmen.



VARIABILITY of the schlepp factors at Suberde is evident in the different proportion of sheep and goat, red deer and ox *A*-skeleton and *B*-skeleton bones found at the site. The small animals, lighter loads, were apparently brought home unbutchered; they were probably killed fairly near home. The contrast between the proportions for ox and for deer, the latter identical with the proportion for Can Hasan oxen, may reflect the greater ease in dealing with a 400-pound animal rather than a 2,000-pound one when both are killed far afield.



Nikon makes light work for you

Light illuminates and reveals. Aided by optics it is a tool, a yardstick, a language. It can perform a thousand tasks.

The name *Nikon* figures prominently in this. Nikon achievements in theoretical optics, optical glass chemistry and optical instrumentation have become something of a legend in their own time.

A photographer is poised for an exposure. His picture may chronicle a great moment in history; depict a fashion trend; show a new plant installation; record a surgical procedure; or simply capture a likeness. The camera is a Nikon.

A sportsman watches the favorite down the stretch; a yachtsman sights a channel marker. A hunter spots a buck; a birder identifies an uncommon specie. Through Nikon binoculars.

A biologist observes the miracle of mitosis; a medical student, the characteristics of cell abnormality. A metallurgist inspects a turbine blade; a pathologist readies a specimen for photo-micrography. In each case, a Nikon microscope.

A QC inspector gages an intricately shaped component with a Nikon Profile Projector. It is capable of repeat measurement accuracy to 0.0001." A maintenance man checks the flatness of a lathe bed with a Nikon Auto-Collimator. He can detect angular deviation to less than ½ seco

a set of process negatives, the first critical step in graphic arts color reproduction. The lens, a Nikon Apo-Nikkor.

An electronic engineer studies the drawings for an integrated circuit. They will be reduced optically to the miniscule proportions of an IC chip. Most likely with a Nikon Ultra-Micro Nikkor lens. And a Nikon Mask-Alignment microscope will probably be used for registration.

Nikon can make light work for you, too. For wherever light has a job to do, you will find Nikon optics and optical instruments in evidence and in use.

Write: Special Applications/Nikon Incorporated, Garden City, N.Y. 11530. Subsidiary of Ehrenreich Photo-Optical Industries, Inc. (In Canada: Anglophoto Ltd., P.Q.)

settled community of the kind that has been thought to have arisen only after men had mastered the growing of crops and the herding of animals. Analysis of the plant remains at the site has not yet been completed. Regardless of the presence or absence of domesticated plants at Suberde, however, one point is clear. The villagers fed largely on meat and were not herdsmen but hunters.

Second, in its early years Suberde depended on cooperative hunting tactics to secure nearly 70 percent of its meat supply. Sweeping through the adjacent foothills, the village hunters slaughtered entire flocks of sheep and goats at a time, perhaps driving them by setting fires. The methods used to rouse boars from the marshy thickets of the region are not apparent from the faunal remains. Among the artifacts at Suberde, however, are ornaments made from boar tusks, and the scant representational art at the site includes pottery figurines of pigs [*see bottom illustration on page 98*]. Although pork played only a limited role in the Suberde diet, the wild pig was evidently much on the villagers' minds. As for the red deer, the lack of immature deer remains makes it probable that only the male herds were stalked. Because a solitary hunter would scarcely find it easy to schlepp more than 200 pounds of butchered meat and hide back to the village, group hunting again seems more likely. In the case of the wild oxen, the 1,000-pound burden of each animal's meat and hide—as well as the heavy work of butchering the animals—means that the pursuit of cattle by the inhabitants of Suberde was almost certainly a group activity.

Finally, the earlier inhabitants of Suberde depended more heavily on sheep and goat meat, or possibly found sheep and goat easier prey than their successors did. Pending a report on the plant remains at the site, we can say only that there is no obvious evidence for a change in climate that might account for the change in hunting pattern. Because the change appears in all the III layers and the site's few cultural innovations do not appear until the II layers, it seems doubtful that a cultural shift was the cause. We are left guessing. Were the local foothills overhunted, so that the villagers had to go farther afield to find other wild herds? Whatever the explanation, the analysis has shown that a change did occur and has measured its extent. Faunal analysis is capable of providing similar information about the lives of prehistoric peoples at other sites throughout the world.

TRANSDETERMINATION IN CELLS

When an embryonic cell begins to differentiate, it is said to be determined for that function. Yet when cells of a fruit-fly larva are transplanted into an adult fly, their determination can change

by Ernst Hadorn

The investigation of how the genetic material guides the development of cells and organisms is surely one of the most exciting enterprises of modern biology. It has already yielded many illuminating discoveries, but it is still full of surprising phenomena. We have encountered such a phenomenon in experiments conducted in our laboratory at the University of Zurich.

Let me first explain what prompted our experiments. We wanted to find out when and under what circumstances the future of embryonic cells is determined, so that the cells will proceed to specialize and form the various differentiated structures of the adult organism. It is well established that all the embryonic cells start out with an identical full set of genes, carrying instructions for the specific development and functioning of every kind of cell in the organism. It is generally assumed that a distinct pathway of differentiation is determined for cells when specific groups of genes are activated, some groups directing the differentiation of muscle cells; some, nerve cells; some, gut cells, and so on. We say that such cells are in a certain determined state. Thus determination is an important event in which cells of identical genotype begin to differ in their characteristics, or phenotype. At what stage in the embryo's development is this determination established? How stable is such a state? Will it be inherited by all cells descended from a determined ancestor, or can the cells perhaps be switched into new pathways?

The organism we chose for our experiments is the fruit fly *Drosophila melanogaster*. This insect has rendered prodigious service to genetics, but at first it seems much less suitable for studies of development than the embryos of amphibians and sea urchins. For our special purpose, however, *Drosophila* offered a most convenient feature.

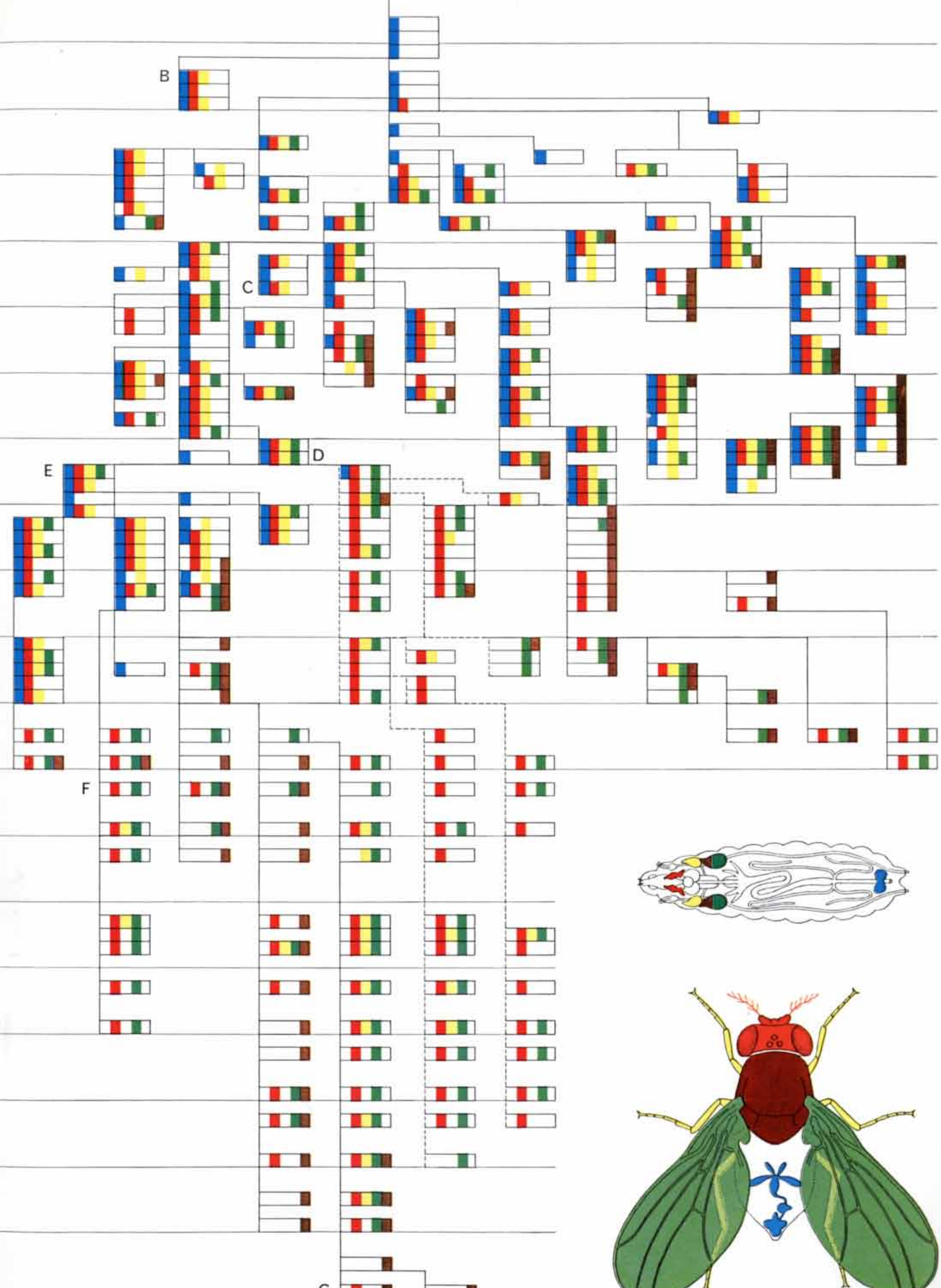
In the early embryonic development of higher insects such as flies, bees and beetles a remarkable separation of cells occurs. In one class of embryonic cells final differentiation proceeds without delay, that is, it is initiated as soon as the cells become established by the process of cleavage and rudiment formation. These cells give rise to the body of the insect larva, with all its functioning organs. Another class of cells is set apart, however, in what are called imaginal disks. Although the cells of the imaginal disks are in contact with their differentiating neighbors, they remain in an embryonic state throughout the larval period. In this first period of insect life the cells of the disks divide. Therefore a few thousand of them are present in each disk when the larva is ready to become a pupa and proceed with metamorphosis. The location of a few of the imaginal disks in the larva of *Drosophila* is shown at bottom right in the illustration on the opposite page.

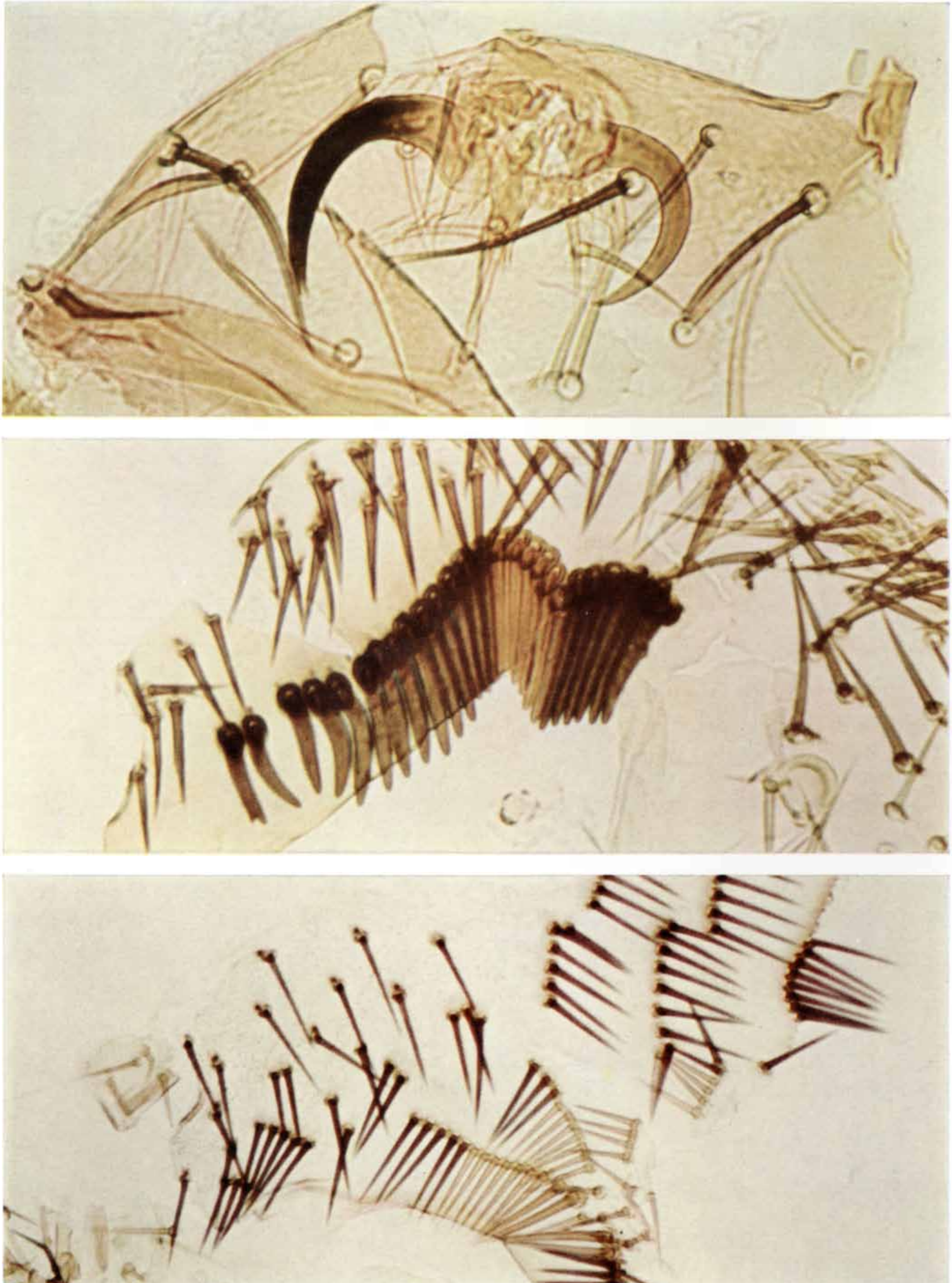
During metamorphosis most of the larval organs break down within the case of the pupa. Their cells eventually disintegrate. At the same time, and only at this time, the cells of the disks lose their embryonic character and differentiate into the specific body tissues of the imago, or adult fly. Each of the disks furnishes its part of the metamorphosed insect, as the illustration shows. One disk, the genital disk, contains cells that will develop into the structures of the sex organs, the back parts of the abdomen and the hind gut. There is a disk for each of the six future legs, and three pairs of disks combine to form the head. (Of these latter disks only the eye-antenna disk appears in the illustration.)

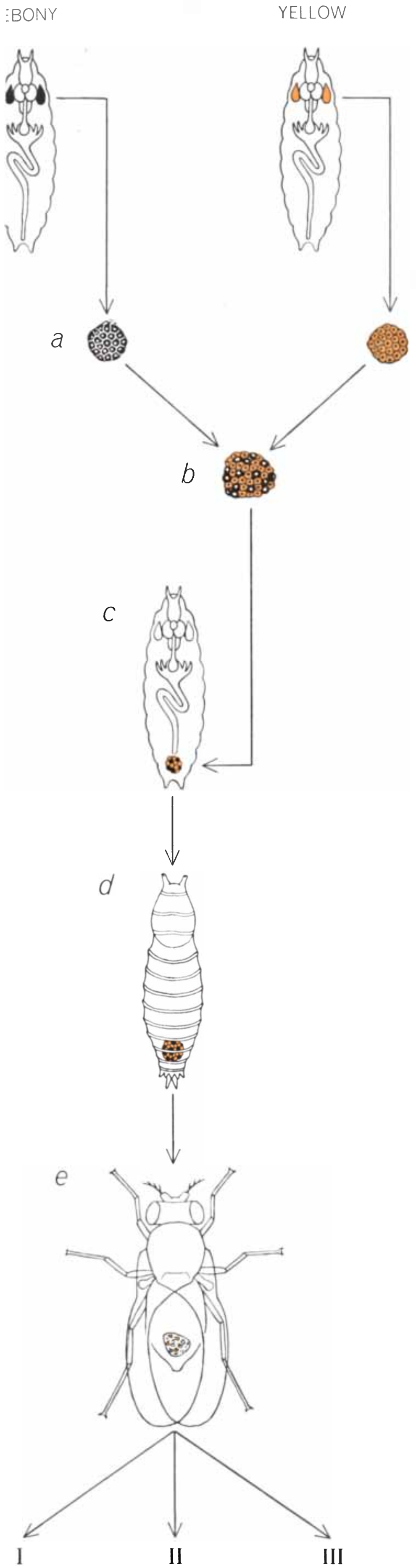
Each disk forms a set of different structures. A leg disk, for instance, contains cells that respectively develop into claws, tarsal parts, tibia, femur, trochanter, coxa and adjoining parts of the thorax. Moreover, in each section of leg many different functions must be conducted. Accordingly bristles and hairs of various sizes and shapes are formed by different cells and are distributed in definite patterns.

Imaginal disks can be dissected out of an insect larva. In our experiments with *Drosophila* we cut the disks with a fine tungsten needle and implant the pieces in the body cavity of other larvae. Then, when the host larvae metamorphose into

CELLS FROM A LARVA of the fruit fly *Drosophila* were kept alive and undifferentiated by transplanting them into the abdomens of 100 successive generations of adult fly hosts; alterations in the genetic control of the cells are plotted in the illustration on the opposite page. The cells were taken from the cell cluster, or imaginal disk, destined to form the adult fly's sex organs and part of the gut and abdomen (*blue area in larva and fly*). At each transfer some of the cells were transplanted into larvae that underwent metamorphosis, as did the transplanted cells. By the eighth transfer (*B*) the cells' initial genetic controls had begun to change; metamorphosis produced head parts (*red*) and leg parts (*yellow*) and soon thereafter wing parts (*green*) and thorax parts (*brown*). By the 56th generation none of the cells in any subculture any longer matured into genital components. The letters *A* through *G* in the illustration refer to the structures shown in photomicrographs on page 118. The subcultures connected by broken lines (*below D*) showed mutant abnormalities.


B
C
D
E
F
G





pupae, the implants also differentiate into adult structures. For example, when a piece of implanted disk contains cells determined for eyes, a fully developed eye is found in the host's abdomen. By much experimentation we found that each imaginal disk contains a mosaic of different cell populations; these rudiments are determined for particular structures within a body region. Some mosaic regions of a male genital disk will develop into a sperm pump, other regions will differentiate into various elements of the penis, still others furnish anal plates and hind gut. In short, the future differentiation of the cells is already determined in the larval stage.

We need more detailed information, however. What about the individual cells? Could it be shown that each cell in a mosaic region of an imaginal disk is primed for a particular differentiation, regardless of the company in which it might find itself later?

We investigated this question by breaking disks down into individual cells and then implanting a mixture of cells from different disks into a host larva [*see drawing at left*]. The fruit fly is particularly convenient for this kind of experiment because of the availability of readily identifiable mutant forms, which differ from one another in visible features such as body color and bristle shape. Therefore we could mix disk cells from, say, a yellow mutant and a dark ebony mutant, allow the cells to clump together and then see where each cell ended up when the implant formed adult structures in the host larva.

It turned out that the individual cells of disks are indeed already programmed for specific differentiation. They collaborate in forming normal structures. For example, yellow leg cells and ebony leg cells combine to produce leg parts that are an ebony and yellow mosaic [*see photomicrographs on opposite page*]. My collaborators Rolf Nöthiger, Heinz Tobler and Antonio Garcia-Bellido performed many experiments, testing mixtures of imaginal-disk cells in various combinations. The results were consistent: Somehow during the development of the host fly those cells in the implanted mixture that carry a particular differentiation program recognize one another and move about until they come together to form precisely the indicated structure. In contrast, cells from different disk regions never combine but separate from one another. A cell from a leg disk never joins one from a wing disk, and wing-base cells do not collaborate with wing-tip cells to form a base or a tip.

We were able to conclude, therefore, that every cell in an imaginal disk of a fruit-fly larva is individually determined for a specific differentiation. This determination is fixed long before any morphological differences of the cells can be detected. We worked with such determined but not yet differentiated genital-disk cells in the experiments I shall now describe.

As we started this work we wondered what would happen if we implanted parts of larval disks directly into adult fruit flies. With such a procedure the pupal stage would be bypassed. When we tried the experiment, there were three quite unexpected results.

First, when larval cells were transplanted into the abdomen of an adult fly, they divided and grew without limit. In the normal course of events the same cells would have stopped dividing as soon as pupal metamorphosis set in. Under the influence of the insect hormone ecdysone they would have begun to differentiate into adult structures such as bristles, hairs, claws and gland cells. The unlimited growth of these cultures has now continued for six years. Since a host fly lives for about a month, we have had to transfer the proliferating cultures about every two weeks. The oldest cultures are now in their 160th transfer generation. For the permanent maintenance of a culture we need only take a small part of an implant to found the next transfer generation. It is thus easy to start many subcultures from a single culture.

The second result was even more surprising. Although the cultured cells have

MIXTURE OF LEG CELLS from the larvae of fruit flies that belong to separate color strains is formed by removing part of a leg imaginal disk from each larva (*a*, *top of drawing at left*). The bits of disk are then separated into their individual cells, mixed together (*b*) and implanted in the body cavity of a host larva (*c*). The host pupates (*d*) and the implanted cells mature. When removed from the adult fly (*e*), the leg organs are partly yellow and partly ebony in color (*see photomicrographs on opposite page*). The organs include (*I*, *top photograph*) a leg tip with one ebony and one yellow claw, (*II*, *middle*) an ebony-and-yellow sex comb and (*III*, *bottom*) ebony-and-yellow tibia bristles. The mixed colors show that cells with the same differentiation potential will find one another and join to form normal organs.

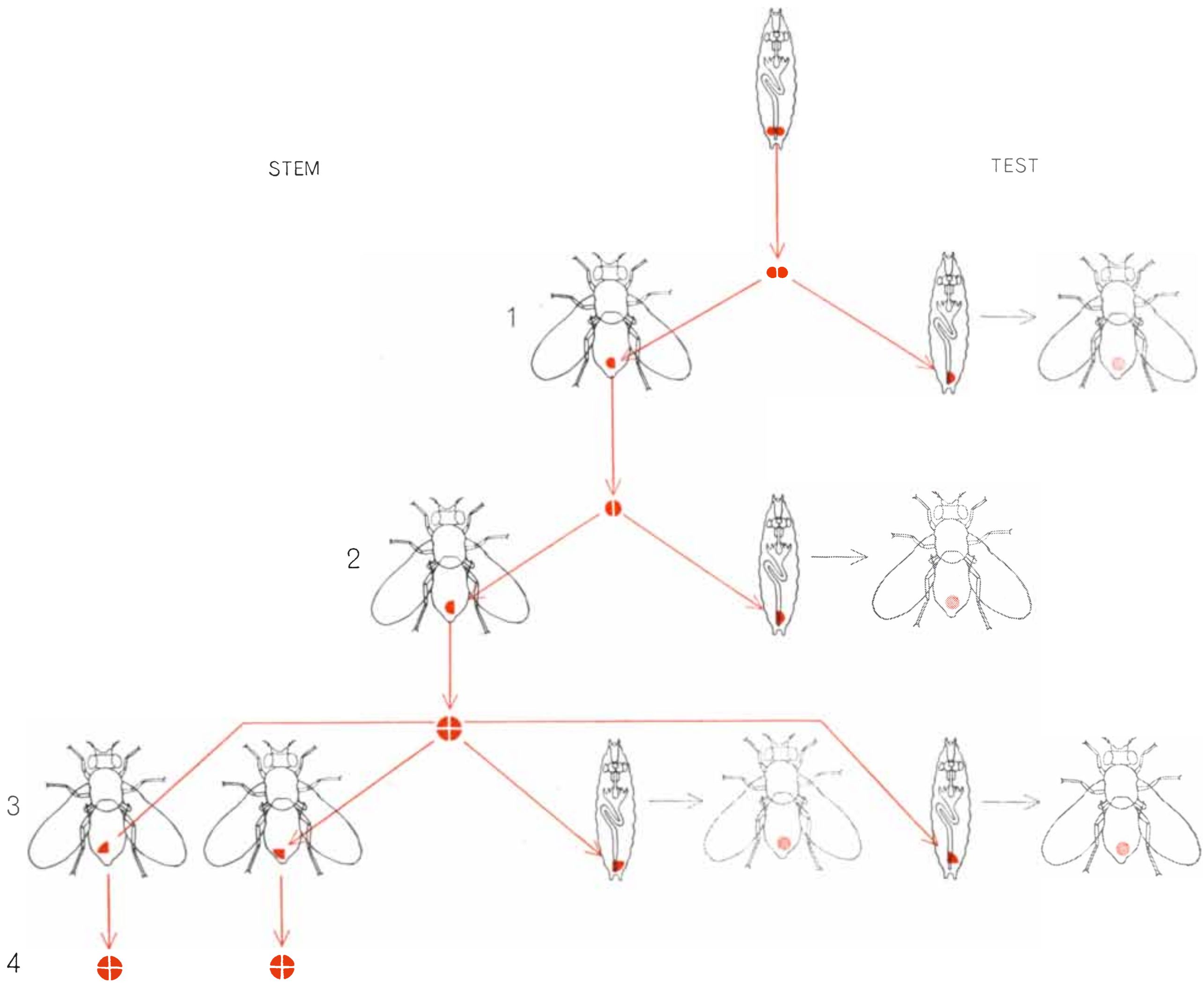
now lived for years in adult flies, they retain their original embryonic character. No differentiation has been observed. Apparently the pupal phase is indispensable for the initiation of differentiation. From this observation we conclude that ecdysone, which is dominant during pupal metamorphosis, is no longer present or active in the imago. The adult body fluid in which the cultured cells float seems to be much like the body fluid of the larva.

The third result is encountered when parts of cultures are transplanted back into larvae. Such implants will now metamorphose along with their new host. With some exceptions, to which I shall refer later, the test pieces taken from the permanent cultures differentiate normally into those adult structures for which they were determined. The capacity for normal development is therefore propagated in our cultures; during all the transfer generations the genetic endowment needed for adult differentiation remains intact. Such stability is unusual for cells in permanent cultures. In all the dividing cells of the cultures we find only the normal set of chromosomes.

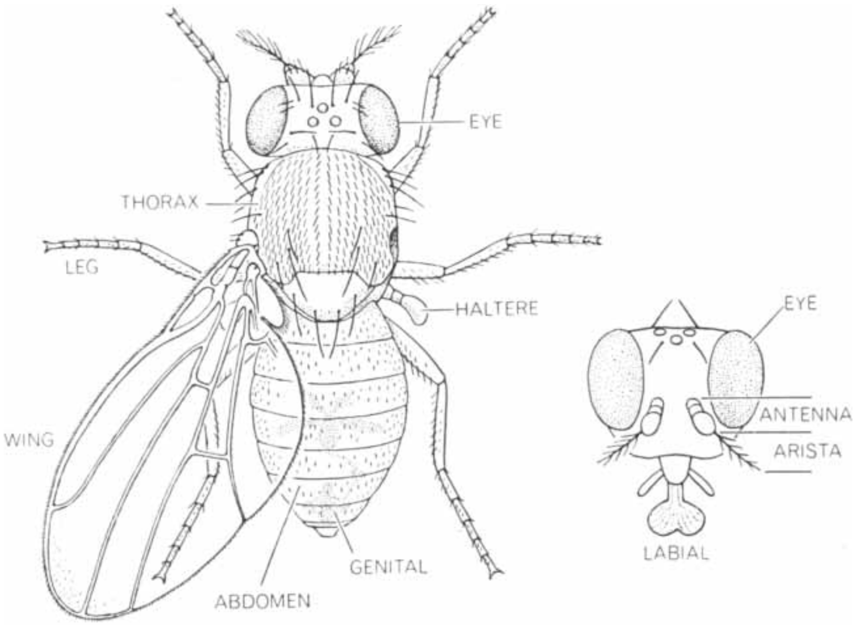
What I have said so far is prologue to the main chapter of our story. Let us now start a permanent culture with half of a male genital disk. One half, the stem piece, is implanted in the abdomen of an adult fly. The other half, the test piece, we implant in a larva within which it will differentiate. The stem piece grows, and after two weeks it is removed from its first adult host. It is again divided into a stem piece, which will maintain the culture, and a test piece, which shows us what kind of adult differentiation it is capable of. After a few transfers the cultures usually grow faster, so that it becomes possible to pass more than one test piece through metamorphosis and to implant several stem pieces and found branched sublines [*see illustration below*].

In the course of 160 transfer generations over a period of six years, several thousand test implants were studied. This experimental situation clearly offers a unique experimental opportunity. At any time we can find out what capacities for differentiation are present in the proliferating cells.

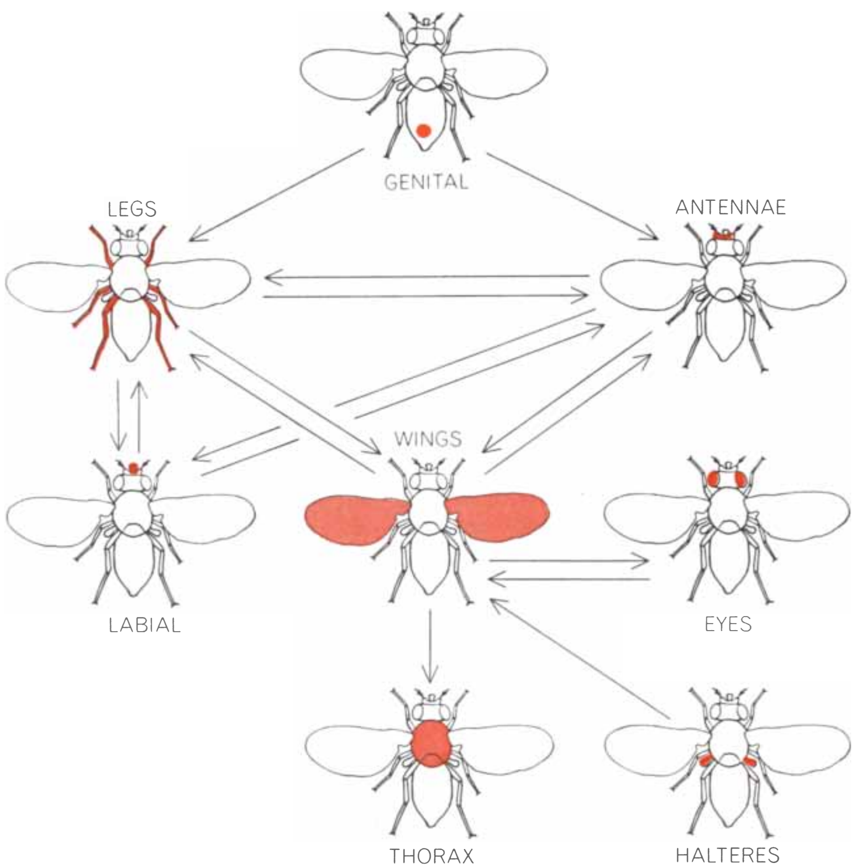
In the first few transfer generations



SUCCESSIVE TRANSFERS of cells grown from a single bit of imaginal disk is diagrammed over four generations. A bit of genital disk from a larva is divided between an adult host (*1, left*) and a larva (*right*), which is allowed to mature so that the condition of the transferred cells can be checked. The process is repeated (*2*) by retransplanting the disk cells of the "stem" host. By the next transplant (*3*) the stem disk cells have increased sufficiently to provide two transplants for testing and two transplants into stem hosts. In the next generation (*4*) the number quadruples. Disk cells have survived and multiplied for more than 150 transfer generations.



ADULT FLY'S ORGANS are formed by the maturation of a number of imaginal disks that are present in the body of the larva. The sex organs and portions of the gut and abdomen are formed from the cells of the genital disk and the head develops from three pairs of disks; each of the fly's six legs develops from a separate disk. Disk cells that are kept in an undifferentiated state by successive transplants into adult hosts for years will continue to mature into the appropriate organs when allowed to undergo metamorphosis. After a number of transfer generations, however, a change takes place and the disk cells turn into adult tissue of some other kind. The "transdetermination" generally follows the same sequence (*see illustration below*) and the change is preserved over many more generations.



TRANSDETERMINATION SEQUENCE undergone by seven kinds of imaginal-disk cells is shown by arrows. Genital cells, for example, may change into leg or antenna cells, whereas leg and antenna cells may become labial or wing cells. In most instances the final transdetermination is from wing cell to thorax cell; the change to thorax appears to be irreversible.

the test pieces from the genital disk developed in accordance with their original determination, that is, they differentiated "autotypically" into genital and anal organs. Thereafter came the surprise. Parts of the test implants developed instead into head organs or leg parts. In other words, populations of cells no longer differentiated as their ancestors had. They now produced "allotypic" organs that in normal development arise only from the cells of a head imaginal disk or a leg disk. For the change from one developmental pathway to another we introduced the term transdetermination.

The entire story of one typical culture can be followed in the illustration on page 111. If the reader will study the illustration, he will see that in the eighth transfer generation (after about four months) head and leg structures appear. A further transdetermination leads in Transfer Generation 13 to wings. In Transfer Generation 19 thorax cells become established for the first time. After many culture transfers we were able to make some generalizations about determination and transdetermination. First, we found that a state of determination can be replicated without any change when the cells divide; the characteristics of a determined cell population are transferred by "cell heredity." This holds true for the initial autotypic state as well as for newly acquired allotypic states after they become established by transdetermination. For example, one can see in the illustration that genital and anal organs appear in the test implants without interruption from Transfer Generation 1 to Transfer Generation 55. By the same token, however, newly initiated allotypic cell populations are also multiplied by cell heredity. In certain sublines head structures, legs, wings and thorax parts appear continuously for years.

For each given state of determination there exists a distinct probability or frequency of transdetermination in a specific direction. In the cells of genital disks a transdetermination of the first order leads with about the same frequency to head or leg cells. From these allotypic states a transdetermination of the second order results in wing cells. We have never observed a direct switch from genital to wing cells. Finally rudiments of thorax arise by a further transdetermination from wing cells.

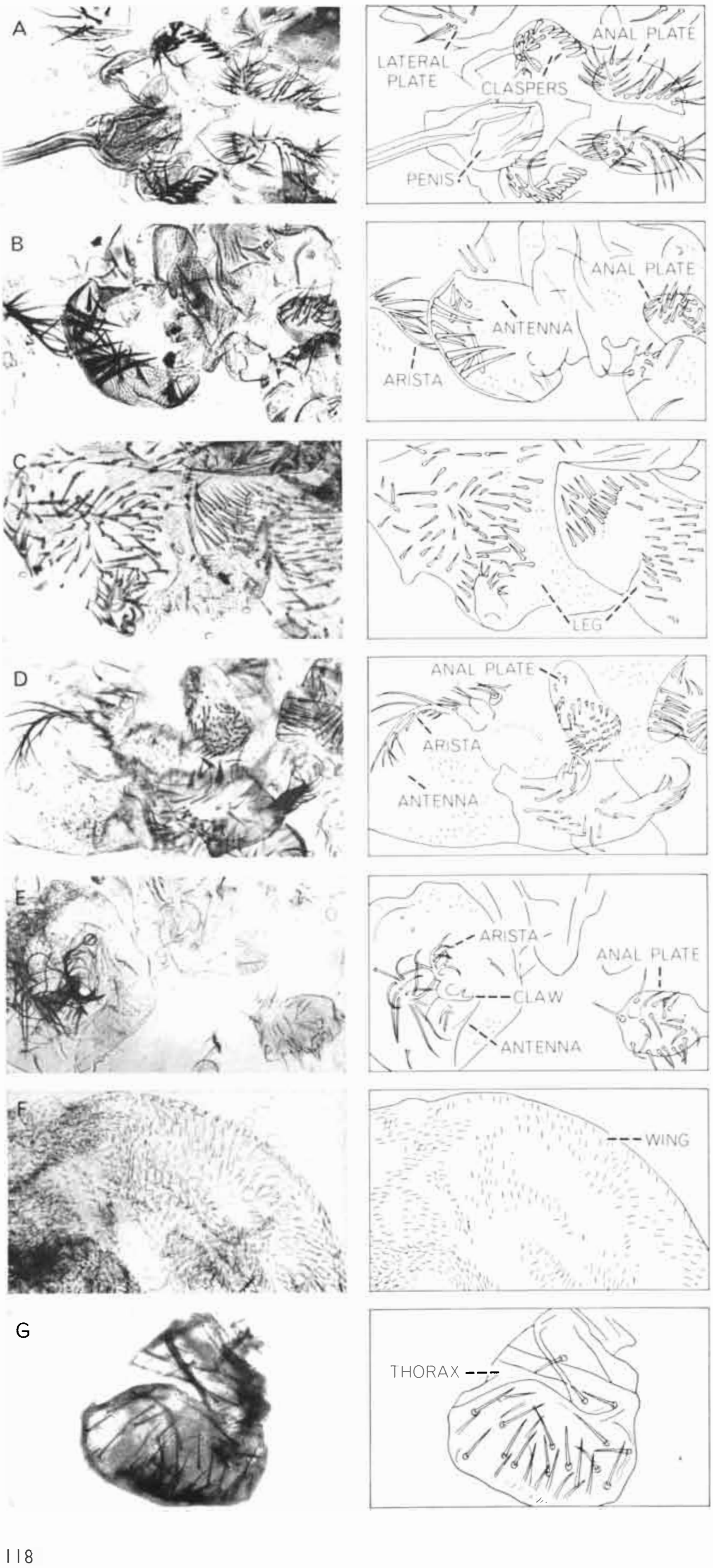
These sequences are summarized in the bottom illustration at the left. Some of the changes are indicated as

being reversible, others as being irreversible. For instance, it seems impossible for dividing thoracic cells to revert to genital cells. The dynamics of transdetermination lead to a shift in the frequency of different kinds of differentiation in the test implants. The initial states represented by the autotypic structures decrease or even disappear, whereas the "end stations," such as thorax, become increasingly frequent.

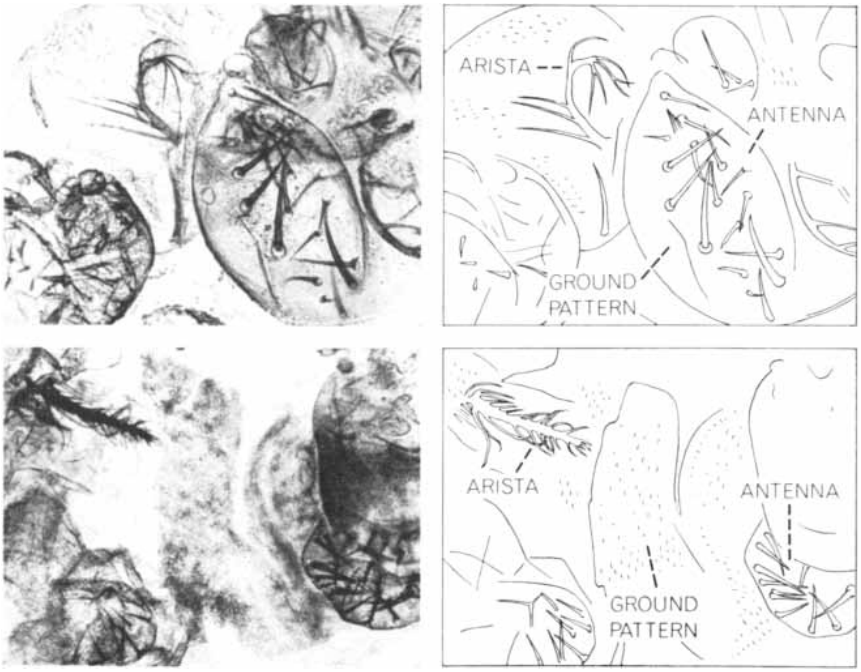
I have given the experiments with genital disks as an example; the same behavior is observed for other imaginal disks. The cells of these disks, which are initially determined for head and mouth parts, for wing parts or for thorax parts, also undergo transdetermination in the course of prolonged culturing. Each series of changes follows its own sequence.

Transdetermination leads, as we have seen, to a change in cell heredity. What factors cause this switching and on what mechanisms might it be based? A satisfactory answer to these complex questions cannot yet be given. We can only offer a few tentative speculations. One fact, established by my co-workers Tobler and Hansruedi Wildermuth, is that the frequency of transdetermination is correlated with the rate of proliferation of the cells: the faster they multiply, the higher the probability of a change in the cell's heredity. We therefore interpret transdetermination as a phenomenon somehow brought about by changes in the dynamics of proliferation on which the functional interaction of different cellular components might depend.

Stability of determination is ensured only when the same group of genes remains active in subsequent cell generations. Transdetermination leading to a



TRANSDETERMINATIONS of cells from a genital disk during 100 successive transfer generations are shown in a series of photomicrographs (*left; organs formed before and after transdetermination are identified in the accompanying drawings*). The generations are those illustrated on page 111. Mature structures from the first transfer generation (*A*) are all normal products of genital cells. By the eighth generation (*B*) some genital cells have matured into head-cell components. A specimen from the 24th generation (*C*) shows leg structures. In the 37th generation (*D*) and the 38th (*E*), specimens still form genital as well as head structures. The wing parts (*F*) are from the 60th generation and thorax structures (*G*), the final products, are from the 100th generation.



NORMAL AND ABNORMAL STRUCTURES are shown in two photomicrographs and identified in the accompanying drawings. At top is mature tissue from the 31st transfer generation of genital-disk cells; it has changed into normal head-cell components. At bottom are the same components but in abnormal forms, as found in tissue from the 41st transfer generation. The abnormalities, probably caused by mutations, have proved to be hereditary.

long-lasting new type of cell heredity, however, requires the action of new sets of genes. From the findings of molecular genetics we know that genes are activated or repressed by certain effector molecules. When our cells divide and grow, the effectors will be diluted and new ones must be synthesized. Differences and changes in the rate of cell division could in different populations of a culture perhaps affect the inventory of cellular components that control the activity of genes, and a new equilibrium between interacting factors might result. Members of a formerly active gene team that established determination for legs, say, could become inactivated. Their role would then be taken over by wing-determining genes.

Only further experiments can bring a better understanding of all the things that happen in transdetermination. I should like, however, to call attention to one additional fact. We have seen that cells determined for genital organs can give rise to descendants that develop alternatively into an entire set of other body parts. As my collaborator Walter Gehring has shown, sequences of diverse differentiations arise even in cell populations (clones) derived from a single cell. Therefore normal determination is certainly not based on an irreversible state of cellular units. Competence for entering many different pathways of development is a persistent characteristic of cells.

Thus far we have dealt with changes in the cultures that lead from one normal type of differentiation to another normal type. Indeed, allotypic thorax implants cannot, even after six years of culturing, be distinguished from autotypic test pieces taken directly from a fresh larval control disk. In addition to such "normotypic" differentiation, however, we encountered in a few sublines an "anormotypic" type of development [*see illustration above*]. In a subline that could be followed from Transfer Generation 38 to Transfer Generation 90 the small hairs and protuberances (trichomes) that cover the cuticle between the bristles look coarse and somewhat distorted. Similarly, the arista, a structure protruding from the antenna, is abnormal in shape. On the other hand, the bristles are all normal. In another subline the ground pattern is fully normal, but here the capacity for forming bristles is lost. Such anormotypic lines might be due to classical mutations. Reversion to normality was never observed. Once established, the abnormal characteristics breed true as long as we have observed the descendants. A further developmental type became established in other sublines. These cultures have an extremely high rate of growth, but the test pieces either disappear during metamorphosis or pass the pupal stage without any visible change; in any case, the ability for adult differentiation is lost. Perhaps such types of cell heredity are due to the kind of mutations that in whole animals would be called developmental lethals.

All the events revealed in the cultures of cells from imaginal disks should now be compared with processes going on in other biological systems. Here I shall mention only a few obvious similarities. Stability in cell heredity—the kind of stability observed in our proliferating cultures—is encountered in, among other tissues, the epidermis of human skin and in human bone marrow. There the stem cells remain undifferentiated, but they breed true throughout life by replicating a specific state of determination.

Transdetermination might also have biological counterparts. Consider certain types of regeneration. Biologists working on leg regeneration in amphibians have demonstrated that formerly specialized and differentiated cells have offspring that become determined for new tasks. In insects and crustaceans one observes occasionally that from an antenna stump a leg or an eye can regenerate. Such allotypic performance is probably based on the same cellular events as transdetermination. Moreover, in *Drosophila* quite a few mutants of the type called homoiotic are known that lead to allotypic organs. One such mutation is termed aristapedia; it steers the developmental fate of the cells in the antenna disks so that leg parts instead of antennal structures become differentiated. The end effect is the same as in our transdetermining cells, but one should not overlook the differences in principle. The effects of homoiotic mutations are due to changes in the genetic material, whereas for transdetermination we postulate a change in the control systems that only regulate the activity of unmutated genes.

Since we observe in cultures so many changes in the proliferating behavior of cells and in their heredity, one is tempted to compare certain of our results with cancerous growths and aberrant differentiation in tumors. I think it is too early for any detailed comparison. All one can say at present is that cancer cells, like transdetermined cells, depart from the pathways of their ancestors and enter on new pathways of development.

Some People don't buy a Hasselblad because they think they know a camera that's almost as good. And so on.

"Almost as good" can mean anything you want it to. Mostly it means "half the price."

If you want the very best camera you can afford, and you can't afford a Hasselblad, we understand. But don't read any further, because we're going to explain why there's no other camera in the world almost as good as the Hasselblad, and we don't want you to feel badly.

Let us begin with the idea of a system. Hasselblad is surely not the only "system" camera, but The Hasselblad System has major features that other systems lack.

Most significantly, it is a 2¼ system, which offers you the speed and mobility of 35mm equipment plus the superior image quality of a larger format camera. With the Hasselblad, you can view your image better while you're shooting, after you develop your slides and contacts, and when you enlarge your pictures.

Another major difference between the Hasselblad and any camera you might want to compare it to is our five interchangeable magazines, which allow you to make 12 or 16 exposures on 120 film, 24 exposures on 220 film, and 70 exposures on 70mm film, as well as permitting a choice of three different formats (2¼ square, 2¼ X 1⅝, 1⅝ X 1⅝). You can also load one magazine with color film, one with black and white, and then switch back and forth between them without losing time or film.

Every system offers lenses, but it is the range and quality of Hasselblad lenses which sets them apart from lenses in other systems. Ours are made by Carl Zeiss and there are 8 of them – 40, 50, 80, 120, 135, 150, 250, and 500mm. Each lens has a built-in Synchro Compur shutter, with automatic stopping down at the moment of exposure, and manual preview for depth of field checks. Every lens has both M and X synchronization, allowing the use of flash and strobe up to speeds of 1/500th of a second.

The System not only offers multiple lenses and magazines, it offers multiple Hasselblads. First, the standard 500C, a 2¼ square format single lens reflex viewing camera which lets you see your three dimensional picture on the ground glass screen in two dimensions, the same way a view camera does. The reflex viewing on an enlarged screen allows you to compose and frame your shot more accurately, with no fear of parallax error. The large 2¼ format also lets you be a better judge of your focusing, so that you may increase the sharpness of each individual shot. And since your contacts and slides will also be larger in proportion to the camera, you can more easily select the ones you want to enlarge. You will also benefit from the superior image quality of 2¼ over 35mm when it is enlarged to any degree.

Second, we have the Hasselblad Super Wide C. Equipped with a 38mm, 90° angle of view Zeiss Biogon f/4.5 lens, this camera allows you to take pictures previously considered impossible. The superb optics of the lens assures perfect distortion-free horizontal and vertical delineation, with sharpness of image from corner to corner of the negative area, even at full aperture. (Depth of field at f/22 is from 12 inches to infinity.)

Third, there is the electrically driven Hasselblad 500EL. This camera automatically advances the film and cocks the shutter, permitting you to make a rapid series of exposures, either by use of the camera release or long release cords, timer, or remote radio control.

Last, there is the 70mm Hasselblad, which is electrically driven like the Hasselblad EL, with a 70mm film magazine allowing 70 exposures on cassette loaded 70mm film. This camera gives you total freedom from mechanical necessities when a job requires a large number of exposures.

The Hasselblad System also offers a huge range of accessories. Proxars. Extension tubes. Bellows extension for close-up work. Filters. Transparency copy holder. Cut film back. Eye level prism finders. Sports view finders. Sun shades. A rapid winding crank. Quick focusing handles. Grips. Underwater housing. Ring light. Microscope attachments. Carrying cases.

We would be the last ones to say that there are no other fine cameras available to you. We only want you to realize the error of comparing any of them to Hasselblad.

The Hasselblad System is a system unto itself.

For more information and a free 40 page catalogue, write to Paillard Incorporated, 1900 Lower Road, Linden, New Jersey 07036.

The Hasselblad System

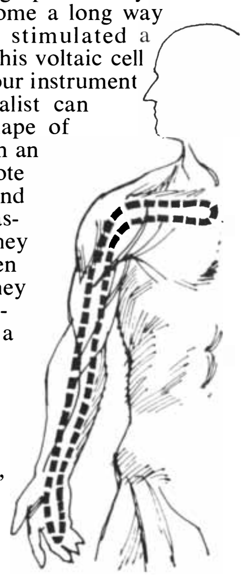
a measure of progress

1. Electromyography
2. Signal analysis in the frequency domain
3. Preparative gas chromatography
4. HP Computers & BASIC
5. Electric writing

1. Checking the speed of your funny bone

If you bang your elbow just right, you'll feel a tingling shock all the way down to your little finger. Almost instantly. The blow on your ulnar nerve artificially stimulates an electrical signal which travels down the nerve at a rate better than 1200 miles per hour. One way to judge the health of nerves in the body's motor network is to check this speed. Neurologists do it with an instrument called an electromyograph.

The electromyograph made by Hewlett-Packard has come a long way since Galvani stimulated a frog's leg with his voltaic cell in 1791. With our instrument a neural specialist can observe the shape of nerve signals on an oscilloscope, note their strength and frequency, measure the speed they travel, and listen to the sounds they make on a loudspeaker. Using a variety of electrodes, he can see how much potential you generate to move your arm, how much stimulus is required behind your knee to move an ankle muscle, or how long it takes for a sensation in your finger tip to make the round trip through your backbone and back to a muscle in the finger.



An electromyograph is useful in diagnosing injuries or diseases of nerves and muscles, following the progress of healing, or distinguishing psychosomatic from physiological problems. The Hewlett-Packard 1510A Electromyograph is versatile enough for research, teaching, diagnosis and evaluation of therapy. It has the latest solid-state design; two input channels for comparing two parts of the same muscle or two muscles that must work together; a range of receiver frequencies and sweep speeds to capture either high frequency fibrillations or slow conduction responses; a choice of stimulator pulse rates, widths and strengths to allow for different sizes and sensitivities of motor units; plus a variable persistence scope to make both observation and photography easier when studying fast, one-shot responses or comparing the effects of multiple stimuli. It costs $3750.

If you would like to know more about today's electromyograph and how it's used, write for Data Sheet 1510A.

2. Waveforms from a new point of view

If you want to look at something small, you use a microscope or projector. If it's fast, you slow it down with movies or freeze it in a photograph. And if it's electrical, you display it on an oscilloscope. But the question today is, what's the best point of view. Generally, we observe electrical signals travelling across a scope face, changing in relation to time. But we might prefer to examine signals from the point of view of their component frequencies.

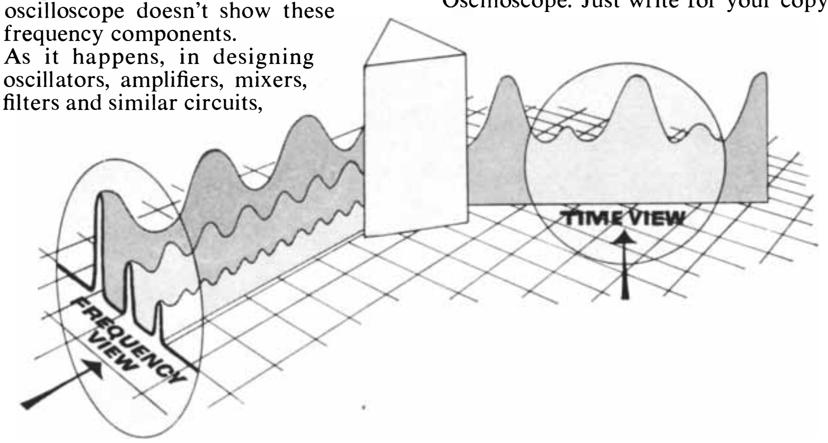
Oscilloscopes that operate in the time domain are fine if you have pure signals, if you want to compare their phase or time relationship, or if you're studying the shapes of waves and pulses. But many a signal is made up of several frequencies, and a conventional oscilloscope doesn't show these frequency components.

As it happens, in designing oscillators, amplifiers, mixers, filters and similar circuits, most engineers think of circuit performance in frequency domain terms. They need to know how circuit characteristics relate to frequency response, signal power output, harmonics, noise, drift, modulation and the like. The question is, how can the designer see or measure these effects in terms of signal frequency composition. Spectrum analysis—the only answer—has in the past been mostly a lab curiosity, turned to only in desperation because of the tedium involved or a lack of confidence in the results. But now Hewlett-Packard has developed a new lab tool that makes frequency domain measurements easily, accurately, and more meaningfully.

The HP 8552A/8553L Spectrum Analyzer sweeps any selected rf range, up to 100 megahertz wide, between 1 kilohertz and 110 megahertz. Every frequency component in the signal within that range is presented on the scope as a vertical line whose height is directly calibrated in millivolts or power, and whose position along the baseline is calibrated in frequency. You can magnify any portion of the spectrum 50,000 times, and can measure a signal adjacent to one 3000 times greater in amplitude.

The designer now has a direct-reading lab tool that delivers information to him in the same terms he uses to evaluate his circuits—those of frequency performance. You might call the instrument a new type of oscilloscope—a Frequency Domain Oscilloscope. We think the instrument is so useful it will soon take its place alongside traditional time domain oscilloscopes in every electronics design lab.

The HP 8552A/8553L Spectrum Analyzer with 141S variable persistence display costs $5225. Our brochure describes all the capabilities of the Spectrum Analyzer and the many applications of a Frequency Domain Oscilloscope. Just write for your copy.

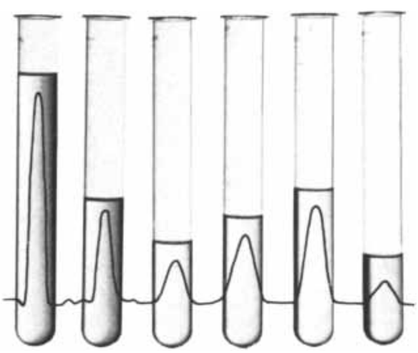


3. Doubling the value of an analytical GC

If you owned a Gas Chromatograph, you'd have one of the fastest, most accurate and economical instruments ever made for chemical analysis. It's a whiz at separating and measuring the chemical components of most any substance. Yet its techniques of vaporizing, separating and detecting can also be used for collecting very pure samples of many chemicals. Because of the highly efficient resolving power of GC, purity of collected fractions can be as high as 99.9%.

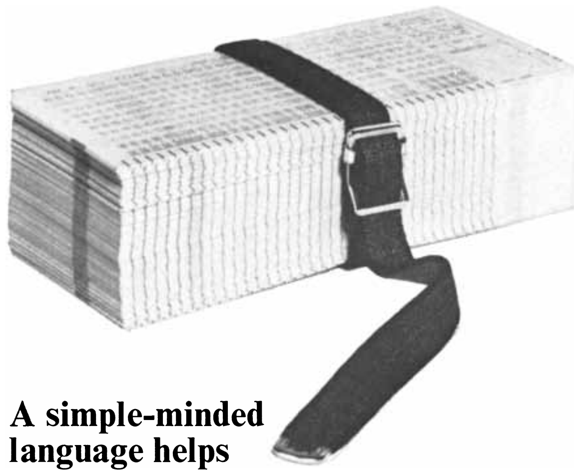
Up to now the analytical job and the collecting, or preparative, job were generally done by separate chromatographs, each most efficient at its own task. That is, until Hewlett-Packard developed a reliable, low-cost extension for the analytical GC instrument that makes it a very efficient collector of small samples—without interfering in the least with its analytical role. Since Hewlett-Packard manufactures both analytical and preparative chromatographs, it was just a matter of time until a unit was designed to give both functions to the analytical GC.

The HP 5795A Automatic Preparative Attachment introduces mechanical simplicity and advanced electronic circuits to eliminate any uncertainty or unreliability. A programmed Control Unit permits continuous, unattended operation overnight or during weekends. It will direct the collection of any six fractions from up to twenty possible components in the original.



The Injection Unit feeds slugs of the bulk sample into your GC with micrometer accuracy. The Collection Unit distributes the vapor fractions from the GC to the proper trap over and over again, until the required amount has been collected. In one test with rectified turpentine, the instrument cycled automatically 53 times during an 18-hour run. The alpha and beta pinene collected were calculated to be 99.95% and 99.92% pure.

The cost of extending your present GC with the HP 5795A is $2500. For more details, ask for Bulletin 5795.



4. A simple-minded language helps

More and more students today need to study computer techniques. The computer has become so widely useful in business and industry, they might miss a good opportunity without some formal training before graduation. And, of course, good training demands the tool as well as the textbook. But by and large, computers have been either too expensive or too complicated to make these courses widely available. Happily, Hewlett-Packard now offers a range of systems based on small, low-priced computers and a very simple programming language . . . BASIC.

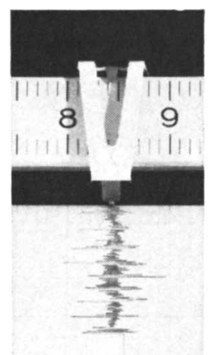
We chose a conversational language resembling English to help students discover the power of a computer without the burden of complex programming procedures. A student can learn to use Conversational BASIC in about four hours. With it he can talk back and forth with the computer on a teleprinter, solving a problem one step at a time. BASIC runs in any of our three computers and doesn't require any nonstandard extras. In fact, we've assembled a small computer system on wheels to roll from room to room. The system includes a teleprinter, a paper tape reader and software — everything needed to learn computers — and it's priced at $18,374.

We also build "time-share" systems that let 16 people use the computer at once. And optical card readers that let you instruct the computer with pencil marks. So we ended up with a number of easy-to-use, relatively inexpensive computer packages with which high-schools and colleges can teach computer techniques through actual, hands-on experience.

If you're interested in computers that you can operate without all kinds of effort, write for the brochure, "Computers for Education."

5. Writing without watching

There are times when graphic recorders must write without anyone around. The recorder may only be in a lab when everyone's home. Or it may be in some far off spot, shielded but alone with the elements. Yet data on weather changes, air pollution, earthquakes or radiation levels can't be left to chance. The recorder must start up and start writing instantaneously.



Hewlett-Packard's *electric writing* technique is one solution. A current-sensitive coating on the recording paper changes color chemically when a small dc current flows from the recording stylus through the paper. All that's required is that the recorder's power be turned on. Heat, light, pressure or humidity have little effect. Sudden starts and stops, slow speeds or fast pose no problem. Electric writing makes certain you get the record down on paper. The electric writing feature is available on Hewlett-Packard 680 and 7100 Strip-Chart Recorders. Write for a free sample of electric writing.

Hewlett-Packard, 1505 Page Mill Rd., Palo Alto, California 94304; Europe: 54 Route des Acacias, Geneva.

HEWLETT hp PACKARD

Measurement, Analysis and Computation

00806

THE AERODYNAMICS OF BOOMERANGS

A computer-assisted analysis of the forces that affect the flight path of a boomerang, causing it to return to the thrower, is tested by experiments in the field

by Felix Hess

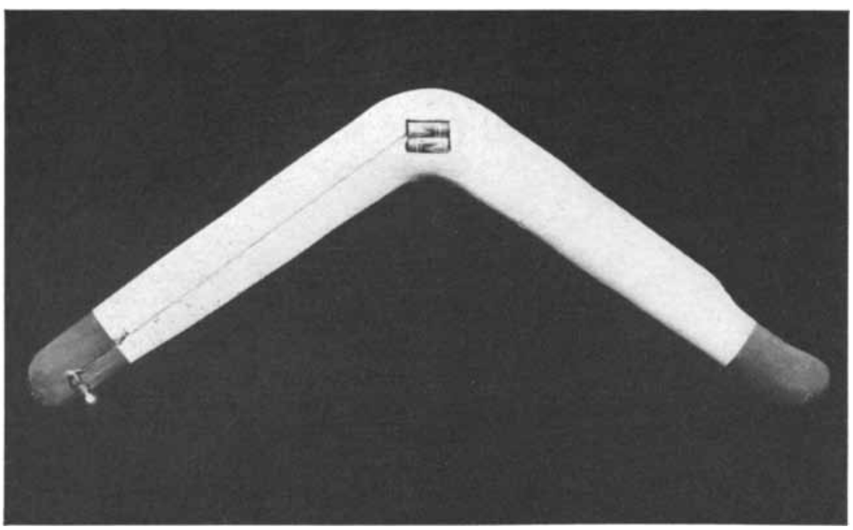
Imagine throwing a piece of wood into the air, making it fly around in a large circle and having it come to rest gently at your feet. Preposterous! Yet of course this is exactly what a boomerang does, provided that it has the right shape and is thrown properly. Like many other people I have been fascinated since childhood by the question of what makes a boomerang return. It was not until a few years ago, however, that I became really irritated with not understanding the behavior of the boomerang. I was then a student of physics at the University of Groningen in the Netherlands, and in my spare time I began to throw homemade boomerangs over the grasslands of Groningen and calculate their flight paths. This interest gradually led to a theory of the returning boomerang, which I shall outline later in this article.

As is well known, boomerangs originated among the aboriginal inhabitants of Australia. Although boomerang-like objects have been found in other parts of the world as well (in Egypt and India, for instance), these objects are not able to return, as far as I know. The reader may be a little disappointed to learn that most Australian boomerangs also do not return. Australian boomerangs can be roughly divided into two types: war boomerangs and return boomerangs. Those of the first type are, as their name implies, made as weapons for fighting and hunting. A good war boomerang can fly much farther than an ordinary thrown stick, but it does not return. Return boomerangs, which exist in much smaller numbers, are used almost exclusively for play.

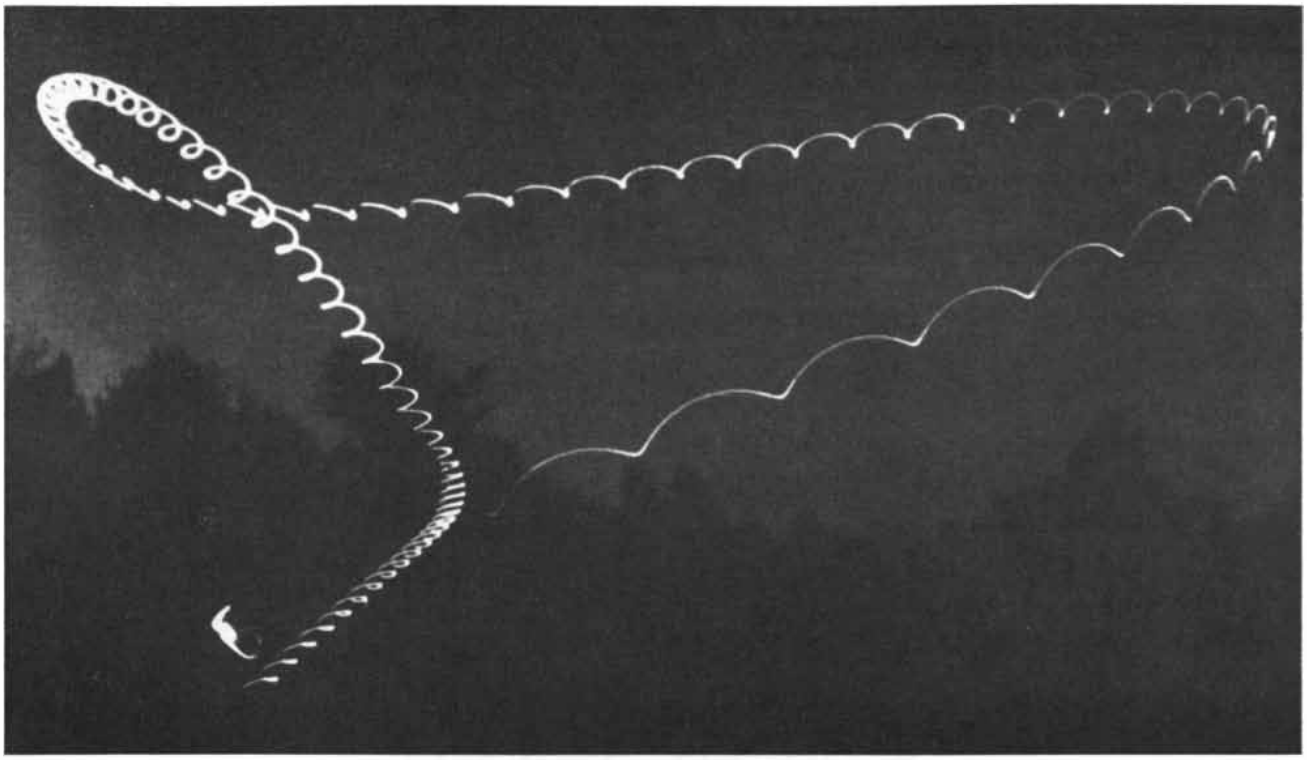
Actually things are not quite as simple as this. There are many kinds of aboriginal weapons in Australia, a number of which look like boomerangs, so that the distinction between boomerangs and throwing or striking clubs is not a sharp one. Neither is the distinction between war boomerangs and return boomerangs. The shape of boomerangs can differ from tribe to tribe, and some tribes along the northern coast of Australia have no boomerangs at all. In the comparatively few places where return boomerangs are found war boomerangs also exist. An unusual type of boomerang, limited to one region in northeastern Australia, consists of two straight pieces of wood fastened together at the center in the form of a cross; it returns quite well.

Whether a given boomerang belongs to the return type or not cannot always be inferred easily from its appearance. Return boomerangs, however, are usually less massive and have a less obtuse angle between their two arms. A typical return boomerang may be between 10 and 30 inches long, one and a half to two inches wide and a quarter- to a half-inch thick. The angle between the arms may vary from 80 to 140 degrees. The weight may be as much as 300 grams (about six-tenths of a pound).

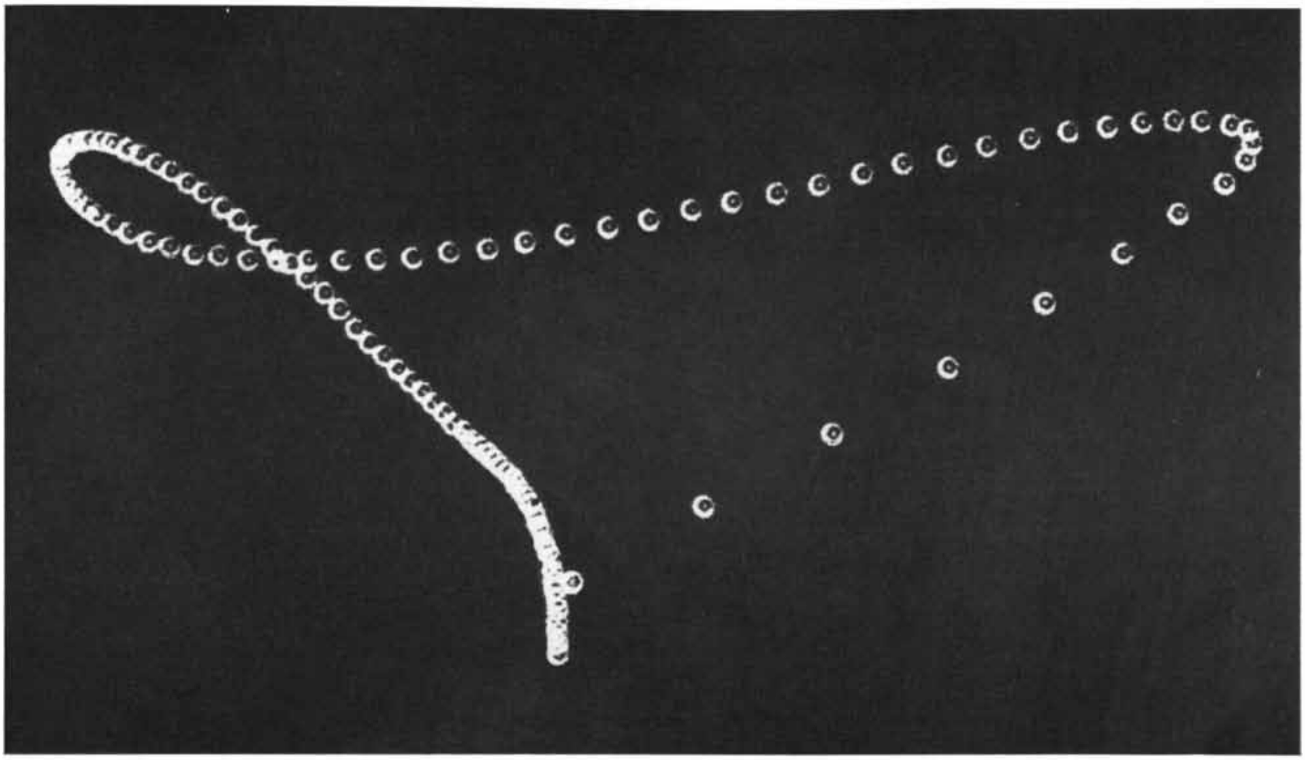
The characteristic banana-like shape of most boomerangs has hardly anything to do with their ability to return. Boomerangs shaped like the letters *X, V, S, T, H, Y* (and probably other letters of the alphabet) can be made to return quite well. The essential thing is the cross section of the arms, which should be more convex on one side than on the other, like the wing profile of an airplane [*see upper illustration on page 128*]. It is only for reasons of stability that the overall shape of a boomerang must lie



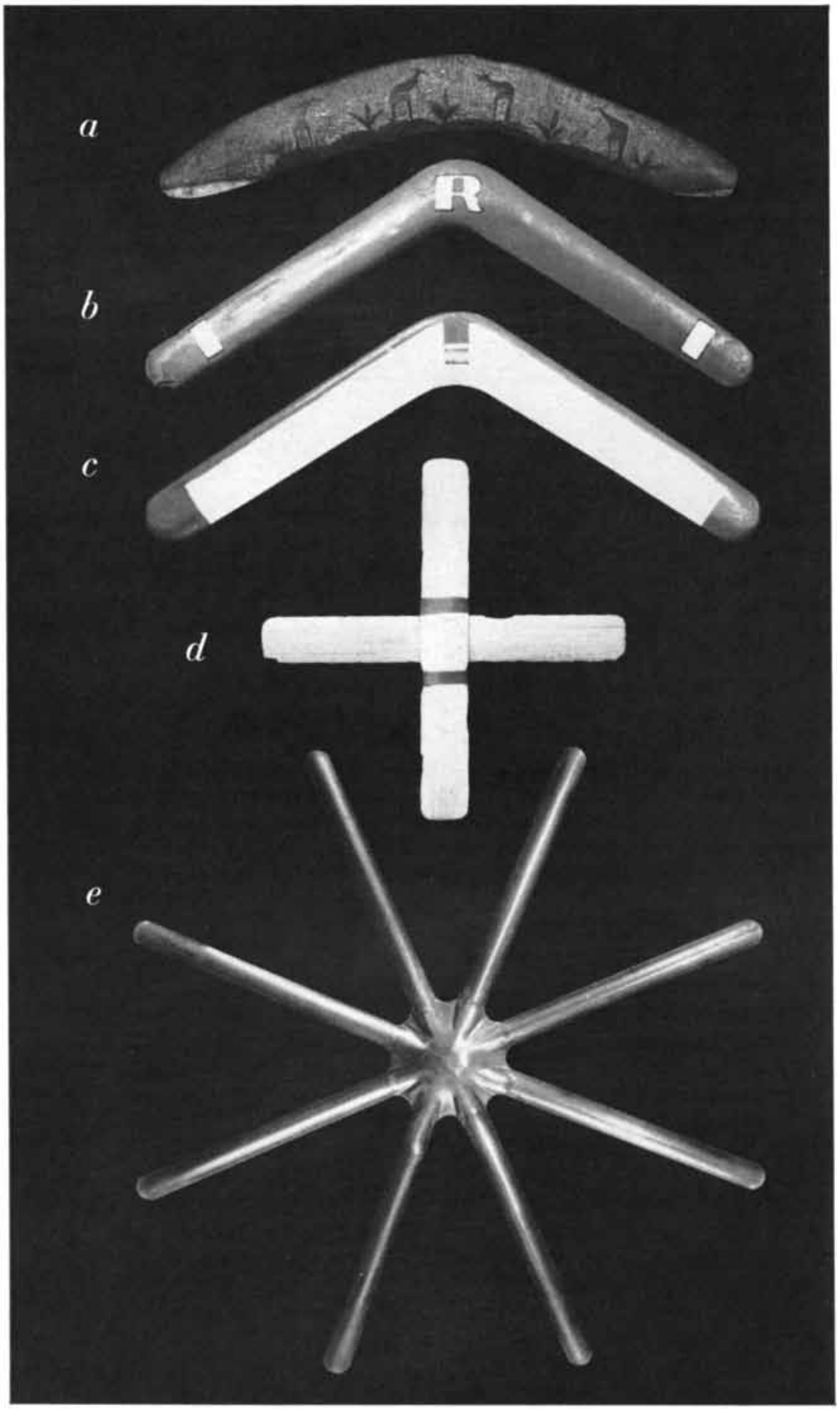
EXPERIMENTAL BOOMERANG built by the author is equipped with a small light bulb, mounted in one wing tip and connected with two 1.5-volt cells, mounted in a hollow in the center. This arrangement makes it possible for the boomerang's flight to be recorded photographically at night. This particular boomerang is left-handed, as is the author.



ACTUAL BOOMERANG FLIGHT was photographed at night in the Groningen Stadspark, using the boomerang shown on the opposite page. (Because the author is left-handed this photograph and those on pages 135 and 136 have been reversed to show a typical right-handed flight.) The camera shutter was left open during the flight. The short, heavy track was made prior to the beginning of the flight when the boomerang was still in the thrower's hand. The boomerang flew first to the right, then away from the camera, crossed the field of view from right to left, approached the camera again and finally descended in the vicinity of the thrower.



THEORETICAL BOOMERANG FLIGHT was calculated on a computer according to the author's theory and then automatically plotted for a perspective-corrected projection corresponding to the view in the photograph at top. The dots represent the boomerang's position at intervals of a tenth of a second. The calculations were continued until the boomerang had descended more than two meters below the starting point. Different initial conditions were tried until an orbit resulted that resembled the recorded path.



AUTHOR'S BOOMERANG COLLECTION includes an Australian aboriginal boomerang made by the Ooldea tribe from a piece of acacia wood (*a*) and a variety of homemade boomerangs. The latter include a typical right-handed boomerang made from plywood and filed into the required airfoil-shaped profile (*b*); a plywood boomerang with a symmetrical shape that is both right-handed and left-handed (*c*); a cross boomerang made from extremely light balsa wood for indoor flying (*d*), and an eight-armed boomerang made from a sheet of aluminum (*e*). Two small pieces of lead are held by means of rubber bands on the arms of the cross boomerang. This ballast can be shifted outward, increasing the boomerang's moment of inertia and hence the diameter of its orbit. By twisting the arms of the aluminum boomerang it can be changed from right-handed to left-handed and vice versa. All eight arms of this boomerang have a zero eccentricity; hence one would expect it to have a zero torque around an axis perpendicular to its direction of motion (this torque is termed T_2 in the text). Yet this boomerang is observed to "lie down" during its flight. In this case "lying down" must be due entirely to wake effects. All the boomerangs shown here return.

more or less in a plane. Thus if you make a boomerang out of one piece of natural wood, a smoothly curved shape following the grain of the wood is perhaps the most obvious choice. If you use other materials, such as plywood, plastics or metals, there are considerably more possibilities.

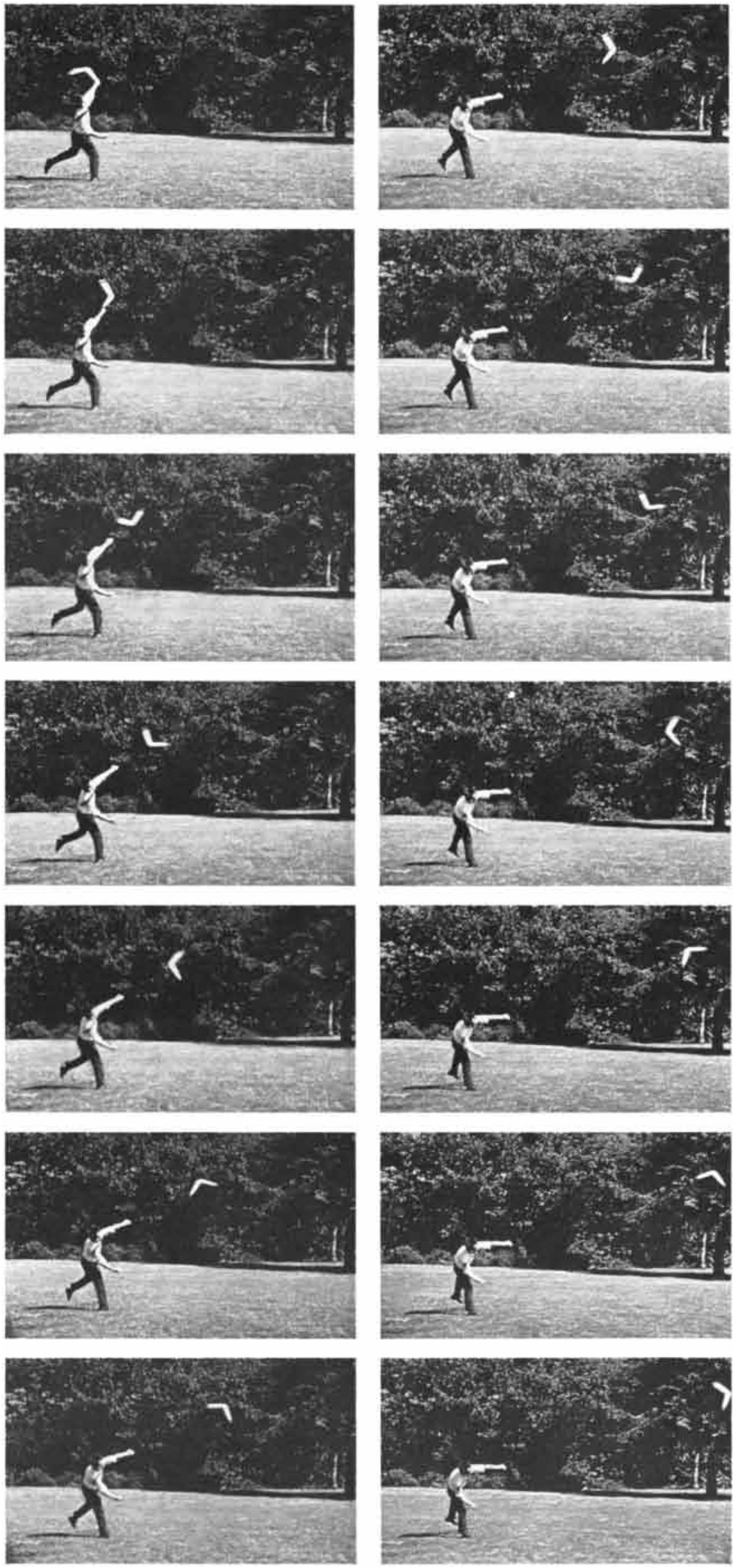
How does one throw a return boomerang? As a rule it is taken with the right hand by one of its extremities and held vertically upward, the more convex, or upper, side to the left [*see illustration on opposite page*]. There are two possibilities: either the free extremity points forward—as is the practice among the Australians—or it points backward. The choice depends entirely on one's personal preference. Next, the right arm is brought behind the shoulder and the boomerang is thrown forward in a horizontal or slightly upward direction. For successful throwing, two things are important. First, the plane of the boomerang at the moment of its release should be nearly vertical or somewhat inclined to the right, but certainly not horizontal. Second, the boomerang should be given a rapid rotation. This is accomplished by stopping the throwing motion of the right arm abruptly just before the release. Because of its inertia the boomerang will rotate momentarily around a point situated in the thrower's right hand. Hence it will acquire a forward velocity and a rotational velocity at the same time. In this way a boomerang starts its flight with a forward speed of some 60 miles per hour and a rotation of about 10 revolutions per second.

At first the boomerang just seems to fly away, but soon its path curves to the left and often upward. Then it may describe a wide, more or less circular loop and come down somewhere near the thrower's feet, or describe a second loop before dropping to the ground. Sometimes the second loop curves to the right, so that the path as a whole has the shape of a figure eight. It is a splendid sight if the boomerang, quite near again after describing a loop, loses speed, hovers some 10 feet above your head for a while and then slowly descends like a helicopter. Descriptions, however, can give only a rather poor idea of what a real boomerang flight is like. One should stand in the open air to see how very three-dimensional this phenomenon is and hear the soft, pulsating, swishing sound of the boomerang arms moving rapidly through the air.

Every boomerang has its own characteristics with respect to ease of throwing, shape of path and hovering ability. Moreover, one boomerang can often describe very different orbits depending on the way it is thrown. The precision of return depends to a large extent on the skill of the thrower, who must take into account such factors as the influence of wind. The greatest distance during a flight may be 120 feet, but it can also be much less or perhaps twice as much; the highest point can be as high as 50 feet above the ground or as low as five feet. I have heard that with modern boomerangs of Australian make distances of more than 300 feet can be attained, still followed by a perfect return, but I regret to say that so far I have not been able to make a boomerang go beyond about 180 feet. When witnessing a real boomerang flying, one is often left with the impression that the flight lasted about half a minute, whereas its real duration was a mere eight seconds or so.

In the foregoing general description it was tacitly assumed that the thrower was right-handed and used a "right-handed" boomerang. If one were to look at an ordinary right-handed boomerang from its convex side while it was in flight, its direction of rotation would be counterclockwise [*see lower illustration on next page*]. Hence one can speak of the leading edge and the trailing edge of each boomerang arm. Both the leading and the trailing edges of an aboriginal boomerang are more or less sharp. The leading edge of a modern boomerang arm is blunt, like the leading edge of an airplane wing. Sometimes the arms have a slight twist, so that their leading edges are raised at the ends.

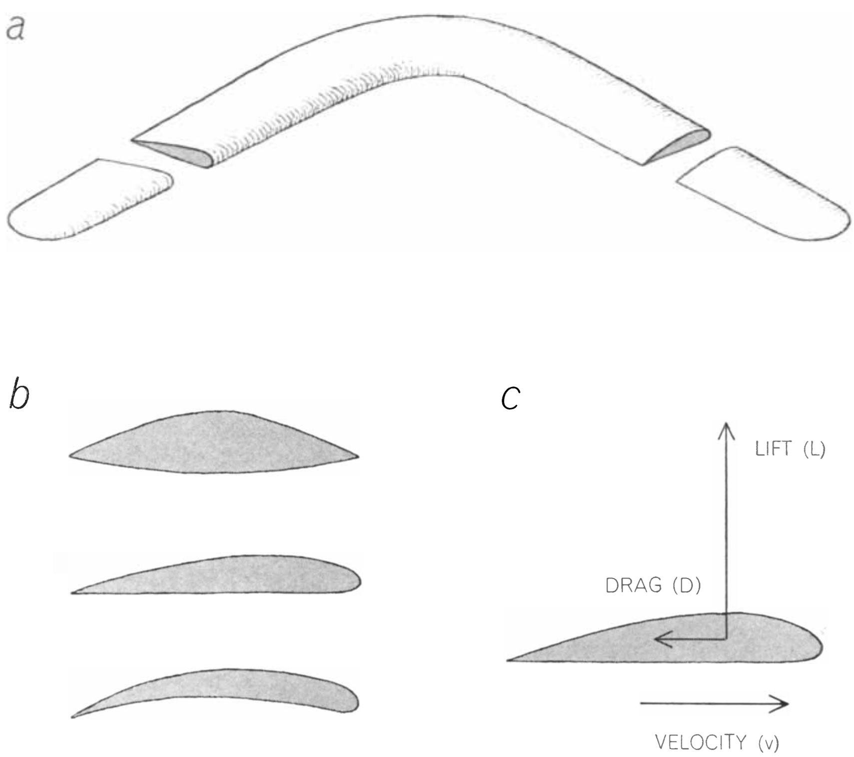
By now it should be clear that a boomerang is designed for only one direction of rotation. If you make it rotate in the opposite direction, it generally does not fly like a good boomerang at all. The mirror image of such a right-handed boomerang, on the other hand, will work well only when the boomerang is rotating clockwise. Such a "left-handed" boomerang is suited to left-handed throwers (such as myself). In every respect, including the orbit, a left-handed throw



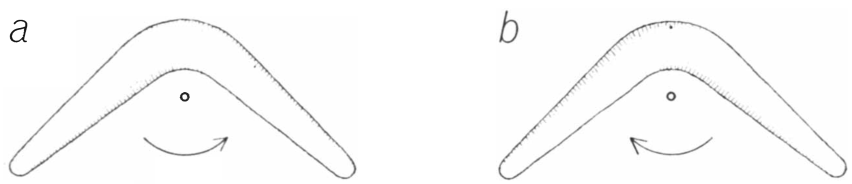
FIRST PART of the flight of a return boomerang is seen in this demonstration by the author. The plane of the boomerang at the moment of its release is nearly vertical and the boomerang has been given a rapid rotation by stopping the throwing motion of the arm just before the release. In the film, made at a speed of 64 frames per second, one revolution takes about six frames. Hence the boomerang rotates at about 10 or 11 revolutions per second.

with a left-handed boomerang is the exact mirror image of a normal right-handed throw. In Australia both left-handed and right-handed boomerangs exist. By carefully shaping a boomerang to give it a symmetrical cross section it is possible to make it "double-handed" so that it will perform equally well either way.

How does one begin to understand the remarkable behavior of a returning boomerang? Naturally such an intriguing phenomenon has attracted the attention of many people, and a large number of articles have been written about it. Most of them appeared between about 1870 and 1920, a time when aerodynamics was still in its infancy. Only a small fraction of this literature might be called scientific. Often the very simplest observations (duration of flight, dimensions of orbit) were left unmade, so that in some cases rather wild descriptions added to the fantastic character of the boomerang. The entire phenomenon must of course be explained in terms of the interaction of the boomerang with the air; in a vacuum even a boomerang would describe nothing but a parabola. This interaction, however, is difficult to calculate exactly because of the complicated nature of the problem. Let us nonetheless look at the matter in a simple way.



CROSS SECTION of a boomerang arm is more convex on one side (the upper side) than on the other (*a*). Three such profiles are shown in *b;* the first is a lens-shaped profile of an Australian aboriginal boomerang; the other two have blunt leading edges, like the leading edge of an airplane wing. When in flight (*c*), the air exerts a force on such a wing, which can be resolved into two components: a lift (*L*), directed perpendicularly to the velocity from the flatter to the more convex side, and a drag (*D*), directed opposite to the velocity (*v*).



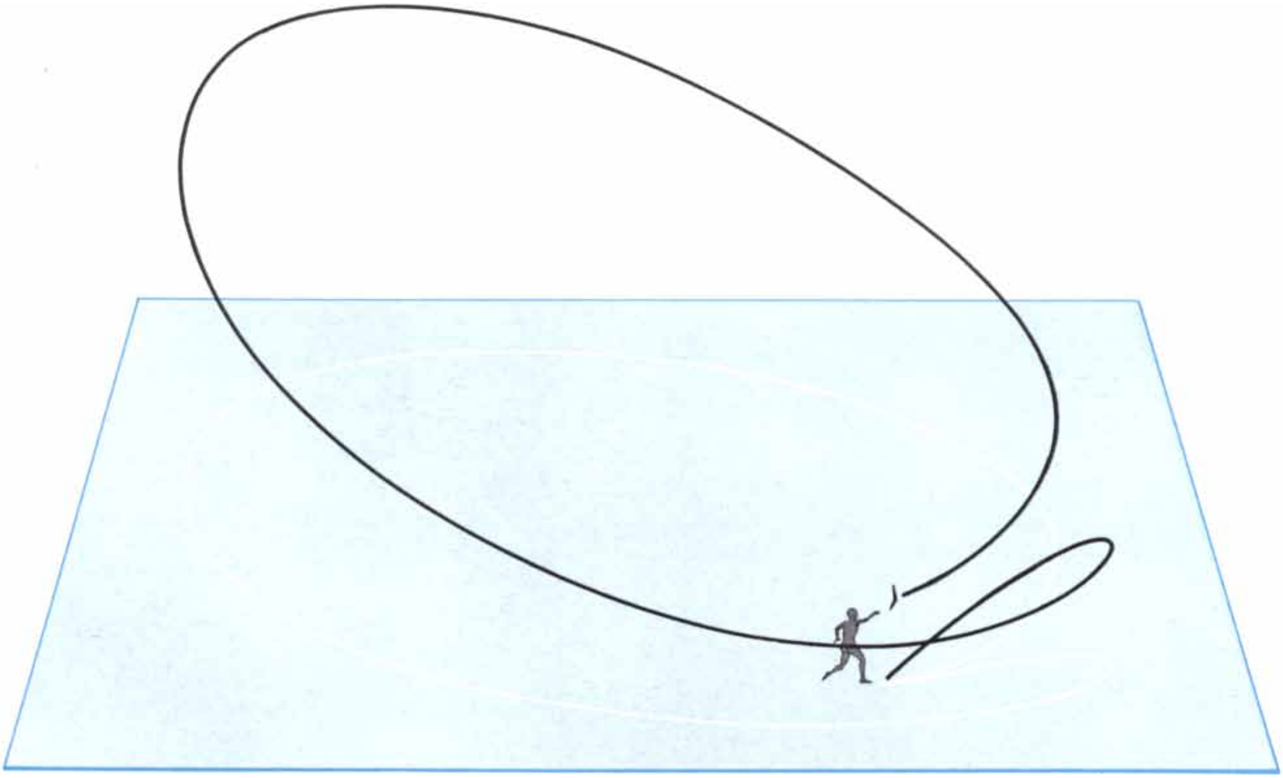
LEADING EDGES of a right-handed boomerang (*a*) and a left-handed boomerang (*b*) are indicated by shading. Both boomerangs are viewed from their more convex, or upper, side. In this orientation the direction of rotation of a right-handed boomerang is counterclockwise, whereas the direction of rotation of a left-handed boomerang is clockwise. Neither boomerang will perform well when it rotates in the opposite direction. In every respect, including flight path, the left-handed boomerang is the mirror image of the right-handed one.

If one throws a boomerang in a horizontal direction, with its plane of rotation vertical, each boomerang arm will "wing" the air. Because of the special profile of the arms the air will exert a force on them directed from the flatter, or lower, side to the more convex, or upper, side. This force is the same as the lifting force exerted on the wings of an airplane. In a right-handed throw the force will be directed from the right to the left as viewed by the thrower. This force alone, however, is not sufficient to make a boomerang curve to the left.

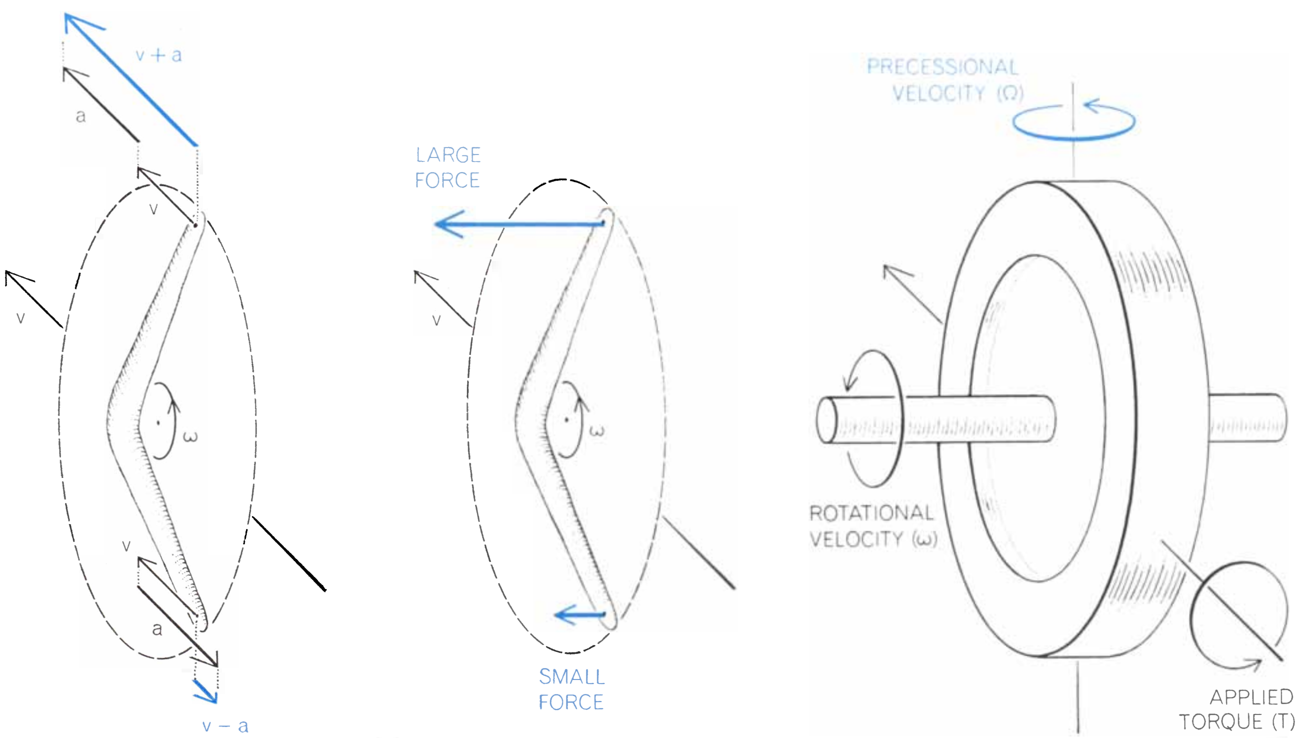
Following one boomerang arm during its motion, one can see that its velocity with respect to the air is not constant. When the arm points upward, the forward velocity of the boomerang adds to the velocity due to the rotation; when it points downward, the two velocities are in opposite directions, so that the resultant speed will be smaller or even vanish at some points [*see bottom illustration on opposite page*]. That is why the aerodynamic forces on a boomerang arm are stronger when it points upward than they are when it points downward. Thus on the average the boomerang experiences not only a force from the right to the left but also a torque acting around a horizontal axis, which tends to cant the boomerang with its upper part to the left. Actually this turning over will not be observed because the boomerang is spinning rapidly and hence behaves like a gyroscope.

Now, a gyroscope (which really is nothing more than a rapidly spinning flywheel) has the property that, when a torque is exerted on it, it does not give way to that torque but changes its orientation around an axis that is perpendicular to both the axis of rotation and the axis of the exerted torque; in the case of a boomerang the orientation turns to the left. This motion is called precession. (The phenomenon of precession is exploited, to cite a homely example, when one bicycles "with no hands" through a curve: leaning to the left makes the spinning front wheel turn to the left.) Thus the boomerang changes it orientation to the left, so that its plane would make a gradually increasing angle to its path were it not for the rapidly increasing forces that try to direct the path parallel to the boomerang plane again. The result is that the path curves to the left, the angle between boomerang plane and path being kept very small.

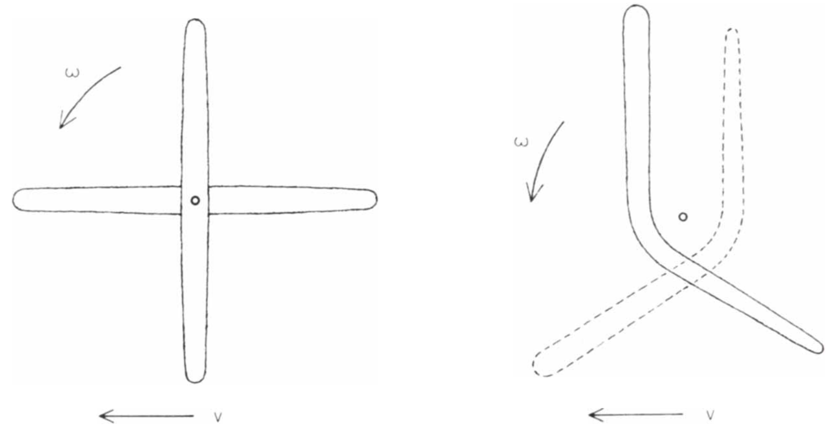
In actual practice one often sees that, although the plane of the boomerang is nearly vertical at the start of the flight, it is approximately horizontal at the end. In other words, the plane of the boomer-



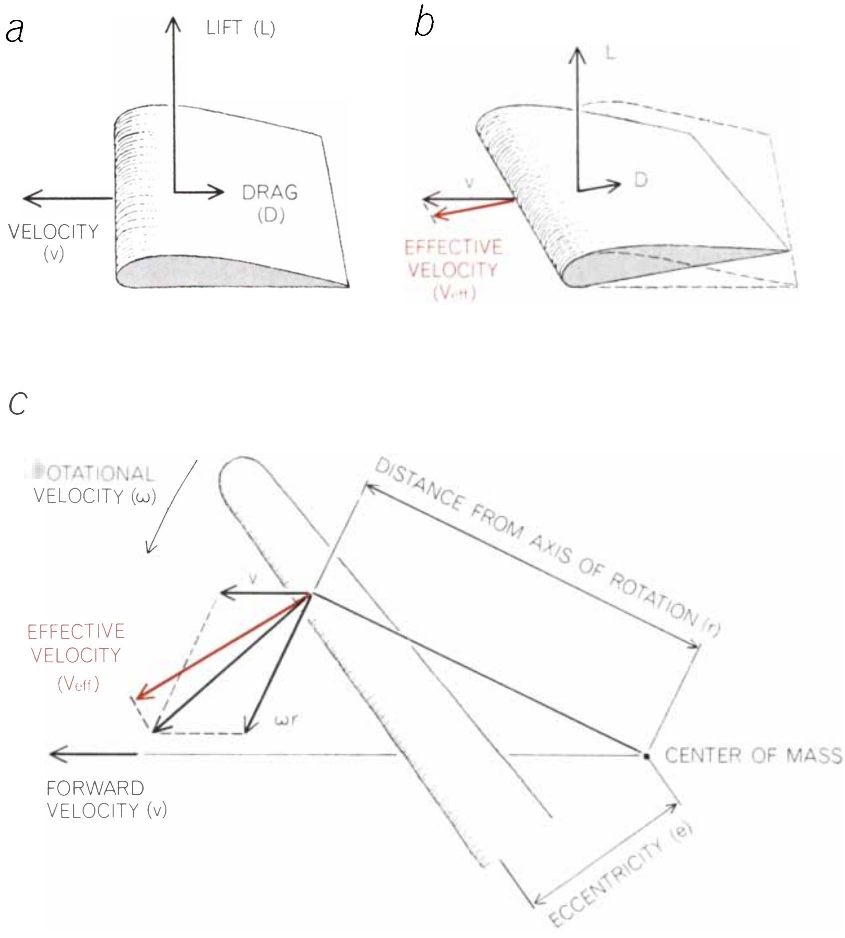
TYPICAL BOOMERANG ORBIT may have a diameter of about 90 feet and a maximum height of about 30 feet. The boomerang starts its flight with a forward velocity of about 60 miles per hour and a rotation of about 10 revolutions per second. It stays in the air for about eight seconds. Widely different path shapes are possible, depending on the properties of the boomerang; in addition very different orbits can be obtained with the same boomerang, although all of these will have approximately the same diameter.



VELOCITY OF A BOOMERANG ARM with respect to the air is not constant. When the arm points upward, the forward velocity of the boomerang adds to the velocity due to the rotation ($v + a$ *at left*), but when it points downward, these two velocities are in opposite directions, so that the resultant speed of the arm through the air will be smaller ($v - a$ *at left*). As a result the aerodynamic force, which is directed from the flatter to the more convex side, is stronger when the arm points upward than when it points downward (*center*). Thus on the average a boomerang experiences not only a force from the right to the left but also a torque acting around a horizontal axis that tends to cant the boomerang with its upper part to the left. Because the boomerang is rapidly spinning it behaves like a gyroscope (*right*). When a torque is exerted on a gyroscope (which is simply a spinning flywheel with a free axis), it does not give way to that torque but changes its orientation around an axis that is perpendicular to both the axis of rotation and the axis of the applied torque. This motion is called precession. Similarly, the boomerang as a whole changes its orientation to the left.



CENTER OF MASS of a cross boomerang (*left*) is at the intersection of the arms. The arms of such a boomerang are said to have a zero eccentricity. In the case of an ordinary boomerang (*right*) one arm precedes the center of mass, whereas the other arm follows it. The preceding arm has a positive eccentricity, the following arm a negative eccentricity.



BOOMERANG ARM RESEMBLES an airplane wing moving in a straight line with a velocity v with respect to the air. In *a* the spanwise direction of the wing is perpendicular to the velocity v; in *b* the velocity v has a component parallel to the wing that has no influence on the aerodynamic forces. Therefore v is replaced by its component perpendicular to the wing, which is called the effective velocity, or v_{eff} (*colored arrow*). Both lift and drag on the wing are proportional to the effective velocity squared, or $(v_{eff})^2$. In *c* the effective velocity of a point on a boomerang arm is found by first adding vectorially the forward velocity v and the velocity due to rotation ωr. This gives the total velocity (*black resultant arrow*). Its component perpendicular to the boomerang arm is the effective velocity v_{eff} (*colored arrow*).

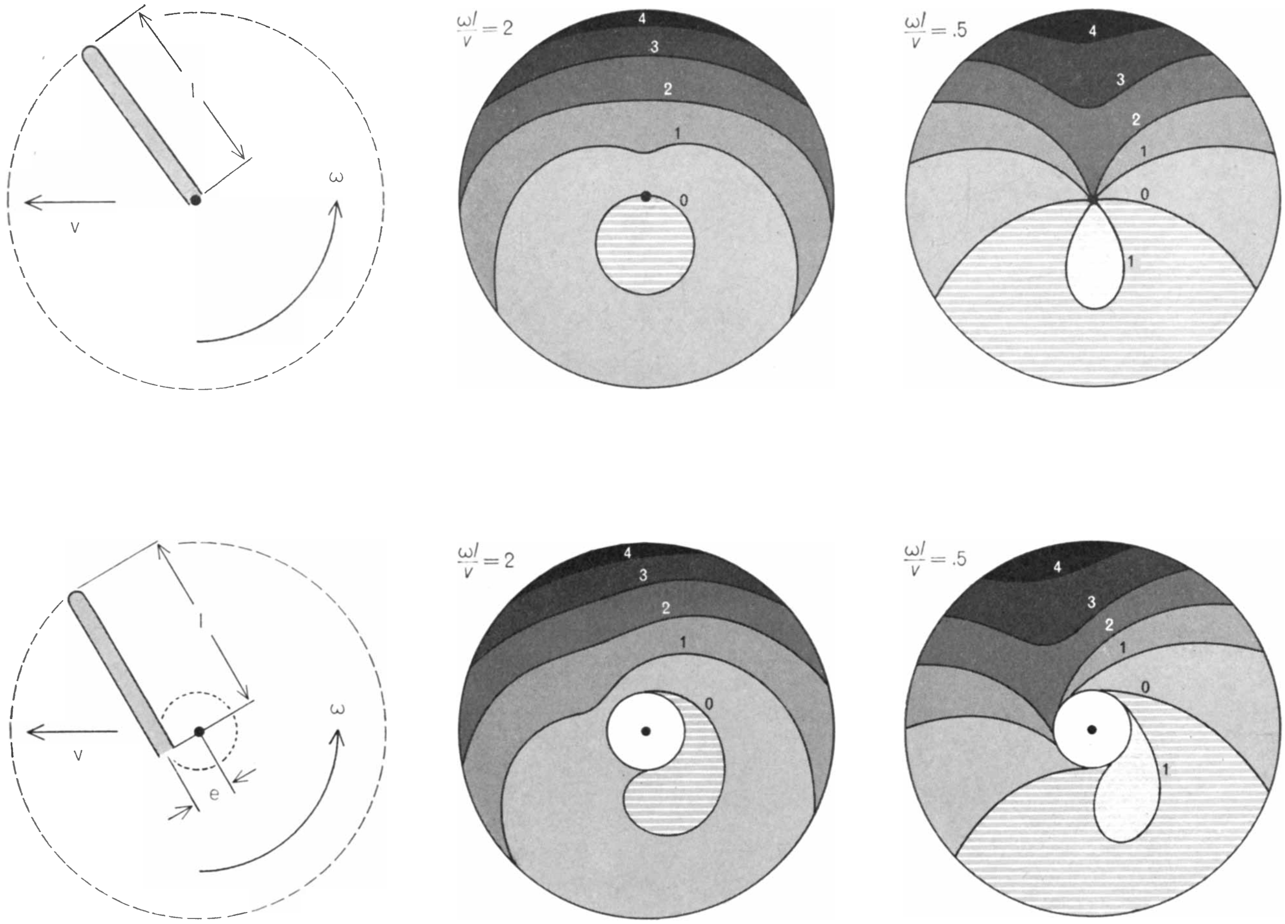
ang slowly turns over with its upper part to the right; the boomerang in effect "lies down." This behavior indicates that the average torque may have its axis not exactly horizontal.

The foregoing explanation is a rough one but it contains the essential elements: the combination of airplane wing and gyroscope is the basis for the behavior of the boomerang. Let us now consider the question in more detail.

Because much is known about the aerodynamic forces on airfoils (airplane wings), it is convenient to regard each boomerang arm as an airfoil. Looking at one such wing, we see that it moves forward and at the same time rotates around the boomerang's center of mass. We explicitly assume that there is no motion perpendicular to the plane of the boomerang. With a cross boomerang (as with the rotor of a helicopter) the center of mass lies at the intersection of the wings, but this is not the case with an ordinary boomerang. Here one arm precedes the center of mass, whereas the other arm follows it [*see top illustration at left*]. We call both arms "eccentric," the eccentricity being the distance from the arm to the center of mass. A preceding arm has a positive eccentricity, a following arm a negative eccentricity. A fixed point of a wing feels an airstream that changes continuously in magnitude and direction with respect to that part of the wing. Sometimes the airstream may even blow against the trailing edge of the wing profile, which can easily be imagined if one thinks of a slowly rotating boomerang with high forward velocity and looks at the arm pointing downward. What are the forces on an airfoil moving in this special manner?

Let us first look at a simpler case: an airfoil moving in a straight line with a constant velocity v with respect to the air [*see bottom illustration at left*]. It is customary to resolve the aerodynamic force into two components: the lift (perpendicular to v) and the drag (opposite to v). These are both proportional to v^2. If the spanwise direction of the wing is not perpendicular to the velocity, v has a component parallel to the wing that has no influence; therefore we replace v by its component perpendicular to the wing, or the "effective velocity" v_{eff}. In this case the forces are proportional to $(v_{eff})^2$.

Looking at the boomerang arm again, it is clear that each point on the arm takes part in the boomerang's forward velocity v. The velocity with respect to



LIFT DISTRIBUTION on a boomerang arm that is moving to the left and rotating counterclockwise is derived from a plot of the distribution of $(v_{eff})^2$ for different ratios of rotational to forward velocity. As mentioned before, the value of $(v_{eff})^2$ depends on the point's position on the arm as well as on the orientation of the arm at any given moment. If for a certain fixed orientation one calculates the value of $(v_{eff})^2$ for every point on the arm, and repeats this procedure after the arm has rotated through a small angle, and so on until a complete revolution has been made and the arm has swept out a full circle, one gets patterns such as the ones shown at center and right. The patterns at top are for an arm with length l and zero eccentricity; the patterns at bottom are for an arm with length l and eccentricity $1/5\ l$. The darker the shading, the higher the value of $(v_{eff})^2$. Some lines have been drawn along which $(v_{eff})^2$ has a constant value; these values, expressed in units of $\omega l v$, are indicated by the numbers labeling those lines. The hatched areas indicate where the wing feels the air blowing against its trailing edge. The ratios of $\omega l/v$ chosen for rotational to forward velocity are 2 (rapid rotation) and .5 (high forward speed). The darker shading in the upper parts of the diagrams indicates that there must be an average torque acting around an axis parallel to v. The diagrams for the arm with zero eccentricity (*top*) show a perfect symmetry, whereas those for the arm with positive eccentricity (*bottom*) do not. In the latter case the highest values of $(v_{eff})^2$ are shifted in the direction of v. This indicates that the average torque has a component around an axis perpendicular to v.

the air due to the rotation, however, is different for each point. For a rotational velocity ω and a point at a distance r from the axis of rotation (which passes through the boomerang's center of mass), this velocity is ωr. For each point on the arm one can reduce the velocities v and ωr to one resultant velocity. Its component perpendicular to the arm is v_{eff}. Of course, the value of v_{eff} for a particular point on the arm will change continuously during one period of revolution. One assumes that the contributions to the lift and drag of each part of a boomerang arm at each moment are again proportional to $(v_{eff})^2$.

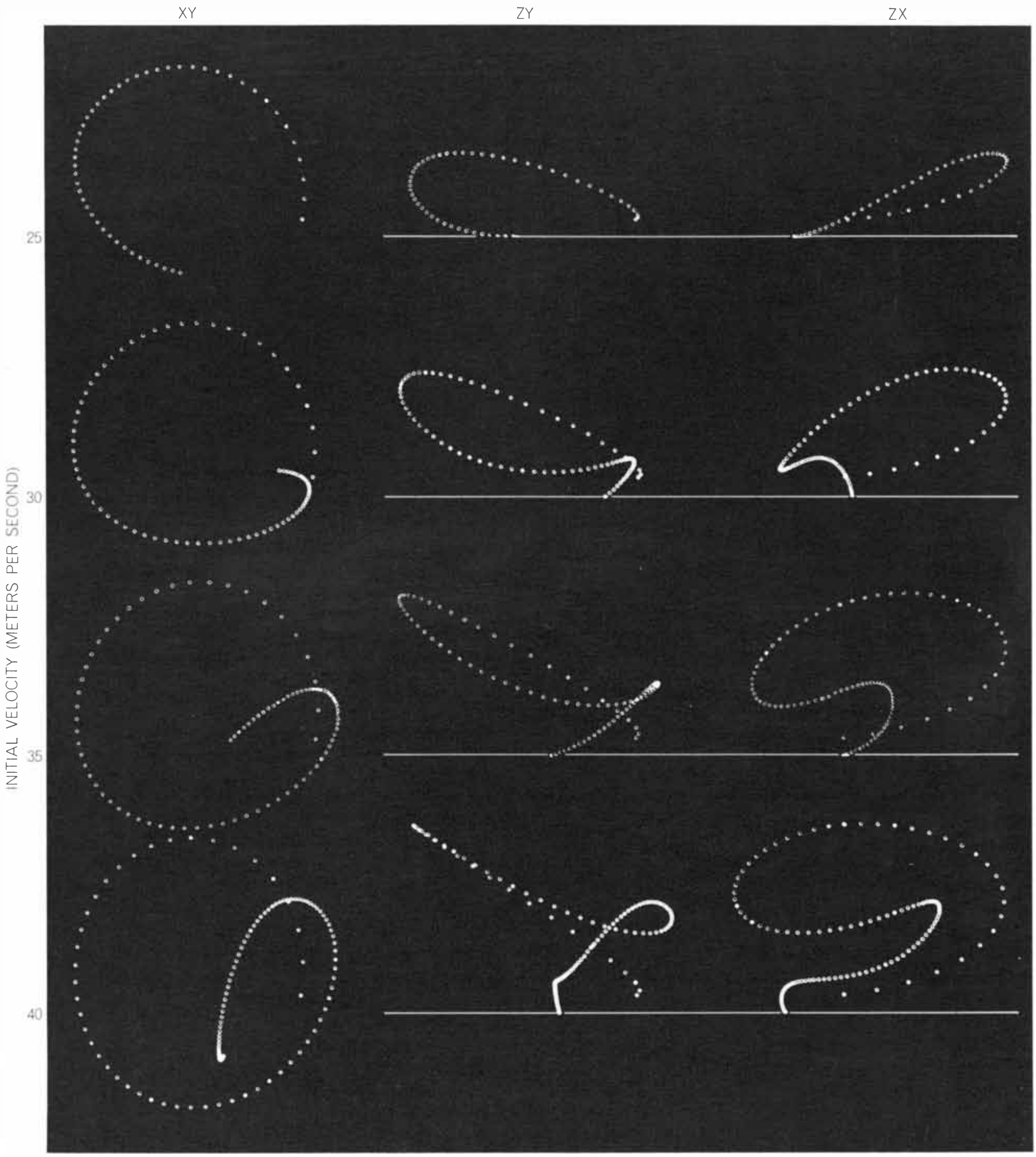
It is evident that the value of $(v_{eff})^2$ depends on the point's position on the arm as well as on the orientation of the arm at the moment under consideration. If for a certain fixed orientation of a boomerang arm one calculates the value of $(v_{eff})^2$ for every point of the arm, and repeats this procedure after the arm has rotated through a small angle, and so on until a complete revolution has been made and the arm has swept the surface of a circle, one gets patterns like those in the illustration above. In these diagrams some lines are drawn along which $(v_{eff})^2$ has a constant value. These figures may give an idea of the distribution of lift and drag on a rotating and forward-moving boomerang arm for different ratios of rotational to forward velocity.

Since the upper parts of all the diagrams are shaded darker than the lower parts, indicating higher values of $(v_{eff})^2$ and hence of the lift, one immediately sees that indeed there is an average torque around an axis parallel to the forward velocity v (horizontal in the drawings). The diagrams for the arm with zero eccentricity show a perfect symmetry, which is not the case for the arm with positive eccentricity. Here the darkest part is shifted forward in the direction of v (for negative eccentricity it would have been shifted backward). This indicates that the average torque also has a component around an axis perpendicular to v.

Calculations were made of the following forces and torques, averaged over one period of revolution: the average lift force L; the average torque T, with its components T_1 around an axis parallel to v (which makes the boomerang turn to the left) and T_2 around an axis perpendicular to v (which makes the boomerang "lie down"); the average drag D, which slows down the forward velocity v, and the average drag torque T_D, which slows down the rotational velocity ω. It turns out that none of these quantities except T_2 depends on the eccentricity for boomerang arms that are otherwise identical; T_2 is exactly proportional to the eccentricity. The approximate dependence on ω and v (for sufficiently rapid rotation) is given by the following table:

$L : \omega^2$
$T_1 : \omega v^2$
$T_2 : \omega v$
$D : \omega v$
$T_D : \omega^2$

(The sign : means "proportional to," the

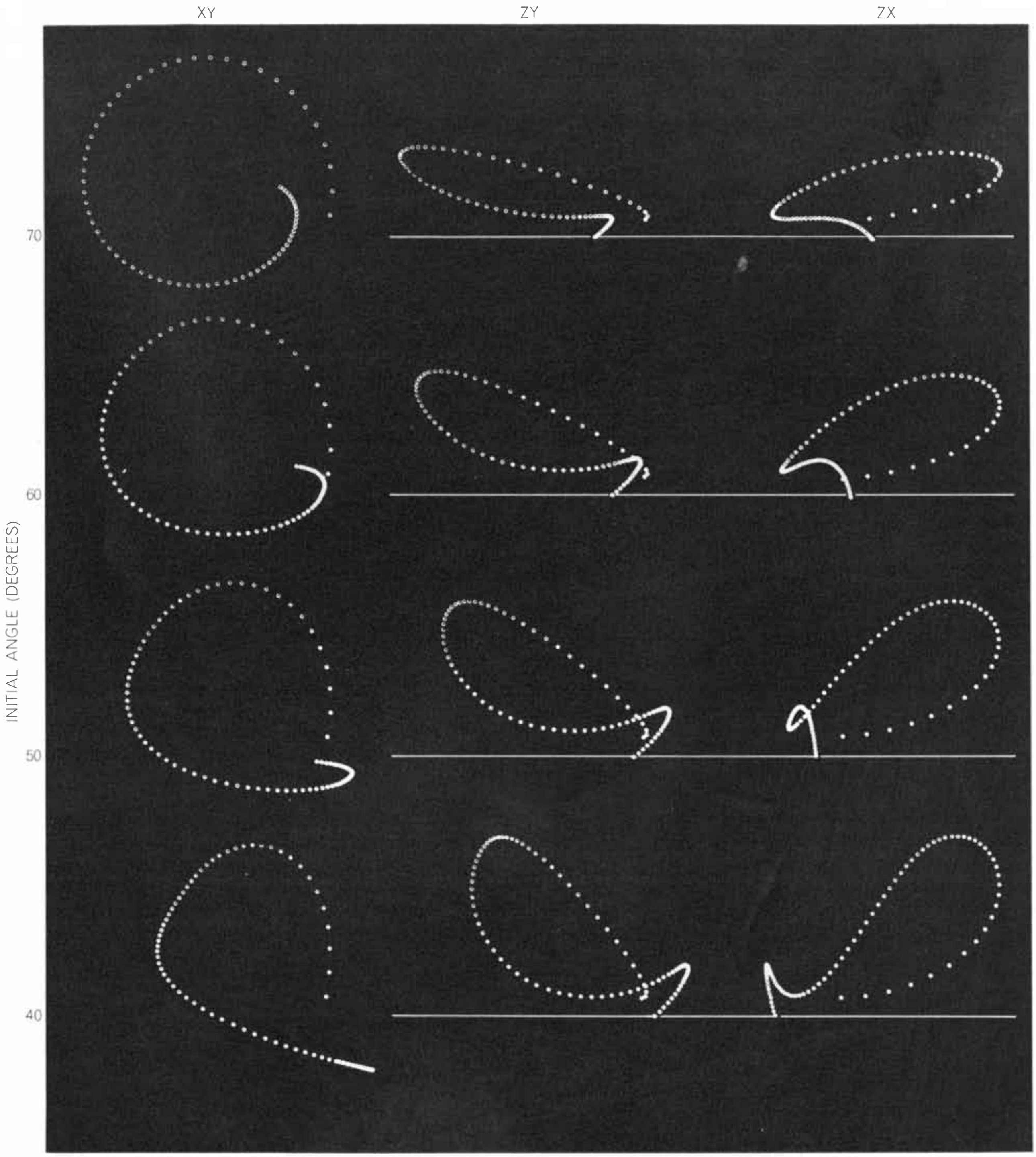


THEORETICAL PATHS for a given boomerang "thrown" with different initial velocities (v) are represented in three orthogonal projections: bird's-eye view (*left*), view from behind the thrower (*middle*) and view from the thrower's right side (*right*). If the initial velocity is small (*top*), the boomerang does not return completely. If the velocity is increased (*center and bottom*), the boomerang stays in the air longer. The diameter of its path, however, remains roughly the same. The dots are spaced at intervals of a tenth of a second.

factors of proportionality depending on the exact shape of the boomerang arm.)

This is the extent of the required aerodynamics. The forces and torques acting on a boomerang as a whole are obtained by adding their values for each of its arms. The contributions to T_2 by arms with opposite eccentricity may partly or completely cancel each other. I must mention, however, that a factor that is probably very important has been completely neglected: the wake. A boomerang arm that traverses air already brought into motion by a preceding arm will not experience the same forces as it would in flying through "virgin" air. It is extremely difficult to take wake effects into account, but it is plausible that they cause an increase of the ratio $T_2 : T_1$.

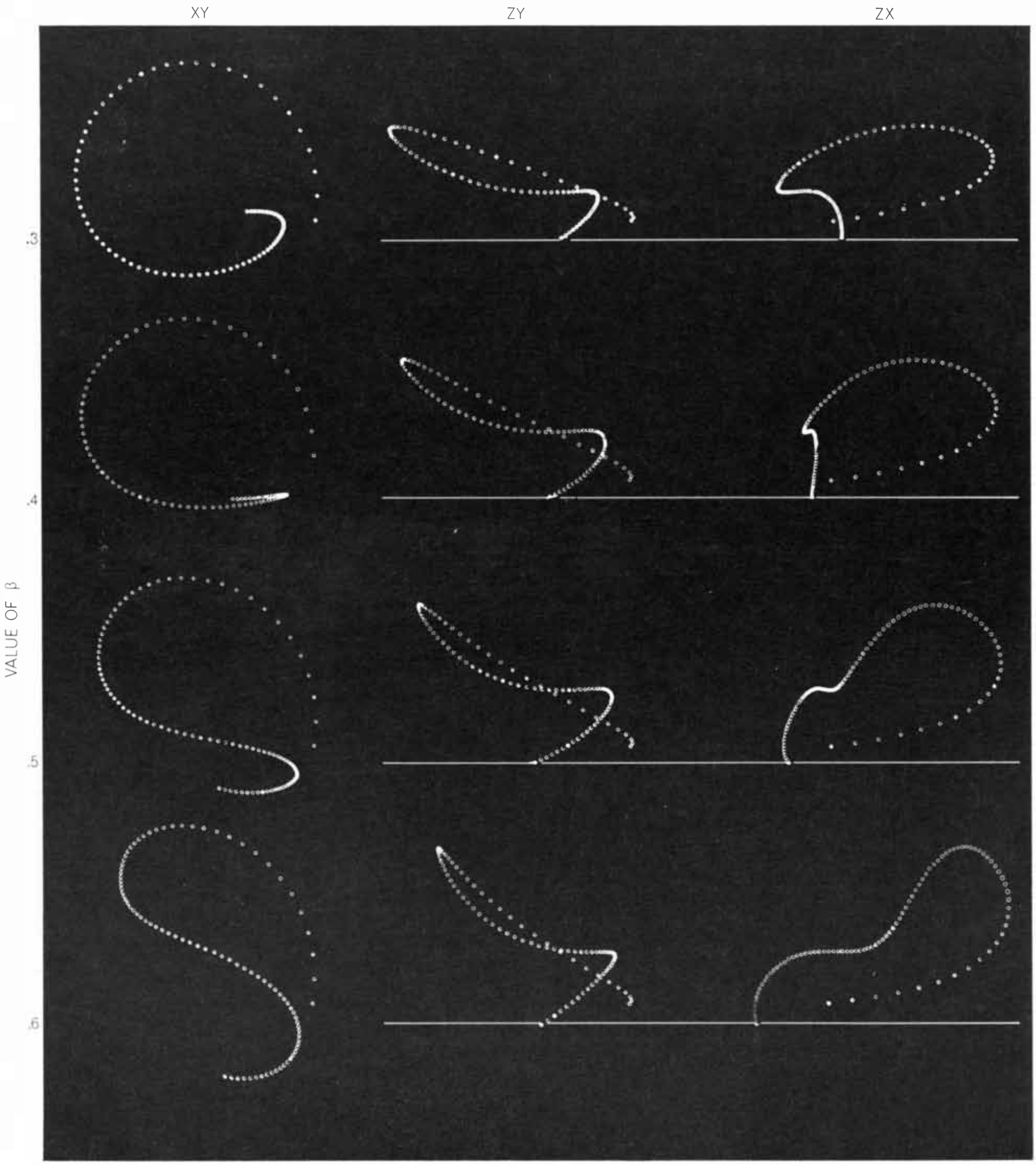
Now we come to the important question: How does a boomerang move under the influence of these aerodynamic forces and torques (and of the force of



MORE THEORETICAL PATHS were calculated for the same boomerang "thrown" at a constant initial velocity but with different initial angles (θ) between the plane of the boomerang and the horizon. If the boomerang plane is nearly vertical at the start (*top*), the boomerang stays low and the orbit curves inward. As (θ) is decreased (*center and bottom*) the orbit rises and curves less inward, or even outward toward the end. The orthogonal projections are the same as those in the illustration on the opposite page.

gravity, of course)? As mentioned earlier, the average torque T causes the gyroscopic precession of a boomerang. Let us take a closer look at the gyroscope. If a gyroscope spins around its axis with a rotational velocity ω and one exerts a torque T on it, acting around an axis perpendicular to the spin axis, the gyroscope precesses around an axis perpendicular to both the spin axis and the torque axis. The angular velocity of the precession is called Ω. A very simple connection exists between Ω, ω, T and the gyroscope's moment of inertia I, namely $\Omega = T/I\omega$. We have seen that for a boomerang T is proportional to ωv, so that the velocity of precession Ω must be proportional to $\omega v/I\omega$, *or* v/I. Hence the velocity of precession does not depend on ω, the rotational velocity of the boomerang.

An even more striking conclusion can be drawn. The velocity of precession is proportional to v/I, the factor of proportionality depending on the exact shape



DIFFERENT THEORETICAL BOOMERANGS, that is, boomerangs for which the boomerang parameter β is varied, were "thrown" in the same way as on the preceding page to obtain these theoretical paths. A higher value of β means that the boomerang "lies down" faster and reaches the horizontal orientation ($\theta=0$) sooner. Where this happens the bird's-eye projections show a point of inflection; thereafter the path curves to the right. In this case also the orthogonal projections are the same as on page 132.

of the boomerang. Therefore one can write $\Omega = cv$, with c a characteristic parameter for a certain boomerang. Now let the boomerang have a velocity twice as fast; it then changes the orientation of its plane twice as fast. That implies, however, that the boomerang flies through the same curve! It is just like bicycling through a curve in the road: pedaling twice as fast and at the same time turning the handlebars twice as fast means that one rides through the same curve.

Thus, roughly speaking, the diameter of a boomerang's orbit depends neither on the rotational velocity of the boomerang nor on its forward velocity. This means that a boomerang has its path diameter more or less built in. Actually this conclusion has to be slightly modified. Under the influence of gravity the boomerang's orbit is described approximately on the surface of a large sphere. It is the diameter of this sphere rather than of the orbit itself that is fixed for a certain boomerang. The diameter of the orbit may be smaller if the path is described near the bottom of the sphere's surface.

The dimensions of a boomerang's flight path are proportional to the moment of inertia of the boomerang, and they are smaller if the profile of the arms gives more lift. Therefore if one wants a boomerang to describe a small orbit (for instance in a room), it should be made out of light material. For very large orbits a heavy boomerang is needed with a profile giving not much lift (and of course as little drag as possible).

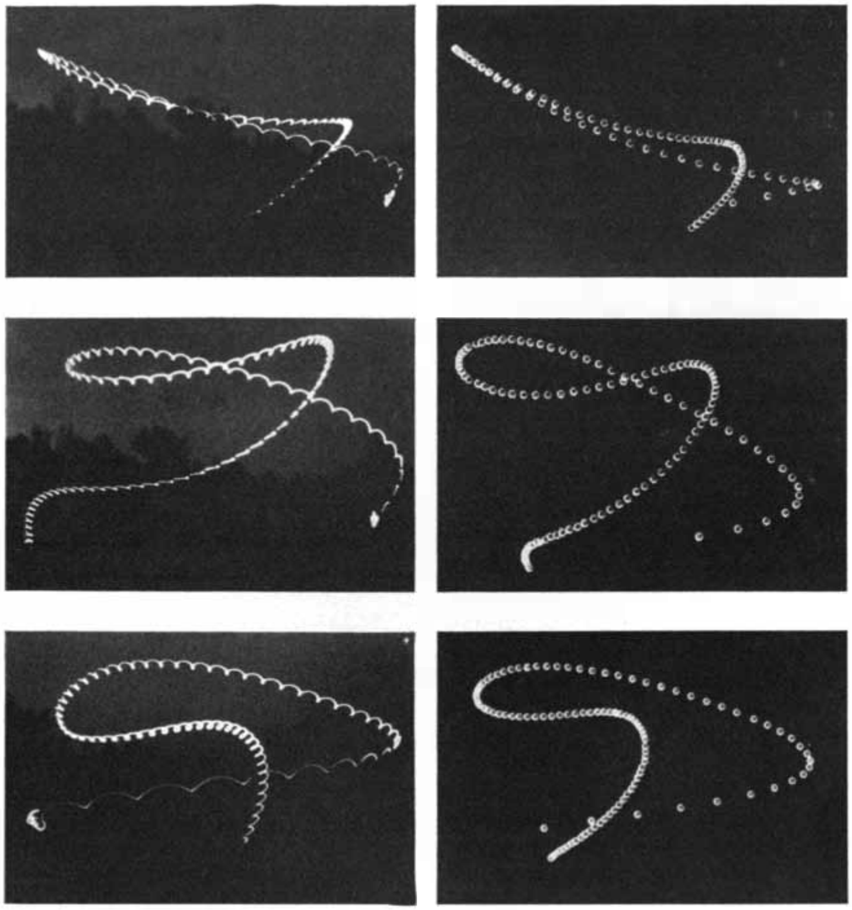
The average force L does not enter the path calculations because in the ideal case any motion of the boomerang in a direction perpendicular to its plane is supposed to vanish. Moreover, of the force of gravity only the component parallel to the boomerang plane is of interest. From observation it appears that a boomerang's rotational velocity ω—unlike its forward velocity v—does not change appreciably during one flight. This allows one to forget about ω (and the drag torque T_D) altogether, as far as path calculations are concerned; ω only has to be sufficiently great. Finally, there is the average drag D, which makes the boomerang lose part of its energy.

Now one has everything needed to form the equations of motion for a theoretical boomerang. These equations can be solved numerically on a computer, giving velocity, orientation and position of the boomerang at each instant, provided that one gives the computer, in addition to the computing program, two sets of numbers. The first set determines the relevant properties of the boomerang; these numbers, called boomerang parameters, are: c, which determines the velocity of precession and has a close connection with the path dimensions (greater c means smaller orbit); β, an angle that is a measure of the ratio $T_2 : T_1$ and determines how fast the boomerang "lies down," and p, which is a measure of the drag. The second set fixes the theoretical way of throwing (initial conditions); these are determined by giving the initial values of v, of θ (the angle between the boomerang plane and the horizon) and of ψ (the angle between the direction of v and the horizontal line in the boomerang plane).

A few theoretical paths were calculated in this way, but it soon turned out that the complete neglect of motion perpendicular to the boomerang plane was not justified. In reality boomerangs appear to sag out of their "ideal" orbits, a tendency that indeed can often be seen, particularly at the end of a flight. Although this sagging can be neglected with very light boomerangs, it apparently cannot with heavier ones. The effect was taken into account by considering it to be a small disturbance of the ideal motion.

For each calculated orbit three orthogonal projections were drawn by an automatic plotter. The plots consist of discrete points representing the consecutive positions of the boomerang with intervals of a tenth of a second. For each path the computation was continued until the theoretical boomerang had descended more than six feet below the starting point. The three projections

θ-DEPENDENCE of actual boomerang orbits is demonstrated in these two moonlit photographs, in which θ (the initial angle between the plane of the boomerang and the horizon) is about 20 degrees less in the bottom picture than it is in the top picture. The recorded paths can be compared with the theoretical paths in the middle column on page 133.



MORE COMPARISONS between actual recorded orbits (*left*) and theoretical orbits obtained with the aid of a computer (*right*) show a remarkable similarity in both general appearance and certain peculiarities between the real paths and the paths computed on the basis of the author's theory. Since the camera was not very far from the thrower (about 50 yards) those parts of the recorded paths where the boomerang was close to the camera appear exaggerated; this effect of perspective was taken into account in the computations.

were chosen as follows: projection *XY* (bird's-eye view); projection *ZY* (view from behind the thrower); projection *ZX* (view from the thrower's right side). The illustrations on pages 132 and 133 demonstrate how the path shape for a given boomerang varies with the way of throwing, in particular with the initial velocity and with the initial angle between boomerang plane and horizon (θ). Finally, the illustration on page 134 shows how, for a fixed way of throwing, the orbit depends on the boomerang parameter β.

How do these calculated paths compare with real boomerang flights? For an objective comparison it would be necessary to record the position of a boomerang during its flight. This could be done by means of two cameras. In order to control the initial conditions, a boomerang-throwing machine would be necessary. As yet I have had no opportunity to do such experiments, but I did manage to record one projection of experimental boomerang paths with a single camera. In the wing tip of a boomerang a tiny electric lamp was mounted, fed by two small 1.5-volt cells connected in series, placed in a hollow in the central part of the boomerang [*see illustration on page 124*]. In this way the boomerang was made to carry during its flight a light source strong enough to be photographed at night. Some of the paths recorded in this manner are shown in the illustration above; calculated orbits are added for comparison.

Because the camera was not very far from the thrower, those parts of the trajectories where the boomerang was close to the camera appear exaggerated in the photographs. This effect of perspective was taken into account in the accompanying calculated paths. The reader may decide for himself whether or not he finds the agreement between theory and experiment satisfactory. At any rate, the general appearance and peculiarities of real boomerang paths are reproduced reasonably well by this theory.

The Fairbanks Morse Caprocon system speeds the processing of cargo—automatically, for United Airlines.

A key to the system is Kleinschmidt

For high speed in automated communications, there's only one answer: Kleinschmidt.

Take the Fairbanks Morse CAPROCON™ system. At United Airlines Cargo Terminal in Los Angeles, Caprocon, aided by Kleinschmidt data printers, brings new speed and efficiency to the processing of random parcels.

Working at a rate of 800 parcels per hour, Caprocon weighs and measures parcels instantly. It feeds the information on cubage and density to Kleinschmidt data printers. Bills, labels, and shipping instructions are printed out automatically. Result: more efficient palletizing, more economical aircraft loading, faster service than ever before.

Kleinschmidt 311™ Data Printer works at speeds up to 4 times faster than most other teleprinters. And, with 70% fewer moving parts, it's extremely reliable.

Like other Kleinschmidt data printers, the 311 is compatible with *all* makes of telecommunication equipment. You can fit it directly into your present system or into one being designed for you.

If you have a problem in telecommunications, shouldn't you communicate with Kleinschmidt?

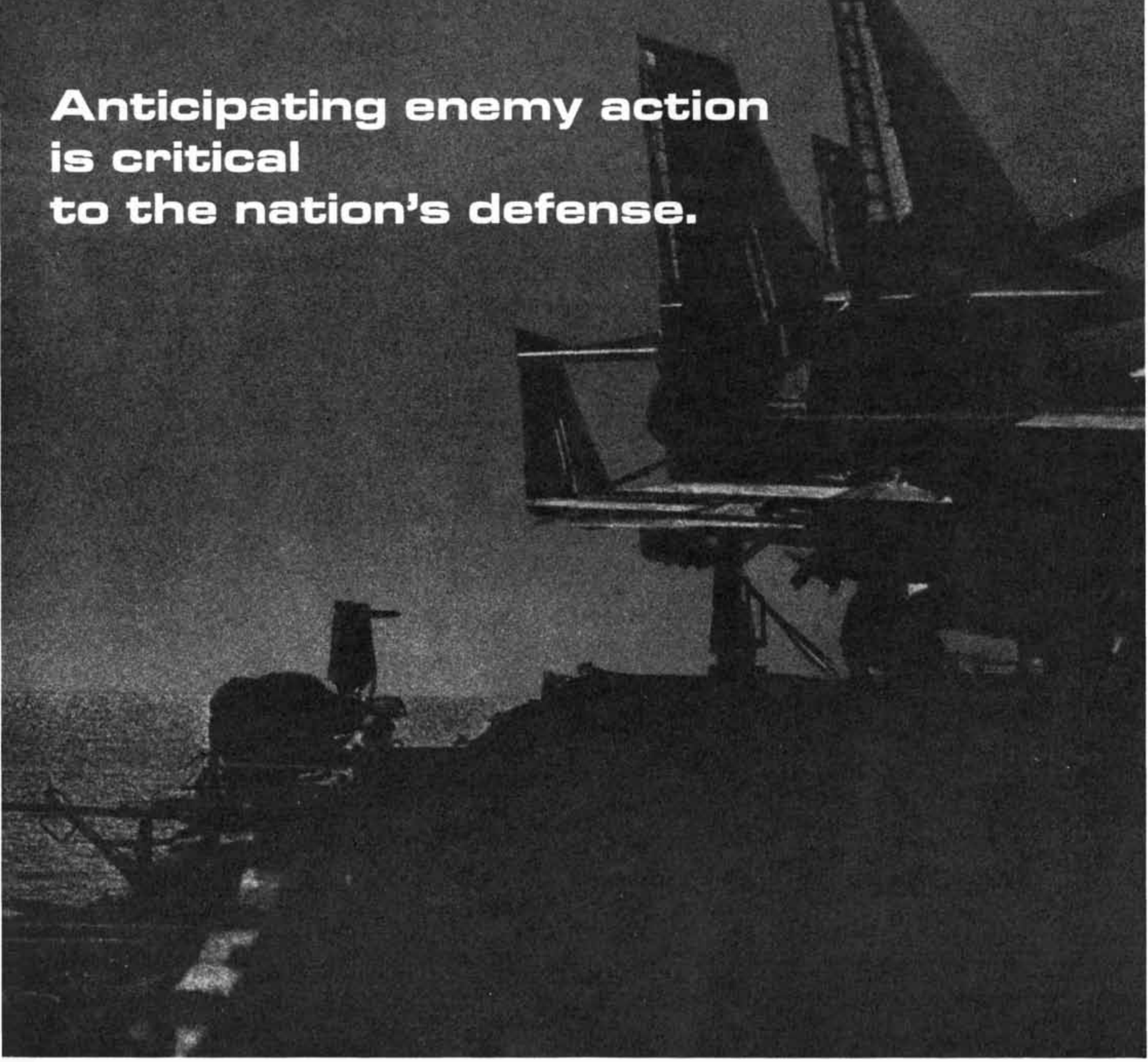
SCM®

The speed and destructive force of today's weapons are such that every action of an enemy that can be anticipated . . . must.

New electronic systems enhance mission effectiveness.

The demand for new concepts in the battle of measures, countermeasures and counter-countermeasures never ends. A vital part in meeting this need is Sanders unique systems capability.

At present, Sanders is involved in programs ranging from battlefield defense measures to missile operations.



Specific projects include ECM systems for Naval aircraft and the F-111A, direction finding systems for submarines, and the FAAR systems that detect and identify low flying enemy aircraft in forward area operations.

At Sanders, specialists in widely diverse technologies combine their talents to solve a single problem. A typical systems team includes experts in such areas as data control, computer evaluation, doppler processing, solid-state physics, magnetic radiation and optical tracking.

This approach has made Sanders a leading supplier of electronic warfare systems that continually improve mission effectiveness by neutralizing enemy action.

Sanders is applying this same systems technique to data management, electro-optics, oceanography, world-wide communications and other fields.

If you'd like to know more about this systems concept of problem solving, contact: Corporate Division Development, Sanders Associates, Inc., Nashua, New Hampshire 03060. Phone: (603) 883-3321, extension 1674.

Systems-oriented scientists and engineers interested in current career opportunities at Sanders are invited to call Professional Placement, Extension 6967.

Creating New Directions
In Electronics

SA SANDERS
ASSOCIATES, INC.

An equal opportunity employer M and F

MATHEMATICAL GAMES

On the ancient lore of dice and the odds against making a point

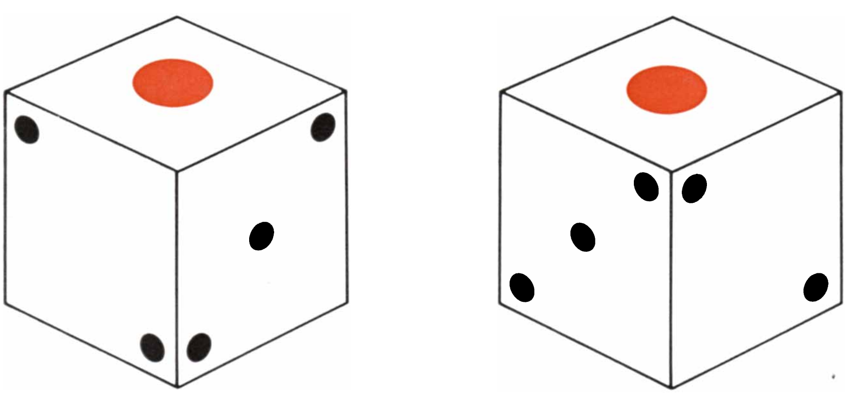
by Martin Gardner

The chance element in thousands of indoor games is introduced by a variety of simple random-number generators. The most popular of such devices, ever since the time of ancient Egypt, have been cubical dice. Why cubical? Because of their symmetry, any of the five regular solids can be and have been used as gaming dice, but the cube has certain obvious advantages over the other four solids. It is the easiest to make, its six sides accommodate a set of numbers neither too large nor too small and it rolls easily enough but not too easily.

The four-sided tetrahedron has been the least popular over the centuries; it hardly rolls at all and will randomize no more than four numbers. Next to the cube the octahedron has been most used as a randomizer for games. Specimens of octahedral dice have been found in ancient Egyptian tombs and are still used today in certain games. Dodecahedrons (12 sides) and icosahedrons (20 sides) have been employed mainly for fortune-telling. A dodecahedral die was a popular fortune-telling device in 16th-century France, and if you break open one of those large fortune-telling balls in which answers to questions float upward in a liquid and appear in a window at the top, you will find the answers printed on the 20 faces of a floating icosahedron.

A few years ago the Japanese Standards Association (Kobikikan-Bekkan Building, 6–1, Ginza-higashi, Chuo-ku, Tokyo) found a clever practical use for icosahedral dice. Since the number of an icosahedron's sides is twice 10, pairs of its sides can be marked with one of the 10 digits from 0 through 9 to make an elegant little instrument for generating random decimal digits to be used in Monte Carlo methods, game theory and so on. The dice are sold in sets of three, each a different color (red, blue, yellow) so that every throw produces a triplet of random digits. Photographs of these dice are on the cover of Birger Jansson's valuable monograph, *Random Number Generators,* written in English and published in Sweden in 1966.

The earliest known cubical dice, found in Egyptian tombs predating 2000 B.C., are not uniform in size, material or the way the sides are numbered, although many are identical with modern dice (on which the digits 1 through 6 are placed so that opposite sides add to 7). If that arrangement is not required, there are 30 ways a cube's face can be spotted to represent 1 through 6, counting mirror-reflection forms as different (but not taking into consideration the two different orientations of the 2, 3 and 6 spots, which, in their traditional patterns, lack fourfold symmetry). If opposite sides total 7, as they do on all modern dice, there are just two ways of arranging the numbers, each a mirror reflection of the other.



Western-style Japanese die (left) *and die for Mah-Jongg* (right)

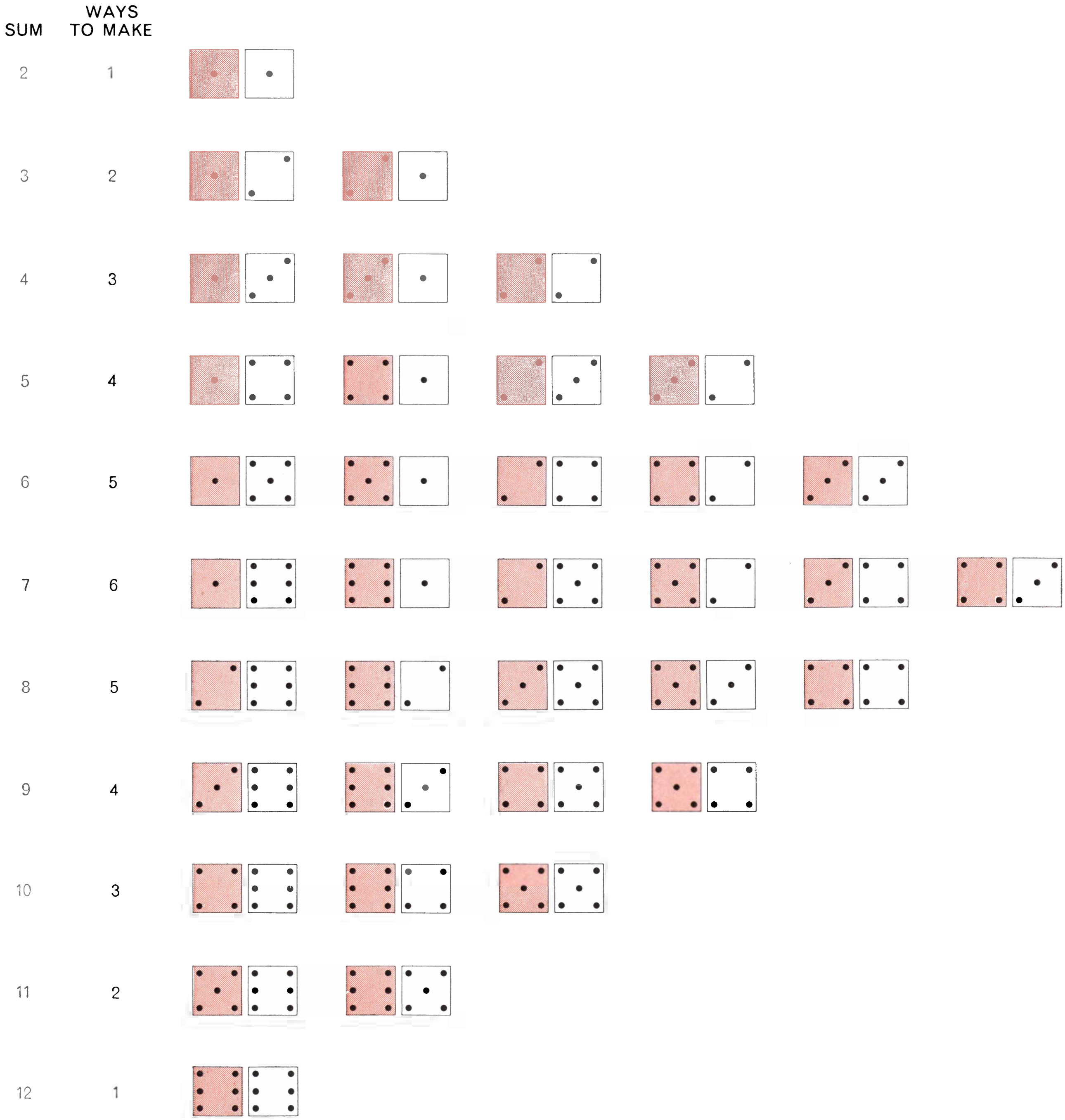
All Western dice are now made with the same handedness. If you hold a die so that you see its 1–2–3 faces, the numbers go counterclockwise. Dice of both handednesses are sold today in Japan [*see illustration on this page*]. The type matching Western dice is used in all Japanese games except Mah-Jongg, which uses dice that—as Lewis Carroll's Alice put it—"go the other way." Dice of either handedness are sold in two forms: the Western, in which all the spots are black, and the traditional Japanese form, in which the ace is very large, deeply indented and colored red. Chinese and Korean dice also have the large red spot, and in addition the spots on the 4 side are also red. Red sides seem to play no role in Chinese and Korean games except in determining who throws first, the first player being the one who rolls the most red spots. The origin of the red coloring is not known. Stewart Culin, in his privately printed monograph *Chinese Games with Dice* (Philadelphia, 1889), recounted some old Chinese myths that explain the red coloring, but he himself believed it derives from earlier Indian dice.

A professional dice gambler is often so well acquainted with the handedness of modern dice—that is, with exactly how any triplet of numbers is arranged around a corner—that if you show him a die with your finger and thumb covering any two opposite sides, he can immediately tell you which number is under the finger and which under the thumb. This knowledge is useful in detecting a common variety of crooked dice known in the trade as "tops." Tops are cubes misspotted so that each bears only three numbers; pairs of identical numbers are on opposite sides. Since no more than three sides of a cube can be seen at one time, a pair of tops resting on a surface appear perfectly normal to all players. There is no way, however, to make a die of this sort so that every triplet of faces goes the "right way." If the reader will take a sugar cube and pencil on it any three pairs of digits that surround a corner on a standard die, putting duplicate numbers on opposite faces, and then inspect the die by viewing each of its eight corners, he will find that at four corners the three faces go the "wrong way" when compared with a modern die. This means that the probability of such a die's falling with its three visible faces showing the wrong handedness is exactly 1/2. When this occurs, a knowledgeable gambler immediately recognizes the die as misspotted.

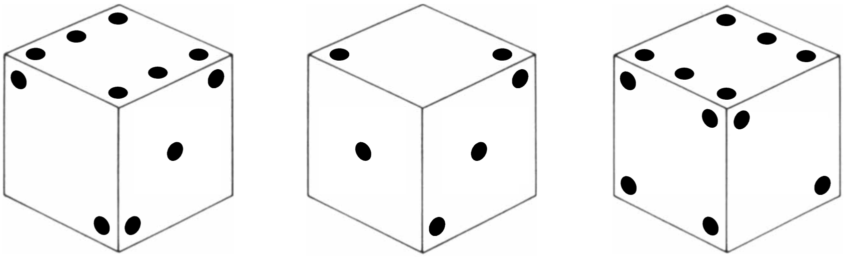
Tops are made in a variety of combinations so that the bust-out man—a man who is expert at secretly switching tops in and out of games—can "bust into" the game whatever kind of tops is needed at the moment. [The essential rules of craps are: If the shooter rolls a "natural" (7 or 11) on his first roll, he wins at once. If he throws a "crap" (2, 3, or 12), he loses. Any other number becomes his "point," and he continues to throw until he either wins by making his point or loses by throwing a 7 before making his point. All of this is accompanied by much betting of various kinds between players, the nature of which depends on whether the game is informal or played in a casino.] For example, if the shooter is trying for a point of 4, 6, 8 or 10, a 1–3–5 and 2–4–6 pair of tops will not form any of those numbers, and so he is sure to "seven out" before he makes his point. Tops of this kind are called "misses." Tops designed to make points and incapable of throwing a 7 (for example, 1–3–5 and 1–3–5) are known as "hits."

Tops cannot be left long in a game because the danger of detection is too great, and so a bust-out man has to work fast, as well as continually and indetectably. "Good bust-out men die young," writes gambling authority John Scarne in *Scarne's Complete Guide to Gambling* (1961); "it's hard on the nervous system."

A "one-way top" is a die with only one



The 36 equally probable ways two dice (color and white) *can fall*



How many spots are opposite the 6 on this mis-spotted die?

number (usually 2 or 5) duplicated. Such dice can be used in pairs or in combination with a legitimate die to give milder percentages, but they are harder to detect and sometimes are left in a game for hours. "Door pops" are still advertised in the catalogues of crooked-gambling-supply firms but are strictly for sucker customers. No professional cheat would consider using them. One set always craps out because one cube bears only aces and deuces, the other only aces. Another set, with 6's and 2's on one die and all 5's on the other, always sevens or elevens. As Scarne puts it, they can be used only on "soft marks" (extremely gullible suckers) "for night play under an overhead light when the chumps can't see anything but the top surfaces of the dice. Strictly for use by cheats who don't know what a set of real tops is."

Mis-spotting is only one of dozens of ways dice can be "gaffed" for cheating. They can be loaded in many ingenious ways: they can be shaped somewhat like bricks; certain sides can be made a trifle convex, causing the cube to favor the flat sides, or sides can be made slightly concave to create suction on smooth, hard surfaces. Edges can be beveled to alter percentages. "Capped dice" are made with certain faces bouncier than others. "Slick dice" have some faces smoothed and others roughened. Magnetic dice are loaded to roll normally unless an electromagnet concealed under the rolling surface is turned on. Ordinary loaded dice are best tested by dropping them in a glass of water many times to see if certain faces show more often than they should. The interested reader will find all of this and much more explained in fascinating detail in the standard work on cheating at dice, *Scarne on Dice,* by John Scarne and Clayton Rawson (ninth edition, 1968).

Dicing was enormously popular in ancient Greece and Rome, particularly among the upper classes, and during the Middle Ages it was a favorite time-waster for both knights and the clergy. There were even medieval dicing schools and guilds. In the U.S. today the most popular dice game is craps. Apparently it dates from the early 1890's, when Negroes in the New Orleans area simplified the complicated rules of the English game of hazard. (Dice are still facetiously called "African dominoes.") Then, like jazz, craps spread up the Mississippi River and fanned out over the continent. The big gambling casinos did not take it up until near the end of the 19th century. Today it gets faster action than any other casino game. Many players believe the shooter has a 50–50 chance of winning, but it is not hard to prove that the odds are slightly against him. To be precise, the shooter's winning probability is exactly 244/495, or .493+.

It is easy to go wrong in figuring the probability of dice throws. In the 10th chapter of the last book of Rabelais's *Gargantua and Pantagruel* the adventurers visit Sharper's Island, formed of two enormous cubic blocks of dazzling white bone. "Our navigator informed us," says Pantagruel, "that these cube-shaped white rocks had caused more shipwrecks, entailing a greater loss of life and property, than... Scylla and Charybdis." Dice were often called "the devil's bones," and Rabelais has Sharper's Island inhabited by 20 devils of chance, one for each combination of two dice, from Double Six, the largest devil, to Double Aces, the smallest. Actually there are 21 such combinations. The chart on the preceding page shows the 6 × 6, or 36, different ways two dice can fall. Inspection reveals 21 different combinations. With this basic chart one can quickly calculate the probability of throwing any sum from 2 through 12. Note that 7 can be made in six ways, more than any other sum. The probability of throwing a 7 is therefore 6/36, or 1/6. It is the easiest of all sums to make.

William Saroyan, in a fine short story about crap shooting called "Two Days Wasted in Kansas City," speaks of 4, the point he is trying to make, as "one of the toughest numbers in the world." The chart proves he is right. Two and 12 are the hardest sums to roll, since each can be made in only one way (probability 1/36), but neither 2 nor 12 can be a point. Three and 11 come next, with probabilities of 2/36, or 1/18, each, but 3 is a crap and 11 a natural and so neither of them can be a point either. The hardest points to make are "Little Joe" (4) and "Big Dick" (10). Since each can be made in three ways, the probability of throwing each is 3/36, or 1/12.

Some of the greatest mathematicians have gone astray in calculating dice odds. Leibniz thought 11 and 12 had equal probabilities because each could be made with only one combination of two dice; he failed to consider that 12 can be made in only one way, whereas 11 can be made with either die 6 and the other 5, making 11 twice as easy to throw as 12. The Greeks and Romans preferred games with three dice, and Plato, in his *Laws* (Book 12), cited 3 and 18 as the most difficult sums to roll with three dice. They are the only sums that can be made in only one way (1–1–1 and 6–6–6). Since there are 6 × 6 × 6, or 216, equally probable ways of rolling three dice, the probability of making a 3 is 1/216. The same holds for 18. That 3 and 18 were the two most difficult throws was well known to both the Greeks and the Romans. The Greeks called 6–6–6 "Aphrodite" and 1–1–1 "the dog," terms corresponding to our slang of "snake eyes" for 1–1 and "boxcars" for 6–6. There are many references to these and other dicing terms in Greek and Latin literature. The Roman emperor Claudius even wrote a book called *How to Win at Dice,* but unfortunately it did not survive.

Sucker bets are bets professional gamblers like to spring on marks because they can be made at odds that seem to favor the mark but actually do not. In craps, for instance, one might guess that it would be just as easy, if the point is 4, for the shooter to make it the "hard way" (by throwing identical faces on the dice, in this case 2–2) as to make 6 the hard way (3–3). Now, it is true that the probability of throwing any sum the hard way is 1/36, but the probability of making a point the hard way is altogether different. There are three ways to make 4. Only one (2–2) is the hard way. The shooter fails to make his point the hard way if he throws 3–1 or 1–3, or if he throws 7 before he makes 4. Since he can roll 7 in six different ways he has eight ways to lose and one to win, and so the odds are eight to one against making 4 the hard way. Put differently, his prob-

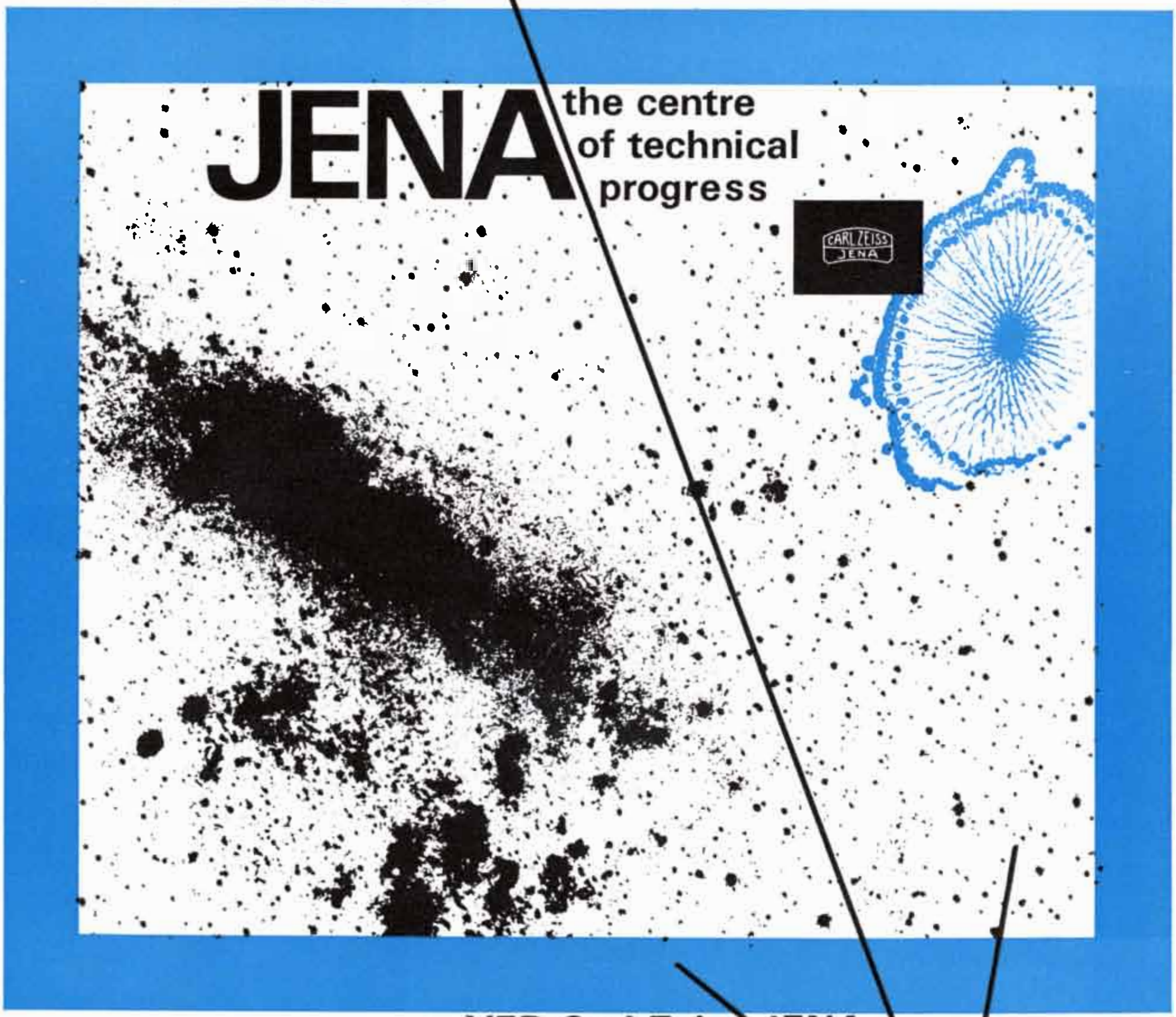
Ahead of time thanks to superior technology

The technical revolution of our age requires in all fields of engineering — from microcosmos to macrocosmos — that all problems of scientific research work be solved at a constantly accelerating pace. In pursuance of their tasks, scientists and engineers of our Works strive incessantly to open up new avenues in the development of precision instruments, which are always ahead of latest standards in science and engineering.

This knowledge, experience, and qualification is always at your disposal. Please submit your problems.

ZEISS

precision instruments of world renown



VEB Carl Zeiss JENA

German Democratic Republic

ability of doing it is 1/9. Now consider making 6 the hard way. There are five ways to roll 6. Only one is the hard way. The shooter can lose by throwing 6 in any of the other four ways or by throwing 7 in any of its six ways, making a total of 10 ways to lose and one to win. The odds against making 6 the hard way are therefore 10 to one and the probability goes down to 1/11.

One of the oldest and subtlest sucker bets goes like this: The hustler first bets even money that the mark will throw an 8 before he throws a 7. The mark, knowing that 7 is easier to make than 8, quickly accepts such bets, which he tends to win. The hustler then switches from 8 to 6, betting even money the mark will throw 6 before 7. Again the hustler tends to lose because 6, like 8, can be made in only five ways as against six ways for 7. Now comes the big swindle. The hustler, who is pretending to be an ignoramus about dice odds, decides to bet even money again, at much higher stakes, that the mark will make *both* 8 and 6 before he throws *two* 7's. This seems to be just as good a bet to the sucker as before; actually the odds now make a surprising shift to favor the hustler. If he had specified the order of the two numbers, first a 6 or first an 8, the odds would have been against him as before. But because the shooter can roll either sum first, it turns out that the hustler has a probability of 4,225/7,744—a bit better than 1/2—of winning.

Here are three easy dice puzzles. The solutions will be given next month:

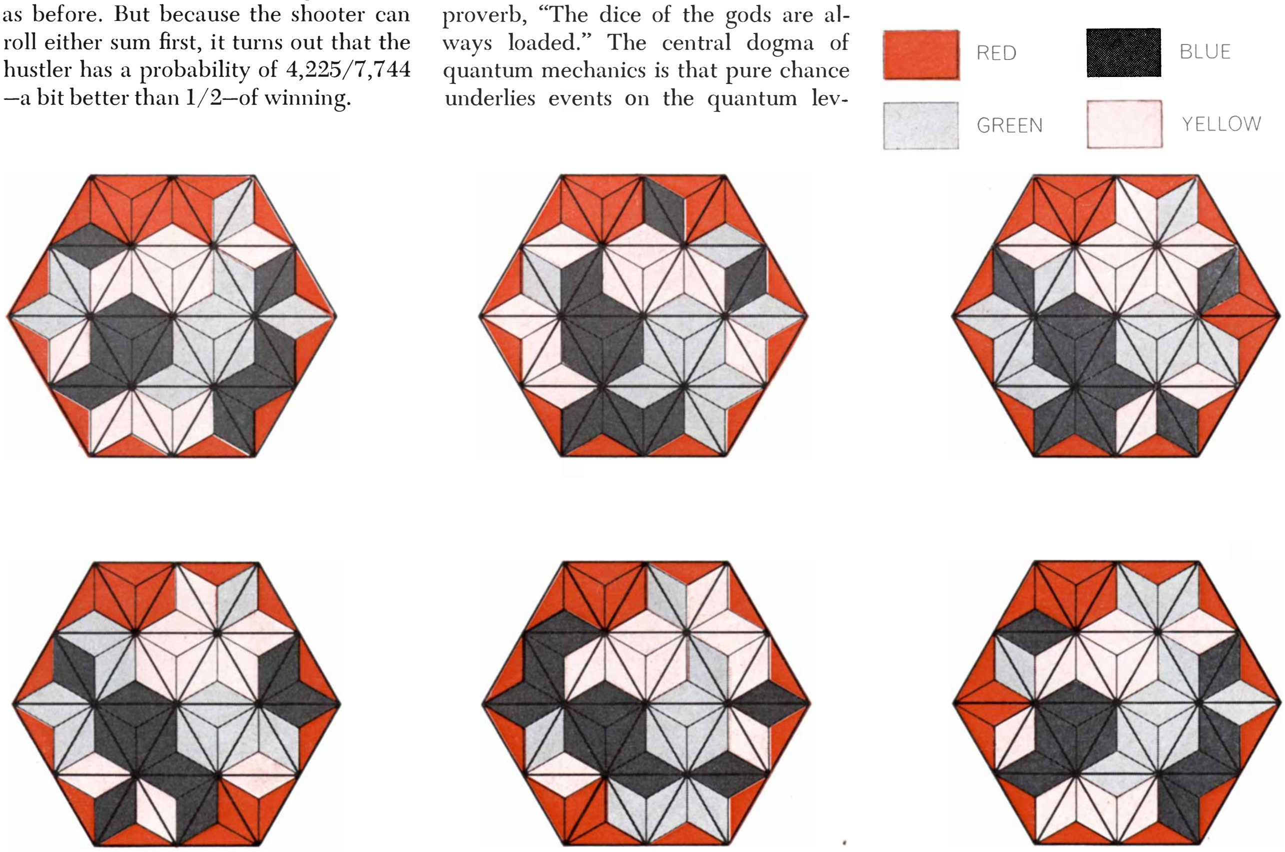
1. A magician turns his back and asks someone to roll three standard dice and add the top faces. The spectator then picks up any die and adds its bottom number to that total. The same die is rolled again and its top number is added to the previous total. The magician turns around for the first time to glance at the dice. Although he has no way of knowing which cube was picked for the extra roll, he is able to state the final total correctly. How does he do it?

2. The same mis-spotted die is shown in three views on page 142. How many spots are opposite the 6? (The problem is from an unpublished manuscript of original puzzles by Aaron J. Friedland, a mathematician with Atomic Power Development Associates, Inc., in Detroit.)

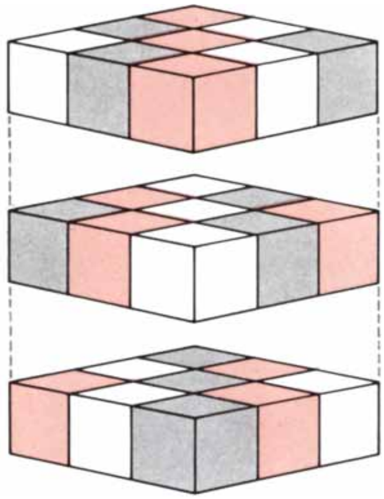
3. How can two cubes be labeled, each side bearing a number from 1 through 6 or left blank, to make a pair of dice that will throw with equal probability each sum from 1 through 12?

The use of the die as a randomizer has made it a popular literary symbol for chance. We are all familiar with such expressions as "The die is cast" (said to have been uttered by Julius Caesar after he had made his decision to cross the Rubicon), and the ancient Greeks had a proverb, "The dice of the gods are always loaded." The central dogma of quantum mechanics is that pure chance underlies events on the quantum level; in Einstein's well-known metaphor, quantum mechanics implies that God dices with the universe. It is sometimes argued that even though this may be true on the quantum level, on the macrolevel of human history strictly deterministic laws must still hold. A simple thought experiment provides a dramatic counterexample. Imagine an artificial satellite carrying a hydrogen bomb. The bomb's release is triggered by a Geiger counter click recording the emission of an electron in radioactive decay. If the timing of such a click is pure chance, as quantum theory demands, then pure chance decides which portion of the earth is demolished. Thus we could, in actual practice, make an instant leap from pure chance in the quantum microworld to a major alteration of macroworld history, a thought most disturbing to philosophical determinists.

The view that God dices with human history found a grimly amusing literary expression this year in Robert Coover's peculiar novel, *The Universal Baseball Association, Inc., J. Henry Waugh, Prop.* J. Henry Waugh, whose name suggests Jehovah, is a lonely accountant who lives over a delicatessen. To amuse himself he invents a way of playing imaginary baseball by rolling three dice, as-



Six solutions to last month's hexagon problem

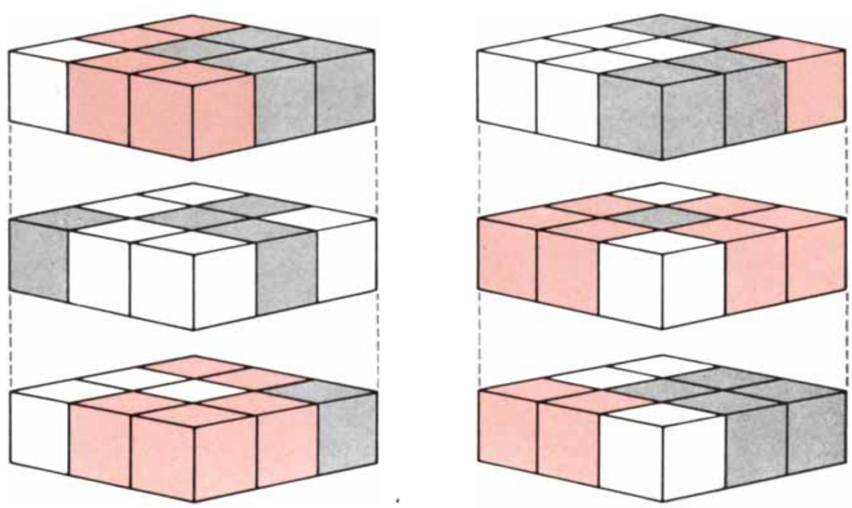


Solution to first cube problem

signing certain events to each of the 56 combinations and various sequences of combinations. (Originally he based his games on the 216 ways three dice can fall, using dice of three different colors, but after almost going blind trying to sort out the colors on every throw he shifted to three white dice, considering only their combinations.) Over the months Waugh begins to imagine actual personalities playing on his team until, like so many great characters of fiction —Don Quixote, D'Artagnan, Sherlock Holmes—the players inside Waugh's skull take on a life of their own to the point where they become, in a sense, more real and permanent than Waugh himself. They even begin to wonder if Waugh exists.

One thinks of Pirandello's play *Six Characters in Search of an Author* and Unamuno's earlier novel *Niebla* (*Mist*), in which the protagonist visits the author to protest the author's decision to have him die at the close of the novel, and to remind Unamuno that he too may be only a misty, impermanent dream in the mind of some inconceivably vast roller of the devil's bones.

The answers to the problems presented last month are given on page 144 and on this page. The illustration on page 144 shows one way of forming the hexagon with the 24 color triangles for each of the six possible varieties of one-color border, with the added proviso that the three solid-color triangles be placed symmetrically around the center in the manner shown. It is not known how many solutions there are for each of these six types. The illustration at the left gives the unique solution (not counting rotations, reflections or permutations of colors as different) for forming a $3 \times 3 \times 3$ cube with 27 unit cubes, nine of each of three colors, so that each of the 27 orthogonal rows contains a cube of each color. The solution was published by Charles W. Trigg in *Mathematics Magazine* for January, 1966. The illustration below gives for the first time in print the only two ways, both found by John Horton Conway of Sidney Sussex College at the University of Cambridge, of arranging the same set of 27 cubes into a $3 \times 3 \times 3$ cube so that each of its 49 straight rows of three (orthogonal and diagonal, including the cube's four diagonals connecting opposite corners) contains neither three cubes of the same color nor three cubes of three different colors.



Two solutions to the second cube problem

What helped the Queen Elizabeth 2 take the plunge like a lady? An ICL 1903 computer cutting out slips on the slipway

With the precise control the computer gives—for example, it can forecast in seconds the effects of a delay in any activity—the Upper Clyde Shipbuilding Management are able to keep the most complicated job right on schedule. For example, there were 2,500 activities on the computer network plan (ICL PERT) for installing the engines of the QE 2, Britain's new super-liner. For the hull, and ship's fittings, there were over 11,000.

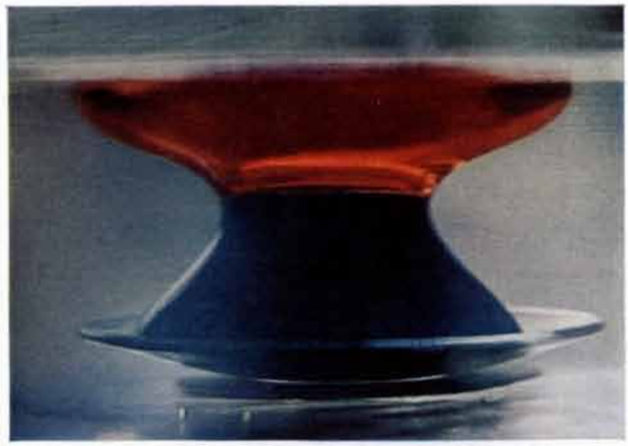
In addition to work of this kind, the computer deals with management accounting; large scale purchasing and invoicing; and mathematical and scientific work. When it comes to efficiency, the Men of the Clyde mean never to miss the boat.

ICL computers go with success

ICL

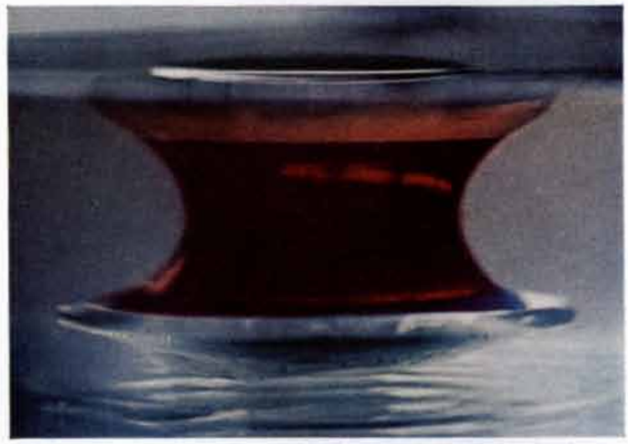
International Computers Limited
ICL House, Putney
London S.W.15 England

Double lens made by Aristid V. Grosse

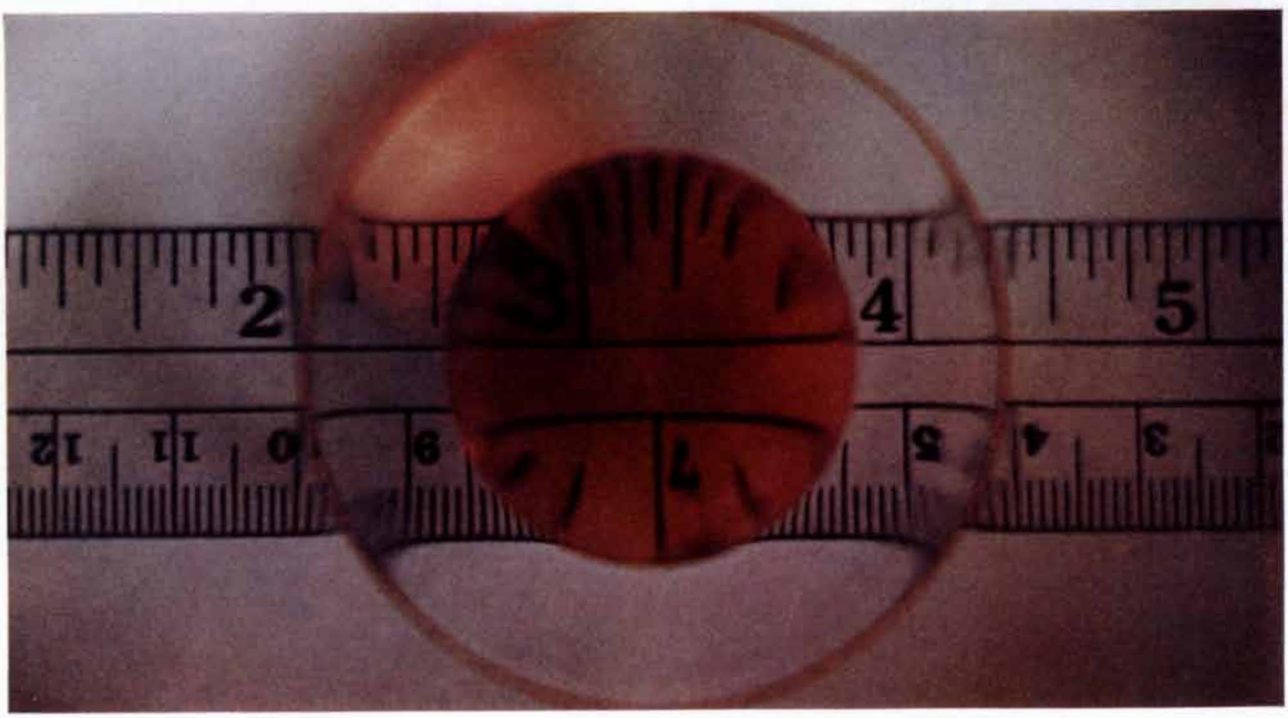


Pillar made of two immiscible liquids

A weightless lens



A three-component pillar



Optical properties of a double lens

THE AMATEUR SCIENTIST

Experiments with various liquids that do not mix

Conducted by C. L. Stong

A number of interesting structures can be made by combining liquids that differ in density and surface tension. An amusing example is the parlor trick in which cream is made to float on the surface of hot coffee. A teaspoon is lowered horizontally into the coffee until the edge of the spoon is even with the surface of the coffee. Cream is poured into the spoon so that it overflows. The cream floats on the coffee.

When a naïve onlooker attempts to duplicate the trick, the cream sinks. It should. Cool cream is denser than hot coffee, meaning that it weighs more per unit volume. The dinner-table performer takes this fact into account before doing the trick and stealthily mixes three spoonfuls of sugar into the coffee, thus making the coffee denser than the cream.

Altering the surface tension of a liquid can also lead to interesting effects. Surface tension arises from attraction between the molecules of a liquid and explains in part why some liquids refuse to mix with others. For example, molecules of mercury are so strongly attracted to one another that they literally squeeze out molecules of water or other substances that do not readily mix with mercury.

A particularly fascinating effect that accompanies a change in surface tension can be demonstrated with an iron nail and a small pool of mercury that is immersed in an electrolyte. The mercury is placed in a shallow container with a spherical bottom, such as a large watch glass, and flooded with about 30 milliliters of tap water. To the water is added four drops of sulfuric acid and about three milligrams of potassium dichromate. (A dozen particles of potassium dichromate about the size of sugar granules approximate this weight.)

A clean iron nail, free of rust, is placed in the solution with the point directed toward the center of the container and the head of the nail overhanging the edge [*see illustration on next page*]. Push the nail slowly toward the center of the watch glass until the point makes contact with the mercury. The mercury will immediately dart away from the nail, return, make contact and repeat the performance again and again. Depending on the amount of mercury and the position of the nail, the oscillation will assume an ever changing pattern of amoeba-like forms.

If the pool contains 40 grams of mercury, the nail can be shifted by trial and error into a position at which the mercury oscillates as a standing wave with three crests and three valleys, as illustrated. The action will continue for half an hour or longer, until most of the potassium dichromate combines chemically with the mercury. The apparatus functions as a voltaic cell in which the mercury and the iron serve as electrodes. Current generated by the cell periodically alters the intermolecular attraction of the mercury that accounts for its surface tension. The variations, which are in effect pulses of force, induce the vibration.

The behavior of liquids that float on or within other liquids without much mixing has in recent years attracted the interest of Aristid V. Grosse, president of the Research Institute of Temple University. Grosse and his associates specialize in research at high temperatures. In the course of this work the need arose for a container that could be heated above the melting point of any known substance. Ultimately they devised one: a crucible made of liquid! The furnace that heats the crucible consists essentially of a horizontal, rotating cylinder of metallic oxide exposed on the inside to a plasma jet that develops a temperature close to 30,000 degrees Fahrenheit. The inner surface of the oxide melts; the resulting fluid is held against the rotating shell of solid oxide by centrifugal force. The liquid metal of interest floats on the molten oxide without mixing. (Carbides, nitrides and other metallic compounds can also be used.)

"In the course of these experiments," Grosse writes, "it became apparent that many facts about immiscible or partly miscible liquids had never been investigated. Since experimentation is much easier at room temperature than at high temperature, I decided to study the behavior of a liquid lens of gallium floating on mercury—the simplest case of two immiscible metals that can exist in the liquid phase at room temperature. Gallium is a rare and costly metal, however, a fact that seriously restricted the scope of the experiments.

"For this reason it became apparent that the investigation could be extended only by substituting selected organic and inorganic liquids for the metals. Experiment soon demonstrated that such substances worked nicely—so nicely that I found myself tinkering with them at home. Thus was born my new hobby: making liquid structures. The structures include double lenses, triple lenses and poly-lenses that float on and in water; 'weightless' lenses and other forms that I suspend between solutions, and multiple-layered pillars that stand in liquid. It is also possible to make such structures as enclosures and walls.

"The variety of structures that can be made appears to be limitless. Some combinations behave in strange and unexpected ways. The forces that bind the liquids together still await thorough investigation. Here, then, is a hobby full of opportunity, one I am delighted to share with amateurs.

"In making the structures I use clear glass dishes of various sizes, including beakers, graduated cylinders and tubes. To prevent evaporation all the containers can be closed, preferably by ground-glass covers or ground-glass stoppers. Lipless beakers and crystallizing dishes with covers are ideal. The various liquids are added to the containers by means of pipettes or, in some cases, by disposable hypodermic syringes with a capacity of two to 10 cubic centimeters.

"For preparing solutions I prefer freshly distilled water. Tap water usually contains air that in time comes out of solution and is deposited on the walls of the container as small bubbles. The bubbles obscure the contents of the container. Moreover, when they break free and rise, they set up currents that may disturb the structures. In addition, tap water may contain dissolved substances that react chemically with the liquids. When tap water is used, it should first be boiled and cooled to drive out dissolved gases.

"Some of the chemicals I have used are listed in the accompanying table [*page 155*], together with their density (at room temperature), surface tension and normal boiling point. In general these materials are available from distributors of chemicals, such as the Fisher Scientific Company, Springfield, N.J. 07081. Exceptions include n-cetane, which can be obtained from the Phillips Petroleum Company; silicone oil, from the General Electric Company, Silicone Products Department; fluorocarbon wetting agent FC-128 and other fluorocarbon preparations, from the 3M Company; Freon materials and oil-soluble dyes, from E. I. du Pont de Nemours and Company. The materials are listed in order of increasing density. Those at the top of the list will float on those below and, in general, will not mix appreciably with near neighbors.

"Experiments need not be confined to the listed substances. Many readily available liquids can be used. The density of ordinary paraffin oil, for example, is approximately .9. Hence it floats on water, which has a density of about 1 at room temperature.

"Paraffin oil mixes with carbon tetrachloride, which has a density of approximately 1.6. A solution of paraffin with a density equal to that of water can be made by adding six parts (by volume) of paraffin oil to one part of carbon tetrachloride. The solution can be made slightly denser than water by increasing the proportion of carbon tetrachloride.

"Similarly, the density of water can be increased by making a solution of table salt. Moreover, a solution that increases gradually in density with depth can be made by partially filling a container with warm water and slowly adding cold brine at the bottom through a slender tube that touches the bottom of the container. The brine will diffuse upward, although a uniform concentration would not be attained for years if the solution were undisturbed. In a brine solution drops of immiscible fluids that are slightly denser than water—for example the mixture of mineral oil and carbon tetrachloride—will descend to the depth that approximates their own density. There they will come to rest as free-floating bodies.

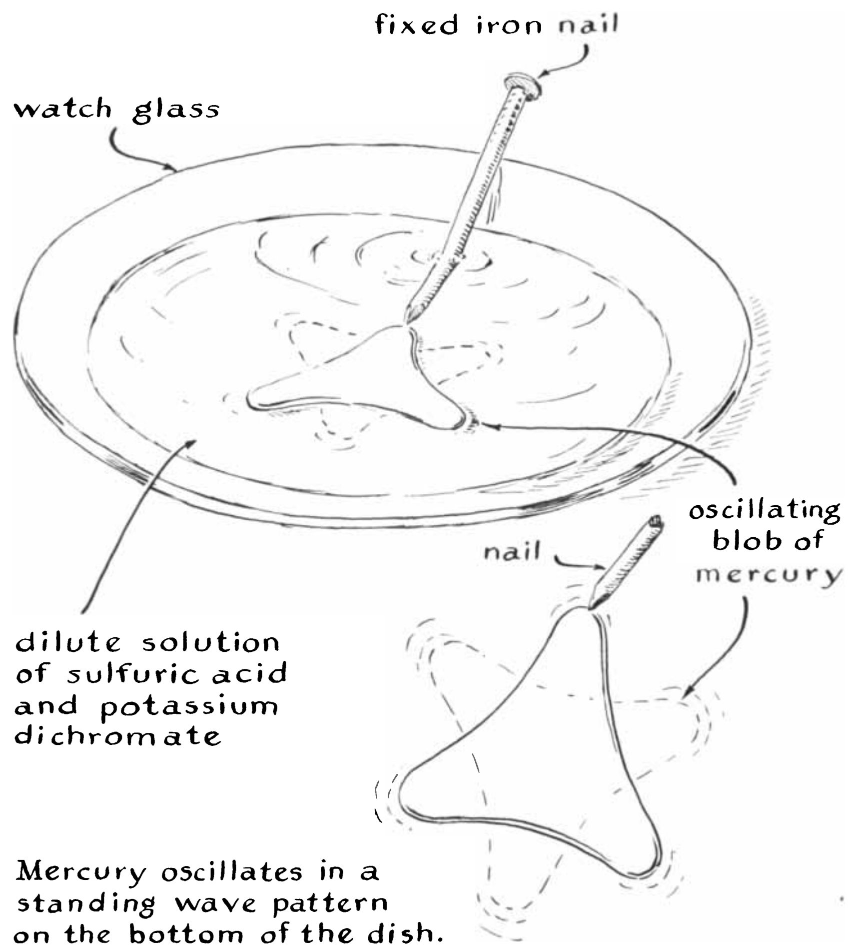
"The case of a single lens on water, such as a floating drop of oil, has been intensively investigated, but I have found no reference in the literature to the study of double lenses or poly-lenses. They are systems of lenses denser than water that are supported by adhesion to one or more buoyant lenses at or near the surface. A simple pair is easy to construct by the following steps.

"Add a lens of paraffin oil to a container of water by placing the tip of an oil-filled pipette in contact with the surface near the center of the container and letting the oil flow into a patch about four centimeters in diameter. Add to the water three or four drops of wetting agent (Kodak Photo-Flow 200). With a clean pipette apply o-toluidine to the center of the paraffin oil. The o-toluidine will migrate through the oil lens and form a suspended meniscus that adheres to the lower surface of the paraffin oil. The optical properties of the combination (acting as a lens) can be judged by the accompanying photograph [*bottom of page 148*].

"A triple lens can be formed by substituting two milliliters of silicone oil for paraffin oil. To the solution add three drops of a 2 percent (by weight) aqueous solution of FC-128 wetting agent. One milliliter of o-toluidine is added to the bottom of the silicone. The third lens is then made by allowing a few drops of Freon E-5 to migrate through the assembly and form a crescent on the bottom surface of the o-toluidine. If desired, the Freon can be colored blue by mixing in a small quantity of fluorocarbon dye, Type L-1802, which is obtainable from the 3M Company.

"A quadruple lens is built up by a similar procedure. First a double lens is made with two milliliters of paraffin oil and 1.5 milliliters of silicone oil, after adding 10 drops of FC-128 wetting agent to the water. The third lens consists of .8 milliliter of o-toluidine. I stained this lens pink so that its boundaries could be examined easily. The fourth lens was made of .15 milliliter of Freon E-5 dyed blue [*see top illustration on opposite page*].

"The quadruple lens is a perfectly stable structure. It has eight interfaces: air-oil, water-oil, oil-silicone, water-sili-



Oscillations resulting from changes in surface tension cone, water-o-toluidine, silicone-o-toluidine, Freon-o-toluidine and Freon-water. It also has four triple-interface lines: air-water-oil, water-oil-silicone, water-silicone-o-toluidine and water-o-toluidine-Freon.

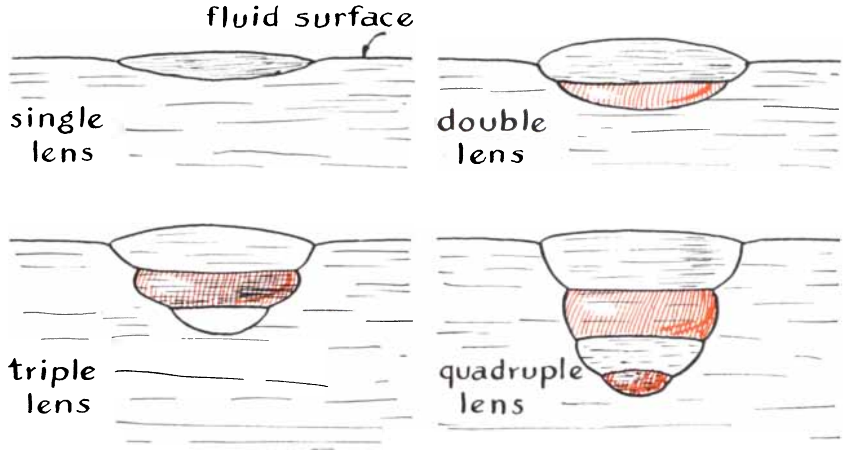
"The first quadruple lens I made did not last long. The o-toluidine dissolved slowly in the water and disappeared after a few days. I learned to prevent this by first saturating the water with o-toluidine. In some experiments it may be desirable to saturate the water with all the substances used for making lenses. Each lens material can also be saturated with the compounds that border it. To saturate a liquid merely add to it an equal amount of the saturating liquid, shake the mixture, let it stand for a few hours and pour off the supernatant.

"The quadruple lens just described is by no means the highest possible number of lenses that can form a stable structure. The problem of the maximum possible number of lenses is closely related to the problem of the maximum number of insoluble liquids that can be poured one on top of another. The problem has fascinated chemists since the Middle Ages.

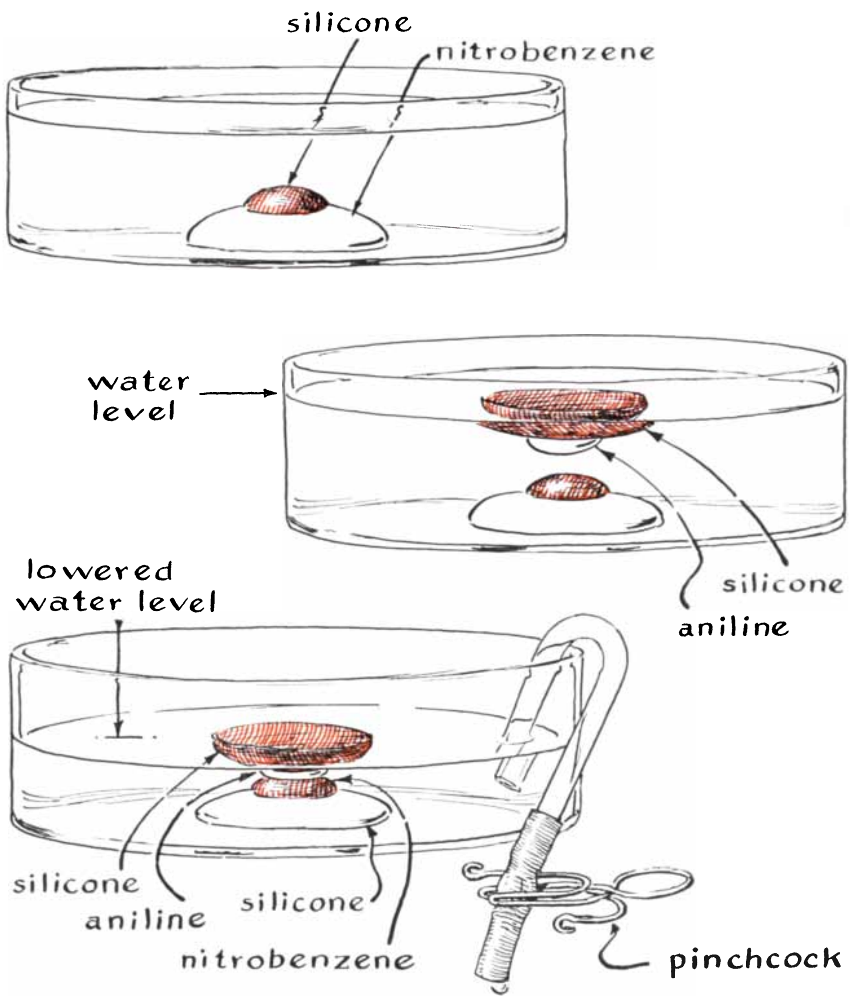
"Joel H. Hildebrand, an American pioneer in the study of liquids, first demonstrated that as many as seven immiscible liquids can be deposited as layers in a cylindrical container. In the order of increasing density they are heptane, aniline, water, perfluorokerosene, phosphorus, gallium and mercury. If these layers are completely mixed by being shaken, they will re-form.

"It is also possible to make a system of nine layers in which all adjacent layers are immiscible even though some layers remote from one another are miscible. The substances are, in order of increasing density, paraffin oil, silicone oil, water, carbon disulfide, n-perfluoroheptane, a 62.5 percent solution (by weight) of zinc chloride, tri-n-perfluorobutylamine, liquid gallium and mercury. If a container holding such a system is shaken, the zinc chloride solution mixes with the water and the two fluorocarbon layers combine. The combinations reduce the system to the same number of layers Hildebrand devised.

"The addition of liquid phosphorus from Hildebrand's system would not increase the number of layers because the phosphorus can be mixed with carbon disulfide. This is not to say that Hildebrand's system of immiscible layers cannot be increased. I have devised a system of 13 layers that have been tested in two sections but have not yet been combined into a single column. The liquids, again in order of increasing density, are paraffin oil, silicone oil, o-toluidine, a 2 percent solution (by weight) of common salt, carbon disulfide, n-perfluoroheptane, a 64.5 percent solution (by weight) of zinc chloride, liquid phosphorus, tri-n-perfluorobutylamine, 100 percent phosphoric acid, lead tetramethyl, liquid gallium and mercury. This list is by no means the ultimate. Compounds could be synthesized that, when sandwiched between two adjoining layers, would not be miscible with them. For example, liquid heavy-metal perfluoroalkyls would be denser than the corresponding metal alkyls and would not be



Four kinds of liquid lens



Steps in making a four-layer liquid pillar miscible with them or with liquid gallium. Hence they would fit between layers 11 and 12 on the list.

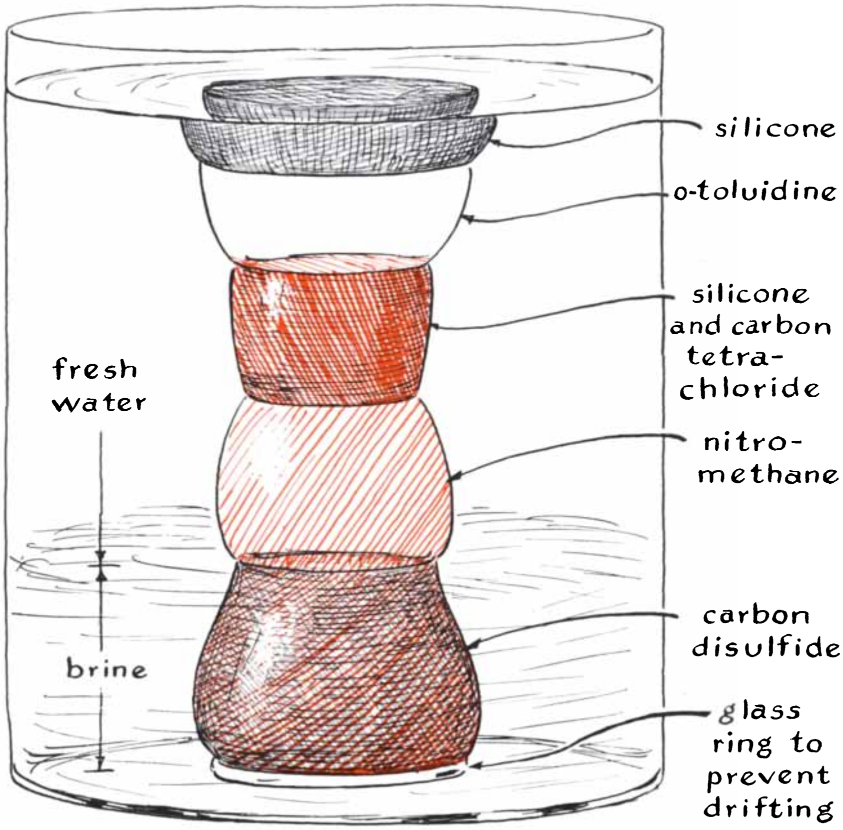
"It is obvious that in addition to suspended poly-lenses it should be possible to stack lenses upward from the bottom of a container. I call such structures 're-verse' lenses. A simple reverse double lens can be made by first placing 200 milliliters of water containing 2 percent of a 2 percent solution (by weight) of FC-128 wetting agent in a circular crystallization dish 9.7 centimeters in diameter, with a flat bottom and straight sides. A ring of thin aluminum wire is then centered on the bottom of the dish to serve as an anchor that prevents the lens from drifting. By means of a pipette aniline is deposited in the center of the aluminum ring. It forms a beautiful reverse lens 1.25 centimeters in diameter.

"A second lens, of silicone oil, is deposited on top of the aniline. The density of silicone oil is less than that of water. For this reason it tends to lift the aniline lens and to decrease its radius. Aniline has a solubility in water at 20 degrees centigrade of about 3.4 grams per 100 milliliters of solution. As the aniline dissolves, the lens shrinks in diameter. After 24 hours the aniline lens matches the diameter of the silicone lens.

"The area of contact continues to shrink, and at a critical moment the silicone lens pulls the aniline lens upward and rises with it to the surface. One can then see the saturated aniline solution stream downward as a diffraction pattern that resembles in reverse action the 'heat' that rises from a steam radiator. In a few hours the aniline portion of the lens vanishes.

"Having made a number of poly-lenses and their reverse counterparts, it occurred to me that it should be possible to combine them to form a layered pillar that would be self-supporting. To devise a structure of this type I first made a reverse double lens with one milliliter of nitrobenzene and .4 milliliter of silicone oil in 200 milliliters of water containing FC-128 wetting agent, as in the experiment just described. The container was a crystallizing dish 9.7 centimeters in diameter. A double lens was added at the top with one milliliter of the same silicone oil and .4 milliliter of aniline, added by the drop inside the oil with a hypodermic syringe. Two double lenses were then facing each other [*see bottom illustration on preceding page*].

"A thin glass rod was used to push the upper lenses until they were centered directly above the reverse lenses. Finally, the upper lenses were lowered into contact with the reverse lenses by



A five-layer pillar of immiscible liquids

For the engineer: The best of two worlds.

Tacking along a windward shore or tackling a complex system analysis – both offer challenge to the creative man whose life and work must satisfy exciting demands.

If this is the life you are looking for, we can offer such a rounded environment: Challenging job. Right location. The best of two worlds.

As our name suggests, our business is electronic systems: total integrated packages for sea, ground, air and space applications – perform the toughest defense missions of the day.

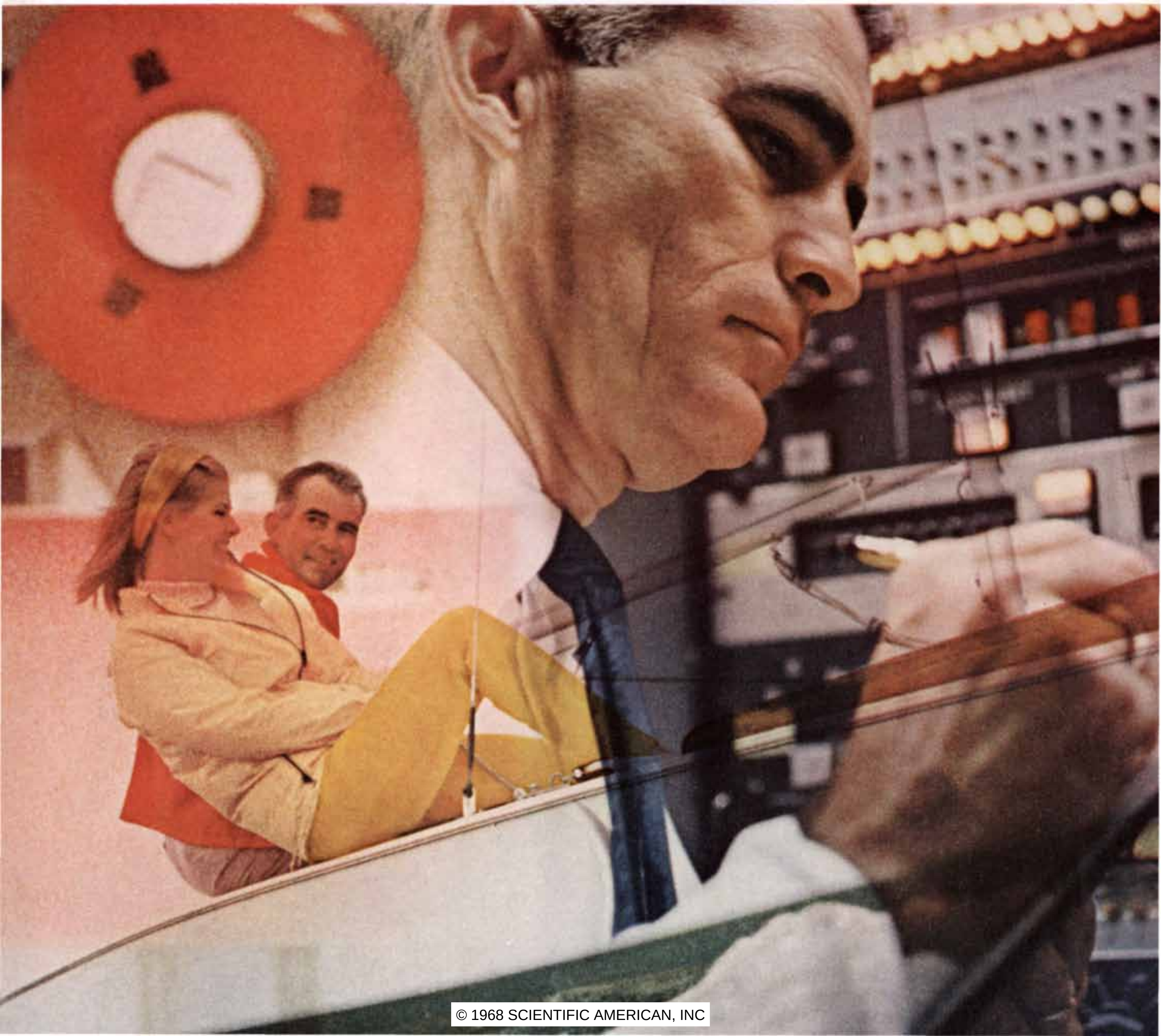
In addition to the Defense Department, our customers include other government agencies, leading aerospace and electronics contractors and many foreign governments.

We serve these exacting customers well. Look at our sales and earnings growth. In 1966, sales were just over $123 million, after-tax earnings were $2.6 million plus. Last year, sales surpassed $181 million and earnings grew to $5.3 million. At present, we have one of the largest backlogs in company history.

To sustain this rate of growth, we need the best specialists we can find – who seek to combine the best of two worlds and grow with us. Our programs range from undersea intelligence studies to electronic warfare to re-entry physics. We have opportunities for specialists in research, design, development, production and management.

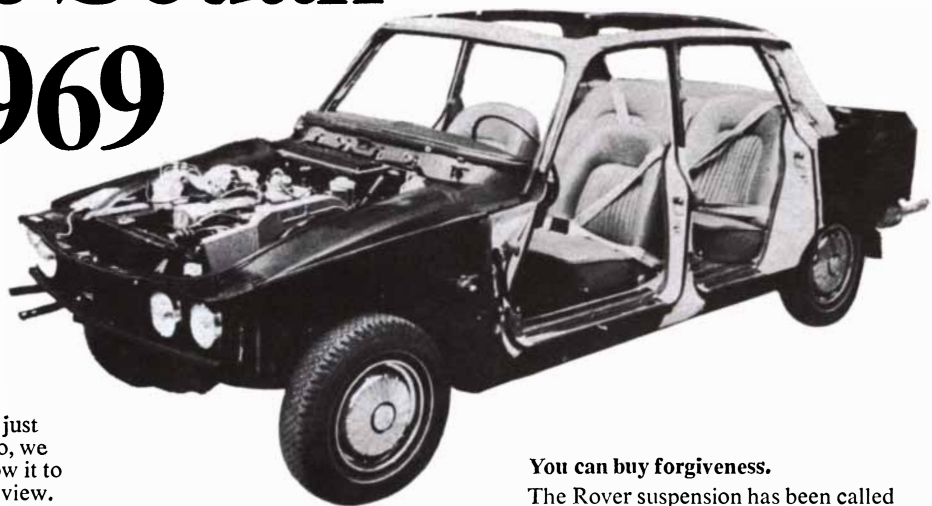
For more information on the exceptional career challenges please write: Bill Hickey, Supervisor of Professional Placement, P.O. Box 6118, Dallas, Texas 75222. An equal opportunity employer.

LTV ELECTROSYSTEMS, INC.
A SUBSIDIARY OF LING-TEMCO-VOUGHT, INC



Revealing the Rover 2000 Sports Sedan for 1969

(only $4,198 complete)



Caught with its panels down.

The Rover 2000 for 1969 looks just like the Rover 2000 for 1968. So, we thought it might be fitting to show it to you in its birthday suit. A fresh view.

To snap this photo, we had to divest the car of nineteen bolted-on steel and aluminum skin panels. We say skin instead of *body* panels because that is exactly what they are. Fenders, door panels, hood and trunk lids, roof covering and so forth, are simply a sleek, metal sheath covering the real structure of the car.

Contrary to the usual practice (in which body and chassis are constructed separately and later joined together) the Rover 2000 is built as a single rigid unit. The concept is much like that of a modern office building whose walls carry none of the load, but serve instead merely to keep out wind and weather, to provide privacy and a reasonably decorative exterior.

Keep the car and leave the fender.

Anytime some reckless stranger crumples the fender of your Rover 2000, the whole car doesn't have to go into dry-dock for repairs. The mechanic simply unbolts the offended fender and off you go with a perfectly roadworthy if slightly out-of-uniform automobile.

The real virtue of showing the Rover 2000 defrocked, as it were, is that it makes crystal clear one of the main reasons why this car might someday save your life. Not just your life, but those of three passengers as well. That rigid steel girder construction does a bang-up job of protecting the car's occupants in the event of collision.

It is difficult to avoid the subject of safety in discussing any part of this automobile. Every aspect of its design has as its primary or secondary purpose either the prevention of accidents or else preserving life and limb should an accident prove unavoidable. Even the ash-trays are designed to be windproof in the hopes of keeping a stray cinder from flying into the driver's eye.

The Rover 2000 for 1966, 1967, 1968...

The Rover Road to Romance.

The Rover 2000 (which, by the way, comes in two incarnations—TC and Automatic) is a rather thinly disguised sports car. Its official designation as a Sports *Sedan* is due solely to the fact that it boasts two more doors and two more bucket seats than the average sportster. In every other respect—steering, suspension, braking, acceleration, roadworthiness, you name it—the Rover 2000 is calculated to gladden the heart of the enthusiast.

You can buy forgiveness.

The Rover suspension has been called the most "sophisticated" in the world. Radial ply tires and Girling disc brakes are standard equipment on all four wheels. Overall handling qualities are unsurpassed by almost any car at any price. The oddly appropriate technical term for this is forgiving—which means that when road or weather conditions are slightly less than perfect but you misjudge them and unwittingly drive as though they were, the car "forgives" you and handles properly anyway.

Status can't be bought.

It has been suggested that we missed a bet by making the Rover 2000 neither spectacularly beautiful nor spectacularly ugly. We've been told that people who regard automobiles as their principal mark of status in this world are apt to seek out more exotic-looking machines and even willingly endure the perpetual mechanical ailments such machines may be heir to. We chose to produce a car that is as unassuming, unselfconscious, and anonymous-looking as money and sound engineering could possibly make it. As a result, the Rover owner doesn't buy his car to impress others, but to satisfy himself. He hasn't the least bit of patience with exotic or even plain mechanical troubles—and that is okay with us.

If it's okay with you, too, why not amble over to your Rover dealer and insist on a test drive? You'll find the dealer very amenable and the car itself is ditto.

the Rover 2000

Imported by Leyland Motor Corporation of North America, 111 Galway Place, Teaneck, New Jersey 07666 slowly draining water from the container through a siphon fitted with a pinchcock. The resulting structure, which was held together entirely by the forces of surface tension, measured about 2.5 centimeters in height. In the course of a few hours the aniline lens decreased in size because of its solubility.

"The force per unit area that tended to pull the structure apart finally exceeded the effective surface tension and the pillar separated. Then the aniline dissolved completely, leaving only the upper silicone lens. The reverse lens remained intact because the solubility of nitrobenzene in water is only .19 gram per milliliter in water at 20 degrees C.

"The tallest liquid pillar I have made so far consists of five layers with a total height of eight centimeters. The structure was self-supporting. It was assembled in a beaker of two-liter capacity and required about two days of patient work.

"The bottom layer, which consists of carbon disulfide, was deposited in a thin ring of glass to prevent drifting and was surrounded by an 18 percent (by weight) solution of table salt to increase the buoyancy of the carbon disulfide. At the time of the experiment I had no access to a silicone oil of a density intermediate between that of o-toluidine (.999) and nitromethane (1.130). Hence I increased the density of the then available silicone oil by adding carbon tetrachloride in the amount of 17 percent (by volume).

"The five-layered pillar lasted many hours. It was, however, inherently unstable because the carbon tetrachloride in the middle layer dissolved slowly in both adjacent layers, with an unexpected effect on surface tension at its boundary. A small 'tongue' of o-toluidine periodically moved down from the center into the silicone, in what can be most clearly described as a 'licking' motion. The amplitude of the motion increased in the course of a few hours. Eventually a cylinder of o-toluidine formed completely around the silicone, which then assumed the form of a beautiful hyperboloid that lasted for about an hour. In time the hyperboloid separated at the waist. The silicone drifted upward, breaking the pillar, and joined the other silicone lens at the surface.

"Multiple-liquid lenses can also be formed at the plane boundary between two liquids. One of many possible examples can be prepared by first pouring cetane and perfluoroheptane into a container five centimeters deep. These liquids separate into two clear, immiscible layers each two centimeters thick. At the boundary insert by pipette one milliliter of o-toluidine. The liquid promptly spreads between the layers to form a classical lens.

"With a hypodermic syringe inject by the drop, at the lower boundary of the o-toluidine, .5 milliliter of water stained deep red with a water-soluble dye. A dozen or more independent droplets should be thus attached to the bottom of the o-toluidine lens. After some hours the drops will coalesce to form the second lens.

"The double lens is merely a special case of what I call 'weightless' structures: systems of liquids suspended between layers of liquids that differ in density, or within a single layer of variable density as represented by the saline solution previously described. To make a colorful triple lens of this type, insert 400 milliliters of cold brine solution below 600 milliliters of warm distilled water in a tall container, such as a one-liter beaker. Put one or more large drops of o-toluidine, dyed pink, in the water. The drops tend to float to the surface. To each drop add with a hypodermic syringe a few small drops of Du Pont E-4 Freon stained blue with fluorocarbon dye. The slightly heavier lens so formed will sink into the zone of diffusion between the salt water and the fresh water.

"The triple weightless lens is now completed by injecting (with a clean hypodermic syringe) colorless silicone oil into the o-toluidine. The buoyancy of the oil causes the third lens to form as a cap on top of the assembly. The triple lens will seek that depth in the zone of diffusion at which the density of the brine equals the average density of the components in the triple lens. By adding silicone or Freon as desired the lens can be adjusted so that it will come to rest at any given depth in the zone of diffusion and will remain there for hours.

"The thickness of the zone of diffusion can be increased by stirring the brine gently and letting the solution come to rest. Spheres in a range of sizes, densities and colors, when injected into the solution, come to rest at various depths and can serve as attractive, although only roughly approximate, models of planets and other astronomical objects in space. It is interesting to speculate on how structures of this type would behave under the weightless conditions of outer space.

"What good are poly-lenses? Aside from their value as entertainment and the beautiful opportunity they provide for investigating surface phenomena, it turns out that single liquid lenses are excellent devices for concentrating solvent-insoluble impurities. For example, an o-toluidine lens with a volume of two cubic centimeters was allowed to shrink in water at room temperature to a sphere one millimeter in diameter—a volume of .0005 cubic centimeter. The concentration of the impurities was thus increased by a factor of 4,000!

"Some of the materials used in these experiments are toxic and must be handled accordingly. Work in a well-ventilated room. Wash your hands frequently with soap in running water and at all times keep them away from your mouth and eyes."

MATERIAL	DENSITY (GRAMS PER CUBIC CENTIMETER)	SURFACE TENSION (DYNES PER CENTIMETER)	BOILING POINT (DEGREES CENTIGRADE)
N-CETANE	.775	26.3	280
BENZENE	.8787	28.88	80.07
PARAFFIN OIL	.8849	31.12	HIGH
SILICONE SF-97 (100) (GENERAL ELECTRIC CO.)	.9625*	20.9*	HIGH
WATER	.9982	72.75	100
O-TOLUIDINE	.9989		199.8
N-PERFLUOROHEPTANE	1.7332	13.6	82.43
FREON E-5 (DU PONT)	1.792*	15.9*	226
FLUOROCARBON FC-75 (3M COMPANY)	1.8		100≃
TRI-N-PERFLUOROBUTYLAMINE	1.856		177.2

* AT 25 DEGREES CENTIGRADE

Properties (at 20 degrees centigrade) of liquids used in the experiments


Where do we go from here?
Snarled freeways. Foul air. Polluted water. Crime in the streets. Soaring medical costs. Overcrowded, understaffed hospitals.
Solving top priority national problems is a TRW specialty.
For over a decade, our balanced blend of systems engineering services and technological skills have been used on America's major space and defense programs. Now we are successfully applying this experience to a variety of Civil Systems problems.
Before a shovel was turned, we saved the Province of Alberta more than $6 million in planning its new $100 million Edmonton Health Sciences Centre. We are working with the Department of Transportation on high speed ground transportation systems for use between Boston and Washington. For California we have developed a statewide land use information system. Our seasoned systems engineers are also working on automobile inspection, public safety, urban re-development, banking, water resources planning and flood plain management programs.
For more information about TRW Civil Systems capabilities, contact Marketing Services, TRW Systems Group, One Space Park, Redondo Beach, California 90278.
TRW®
TRW Systems Group is a major operating unit of TRW INC. (Formerly Thompson Ramo Wooldridge Inc.), where 75,000 people at over 200 locations around the world are applying advanced technology to electronics, space, defense, automotive, aircraft, and selected commercial and industrial markets.

BOOKS

National science policy and the new "science of science"

by Amos de-Shalit

CIBA FOUNDATION SYMPOSIUM: DECISION MAKING IN NATIONAL SCIENCE POLICY. Little, Brown and Company ($12).

The increasing demands on funds for scientific and technological research have naturally led to an increasing interest in the methodology of establishing a "science policy." The proceedings of the Ciba Foundation Symposium *Decision Making in National Science Policy* are testimony to the liveliness of the effort to find a path through this maze of social, economic, scientific and technological problems. They vividly demonstrate the chaos that characterizes the initial stages of an intellectual movement, in this case the creation of a "science of science."

Several factors contribute to the yearnings for a science of science. In several of the more developed countries the rate of increase in the allocation of funds to research and development since the end of World War II has been higher than that in any other single field of human activity. In the developing countries a mythology has evolved that endows science with a legendary ability to provide easy solutions to the most pressing (and often the most depressing) problems. In both the developed and the developing countries the legislative and executive branches of government are composed largely of people with little understanding of science; many of these individuals have a scarcely concealed phobia about science that doubtless dates back to their high school days. It is against this background that the need for national science policies has arisen. The science of science is an effort to tackle the problem rationally.

The science of science is clearly still in its infancy. Even its first toddling step is controversial. It is taken for granted that science (here including technology) has much to do with achieving such popular group goals as longer life, less illness, individual and national security, high consumption and so on. There is no general agreement, however, on the need for an *indigenous* science to achieve these goals. A study of the economic development of various European countries (not to mention Japan) makes it clear that there is no simple direct relation between a country's gross national product and the percentage thereof that is allotted to research and development. The benefits of science diffuse across national boundaries more easily than those of a properly trained labor force or management, and since science policy is made on a national level rather than on a worldwide one these boundary effects cannot be disregarded. It therefore seems that the science of science is still much more of an art than a science. To quote Al Weinberg of Oak Ridge, "the best scientific administrator is the one whose taste and judgment is the most exquisite." All the same, some general principles do seem to emerge from the accumulated experience of science-policy makers at various levels and in different countries. The sharing of such experience may therefore be of some value, and the Ciba Symposium is an important contribution in this direction.

In attempting to establish a science policy it is wise to separate the choice of objectives from the detailed decision-making. Decisions are in general best made by those closest to the scene of the action; a decision on priorities or preferences among different possibilities requires at least some expert knowledge of the subject matter. The requirements for setting up objectives are of a different nature; they consist of an overall familiarity with a broad spectrum of the problems facing the particular organization whose science policy is being worked out. Thus on a national level the choice of objectives in science may require broad familiarity with national economic forecasts, problems of national security, trends in foreign relations, developments in the labor force, development of natural resources and so on. On an institutional level the choice of objectives may require familiarity with the general trends of scientific development and the plans of other institutions, the proper understanding of objectives set by higher organizations such as various mission-oriented offices and ministries, and a realistic assessment of human and financial resources.

The choice of an objective and the decision on the methods for implementing it also concern the individual scientist. On that level, however, the two functions are so thoroughly interwoven that one is often not aware of their separate existence. As one goes up in the hierarchy of organized and institutionalized research—from group leader through head of department and head of division or faculty to the head of the institution or university—there is a more distinct separation between objectives and their implementation. This unavoidable separation creates the hardest problem in carrying out a science policy, namely the problem of communication. It is the failure in setting up a proper communication system that sometimes leads objective-choosing bodies to make the mistake of engaging in rather detailed decision-making, thereby depriving that end of science policy of the expert knowledge it requires. An ineffective communication system also blocks meaningful feedback from reaching the objective-choosing bodies, thereby reducing the value of their deliberations.

The structure of a nation's scientific and technological organizations is usually intended to provide the proper communication network for the scientific community. The Ciba Symposium includes a rather detailed survey of a number of such structures, all quite different from one another. Comparisons of these various systems, however, are probably not very meaningful. In the first place, it is hard to determine which element in a given structure is responsible for which success or failure. What one wants, in principle, is the possibility of studying the response of the entire system to small variations in some of its parameters, and this can hardly be done in practice. Thus the characteristic difficulties of many studies in the social sciences also afflict the science of science, and their resolution will probably have to await further progress in the methodology of the social sciences.

It also seems that the usefulness of a given communication network in the scientific system cannot be judged in isolation from other social activities. The coupling of activities in science and technology to other systems in the society is too strong for such systems to be dealt with independently. This is probably the reason why there is usually not much a science policy in one country can copy from the policy of another. The very frank remarks of A. Rahman in the Ciba Symposium, commenting on the Indian experience, bear this out most dramatically. Still, the fact that we cannot copy one another does not preclude the possibility of our learning from one another. There are several important lessons to be learned.

The entire science-policy network, composed of objective-choosing bodies, decision-making organs and the communication system, is based on human beings. The coupling to other systems in the society, which is so important for the proper choice of objectives, is carried out through human understanding. Communication inside the scientific community is entirely dependent on human beings. Accordingly there is a high premium on good human qualities, and a system should first and foremost be flexible enough to make the best use of such qualities. Although this may sound trivial, it is surprising to find out how often one encounters systems that are extremely slow in responding to the appearance of a gifted person in the scientific life of an institution or a nation. At the same time the possibility of human beings making wrong judgments should also be kept in mind. To minimize the harmful effects of such errors in the science-policy network it is probably advisable to deliberately introduce some redundancy into the system. Exactly how far one should go in this direction is one of the great secrets of the art, but the often-made statement about the necessity of planning to avoid duplication has to be taken with a grain of salt.

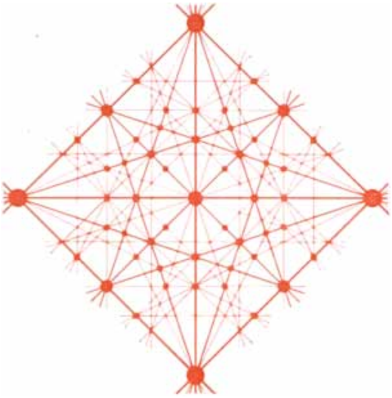
It is frequently stressed that science and technology have to be directed to serve national goals. This, of course, is the main task of the objective-choosing bodies. There is great danger in taking this statement too literally. In some political systems "national goals" may change quite often, with a characteristic period of four or five years. This is particularly true of a broad class of developing countries. Science also has its ups and downs, the ups being triggered by breakthroughs and new technologies. Here, however, the characteristic period is much longer, usually of the order of 20 or 30 years. If a rapidly changing national goal is to become the driving force of scientific and technological development, there is a risk of very low amplitude in the response of science and technology. Under such circumstances the wisest thing may be a quick decoupling of one system from the other. Only quite broad objectives can as a rule be chosen as national goals in the real sense of the word. Most of the more operational objectives are immediate ones, and relate to identifiable sectors in the economy or in defense.

In assessing the role of long-term goals in establishing the science policy of a country it is useful to borrow from the description of physical phenomena. Two extreme possibilities exist for such a description. What is called the variational approach looks for the best path a physical system should follow, given its initial conditions, if it is to reach a certain conclusion; it is a kind of long-range planning. The other way to describe a physical system is by means of differential equations that determine the system's immediate behavior; here, in a way, one crosses bridges as one comes to them. The two approaches are equivalent and are related to each other in a fundamental way; they only seem different. It is possible that the establishment of a science policy similarly allows two different approaches. In this case one can argue that until the science of science becomes a real science we would do better to rely on our intuition, and intuition is possibly better for responding reliably to immediate situations rather than to long-range planning.

Several conclusions follow from this philosophy. It seems, for instance, that higher education, even in the smaller countries, should be as broad as possible, rather than being artificially limited to areas closest to real or imaginary national goals. I know of a country where an apparent need for self-reliance in aeronautics led to a disproportionate effort in the system of higher education. By the time the educational system had started to turn out its highly trained people five years later, market conditions had changed drastically and the country was again relying on outside supply, which was faster and cheaper. It took some time for the institutions of higher learning to taper off on this subject, during which period the highly trained people were produced essentially for export. When the educational system finally got back to normal, a new crisis developed and the country is about to go through the experience again.

In the same country there was set up in the 1950's a computer-development laboratory that engaged in thoroughly "useless" research in computer hardware and software, in spite of some opinions that it was a luxury the country could not afford. As a matter of fact, the whole program was carried through only because a good man in the field was available and his laboratory had adopted a local policy of supporting good people regardless of the visible or invisible ties they might have with declared national goals. When several years later a boom in the computer industry made it a field of the highest national priority, a pool of trained people existed in the country who could advise the interested parties on the state of the art and its trends. Eventually they also staffed key positions in some very important computer developments that then took place in that country. Isolated cases should never lead to generalizations, and this story is no exception. Its only purpose is to serve as an example of the possible results of rapid fluctuations in long-range national goals, and of the useful end that was served by an unplanned action based on entirely local considerations.

There is much other evidence to suggest that one of the most important ingredients of a national science policy is a built-in flexibility that will allow the development of the full potentialities of good people. It is not hard to imagine the possible effects on science in Latin America if the road of a single Bernardo Houssay (who won the Nobel prize in physiology and medicine for 1947) had been blocked at the beginning. Or, to take an example from the applied sciences, Edwin Land's Polaroid camera was considered to be of little interest by a certain company that did market research on it; in a system where a similar group of people had the authority of a ministry the entire development would have been doomed. "Invest in people" should be the slogan of every science policy, and the decision as to which people are worth investing in should be left to those whose expert knowledge is closest to theirs. It is the exceptional people who are bound to come up with interesting innovations



for Christmas and all of 1969

For Christmas and all of 1969, you couldn't choose a more perfect gift for your friends and associates than a subscription to SCIENTIFIC AMERICAN. Whether they are executives in industry, engineers, scientists, students or interested laymen, they will be enjoying their issues and thanking you for them long after most people have forgotten other gifts.

Take advantage of the low gift rates by sending your gift list today. If you indicate, each of your friends will receive an attractive Christmas card to inform him of your thoughtful gift.

P.S. If you are not now a subscriber, this is a timely opportunity for you to take advantage of this Christmas subscription offer.

Please enter the following gift subscriptions to SCIENTIFIC AMERICAN

Name and Address–Please Print ☐ New ☐ Renewal

CITY STATE ZIP

Occupation ______ Company ______

Major Product or Service ______

☐ Send Gift Card and Sign ______

Name and Address–Please Print ☐ New ☐ Renewal

CITY STATE ZIP

Occupation ______ Company ______

Major Product or Service ______

☐ Send Gift Card and Sign ______

Name and address of donor of above gifts

CITY STATE ZIP

Occupation ______ Company ______

Major Product or Service ______

☐ Send Gift Card and Sign ______

Special Christmas Gift Rates

First subscription:

☐ 3 years $21

☐ 2 years $15

☐ 1 year $ 8

Each additional:*

____ 3 year sub. @ $20

____ 2 year sub. @ $14

____ 1 year sub. @ $ 7

*Applies only if two or more subscriptions are entered at this time. These rates apply throughout the world.

11-8

You may also enter my own ☐ New ☐ Renewal subscription as part of this order. (Renewals begin when present subscription expires.)

☐ Bill me later ☐ Enclosed is $____ for ____ subscriptions.

SCIENTIFIC AMERICAN 415 Madison Avenue, New York, N.Y. 10017 that conventional ones in planning positions can never dream of.

Science policy is most often associated with opening up new fields and encouraging new directions. It is nonetheless obvious that to serve the same purpose it is equally important to have a thorough look at ongoing activities and assess the desirability of their continued existence. Disregarding the human element for the moment, such a decision is often easier to make than one relating to new possibilities, since one is judging an activity that has already shown what it can lead to. Unfortunately the complexities of the human problems involved deter most organizations from looking into current activities with the same seriousness they apply to new activities. The result is that policy often affects only small, marginal and uncommitted resources.

To be even more effective, a science-policy system should be able to deal with such questions as: What do we do with a mission-oriented laboratory when the mission is completed or no longer relevant? What do we do with a laboratory built around an expensive piece of equipment when other developments make the equipment rather useless? One thinks of the people sidetracked into unimaginative nuclear-reactor work in several developing countries, and one wonders how long these countries are going to produce such reactor-users only to keep a reactor going. Here is a concrete example of where science policy interacts strongly with employment policies, worker mobility, the availability of housing and so on. These are hard practical problems, but their resolution may affect scientific and technological development critically, particularly in situations where the total allocations to such activities are reaching a ceiling.

In summarizing the Ciba Symposium, Raymond Aron said: "How does the decision-making machinery function? The impression I have received from everything I have heard is that whatever the institutional setup, nobody knows for sure how decisions are taken." It is probably desirable to continue to have such exchanges of opinion among science administrators, policy-makers, chairmen of various national committees and directors of laboratories in order to further clarify the methodology and the practical functioning of decision-making in national science policy. It might be equally useful to have such people exposed from time to time to extensive summaries of the present state of the various sciences, given by leading workers in those disciplines. On such occasions one might want to present a survey of the achievements in a given field, an assessment of the ongoing efforts and an outline of the problems with the possible import of their solution. Such conferences on the progress of science, designed for the science-policy makers at all levels, might prove to be of real practical value in providing a better guide for such people until the science of science becomes a science.

Short Reviews

FIREARMS, TRAPS, & TOOLS OF THE MOUNTAIN MEN, by Carl P. Russell. Alfred A. Knopf ($12.50). Kit Carson out of Taos, Jim Bridger on the Yellowstone, Jedediah Smith across the Columbia—such were the mountain men. Between the 1806 military reconnaissance of Lewis and Clark and the 1840's, when wagon trains began to roll on the Oregon Trail, the self-reliant beaver trappers were the point men of American industrial society between South Pass and the Sierras. They were brought there by adventure and by the "westering" of our forebears; they lived by rifle and trap, and they sent skins east for the famous beaver felt hat industry, in exchange for the ironware that is the motif of this precise and reflective book. Their sovereignty grew out of the rifle, a 12-pound weapon from some St. Louis gunshop, caliber just above half an inch, using round lead balls rammed against the rifling and grainy black powder fired by percussion cap. It was a sleek rifle, with no extra projections to catch in buckskin fringe; it had a flat trajectory across open sights to 150 yards, with the strength to withstand an occasional "double charge" for range. It worked well against both buffalo and men.

The steel trap, hand-forged to a design not much changed since the 17th century (a pattern that is still available, although machine-made), was the pelt-taker. A trapper owned eight or 10; he set six a day in the shallow water of beaver ponds, chained to a bottom stake and baited above water with a smear of the pungent castoreum of the beaver. The animal usually tripped the jaws with a forepaw, moved off trapped into deeper water and drowned, unable to stay afloat with the three- or four-pound load.

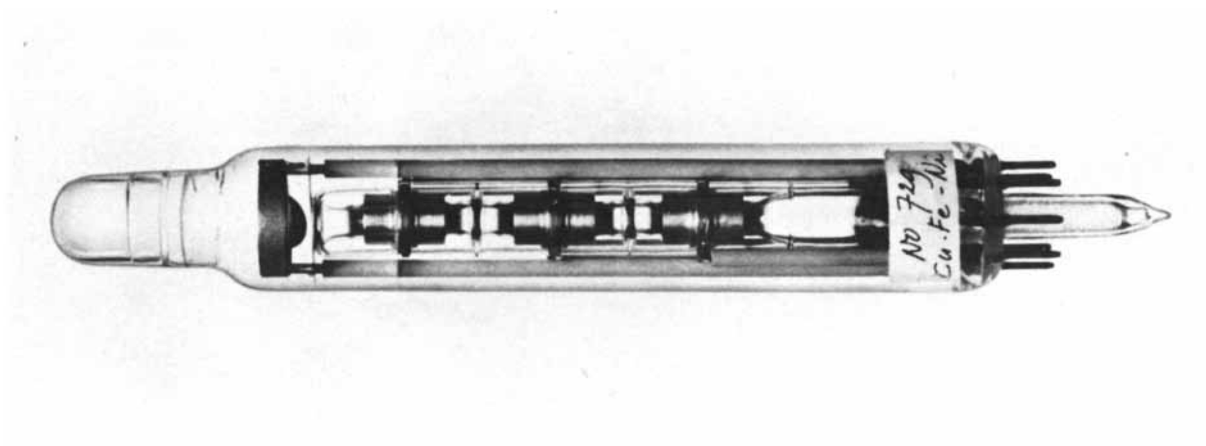
The trapper's knife was typically a wide-bladed butcher knife, called a scalping knife, used in skinning and in barroom fights. It was the source of a mountaineer's rude proverb. In the middle of the blade it bore the legend "Green River," after the Massachusetts site of the water-powered factory that made the knife; "up to Green River" meant a job well done.

His felling ax was of the Yankee pattern, the first major modification in form of this ancient tool since its prototypes were made in the Basque iron lands during La Tène time, nearly 3,000 years ago. Those axes, called "French," had a long bit and a thin section around the haft; the American pattern became almost square, with as much weight behind the haft as in front of it. Bigger trees and more of them called for an ax that had better balance to take a deep bite without wobble. A beaver pelt or two bought such an ax.

Extra needles and fire steels were always with the mountain man; it was these he gave the Indians he sought to befriend. The Indians of the Plains had the horse from the Spaniards long before. The American ironware was almost equally useful: needles, fire steel, tomahawk and trade rifle. In collections today these trade rifles often have sewed rawhide repairs "characteristic of used Indian arms." The Indian user neglected finish, cleaning and careful gauging of the powder charge; soon the "precision machine became something less than positive and accurate." The gunsmith was generally not available to the Indians, although brave and clever blacksmiths came West with pole bellows, hammer, anvil, vise, charcoal and bar iron to work in the trading posts and forts of the mountain men. If destiny was manifest, it was in those forges.

Dr. Russell has given us a loving work, which by its intensity of thought and evidence passes beyond the interests of antiquarian and collector into a true history, but a history whose main sources are the objects themselves, presented to us in hundreds of careful line drawings made by several artists. He ends his work with an essay on his method, an appeal for a new profession, historian-archaeologist, for which he sets a high standard.

FORGOTTEN SCRIPTS: HOW THEY WERE DECIPHERED AND THEIR IMPACT ON CONTEMPORARY CULTURE, by Cyrus H. Gordon. Basic Books, Inc., Publishers ($6.95). Somewhat obscured behind its puffy subtitle, this tight, engaging, surprisingly personal book describes the software brilliance that in the eastern Mediterranean enriches the work of the spade. Archaeology and decipherment, twin fruits of the Enlightenment, are indispensable to the modern mind. Professor Gordon has practiced both, and he has also served as a military cryptanalyst. He tells us just how he deci-



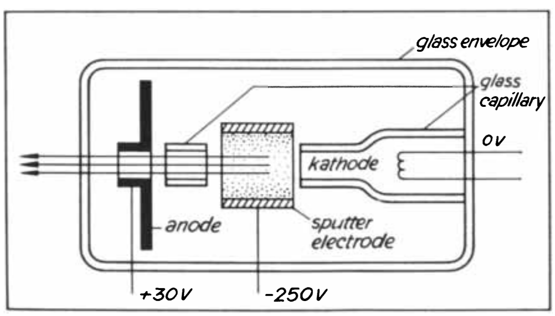
Narrow emission profile source highlights flame spectrometry

In flame absorption spectrometry, the source providing the spectral emission lines of the element to be detected in the flame, should give bright lines, which must be as narrow as possible. Hollow-cathode gas discharge tubes, normally used for this purpose, all suffer from self absorption. Metal vapour is diffused throughout the discharge column, and much of the light emitted is re-absorbed by the vapour. In consequence, the peak in the "emission line profile" is selectively reduced so that the line is undesirably broad. Moreover the light output is low. Both factors impair the measurement system sensitivity.

Recent work by Z. van Gelder, of the Philips Research Laboratories, Eindhoven Netherlands, has resulted in the design of a new spectral source tube, which gives a useful light output some ten times greater than the conventional tubes, besides having a much narrower emission line profile. The new tube can be used to trace metallic elements in such diverse samples as blood, fuel additives and lubricating oils.

The basic ideas for the improved tube can be expressed in a few words: "The emission of excited atoms is proportional to $n_e \times n_a$ (electron and atom density respectively), the self absorption to n_a only." The positive column between cathode and anode with a high current gives a large n_e, with maximum electron density along the axis. A sputter electrode is made from the element whose spectrum is desired. A low ion current of the filler gas is drawn towards the sputter electrode and releases atoms, which diffuse into the plasma. The already low density n_a of these atoms is lowest near the axis. The metal vapour is confined to a small region of the plasma by glass capillaries. The light output in the direction of the axis is thus obtained from the region with lowest n_a and highest n_e, as required.

Measurements on tubes made in the research laboratory show that, unlike conventional tubes, line profile and hence absorption sensitivity in the flame is independent of light output. As a result a double-beam method, which eliminates variations in the source output, is now really possible. Finally, the confinement of metal vapour to a small region enabled us to build 3 different elements into one single tube. A research sample is shown in the photograph above.



Electrode configuration of the tube

In the Research Laboratories of the Philips group of companies, scientists work together in many fields of science. Among these are: Acoustics, Cryogenics, Information Processing, Mechanics, Nuclear Physics, Perception, Solid State, Telecommunications and Television.

Our research is an essential tool for maintaining the standards implied in the slogan:

PHILIPS

trust in PHILIPS is world-wide

phered Minoan, as one late, intimate link in a chain of even greater successes that have revealed Egyptian, Old Persian, Sumero-Akkadian, Hittite, Ugaritic and the Cretan Linear B script in which the Mycenaeans wrote their dialect of Greek.

The Minoan (Linear A) chapter is a candid and engaging piece of autobiography. The talent and the equipment such a Philadelphia-born scholar brings to his work is awesome to that halting reader of foreign menus who must be the modal American. Hebrew he learned at five; Aramaic, Latin and German in high school years; Swedish, Greek and Arabic in college, and "one summer I decided to learn French, Italian, Spanish, Portuguese, Dutch and Dano-Norwegian by myself, through studying each one of them one hour per day during the three-month vacation.... I took... examinations in the autumn... and was awarded... certificates in all of them." He gives a glowing account of his deeply polyglot teachers in graduate school, men to whom such learning was commonplace. In 1931 a voyage past Crete consciously kindled his wish to crack the mystery of Minoan. In 1956, known as a scholar both of technical distinction (author of *Ugaritic Handbook*) and of public esteem (*Homer and Bible*), he received the volume of newly deciphered documents in Linear B from Michael Ventris and John Chadwick. A tablet written in Linear A, which uses similar phonetic signs, figured there incidentally. It was an inventory of pots with syllabic descriptions. Three of the five vessel names looked Semitic; the word for "totals" in Linear A had been guessed. It was *ku-ro;* "Semitic *kull-,* 'all,' occurred to me immediately." Four words were the basis of a paper. By now, after a lengthy pursuit of false clues, Minoan is pretty well on the road to full decipherment, as close kin to Phoenician. The archaeologists confirm it; the copper bars in the Bronze Age Aegean shipwreck off Cape Gelidonya were being carried by a Phoenician merchant.

"It is the lucky guess that pays off. When the lucky guess leads to the breakthrough, the decipherer experiences an illumination... mystics know. But the breakthrough must be objectively demonstrable."

The three-script tablet, the Rosetta stone, led in one generation to the reading of Egyptian, mainly through the work of three men, Johan David Åkerblad, Thomas Young and of course Jean François Champollion. The Swedish diplomat first recognized that the Demotic system was cognate with Coptic, which preserves the old tongue in Greek script; Young realized that the script could not be alphabetic but was phonetic; Champollion went all the way to translation of some unilingual texts. Old Persian, the first of the cuneiform scripts to fall, was deciphered from a unilingual text of a royal edict, trading on the preservation of the language by the Parsees, the Zoroastrian refugees in western India. The great trilingual cliff inscription left by Darius at Behistun in Kurdistan, carved in Old Persian, Elamite and Babylonian, opened the path to the most ancient texts. Sumerian, the oldest written tongue, is not yet fully readable; passages are ambiguous, although the general meaning comes through. We have many polylingual texts including Sumerian versions, but the language itself has no known close relatives. Ugaritic was a wholly new Semitic language in cuneiform script, the first text found by chance in a Mycenaean tomb in Syria in 1928. By 1930 the script could be read; the decipherment was a matter of a substitution cryptogram with complications. A tablet was found that gives the Ugaritic alphabet in Akkadian signs; it was discovered in 1955, too late to help. It is a fine confirmation of the work.

Samples of all these strange signs appear drawn and photographed throughout the book.

GALILEO: MAN OF SCIENCE, edited by Ernan McMullin. Basic Books, Inc., Publishers ($15). In the anniversary year of 1964 half a dozen congresses evoked the name of Galileo. They all produced volumes. This book, based on the quatercentenary celebration at the University of Notre Dame but strongly supplemented, is the weightiest in form and content. It has papers from scholars who were not present, the first English translations of essays by four noted savants now dead and a section bringing the great Italian bibliography of Galileiana up to 1964. Names such as Stillman Drake, Bernard Cohen, Willy Hartner and Rupert Hall indicate the depth and range of the essays. The most telling are a pair of papers, one by Vasco Ronchi of Florence, one by Silvio Bedini of the Smithsonian, with the half-dozen photographs that illustrate them.

They present Galileo, the first telescopic astronomer, in his true light as farseeing developer of novel instruments that worked. He first heard in the spring of 1609 that people were using the telescope to make distant things larger and clearer. The instruments, made of two ordinary spectacle lenses (which had been a standard article of commerce since soon after 1300) mounted in a cardboard or metal tube, were for sale all over Paris in 1609, by a contemporary account, "in the shops of the lens-makers." They were mere novelties; they had been on the market in Holland from 1604. These first Dutch examples were themselves modeled on a single specimen brought from Italy and dated 1590. Hence Galileo by no means invented the telescope, if indeed, as he liked to assert, he really had independently reinvented it from a brief account of its nature and existence. But just as the mistrusted spectacle lenses had meant nothing to science for three centuries (the first scientific account of lenses seems to date to 1589), so the combining of a pair of lenses into a magnifying instrument had meant nothing to science for 20 years. In fact, one cannot easily make a useful astronomical telescope from today's spectacle lenses. Their glass and their shape are simply not adequate. Galileo, however, had the insight to push the art ahead. He worked up "a telescope producing good images and magnifying thirty times... in a basic sense a quite different instrument than one which gave a blurred image and magnified only three times." Galileo owned a shop, where his professional instrument-maker had spent a decade making for sale the proportional compasses of which Galileo was so proud. He ordered his own optical glass, "most pure and excellent for these artifacts," and sent off to Murano and even to Florence for lenses. He made up many telescopes, but the yield of workable ones was low. "I still have ten... which alone, of a hundred and more which I have constructed at great expense and effort, are suitable for... observations of the new planets." On one occasion he made a telescope so good he was unable ever afterward to equal it. He used ruthless selection, once mentioning a yield of only one in 16. Determination and "new artifices" of glassworking and construction, without any theory but with much experience and feeling, made his telescopes superior. What a fresh sense of the man and his work this documented story gives us! It rings like gold to anyone who knows himself how uncertain it is to make something even a little novel. That time the hard work was worth it; through those rare "most exquisite" tubes a new universe—ours—was seen.

THE BIG MACHINE, by Robert Jungk. Charles Scribner's Sons ($6.95). The Big Machine is, of course, a multi-BeV

Books filled with the joy of mathematics

James R. Newman's THE WORLD OF MATHEMATICS

A monumental anthology of the great literature of mathematics, from A'h-mosé the Scribe to Einstein. Plus a brilliant 130,000-word commentary by Newman. 4 vols., boxed.
Cloth $30 **(1)**; paper $9.95 **(2)**

Martin Gardner's

THE *SCIENTIFIC AMERICAN* BOOK OF MATHEMATICAL PUZZLES AND DIVERSIONS
Cloth $4.50 **(3)**; paper $1.45 **(4)**

THE 2ND *SCIENTIFIC AMERICAN* BOOK OF MATHEMATICAL PUZZLES AND DIVERSIONS
Cloth $4.95 **(5)**; paper $1.75 **(6)**

NEW MATHEMATICAL PUZZLES AND DIVERSIONS FROM *SCIENTIFIC AMERICAN* Cloth $5.95 **(7)**

THE UNEXPECTED HANGING and Other Mathematical Diversions
Cloth $5.95 **(8)**

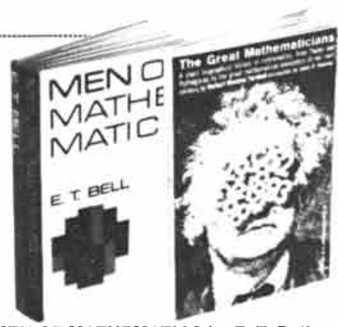
Edward Kasner & James R. Newman

MATHEMATICS AND THE IMAGINATION
One of the world's great mathematicians and his former pupil show non-mathematicians the pleasure and fascination of mathematics. Cloth $4.50 **(9)**; paper $1.95 **(10)**

Clifton Fadiman

EDITOR

FANTASIA MATHEMATICA
Cloth $4.95 **(11)**; paper $1.45 **(12)**
THE MATHEMATICAL MAGPIE
Paper $1.75 **(13)**
Two delightful books of stories, anecdotes, oddments, etc., by various authors, all derived from the infinite domain of mathematics.



MEN OF MATHEMATICS by E. T. Bell
Cloth $7.50 **(14)**; paper $2.25 **(15)**
THE GREAT MATHEMATICIANS by Herbert Westren Turnbull. Introd. by James R. Newman. Paper $1.25 **(16)**
Two excellent books about the great men of mathematics — the first full-scale, the second a shorter treatment.

A GUIDE TO MATHEMATICS FOR THE INTELLIGENT NONMATHEMATICIAN
by Edmund C. Berkeley
The basic ideas and techniques of modern mathematics — lucidly presented for the person who "was never good at math". Cloth $6.95 **(17)**; paper $2.45 **(18)**

SUPERIOR MATHEMATICAL PUZZLES

by Howard P. Dinesman
Tantalizers both classic and new, such as "How many different ways can two eight-tentacled octopi kiss?" Cloth $3.95 **(19)**

Now at your bookstore, or use this coupon to order direct from Simon and Schuster, Dept. SA, 630 Fifth Ave., New York, N. Y. 10020. Please refer to numbers in parentheses after book prices in the ad. ***Note that cloth and paper editions of the same book are numbered separately.***

SIMON AND SCHUSTER, Dept. SA
630 Fifth Ave., New York, N. Y. 10020
Please send me the books whose numbers I have circled below, for which I enclose remittance totaling $........... If I wish, I may return any or all of the books within 10 days for full refund.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Name ____________________

Address ____________________

City ____________________ State __________ Zip __________

(N. Y. residents please add applicable sales tax.)

particle accelerator. Three of the species appear on stage, one at CERN near Geneva and two in the suburbs of Moscow; also featured is the planning office near Chicago where the mile-in-diameter ring of 1973 is still growing on paper. There is not much particle physics in the book (not enough, in fact, for clarity), but there is a careful and many-sided report of the history of the machine of the Conseil Européen pour la Recherche Nucléaire, heart of a hugely successful daily example of all-European cooperation in a wholly open and peaceful venture. (Believe it or not, the bureaucrats' first acronym for CERN in 1952 was CREEPLIOAFCRN.) The execution of a big and vexed neutrino-detection experiment is reported from concept to completion, mostly in the words of a key participant; many good conversations are recorded, if a little stiltedly, about big laboratories and about the people in them. It is not all roses, although Jungk does appear to be a bit overawed by all those restlessly clever people and their fast talk. He raises the central questions, never far from the reflections of the trade: Is it as healthy as it is inevitable that the ingenious experimenter who was once a cheerful Rutherford has become an organization man? Is it wise to spend $50 million a year in a laboratory that has no economic product and that may house only a "caste of maniacs, who try to solve problems created only by our machines"? The author is in no doubt. It *is* worthwhile; the freedom, internationalism, rationality and enthusiasm of these men create a fresh climate of the mind, a match for the problems they are engaged in solving, problems whose attack and solution is finally a challenge to the curiosity and pride of mankind. Yet there is arrogance to report as well: the young physicists at CERN, a self-conscious elite, look down on the many indispensable specialists who keep their machine alive. "In their eyes we're only blacksmiths." (Blacksmiths, of course, were once themselves masters of the essential mystery.)

The fascination of this book is its eyewitness account of the two Russian laboratories. The newer one, Prodvino, is today the lively site of the world's largest working high-energy machine. The machine runs like a clock; the buildings are like those in the West, "functional, not... without elegance... comfortable." The Russian character is not to be seen, although the legacy of the war is strong: the district was a battlefield. Dubna, isolated, still under a heavy-handed regime of passes and strict guards, its main laboratories in the columned style of the classic revival, with window draperies of heavy red plush, and its homes with their fenced gardens on the calm tree-lined streets, is Russia before the thaw. It was built by Beria's men; the big machine itself, the first large Russian venture into the high-energy world, is of a grandiose and "technically archaic" design. Yet Brecht was performed in Dubna before his plays could be seen in Moscow ("I have never been anywhere where foreign languages are studied with such alacrity"), and in Dubna, as never at CERN, the "attractive and highly intelligent women scientists" make up a third of the group. At CERN women work almost entirely (Jungk says "only," but he is here wrong by one or two) at the typewriter or in the library and the computer room. Dubna parties do not split up into two knots, men and women. One hears a Moscow professor who was raised in Paris speak: "I envy [the Westerners] for a number of reasons. But even more, I pity them.... I mean the coldness in which almost everyone lives. Everyone is basically alone there. My co-workers and I—we are friends. We belong together.... At the beginning, when the war brought me back...this Russian lack of discretion seemed unbearable. Today, I know it is genuine sympathy, or—if you cynics can still tolerate such a weighty word—love, and I now would no longer want to live the way my former countrymen do."

HYDROGEN BONDING IN SOLIDS: METHODS OF MOLECULAR STRUCTURE DETERMINATION, by Walter C. Hamilton and James A. Ibers. W. A. Benjamin, Inc. ($13.95). Structural chemists intend to learn the shape, binding and motions of molecules. The wonderful iterative fabric of a crystal serves to hold molecules in such a way that subtle means are applicable to learn their nature. Of all the specific interactions of molecules the best-studied is the hydrogen bond. That is the manifesto of these candid authors, who present this clear text for advanced students in a critical and reflective vein, seeking to illuminate by this significant example the many ways now open to us for knowing molecules.

A line of hydrogen bonds forms the backbone of the alpha helix of a protein; the base pairs of the famed double helix of DNA are joined by hydrogen bonds; ice and the many compounds whose solid phases contain the classical "water of crystallization" are crystals whose molecules are much linked by hydrogen bonds. That bond is not easy to define with precision; it is no well-defined overlap of electrons as the covalent bond


Would your family like it
if you took a job at Hughes in California?
It's easy to find out.
Let's exchange resumes.
Ours includes a 126-page book on Southern California. Do you want to know about living costs? Weather? Taxes? Cultural advantages?
Want to know how to pick a hilltop homesite? How to catch a shark? What to expect on your driver's license test? How much it costs to build a pool? How reading is taught in the public schools?
It's all here, in a good book about a good life. (You'll also find California isn't mere tinsel and glitter. Actually one-fourth of America's physicists live here. So do one-fourth of the members of the National Academy of Sciences and almost half of America's Nobel Prize winners.)
And of course Hughes has a story too. You can imagine the benefits of working with the men who designed Surveyor, Syncom and dozens of other highly advanced systems. We've gathered lots of material for you—facts on everything from programs to fringe benefits.
If you're an E.E. from an accredited university with 2 or more years of professional-level experience applicable to aerospace research and development technology, please send us your resume.
We'll send you ours by return mail.
Mr. Robert A. Martin
Head of Employment
Hughes Aerospace Divisions
11940 W. Jefferson Boulevard
Culver City, Calif. 90230
U.S. citizenship is required
An equal opportunity employer—M&F.
HUGHES
HUGHES AIRCRAFT COMPANY
AEROSPACE DIVISIONS
CALIFORNIA

is. Rather it is a group of three atoms, the intermediate one being hydrogen, which is linked to one partner by a near-normal covalent bond and drawn by electrostatic attraction closer to the other than the normal distance of contact. Many complicated networks of bonds are known. In ice the hydrogen atoms form a shifting net joining the tetrahedral array of oxygens.

The book is distinguished by a rich collection of stick-and-ball drawings of structures that can be viewed in three dimensions. (A stereo viewer is provided in each copy.) The alpha helix twists its spiny way up an entire page; ice looks like a section of honeycomb. These interesting diagrams were prepared by computer.

X-ray diffraction is not the royal road to locating hydrogen bonds. Electrons alone respond to X rays, and the hydrogen atoms contribute an unnoticeably small share of the total electron density in most solids. Neutrons, however, can feel protons about as well as they feel any other nuclei; neutron diffraction, using the de Broglie wave-scattering of slow neutrons, is the most direct method of study. There are others: the dynamics of the vibrating hydrogen atom can be learned from infrared spectra, the proton spin can interact magnetically with other nuclear magnetic neighbors to show up as a modification of the free-proton resonant response to radio-frequency oscillations in a magnetic field. All of these are discussed; the complex weaving of configuration, analogy, bond theory and comparative molecular anatomy, so typical of the ingenuity and learning of the chemist, is applied to a subject that is by no means straightforward or complete. The authors conclude their careful summary of methods by pointing out that understanding is what "should be the result of any chemical investigation.... Attention to method and instrumentation is only a means to an end."

Animals in Splendour, by E. L. Grant Watson. The Horizon Press ($4.95). They do these things well in France. But here, in a score of poetic and yet somehow spare essays, a British naturalist for once has celebrated the spirit of the zodiac in our uneven and many-parented tongue. Each piece is the evocation of some beast, be it pig, hawk, toad or slug, seen with the eye of a careful watcher, woven from myth and tale, from a comment by Martin Buber or by Charles Darwin, out of experience in an Australian upland ranch or with journeyers by camel in the Palestinian desert. The animals are seen as having human qualities in myth, we as bearing their images in our soul. So it must have been before men wrote, when they assigned to a ring of strange creatures the circle of the sun. It is all examined pointedly, informed throughout by science. Not all readers will come to like these pages, but some readers will keep them for a long time. The intricacy of interdependence is one clear theme. Foxes abound now in rabbit-free England because the culled dead fowl from those broiler houses whose "stench is sufficient to tell all nature of our sin" are chucked out unburied for the foxes. "In this way is the balance of nature upset by lazy farmers in a dirty trade." Or watch the yellow slugs outside the kitchen in their hermaphrodite double conjugation, suspended in midair on a thread of slime: "A sensual tenderness was not to be mistaken. No crude, stiff, ill-adjusted mechanism was there present. The fire of love was in their moisture."

Oceans, by Karl K. Turekian. Prentice-Hall, Inc. ($5.95). A hundred somewhat too laconic pages make up this remarkably up-to-date little book (a bargain in a $2 paperback), which belongs to a series presenting a detailed first textbook of geology. Marine geology was something rather apart from the old college geology; today it is growing to its proportionate importance. Here we can read of the ocean basin, of its great ridges and peaks, of the oozes and nodules of the floor and whence they come, of the ebb and flow of currents and tides, of the chemistry of seawater, the most abundant of all minerals. It is not all easy going, for the substance and motions of the sea are more subtle than the tracing out of visible layers or the palpable cutting of river valleys that make up elementary physical geology on land. The treatment of chemical equilibrium in the sea is somewhat too technical for the general level assumed in an introductory text (the author is a marine geochemist), but one can find no better brief guide to the modern flood of understanding of the ocean as a part of the earth. Marine life, however, is treated only incidentally. The magnetic bands of the spreading sea floor, the opinions that the sea originated with gases from the rocks, that its floor is always new, that one must ask rather why the rivers are fresh than why the sea is salt—all these matters and many more are put forward with evidence and tentative conclusion equally clear. Even the destruction of Atlantis (probably in the Aegean, where it is marked by a great ash layer 5,000 years old) is mentioned.

INDEX OF ADVERTISERS

NOVEMBER 1968

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

THE DIMENSIONS OF WORLD POVERTY

THE WORLD'S FOOD SUPPLIES. P. V. Sukhatme in *Journal of the Royal Statistical Society*, Series A, Vol. 129, Part 2, pages 222–241; 1966.

THIRD REPORT ON THE WORLD HEALTH SITUATION 1961–1964. No. 155, Official Records of the World Health Organization, 1967.

WORLD ECONOMIC SURVEY 1967 E4488 ADD. 1–5 E4485. United Nations, Department of Economic and Social Affairs, 1968.

STRONG AND DUCTILE STEELS

HIGH-STRENGTH MATERIALS. Edited by Victor F. Zackay. John Wiley & Sons, Inc., New York, 1965.

THE ENHANCEMENT OF DUCTILITY IN HIGH-STRENGTH STEELS. Victor F. Zackay, Earl R. Parker, Dieter Fahr and Raymond Busch in *ASM Transactions Quarterly*, Vol. 60, No. 2, pages 252–259; June, 1967.

TENSILE PROPERTIES OF TRIP STEELS. M. D. Merz, G. Chanani, V. F. Zackay and E. R. Parker in *UCRL Report*—18466. University of California Radiation Laboratory (in press).

THE PREVENTION OF "RHESUS" BABIES

SUCCESSFUL PREVENTION OF EXPERIMENTAL RH SENSITIZATION IN MAN WITH AN ANTI-RH GAMMA$_2$-GLOBULIN ANTIBODY PREPARATION: A PRELIMINARY REPORT. Vincent J. Freda, John G. Gorman and William Pollack in *Transfusion*, Vol. 4, No. 1, pages 26–32; January–February, 1964.

THE PREVENTION OF RH HAEMOLYTIC DISEASE. R. B. McConnell in *Annual Review of Medicine*, Vol. 17, pages 291–306; 1966.

PREVENTION OF RH-HAEMOLYTIC DISEASE. C. A. Clarke in *British Medical Journal*, Vol. 4, No. 5570, pages 7–12; October 7, 1967.

PROPHYLAXIS OF RHESUS ISO-IMMUNIZATION. C. A. Clarke in *British Medical Bulletin*, Vol. 24, No. 1, pages 3–9; January, 1968.

TRANSFUSION, Vol. 8, No. 3. May–June, 1968.

PREVENTION OF RHESUS ISO-IMMUNISATION. C. A. Clarke in *The Lancet*, Vol. II for 1968, No. 7558, pages 1–7; July 6, 1968.

VISUAL ILLUSIONS

SENSATION AND PERCEPTION IN THE HISTORY OF EXPERIMENTAL PSYCHOLOGY. Edwin Garrigues Boring. D. Appleton-Century Company, 1942.

OPTICAL ILLUSIONS. S. Tolansky. Pergamon Press, 1964.

EYE AND BRAIN. R. L. Gregory. McGraw-Hill, 1966.

WILL SEEING MACHINES HAVE ILLUSIONS? R. L. Gregory in *Machine Intelligence I*, edited by N. L. Collins and Donald Michie. American Elsevier Publishing Co., Inc., 1967.

ARTIFICIAL PLASMA CLOUDS IN SPACE

THE TAILS OF COMETS. Ludwig F. Biermann and Rhea Lüst in *Scientific American*, Vol. 199, No. 4, pages 44–50; October, 1958.

ARTIFICIAL STRONTIUM AND BARIUM CLOUDS IN THE UPPER ATMOSPHERE. H. Föppl, G. Haerendel, L. Haser, J. Loidl, P. Lütjens, R. Lüst, F. Melzner, B. Meyer, H. Neuss and E. Rieger in *Planetary and Space Science*, Vol. 15, No. 2, pages 357–372; February, 1967.

EARTH'S PARTICLES AND FIELDS: PROCEEDINGS OF THE NATO ADVANCED STUDY INSTITUTE HELD AT FREISING, GERMANY, JULY 31–AUGUST 11, 1967. Edited by Billy M. McCormac. Reinhold Book Corporation, 1968.

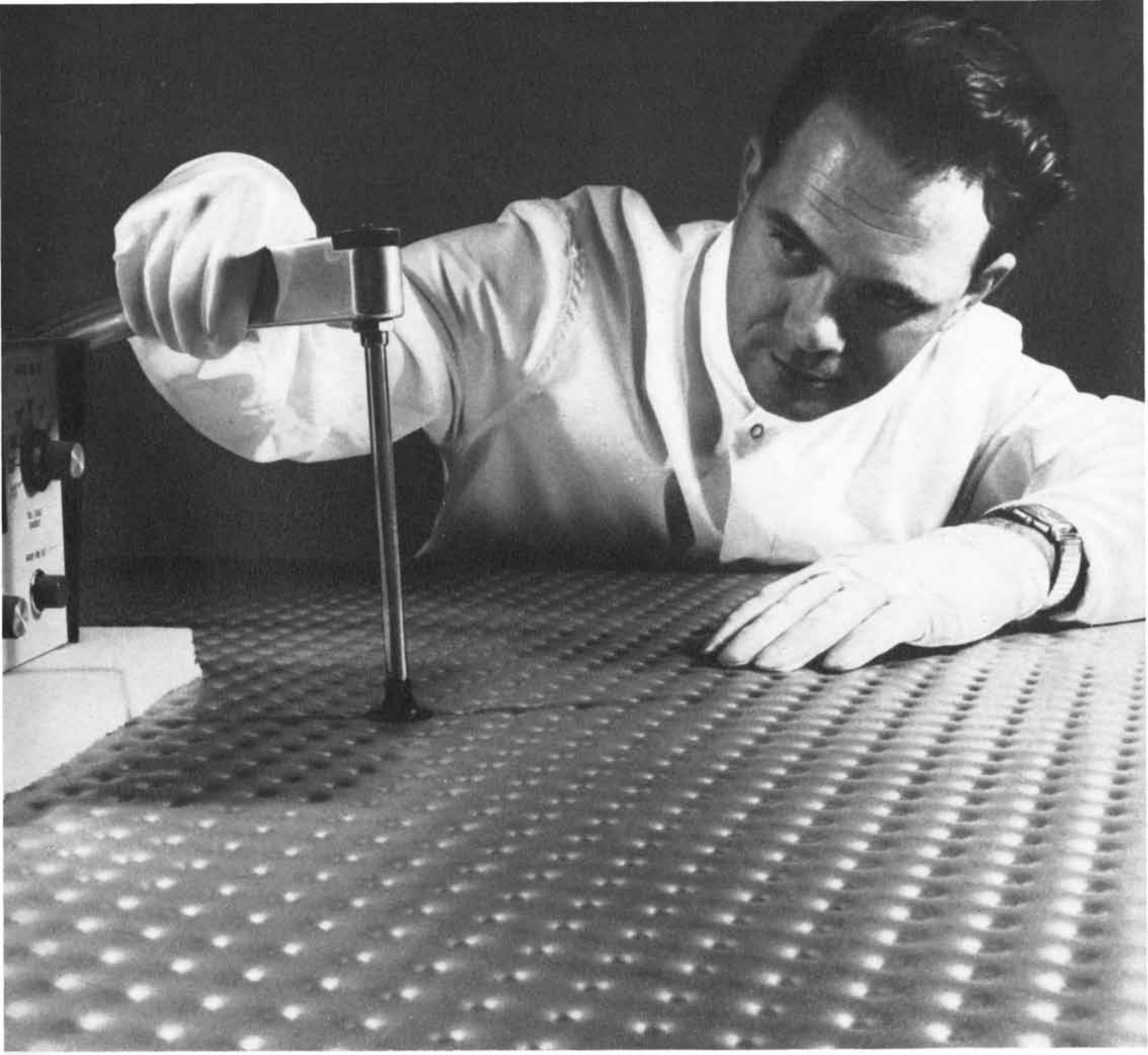
PRELIMINARY RESULTS OF ELECTRIC FIELD MEASUREMENTS IN THE AURORAL ZONE. H. Föppl, G. Haerendel, L. Haser, R. Lüst, F. Melzner, B. Meyer, H. Neuss, H.-H. Rabben, E. Rieger and J. Stöcker in *Journal of Geophysical Research*, Vol. 73, No. 1, pages 21–26; January 1, 1968.

A HUNTERS' VILLAGE IN NEOLITHIC TURKEY

A METHOD OF CALCULATING THE DIETARY PERCENTAGE OF VARIOUS FOOD ANIMALS UTILIZED BY ABORIGINAL PEOPLES. Theodore E. White in *American Antiquity*, Vol. 18, No. 4, pages 396–398; April, 1953.

PREHISTORIC FAUNA FROM SHANIDAR, IRAQ. Dexter Perkins, Jr., in *Science*, Vol. 144, No. 3626, pages 1565–1566; June 26, 1964.

SUBERDE EXCAVATIONS, 1964. Jacques Bordaz in *Anatolian Studies: Journal*



At Martin Marietta you could be cooking up leakproof waffles to test meteoroid shower power.

NASA needs to know what will happen when spacecraft of the future collide with meteoroid showers. To find out, they asked us to devise meteoroid detectors to send into outer space. And so we came up with these waffle-like detector panels filled with helium. They're completely leakproof and they'll stay that way for 100 years.

That's quite a claim, we agree. But look at what we do to prove it. The panels are put into our new space chamber for 15 days under an oppressive +350°F and for another 15 days at a frigid −250°F. Prior to this, the panels are recycled 21,344 times under temperatures ranging from −100° to +325°F. After that, they'll be ready to take on anything in outer space. For 36,500 days, at least.

This is just one of the challenging assignments we've got going in space science and engineering. To find out what opportunities there are in your field, write to: Professional & Management Relations, Aerospace Group, Friendship International Airport, Baltimore, Maryland 21240.

Martin Marietta is an equal opportunity employer.

MARTIN MARIETTA

of the British Institute of Archaeology at Ankara,* Vol. 15, pages 30–32; 1965.

SUBERDE. Jacques Bordaz in *Anatolian Studies: Journal of the British Institute of Archaeology at Ankara,* Vol. 16, pages 32–33; 1966.

TRANSDETERMINATION IN CELLS

DEVELOPMENTAL GENETICS AND LETHAL FACTORS. Ernst Hadorn. Methuen & Co., Ltd., 1961.

PROBLEMS OF DETERMINATION AND TRANSDETERMINATION. Ernst Hadorn in *Brookhaven Symposia in Biology, No. 18: Genetic Control of Differentiation,* pages 148–161; December, 1965.

DYNAMICS OF DETERMINATION. Ernst Hadorn in *Major Problems in Developmental Biology: The Twenty-fifth Symposium,* edited by Michael Locke. Academic Press, 1966.

KONSTANZ, WECHSEL UND TYPUS DER DETERMINATION UND DIFFERENZIERUNG IN ZELLEN AUS MÄNNLICHEN GENITALANLAGEN VON DROSOPHILA MELANOGASTER NACH DAUERKULTUR IN VIVO. Ernst Hadorn in *Developmental Biology,* Vol. 13, No. 3, pages 424–509; June, 1966.

THE AERODYNAMICS OF BOOMERANGS

ON BOOMERANGS. G. T. Walker in *Philosophical Transactions of the Royal Society of London,* Series A, Vol. 190, pages 23–41; 1897.

FUNDAMENTALS OF HYDRO- AND AEROMECHANICS. L. Prandtl and O. G. Tietjens. Dover Publications, Inc., 1957.

A TREATISE ON GYROSTATICS AND ROTATIONAL MOTION. Andrew Gray. Dover Publications, Inc., 1959.

MATHEMATICAL GAMES

THE CASINO GAMBLER'S GUIDE. Allan N. Wilson. Harper & Row, Publishers, 1965.

SCARNE ON DICE. John Scarne and Clayton Rawson. Military Service Publishing Co., 1968.

THE AMATEUR SCIENTIST

THE SOLUBILITY OF NONELECTROLYTES. Joel H. Hildebrand and Robert L. Scott. Reinhold Publishing Corporation, 1950.

DOUBLE, TRIPLE AND POLY LENSES OF ORGANIC LIQUIDS ON AND UNDER WATER. A. V. Grosse. Research Institute of Temple University, 1967.

The Continental Mark III.

The most authoritatively styled, decisively individual motorcar of this generation.
From the Lincoln-Mercury Division of Ford Motor Company.