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March 1961

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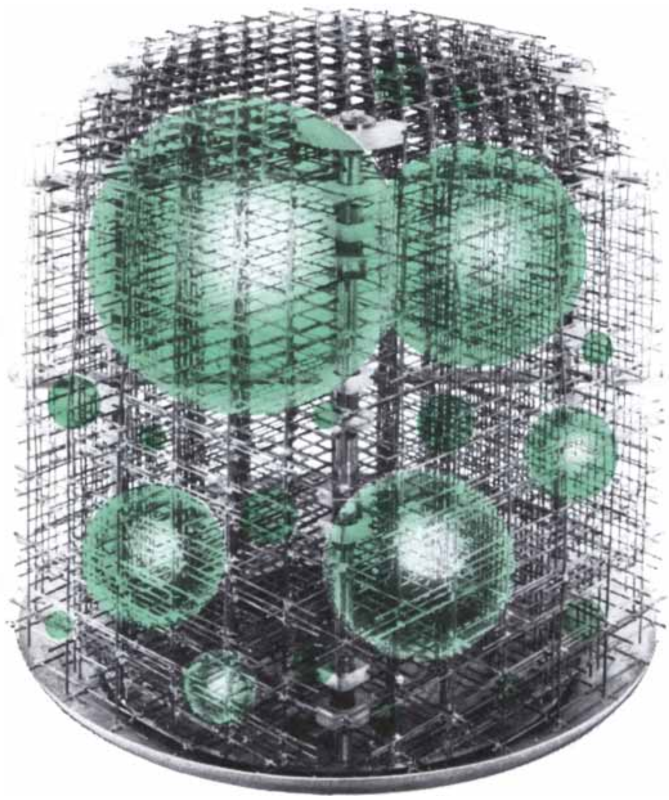

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ARTICLES

DEPARTMENTS

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THE COVER

The photograph on the cover shows the impression of a Pre-Cambrian animal, *Tribrachidium heraldicum*, in a sandstone of South Australia (*see page* 72). The impression is enlarged some four diameters and is lighted so that it appears to be a cast. *Tribrachidium* resembles no other known animal.

THE ILLUSTRATIONS

Cover photograph from Martin F. Glaessner

Page	Source
58	James Egleson
59	Plasmadyne Corporation
60	James Egleson
61	Electro-Optical Systems, Inc.
62–65	James Egleson
67	Bristol Laboratories, Inc.
68–71	Evelyn Urbanowich
72–73	Bunji Tagawa
74–75	M. F. Glaessner, J. Thompson, Mary Wade
76–78	Bunji Tagawa
95	Bernarda Bryson
96–97	New York Public Library
98–104	Bernarda Bryson
111–112	Michael H. Jameson, University of Pennsylvania
113	Gabinetto Fotografico Nazionale, Rome
114–116	Bunji Tagawa
117–118	Michael H. Jameson, University of Pennsylvania
125	Philip Wills
126	Robert R. Long, Johns Hopkins University (*top*); Eric Mose (*bottom*)
127	Harold E. Klieforth (*top left and bottom left*); R. S. Scorer, Imperial College of Science and Technology, London (*top right and middle*); Shell Refining Company, Limited (*bottom right*)
128	Charles E. Brown (*top*), Eric Mose (*bottom*)
130–131	Eric Mose (*top*); Robert R. Long, Johns Hopkins University (*bottom*)
132	Eric Mose
133	Robert Symons (*top*), Eric Mose (*bottom*)
134	Eric Mose
138	Mount Wilson and Palomar Observatories, American Museum of Natural History (*top*); Fairchild Aerial Surveys, Inc. (*bottom*)
140–142	John Langley Howard
144–145	Eckhard H. Hess, University of Chicago (*top*); John Langley Howard (*bottom*)
146	John Langley Howard
153	Wayne A. Kimball and Norman Isaacs, Whiting Research Laboratories of the American Oil Company
154–155	Gordon Coster
156–159	René Martin
160	Evelyn Urbanowich
161	Evelyn Urbanowich (*top*), René Martin (*bottom*)
162	René Martin
164	Wayne A. Kimball and Norman Isaacs, Whiting Research Laboratories of the American Oil Company
168–176	Alex Semenoick
182	Jack Rudloe
184–190	Roger Hayward

See Following Pages ➧

1761

No. 4 Timekeeper Preserved in working order at the Greenwich Observatory

JOHN HARRISON, an English watchmaker, developed a successful chronometer that was unaffected by vibration and temperature changes and could be used on board ship. Navigation was so important to the Crown that the British government had, in 1713, offered "publick rewards" of £10,000, £15,000 and £20,000 to any person constructing chronometers that would determine a ship's longitude within 20, 13, and 10 leagues respectively. In 1762, Harrison's son William returned to Portsmouth after a test voyage to Jamaica, and the No. 4 Timekeeper was found to have lost only 1 minute 54½ seconds. This surprising stability had enabled the ship's master to determine his longitude to within six leagues. Harrison claimed the reward, and in 1773, after court action, was granted the £20,000 prize. Harrison, while developing the instrument which won him recognition, had discovered the concept of temperature compensation by differential expansion and was thus able to give the world its first portable time standard, free from environmental restrictions.

1961

THE STL RUBIDIUM FREQUENCY STANDARD

STL Products announces the development of the STL Rubidium Frequency Standard. This device embodies a new operational concept—the optically pumped rubidium maser—as new today as the basic concept of the Number 4 Timekeeper was 200 years ago. This advanced principle of operation stimulated the development of an atomic frequency standard weighing just twenty pounds and free of environmental restrictions in its use. The rubidium cell provides a stability of two parts in ten billion and an accuracy of one part in one billion. This performance establishes a time base for the development of universal navigational concepts and provides science and industry with an independent means of frequency calibration.

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This product of Space Technology Leadership is available now at a price of $22,500, or £8,000. Inquiries are invited.

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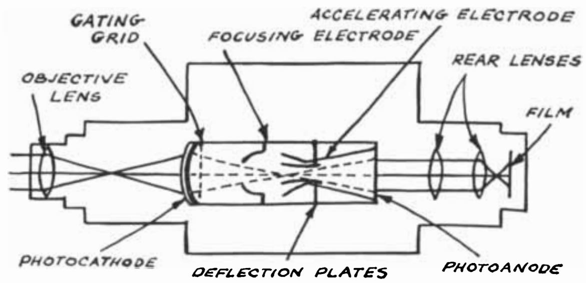
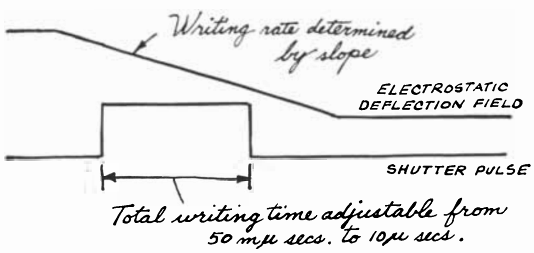
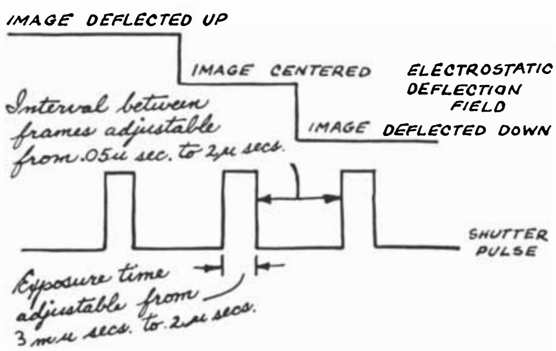
The successful development of STL Products' Image Converter Camera answers the growing demand of scientific laboratories for millimicrosecond photographic instrumentation. The image converter tube, in conjunction with STL's new techniques for generating fast-rising precise voltage pulses, provides almost unlimited speed and flexibility in the analysis of transient luminous events. Electronic shuttering, focusing, and amplification of luminous data now permits high speed framing and streak photography in regions hitherto inaccessible for scientific investigation.



light is focused on the photocathode which transforms the optical image into an electron image — shuttering and amplification can now be accomplished electronically — the electron image is focused to cross over between deflection plates for distortion-free image displacement — the electron image is then focused on the photoanode, where it is reconverted to a higher intensity optical image.



time resolved streak data is obtained by applying a linearly falling pulse to sweep the image across the photoanode — writing rate is determined by the slope of the ramp pulse while total writing time is controlled by the width of the rectangular shuttering pulse.



three frames are taken by applying voltage pulses to the deflector plates properly timed with the rectangular shuttering pulses — the combination of a constant voltage deflection pulse and the accurately timed shuttering pulse provide a stationary image on the photoanode.

The STL Image Converter Camera is the only complete diagnostic tool for instrumentation of high speed luminous transient events encountered in plasma physics, chemical kinetics and hypervelocity experiments. Exposures have been made in less than 3 one billionths of a second—twice as fast as any previous picture obtained with any technique. This high speed, combined with a 50X light gain and time resolution capabilities enable the scientist to gain data not previously available.

Four interchangeable plug-in units make possible low inductance connections and simplified switching over all ranges of operation. Three frames are provided with independently adjustable intervals from 0.05 to 2 microseconds. Exposure times are adjustable from 3 to 200 millimicroseconds. The streak units provide writing times from 50 millimicroseconds to 10 microseconds. Advanced engineering of the pulse forming circuits has allowed the construction of a light weight instrument easily portable throughout the laboratory. All voltages are preset—no adjustment by laboratory personnel is required.

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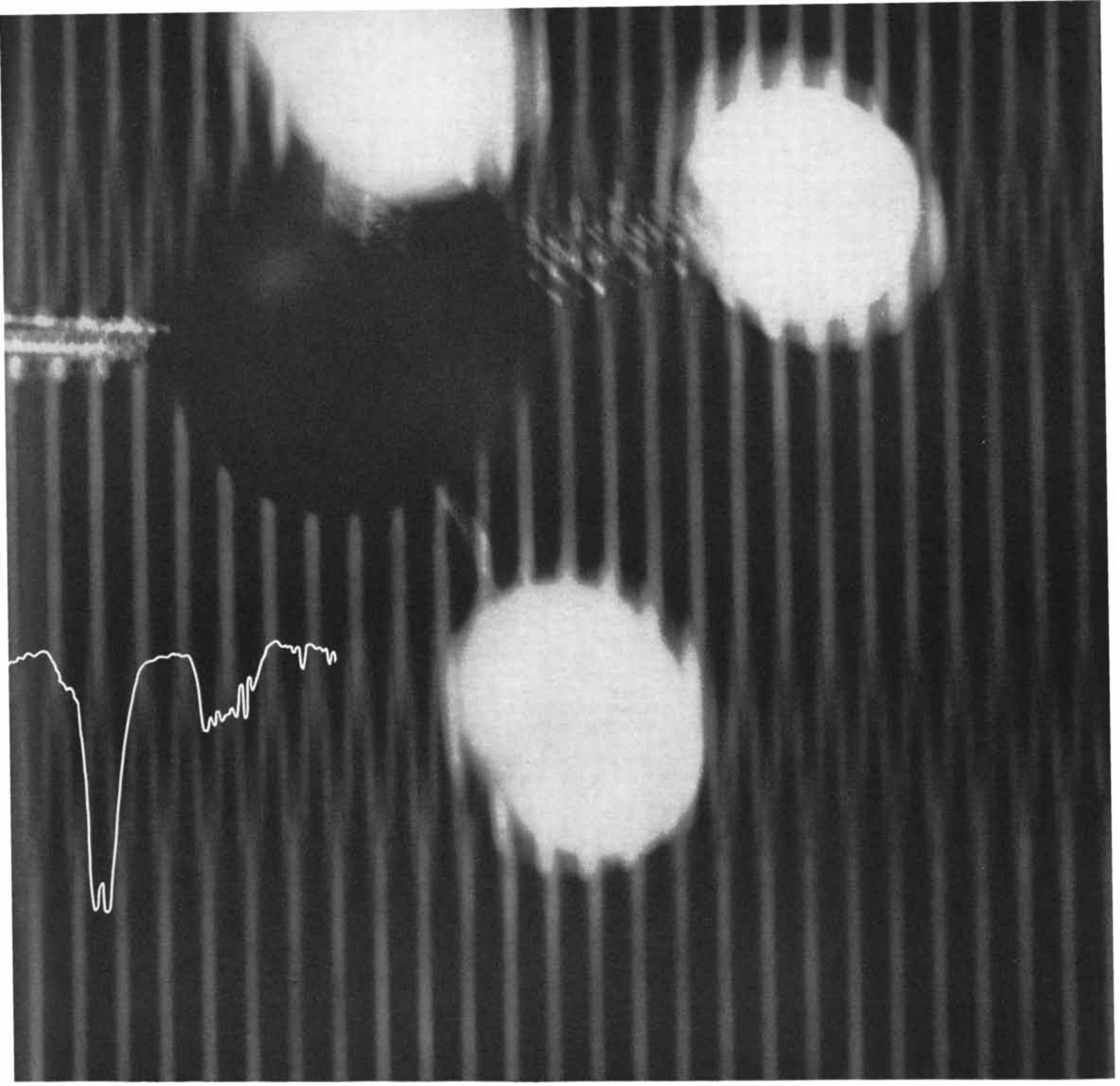

bond of the carbonyl group. The record was made with a Perkin-Elmer Infrared Spectrophotometer. This instrument has become an indispensible quantitative and qualitative tool of chemists, scientists and engineers. It is used to analyze molecular structures, check quality, identify substances in a wide range of industries including chemical, petrochemical, plastics, food, pharmaceutical, cosmetics.

This is another example of Perkin-Elmer instruments for scientific measurement. P-E's experience with precise measurement techniques is applied in building other complex electronic-optical systems. These do vital jobs such as tracking missiles, controlling process streams, mapping the ground from high altitudes. Qualified scientists and engineers interested in careers with Perkin-Elmer are invited to write to the Director of Industrial Relations. Perkin-Elmer Corporation, 800 Main Avenue, Norwalk, Connecticut.

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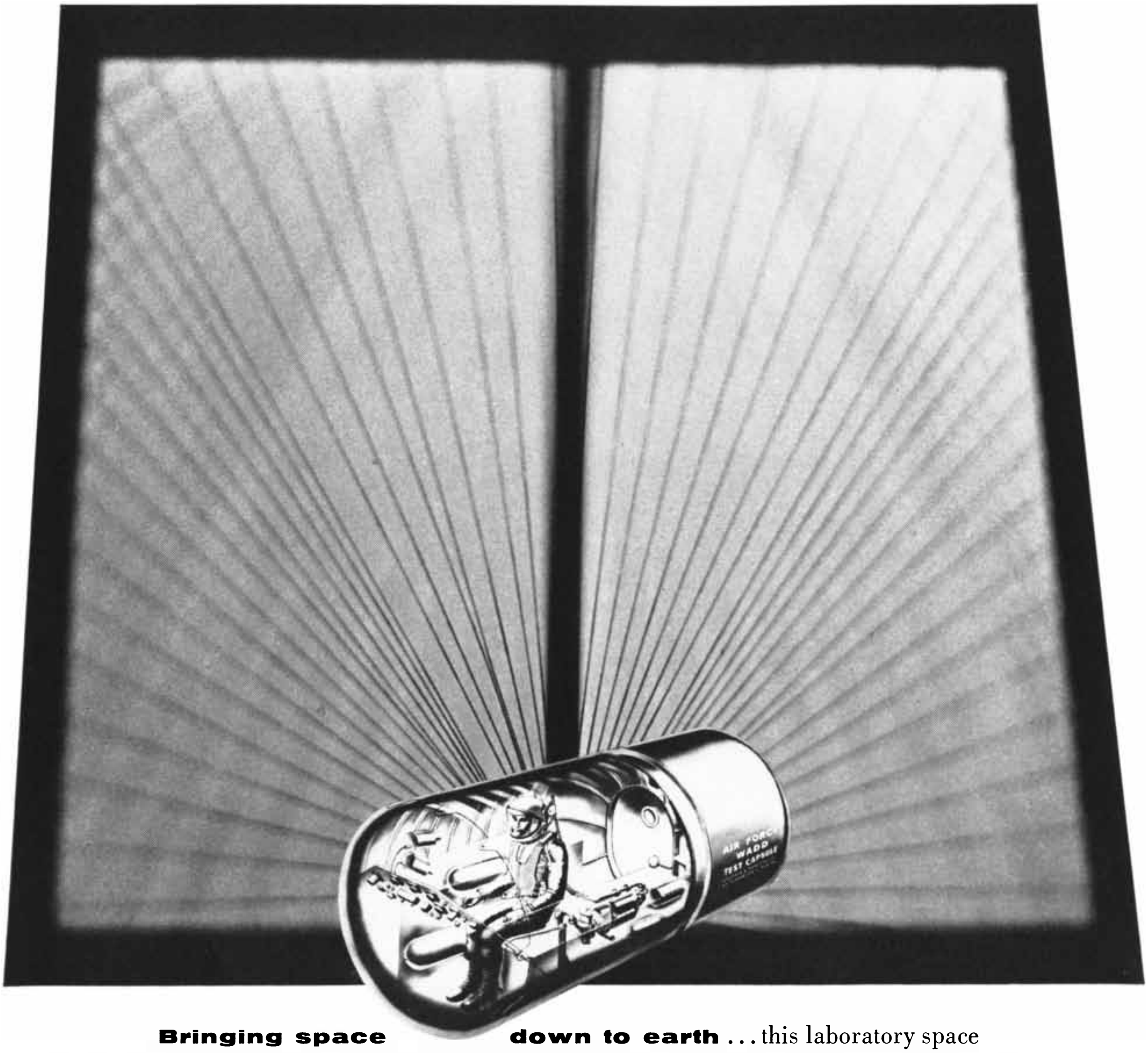

Bringing space down to earth . . . this laboratory space capsule is designed to measure man's physiological and psychological limits and test life support systems under simulated space flight conditions. For the first time, scientists will be able to study, simultaneously, the space flight stresses of high altitude, acceleration, heat and isolation. Developed and being built by Garrett's AiResearch divisions for the U.S. Air Force's Wright Air Development Division, this ground test space capsule is another example of Garrett's research and development leadership in the life sciences and advanced flight systems.

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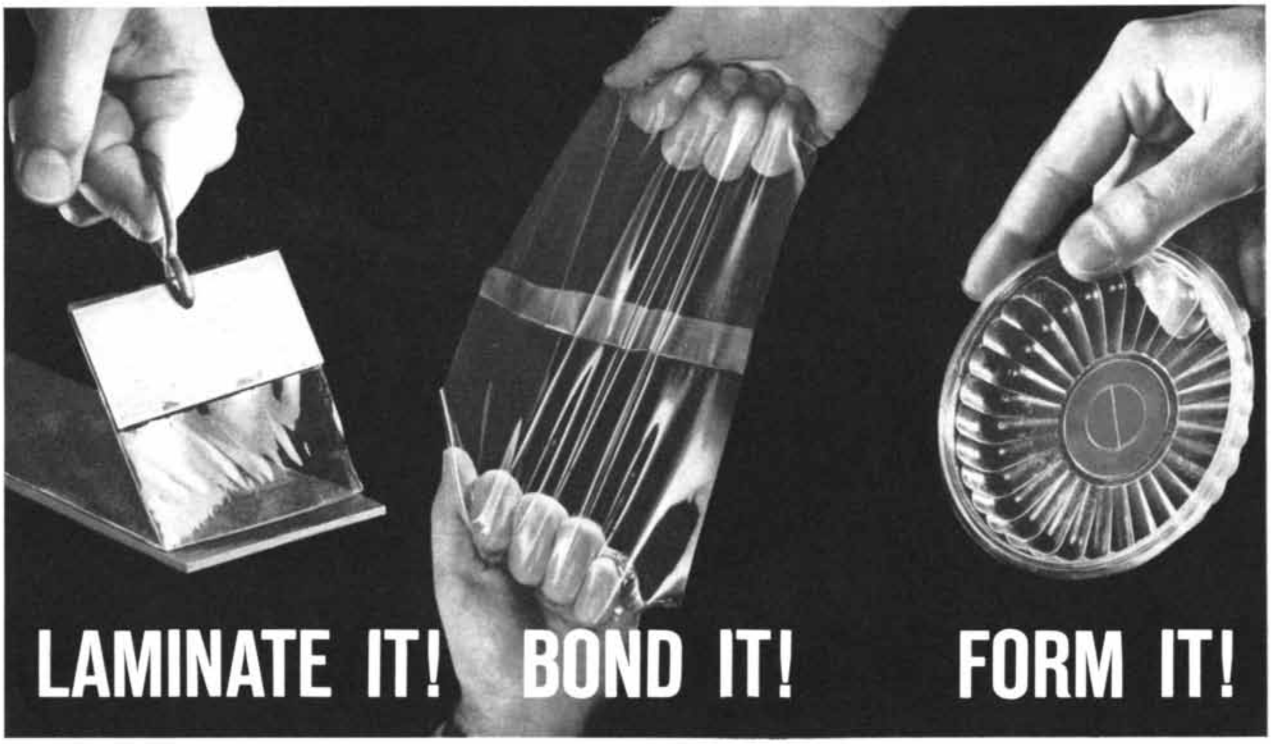

New "TEFLON"* FEP-fluorocarbon film has nearly *all* the unique advantages of "TEFLON" TFE with one big plus. It's a true thermoplastic that can be easily formed and sealed. One type of this new film can be applied *with* adhesives, another can be laminated and heat-bonded *without* them.

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THE 7 HATS OF BORG-WARNER . . . (top) national defense; oil, steel and chemicals; (middle row) agriculture; industrial machinery; aviation; (bottom) automotive industry; home equipment.

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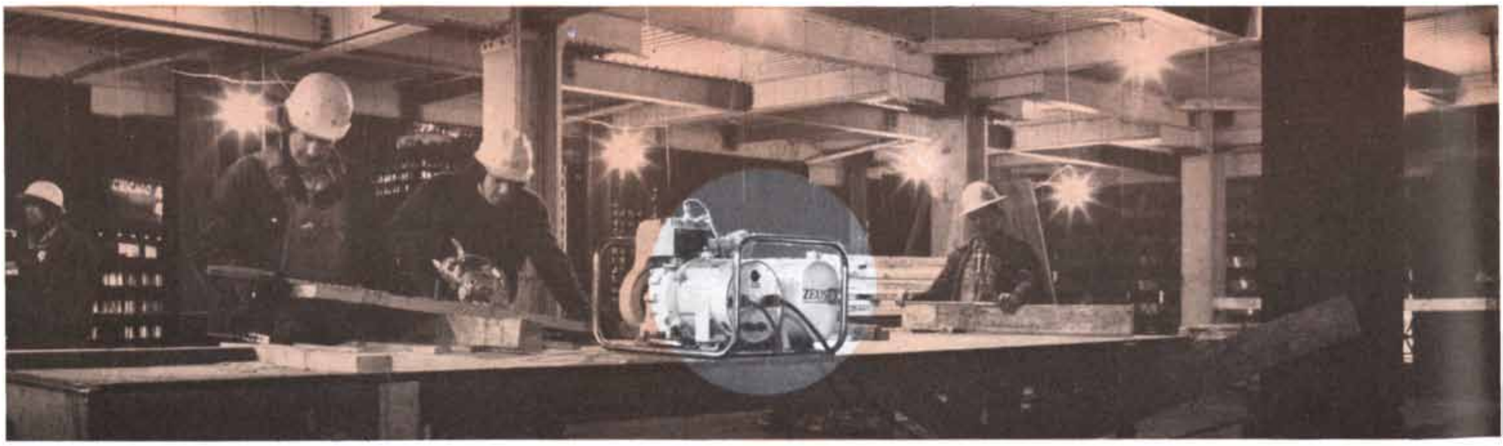

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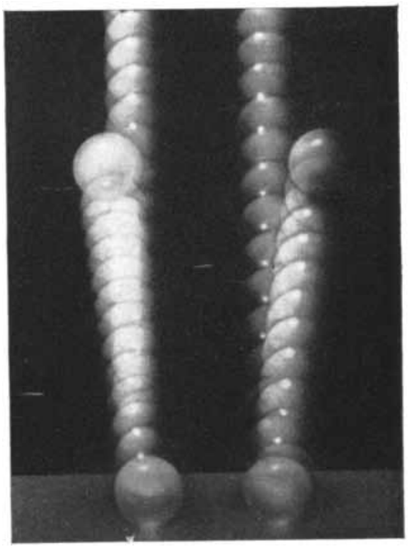
BULLETIN:

Shell Chemical announces the most remarkable rubber achievement since the development of synthetics

The first commercial synthetic rubber to duplicate the molecular structure of natural rubber is now in full scale production. It is called Shell Isoprene Rubber.

Read about this new man-made product. Why it bounces like tree-grown rubber. And why this bounce is so important.



A bounce test proves that the polyisoprene ball, left, duplicates the resiliency of the natural rubber ball, right. Note they rebound to the same height.

SHELL Isoprene Rubber is Shell's name for *polyisoprene*. It is the first commercially made synthetic to have the same basic *cis*-polyisoprene molecular structure as nature's product.

Shell Chemical can produce over 40,000,000 pounds of polyisoprene this year. That's enough rubber to make one million heavy-duty truck tires.

This achievement ends the rubber industry's search for an economical way to make large quantities of polyisoprene. Here is the story in brief.

Rubber made from oil

During the Korean conflict, our nation faced its most acute shortage of natural rubber since the Second World War. To help meet our rubber demands, Shell Chemical and other companies increased the production of synthetics made from petroleum hydrocarbons.

Why bounce is so important

These synthetics proved adequate substitutes for natural rubber in hundreds of products. And they still do. But they all lack one vital property inherent in natural rubber—*high resiliency*.

This excludes them from use in heavy-duty truck, bus and airplane tires which consume two-thirds of the natural rubber we import each year. Without the high resiliency or "bounce" of tree-grown rubber, these tires could not withstand the extreme temperatures or heat build-up caused by repeated flexing at high speeds. They would wear out at an uneconomic and hazardous rate.

Now, new Shell Isoprene Rubber can supply this "bounce" in tires, motor mounts, basketballs—anything that needs it.

Reduces rejects

Shell Isoprene Rubber will not be confined to a few specialized uses. On the contrary.

Its white color, uniformity and ease of processing mean brighter, more economical products. Its ability to flow freely allows for finer detailing of molded goods—it actually increases manufacturers' production by *reducing costly rejects.* And because this rubber is made by a chemically controlled process, it is a logical choice for surgical and pharmaceutical products that demand exceptional purity.

Report from Washington

Shell's success with polyisoprene means more than a plentiful supply of natural rubber for American industry.

Recently, a U. S. Cabinet member stated: "Commercial development of polyisoprene is an important aid to national defense. Its availability in sufficient quantities will free the United States completely from dependence on foreign sources of rubber in time of emergency."

How to learn more

To learn more about new Shell Isoprene Rubber or any of the other industrial and agricultural products that Shell Chemical makes, just write us at 50 West 50 Street, New York, N. Y. They were all developed to make your life a little bit better.

A Bulletin from

Shell Chemical Company

SHELL

LETTERS

Sirs:

In your department "The Amateur Scientist" for November, C. L. Stong observes that the history of science is a "treasure house for the amateur experimenter" and that "many devices invented by early workers in electricity and magnetism attract little attention today because they have no practical application." An interesting example of the truth of this remark—which is by no means to be confined to amateurs—is Herbert A. Pohl's account of dielectrophoresis in the December issue.

No less a forerunner of Dr. Pohl's than Michael Faraday noted in 1838: "When the phenomena of currents are observed in dense insulating dielectrics, they present us with an extraordinary degree of mechanical force. Thus, if a pint of well-rectified and filtered oil of turpentine be put in a glass vessel, and two wires be dropped into it in different places, one leading to the electrical machine and the other to the discharging train [*i.e.*, ground], on working the machine the fluid will be thrown into violent motion throughout its whole mass, whilst at the same time it will rise two, three or four inches up the machine wire and dart off in jets from it into the air." [*Philosophical Transactions of the Royal Society of London*, Vol. 128, 1838.]

Even Faraday may have been discussing a result that was already known in his day, for more than 60 years earlier the Anglo-Italian natural philosopher Tiberius Cavallo had experimented with a kind of electrostatic water pump. Cavallo had written: "Let a small bucket of metal, full of water, be suspended from the prime Conductor [high-voltage output of an induction generator] and put in it a glass siphon of so narrow extremity [a capillary of such narrow bore] as the water will just drop from it. If in this disposition of the apparatus the winch of the induction machine be turned, the water, which, when not electrified, only dropt from the extremity of the siphon, will now run in a full stream, which will even be subdivided into other smaller streams; and if the experiment be made in the dark, it will appear beautifully illuminated." [*A Complete Treatise on Electricity*, 1777].

Dr. Pohl speaks of the electric wind. This too is a very old effect and seems to have been discovered in 1709 by Francis Hauksbee, curator of instruments for the Royal Society. [*Physico-Mechanical Experiments on Various Subjects*, 1709.] An electrostatic motor, called an "electric fly" and employing the electric wind as its driving mechanism, was a favorite experimental device of the older electrical investigators. The fly, in one common form, comprises a wire swastika, its end sharpened to points, mounted horizontally at its hub on a vertical metal shaft and free to rotate. Upon electrification, a corona discharge at the points ionizes the adjacent air. Since the air and points are similarly charged, they repel one another and the swastika rotates, the points moving backward.

In 1864 Charles Tomlinson, lecturer on physical science at King's College in London, reported submerging the electric fly in liquid dielectrics with the following surprising outcome: "On pouring in enough turpentine to cover the fly completely, and holding an uninsulated point over the vessel [containing the fly and turpentine, the point and fly being oppositely electrified], the liquid was thrown into great commotion, welling up the sides of the vessel and spitting out numerous globules. But the most remarkable effect was on the fly: it rotated rapidly and uneasily, frequently rising and falling on its support; but its motion was not, as in air, with the points backward; the points were now moving forward." [*The Philosophical Magazine*, Vol. 27, 1864.]...

MYRON ROBINSON

Research-Cottrell, Inc.
Bound Brook, N.J.

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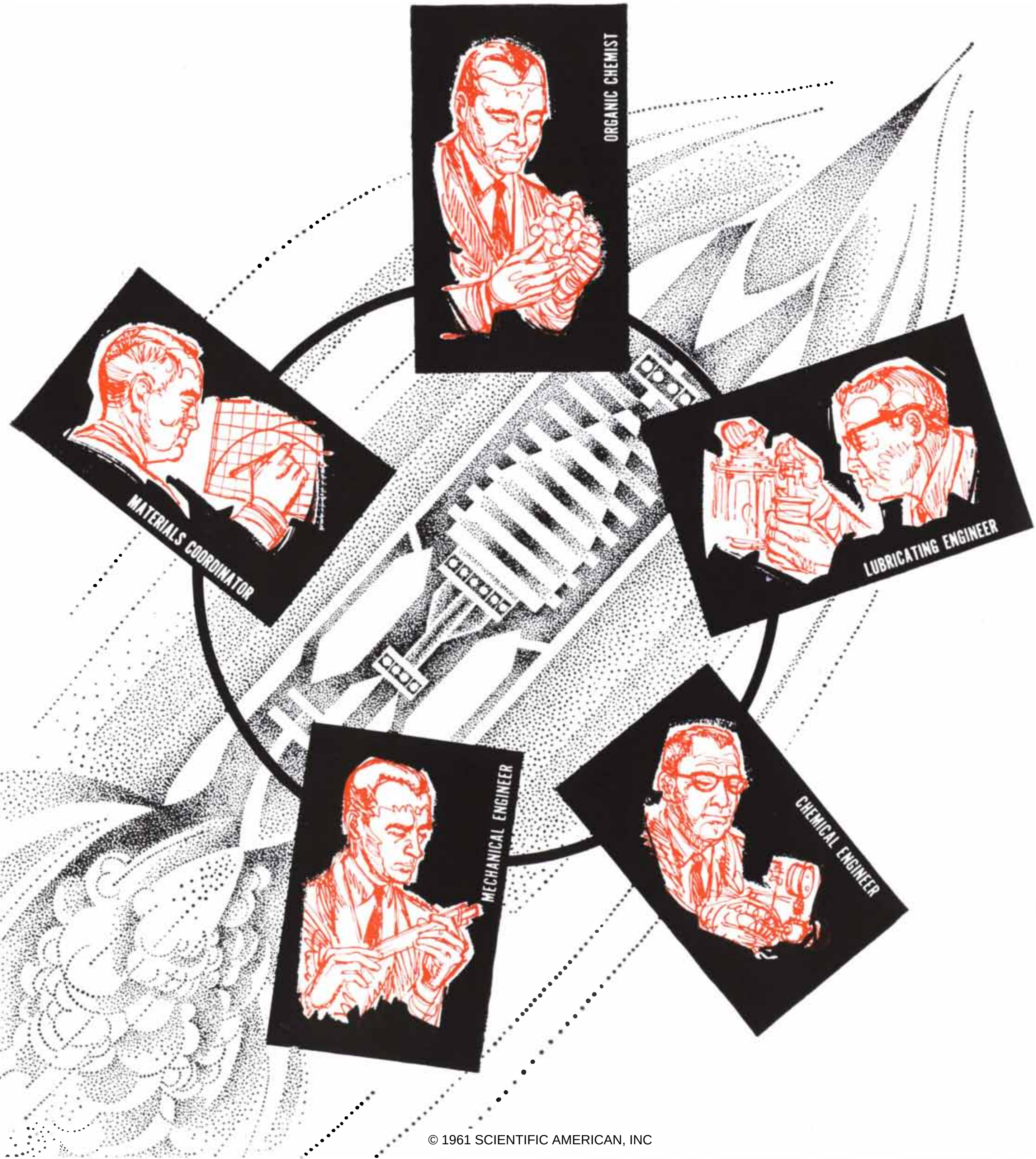
Monsanto **Space-Age Project "HIGH-TEMP-LUBE"**

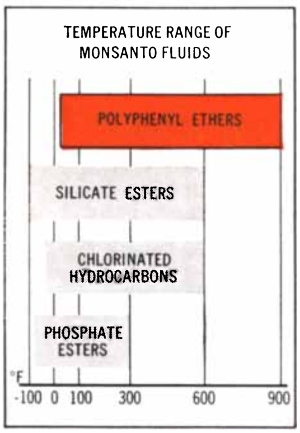
A CHEMICAL EXPEDITION . . .



......seeking high-temperature lubricants for advanced jets and missiles...discovering new fluids that operate up to 900°F.

Monsanto has established a base of "know-how" in a new area of synthetic fluids: the polyphenyl ethers, fluids that exceed the high-temperature performance of all other known lubricants and hydraulic fluids. These newly synthesized liquids resist radiation damage, oxidation and chemical decomposition: as liquids they cover a temperature range of 20° F. to 900° F. Polyphenyl ethers are the result of creative chemistry applied to the problem of high-temperature lubricants; they were developed under contract and in cooperation with Wright Air Development Division, U. S. Air Force.

The heat stability of Monsanto's polyphenyl ethers is the result of enlisting chemical know-how on a problem of mechanical engineering. By design, lubricants for jet engines (and liquid fuel missiles) must lubricate and cool the bearings and accessory drive gears. Existing lubricants could not meet the requirements of advanced engine design. So the logical step was a Monsanto expedition into little-known fields of chemistry. A team of Monsanto scientists found and developed the polyphenyl ethers: to date, nineteen new compositions of matter.



In comparison with other synthetics, these lubricants are as thermally stable at 840° F., as are silicones and petroleum hydrocarbons at 740° F., and present commercial diesters at 540° F. Their useful temperature range exceeds all other fluids by 100° to 400° F.

Their chemical stability, physical properties, and lubricity recommend them for a host of other fluid applications: "hot" hydraulic systems; base stocks for high-temperature and/or radiation-resistant greases; and heat-transfer fluids.

Until development of the polyphenyl ethers, the calculated* useful life of the *best* synthetic lubricant was a scant 18 minutes at 900° F. Presently used synthetic lubricants would be effective for only 6 seconds to 3 minutes at this temperature. Polyphenyl ethers, however, would have useful lives of *20-80 hours* at 900° F.

*Based on the activation energy derived from isoteniscope data.

THERMAL STABILITY OF POLYPHENYL ETHERS VERSUS OTHER SYNTHETIC LUBRICANTS

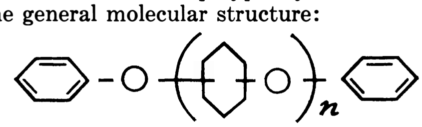
Compound	Decomposition Point, °F.	Useful Life at 900° F.*
Bis (p-phenoxyphenyl) ether	824	25 hours
m-Bis (m-phenoxyphenoxy) benzene	862	80 hours
Bis-p (m-phenoxyphenoxy) phenyl ether	832	20 hours
Quaterphenyl	826	30 hours
Silicone	740	18 minutes
n-Octacosane	662	3 minutes
Tetra (2-ethylhexyl) silicate	638	14.4 seconds
Pentaerythritol tetrahexanoate	585	7.2 seconds
Bis (2-ethylhexyl) sebacate	525	7.2 seconds

Time to decompose 10%

Heat stability is one important facet of these new molecules. The polyphenyl ethers also match the lubricity and viscosity indexes of other good lubricants and possess better hydrolytic stability. They are two to five times more stable than most other synthetic fluids under nuclear radiation.

THE PROPERTIES OF THE MOLECULES

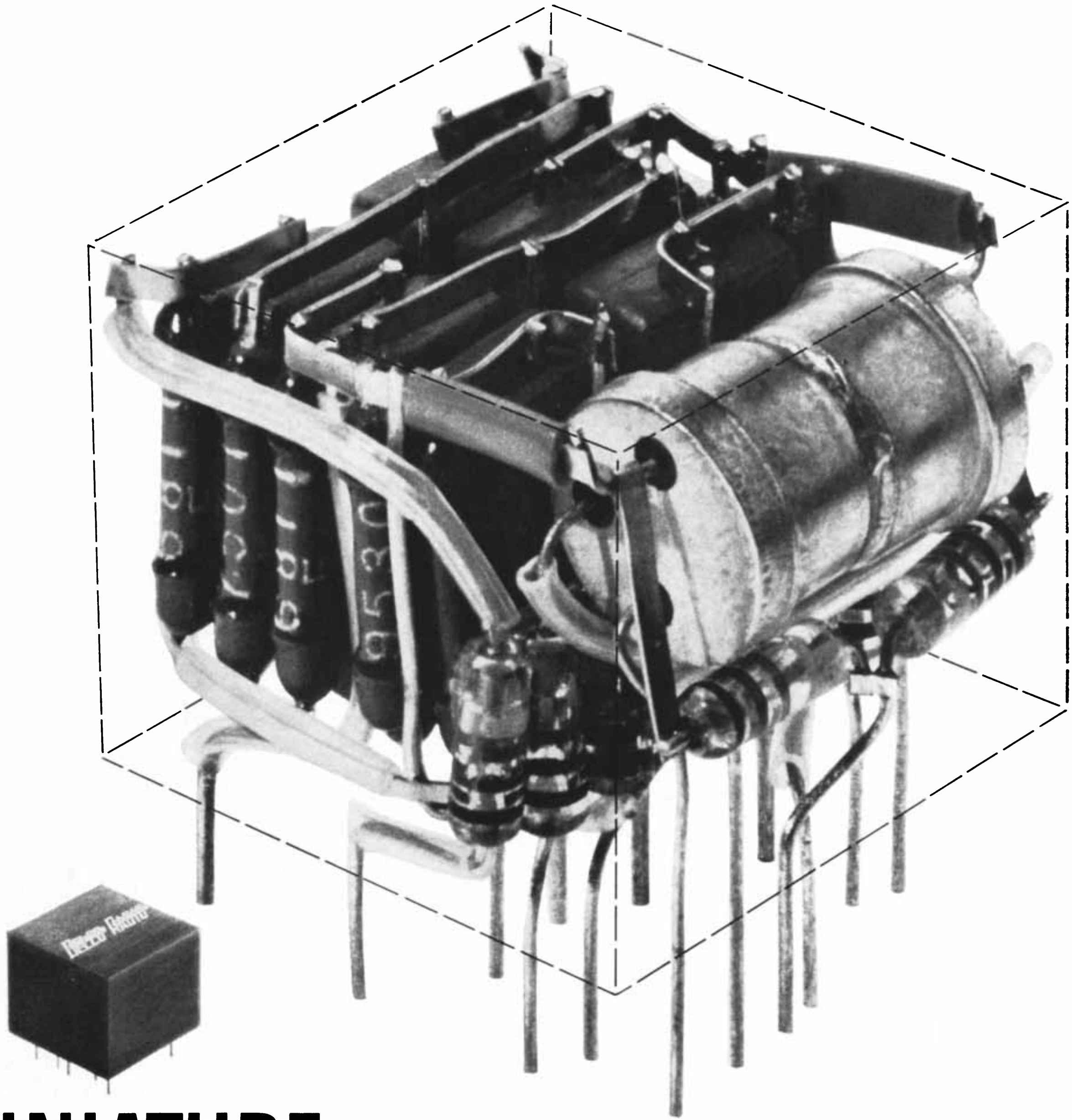
The unsubstituted polyphenyl ethers have the general molecular structure:



The "*n*" values range from 1 to 8, each with linkages in various combinations of the *ortho*, *meta* and *para* positions. The various isomeric polyphenyl ethers are all good lubricants: they show heat stability within a narrow range (the 7-ring ether decomposes only 20° F. higher than the 4-ring ether; a 5-ring appears to have the optimum thermal stability).

Varying the chain length does not materially affect lubricity or heat stability—as chain length increases so does pourpoint, and, conversely, volatility decreases. A 7-ring *meta* ether boils at 1150° F., has a pourpoint of 70° F. Chemically "tailoring" and blending can provide optimum lubricant properties.

While the properties of these fluids may solve many needs, the chemical expedition which found them set out to answer the specific problem of advanced turbojet engine and accessory lubrication. Turbine bearings, surrounded by hot gases, must be kept clean, cool and smooth-spinning. (*Please turn page.*)



MINIATURE BUILDING BLOCK MODULES

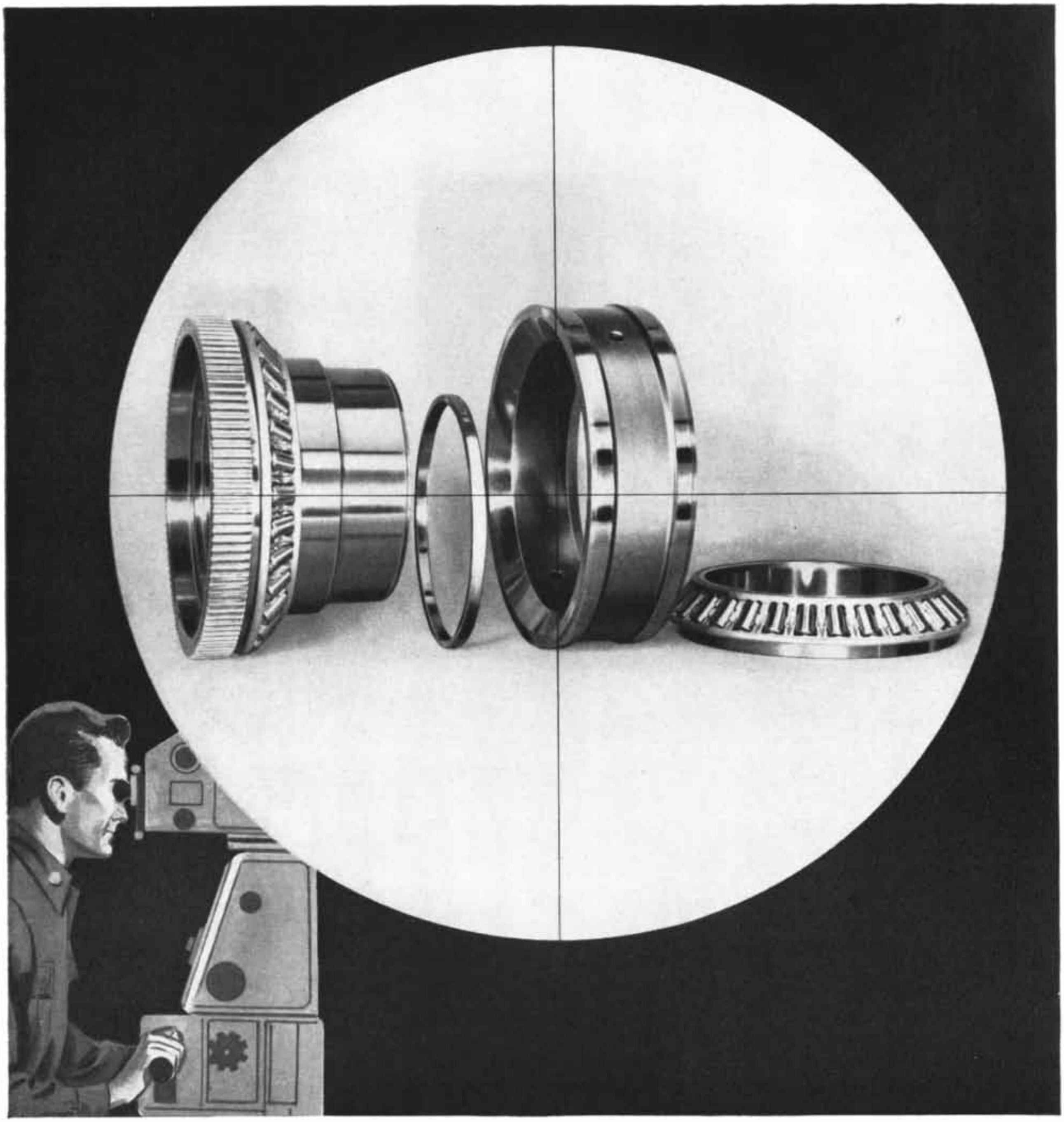
5 times actual size to better show the 28 standard-sized components

Delco Radio's high density packaging of reliable standard components utilizes the unique three-dimensional welded wiring technique. These miniature modules are available off the shelf in 16 basic types. Or with them, Delco Radio can quickly build for you a compact, reliable digital computer for airborne guidance and control or any other military application. Vacuum encapsulated with epoxy resin, the modules perform all the standard logic functions. They meet or exceed all MIL-E-5272D (ASG) environmental requirements, and operate over a temperature range of −55°C to +71°C. Too, these same reliable digital circuits are available packaged on plug-in circuit cards. And we can also supply circuits to meet your specific needs. For complete details, just write our Sales Department. *Physicists and electronics engineers: Join Delco Radio's search for new and better products through Solid State Physics.*

PIONEERING ELECTRONIC PRODUCTS THROUGH SOLID STATE PHYSICS

DELCO RADIO

Division of General Motors • Kokomo, Indiana



ON TARGET WITH TORRINGTON!

Torrington's ability to handle the unusual in anti-friction components is typified by this two-row tapered roller bearing specially engineered for the Kollmorgen Corporation, Northampton, Mass.

The bearing plays a critical role in the hoisting yoke of the type 6C submarine attack periscope. It has been designed with an extended cone to accommodate gear teeth, and other unusual features include fluted cone bore, keyways and drilled and tapped holes. As an integral component in the submarine's fire control system, the bearing must operate with the utmost precision, efficiency and reliability.

Whatever your bearing needs—standard or non-standard—Torrington's uncompromising workmanship is your continuing assurance of the best in every aspect of design, material and performance.

THE TORRINGTON COMPANY

Torrington, Conn. • South Bend 21, Ind.

RESEARCH FOR PROGRESS IN BEARING DESIGN AND PERFORMANCE

The achievement: reproducible 60 megacycle high-resolution proton spectra that anyone can run. And this is from an instrument smaller, more stable and much lower in cost than any NMR Spectrometer that has existed before. Reproducibility of spectra enables instrument calibration. This means that interpretation, cataloguing, discussion and exchange of NMR information will be greatly facilitated. The spectrometer's new speed and freedom from complexity mean that NMR – a unique physical property and key to abundant molecular information – becomes available to organic chemists everywhere.

FEATURES

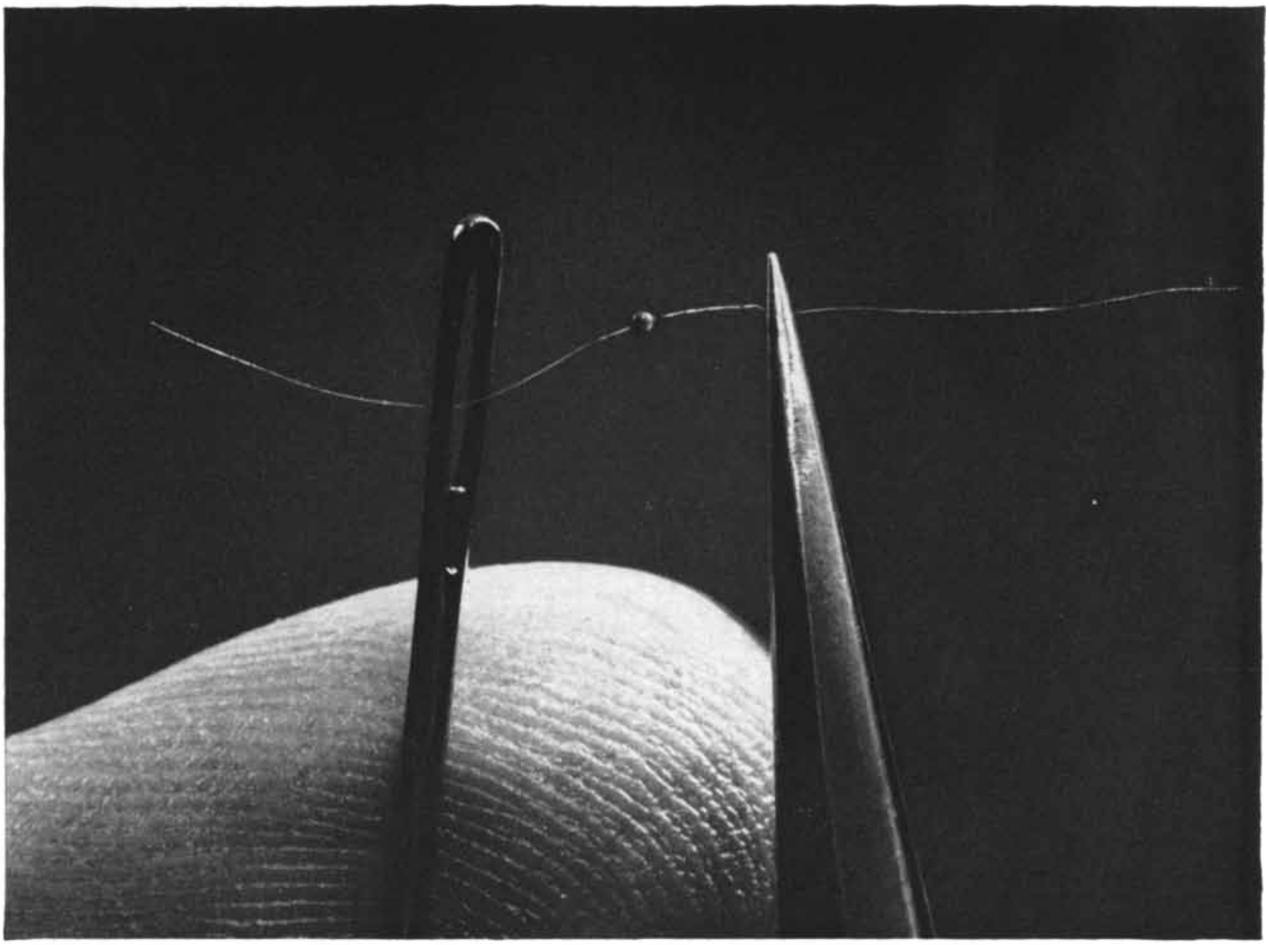
• Precisely reproducible NMR spectra on precalibrated charts • 1-part-in-10^8 resolution at 60 megacycles • Fewer, simpler and more direct controls, enabling operation by nonprofessional personnel • Positive reference to a drift-free standard; controls for sweep ranges, RF amplitude and zero offset all in calibrated steps • Proton spectra only – to provide great reductions in size, complexity and price while giving the NMR capability most universally needed in organic chemistry • Integrator as a built-in standard part of the instrument to provide a quantitative capability • Non-critical environmental requirements and small floorspace needs.

Price of complete system $23,750

For complete information, write the Instrument Division

VARIAN associates

PALO ALTO 7, CALIFORNIA



Needle's eye reveals relative size of the thermistor, a tiny bead of Nickel oxide and other materials, used to measure temperatures in and beyond the earth's thin envelope of atmosphere. Made by Gulton Industries, Inc., the thermistor now serves in more than a dozen different missiles and satellites.

"Space thermometer" goes thru needle's eye

Meet the bead thermistor, member of a family of electronic devices now going into everything from midget radios to giant computers and missiles.

This particular thermistor measures temperatures in space — temperatures ranging from 572° F all the way down to 76° below zero Fahrenheit.

You can hardly see the bead with your naked eye. Although it's only *a hundredth of an inch* in diameter, and the lead wires are a mere thousandth of an inch thick, the thermistor is an extremely stable and rugged device, accurate to within a fraction of a degree Fahrenheit.

Made of Nickel oxide and other materials, the thermistor is a space-traveler in many of today's missiles and satellites. It reliably reports on gradients of temperature within the earth's thin atmospheric shield and in outer space. At the same time, it helps record the temperature changes in the missile's skin and its interior.

What is a thermistor? Its name, which comes from THERMal resISTOR, begins to explain. Temperature changes as small as 1/50th of a degree produce a measurable change in the electrical resistance of the pellet. The resulting increase or decrease in circuit current can then be used directly, as a signal, or can be recorded in the form of temperature readings.

Originally developed by Bell Telephone Laboratories for communications equipment, thermistors are now widely used where a tiny, precise, and dependable thermometer is needed: in medical research, in over-load switches to protect electric motors, and in shipment of perishable foodstuffs, for example.

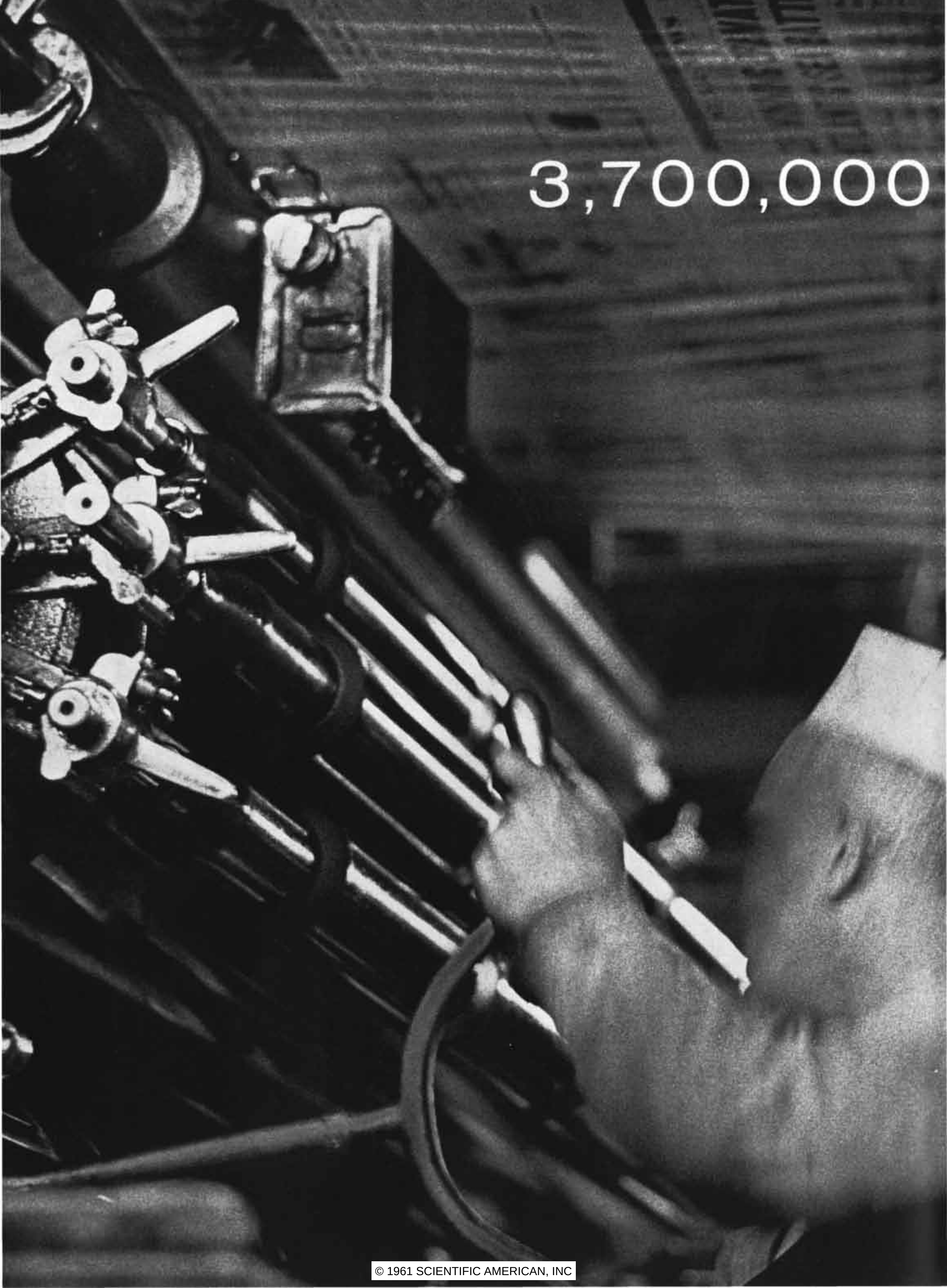
The role of Nickel in the thermistor is only one example of the remarkable versatility of this element.

Be sure to investigate Nickel and Nickel compounds whenever you are faced with a problem calling for unusual electrical or electronic properties...in fact, for *any* unusual metal problem. And don't hesitate to call on us for technical data to help you solve your material-selection problems.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N.Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER


3,700,000

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MARCH, 1911: "Of the hundreds of animals killed by Roosevelt and sent to this country, comparatively few will be mounted by the Smithsonian Institution —in fact, only 50. The Colonel was not in the best of moods when he learned that of the 3,000 skins of animals but a few will be generally useful. The Smithsonian Institution states that not more than 50 different kinds of animals could be detected among the many killed by an untrained observer, and that the general public would only be fatigued and confused by an inspection of the entire series. Besides, there does not seem to be enough money to handle all the collection adequately."

"The eminent Dutch physicist, Professor Johannes van der Waals of Leyden, who has just received one of the Nobel prizes, is justly celebrated throughout Europe for his contributions to the advancement of science. His name, however, is as yet little known in this country, and this is the more strange because his fame largely rests upon his development and application of a scientific theory first promulgated by an American physicist, W. Gibbs. Born at Leyden in 1837, van der Waals became celebrated upon his discovery of an equation that permits the expression of the characteristic relation of fluids, *i.e.*, the relation between specific volume, pressure and temperature."

"Commenting upon the advantages of the Diesel motor in one of our recent issues, we pointed to the apparent neglect that this engine has suffered in our States. We have since received several communications in which it is urged that the Diesel system has not been wanting in appreciation, and that the motors have been regularly manufactured and put upon the market under a series of patents controlled by a leading St. Louis capitalist, with such effect that the aggregate horsepower in use at the present day has reached quite a considerable figure. Nevertheless, it does not appear that the spread of the Diesel has been at all proportionate to its virtues. The immediate gain derived from the substitution of the Diesel in place of steam power depends, of course, in considerable measure on the relative costs of coal and oil. It is largely for this reason that its adoption in Europe, in localities where the price of coal is comparatively high, has progressed with more rapid strides than here."

"Of all the arguments for fortifying the Panama Canal, the most potent is that recently presented by President Taft, when he drew attention to the fact that a very considerable proportion of the nations of the world have not yet progressed to the point where they have at all times stable, reliable and responsible governments. Incidentally, we might mention that the two most powerful dreadnoughts in the world were for a time in the hands of mutineers in the navy of a South American republic. One of these ships, regardless of international agreements as to neutralization, could easily have destroyed the finished canal."

"Secretary of War Dickinson is to be congratulated on the position that he has taken on the subject of lengthening the piers of New York City to accommodate large ocean steamships. In permitting a temporary increase of length, he meets the pressing necessities of the White Star Company, whose 882½-foot *Olympic* will reach this port during the coming summer. At the same time, by granting the extension for a limited period only, he sustains the Army engineers in their jealous guardianship of public rights in our national waterways."

"There is now under construction at Barrow, England, for the Japanese government a large armored cruiser of the dreadnought type, which, it is reported, will be the largest and most powerful vessel of her kind. Her reported displacement is 28,000 tons. The whole of the work on this vessel, including armor and armament, will be done by the contracting firm."

"An investigation has recently been made of locomotive smoke in Chicago in order to determine what share of the smoke in the city comes from this source, and to show that by eliminating steam locomotives there will be a decided abatement of the smoke nuisance. Mr. Paul P. Bird, the city smoke inspector, estimates that 14 carloads of cinders pour out of the locomotive smokestacks at Chicago every day, that 10 per cent of all the coal shoveled into the firebox of a locomotive issues from the stack in smoke and cinders, that railroads contribute 43 per cent of the total smoke in the city, power plants 30 per cent and special plants 12½ per cent, while the smoke from business buildings and dwellings, and from boats, amounts to but 14½ per cent."

"The Norwegian navy has recently been strengthened by the acquisition of a new submersible, the *Kobben*. This vessel is of the *Germania* type, evolved and developed by Fried. Krupp A. G., the eminent German armament manufacturer and naval builder, which has now become the standard class of submarine in the Imperial German navy. In fact, the *Kobben* may be considered the latest development of the Krupp submersible, and is not only powerful but possesses many interesting features. The recent trials of the craft have aroused keen interest among European naval circles, owing to her striking seagoing qualities and general technical perfection. The Krupp firm have always considered the 'diving' boat to be the most efficient form of submarine. It may be mentioned that their contentions as to its all-round superiority are upheld by the German government's naval authorities, for there were 12 submersibles fitted for service on the the high seas in the Imperial navy at the end of 1910, which on account of their speed and endurance are suited to all the conditions of modern war."

Scientific American.

MARCH, 1861: "On the subject of the mechanical employment of women, the London *Mechanics' Magazine* contains the following sensible remarks: 'At the moment 650,000 females are employed in the United Kingdom as milliners, dressmakers, seamstresses and shirtmakers; and their labor being manual, they are, on the average, the most enslaved, most dependent and most unhappy of the industrial classes. Half a million of sewing machines is much needed amongst them, which would double their wages and enable them to obtain three times the quantity of clothing they can purchase out of their present earnings. Nor is there any danger that this market for female labor will be overcrowded, at least for several generations. Men must eventually resign the monotonous drudgery of hand-sewing to

"IMAGINATION IS MORE IMPORTANT THAN KNOWLEDGE"

Albert Einstein

There are some who might argue this point with Einstein. But this much is certain: Wherever new knowledge is sought, imagination lights the way. And surely, only imagination of rare quality could have led Einstein to formulate his principle of relativity.

Einstein applied the insight of imagination to basic science. But imagination can be just as powerful in the creation and application of technology. And nowhere, perhaps, is imagination challenged over so wide a range in both science and technology as in the problems of electrical communications.

At Bell Telephone Laboratories, scientists and engineers range far and deep in search of the answers. They probed deep into solid-state physics to discover the transistor principle, and they speculated and synthesized in an entirely different area of knowledge to create the giant microwave system that carries your TV programs across the country. They study ways to protect the giant molecules in plastic cable sheath, and they explore the basic information content of speech to devise better ways to transmit it. They devise ultrasensitive amplifiers to capture radio signals from distant places, while they conceive and develop new switching systems of unprecedented capabilities. Side by side with the development of transoceanic cable systems they are exploring the possibilities of world-wide communications via man-made satellites.

By exploring every pathway to improved electrical communications, they have helped make your Bell System communications the world's best and they will work to keep it so.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT machines wrought or attended to by women. The stitching of men's clothing is a field for labor that women are only beginning to occupy, that is practically unlimited in its extent and that will give them constant, suitable and remunerative employment. And improvements in the machinery for spinning, weaving and sewing must be ranked among the most important agencies that are at work for the elevation of women and the civilization of our race.' "

"The President-elect has recently passed through New York City on his way to Washington to assume the duties of Chief Magistrate; but, while he has been warmly welcomed everywhere by thousands of people, if we take the concurrent testimony of the daily press, a crowd of hungry office seekers has followed the Presidential train, the number increasing at every point of arrival and departure, doubtless much to the annoyance of the 'coming man.' All the way down to the Federal Capital the expectants pushed on and are now waiting under the eaves of the Presidential mansion, in breathless suspense, for the working of the political machine."

"In a letter to the *Times* of London, referring to the absence of all provisions for the construction of iron-coated ships in the new year's program for the American navy, Mr. J. Scott Russell writes as follows: 'The entire mercantile steam navy of Great Britain, with the exception only of some old vessels, is of iron. The entire mercantile steam navy of America, without any exception known to me, is of wood. The reason is obvious. Timber is one of the staples of America, and we are obliged to import large quantities of it from America into England. Iron is the staple of England, and America is obliged to import large quantities of it from us. Hence, America builds timber vessels far more cheaply than we can. We build iron vessels more cheaply than America can.' "

"An act of great importance to the inventive interests of the country passed the Senate on the 11th ult. It will be remembered that, through the instrumentality of Hon. Jefferson Davis, an amendment to the Appropriation Bill was agreed on at the last session of Congress, prohibiting any department from purchasing patented articles for various bureaus, either naval or war. This cut off a large number of manufacturers and crippled some branches of Government materially. The last reports of the secretaries of War and Navy recommended the repeal of this law, which the Senate has effected, but with the proviso that no more patented firearms are to be purchased. The latter important interest is stricken down, not withstanding the general protest from an immense number of inventors."

"For many years New Bedford, Mass., has been known not only as the greatest whaling port in the United States but the whole world; it is now, however, falling fast from its former oily greatness. In 1857 there were 329 vessels of 111,364 tuns belonging to New Bedford; but at the present time there are only 291 vessels of 98,760 tuns. The price of whale oil has been greatly affected by substitutes, especially coal oil, and the more general adoption of gas in cities and large villages. In 1860 the price of whale oil was only 50 cents per gallon, while in 1857 it was 73 cents. The amount invested in the whaling trade in New Bedford is $10,000,000. Many of the merchants in that place are now looking around to see if they cannot enter upon a more profitable business. The total whaling fleet of the United States now comprises 514 vessels of 158,746 tuns. There has been a total decrease of 141 ships in four years. In 1858, 200 ships went to the North Pacific for whale oil; it is expected that only 100 will go this year."

"A mail train recently ran between London and Rugby, a distance of 83 miles, without stopping. The London *Engineer* states that this is believed to be the longest continuous journey ever made upon any railway."

"The *Great Eastern* is now getting ready to make a second voyage to New York, as a regular trader. It is expected that she will start at the beginning of next month. This second voyage, if she has anything like a tolerable cargo, will afford a better criterion of her speed and capacity than her former trips across the Atlantic."

"The formula of water, according to recent discoveries, must soon be changed from HO to H_2O."

"The price of cotton at the present moment averages half a cent per pound more than it did at the same period last year. About 12,000 bales arrived in New York last week, of which only 5,000 were sold. By the latest news from Europe we learn that there has been a decline of about half a cent per pound on cotton, and the Manchester manufactories were very dull."

THE NEW AGE OF COMMUNICATION

RADIATION INCORPORATED

COMMUNICATIONS UNLIMITED

SATELLITES WILL MEAN FEWER BUSY SIGNALS

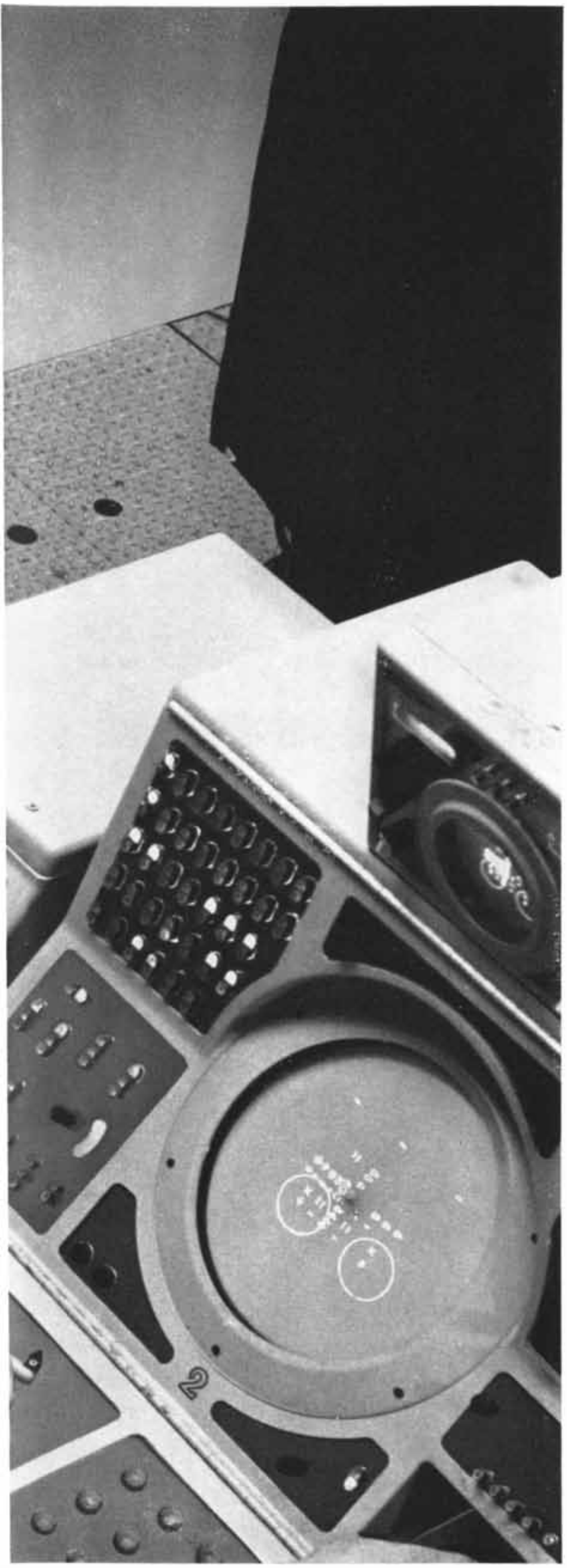
The decade of the Sixties will see both a crisis in communications and its solution. Experts say that by 1962 present transoceanic cables will be saturated by growing message volume. Radio links, too, are reaching the limits of their capacity, with little room in the frequency spectrum for expansion.

The answer? Microwave communication by satellite. Microwaves can't be exploited for distant communication in earthbound systems because they travel in a straight line. But every spot on earth will be in point-blank range of satellite relay stations, and thousands of new telephone, teletype and TV channels will be opened to serve man's burgeoning communication needs.

RADIATION Incorporated is at work today on Tiros I & II and Courier, forerunners of the New Age of Communication. The company is recognized by government and the missile industry as an important contributor to the present state of the art in telemetry, electronic data processing and antenna systems. If advanced electronics figures in your business, write for our "Capabilities Report." Address Radiation Incorporated, Dept. SA-2, Melbourne, Florida.

MAIN OFFICES AND PLANTS ARE LOCATED AT MELBOURNE AND ORLANDO, FLORIDA; AND PALO ALTO, CALIFORNIA.

How to read an enemy mind



Today, Navy battle commanders can predict where an enemy will be next.

Deep in the control room of a giant carrier, they see the enemy deploy. They watch the entire tactical situation—every movement of every ship, aircraft and submarine in the battle area.

Their "eyes" are new Hughes Display Consoles. These TV-like consoles present the over-all situation in quick pictorial form.

The consoles are part of a complete system which also analyzes the enemy's movements and gives split-second recommendations for countermoves.

With this information commanders can coordinate defensive task force movements and assign weapons with unprecedented speed and precision.

Soon to be installed on carriers and guided missile ships, the complete Naval Tactical Display System includes the Hughes console, a high-speed computer and radio and data transmission equipment.

Other projects at the Hughes Fullerton facility include development of new types of computer and circuitry and memory cores. Still other projects are expanding on the Hughes 3-D (electronic scanning) radar principle—one of the major breakthroughs in the electronic arts.

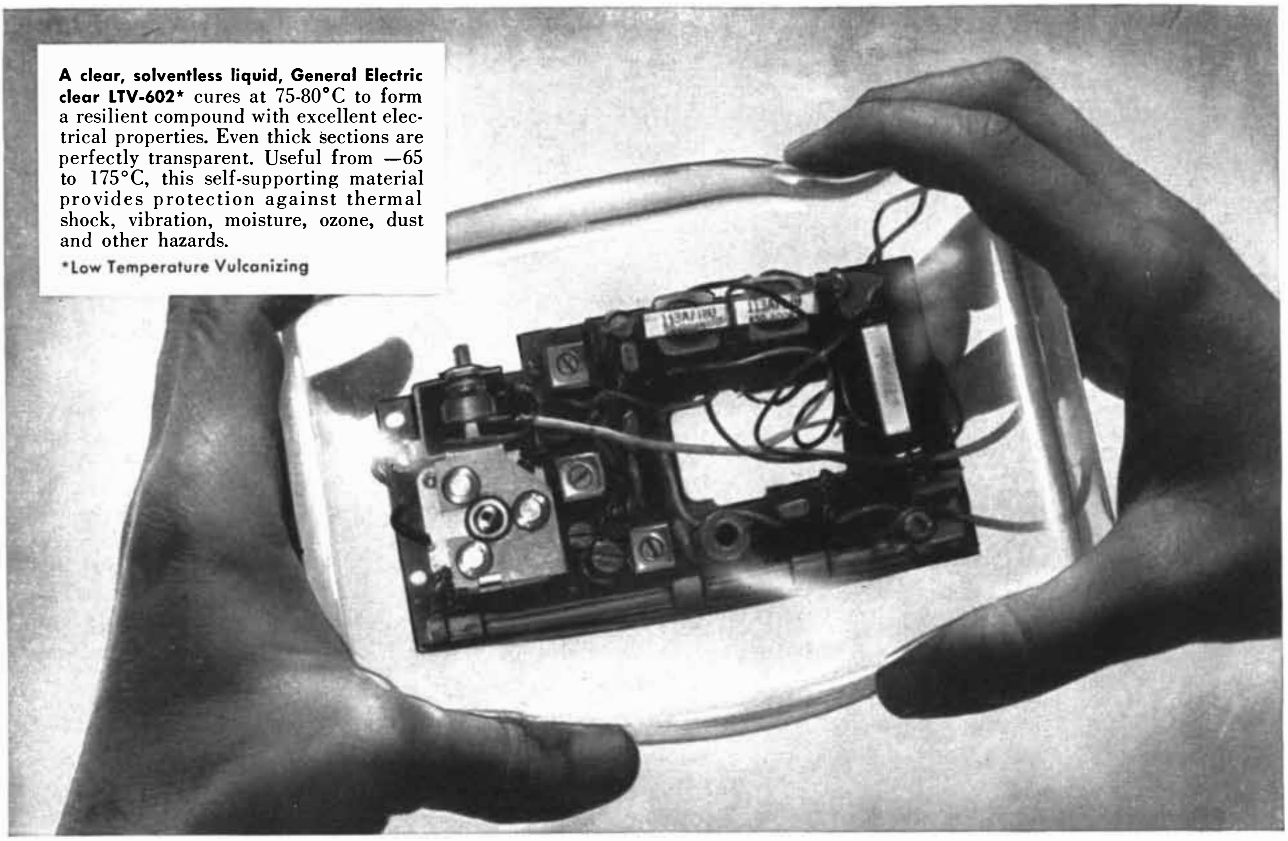
Electronics is our business. Over 5,000 Hughes engineers and scientists constantly search for the best ways to do jobs never done before—for new ways to do old jobs better. Your problem may be an opportunity for both of us.

High over the deck of the missile cruiser USS Galveston, this new Hughes 3-D radar antenna simultaneously detects the range, bearing and altitude of a great number of targets. The sailor shows comparative size.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

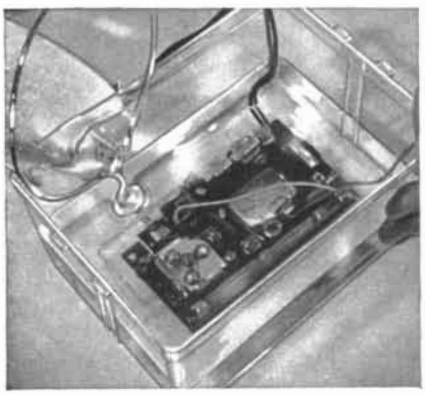


A clear, solventless liquid, General Electric clear LTV-602* cures at 75-80°C to form a resilient compound with excellent electrical properties. Even thick sections are perfectly transparent. Useful from —65 to 175°C, this self-supporting material provides protection against thermal shock, vibration, moisture, ozone, dust and other hazards.

*Low Temperature Vulcanizing

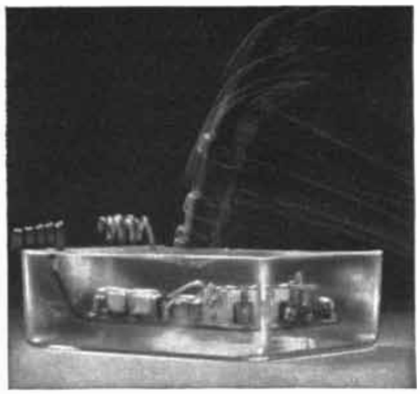
General Electric clear LTV silicone compound for potting and embedding

Transparent, resilient, self-supporting and easy to repair



LTV-602 is easily applied, flows freely in-and-around complicated parts. Having a low viscosity in the uncured state, 800-1500 centipoise, LTV is ideal for potting and embedding of electronic assemblies. Unlike "gel-like" potting materials, LTV-602 cures to a flexible solid. Oven cure is overnight, or from 6 to 8 hours at 75 to 80°C.

LTV-602 is easy to work with and easy to repair. To repair parts embedded in LTV, merely cut out and remove section of material, repair or replace defective part, pour fresh LTV into opening and cure. Pot life, with catalyst added, is approximately 8 hours and may be extended with refrigeration. When desirable, LTV may also be cured at room temperature.



Resiliency offers excellent shock resistance. LTV-602 easily meets thermal shock tests described in MIL-STD-202A test condition B which specifies five temperature cycles from —65 to 125°C. Tests indicate that LTV retains protective properties even after 1800 hours aging at 175°C. Other tests confirm LTV's resistance to moisture and water immersion.

LTV-602 is the newest addition to the broad line of G-E silicone potting and encapsulating materials which also include the RTV silicone rubbers. For more information, write to General Electric Company, Silicone Products Department, Section U340, Waterford, New York.

GENERAL ELECTRIC

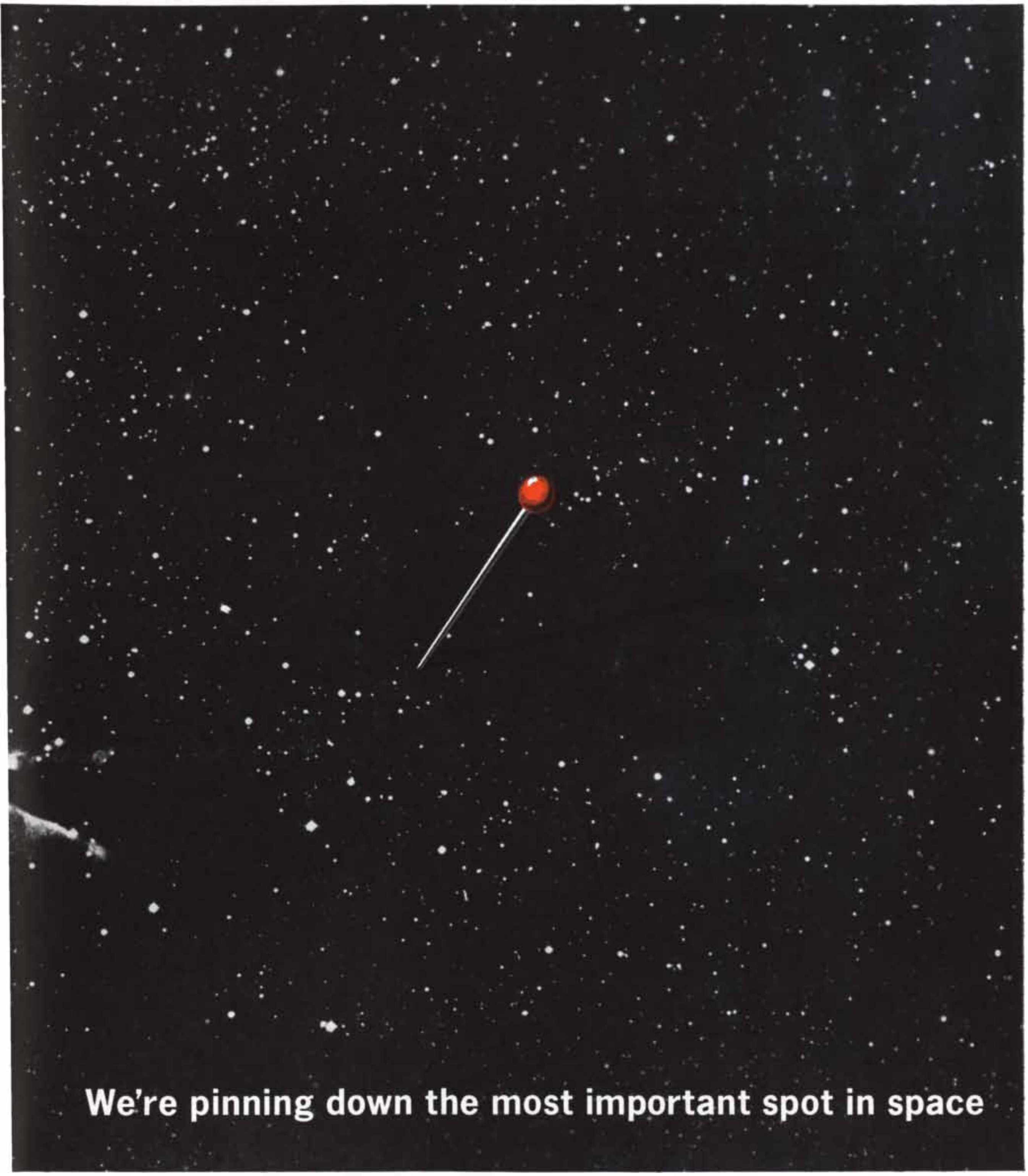
"SATELLITE SPEAKING" loud and clear to the four corners of the earth. This is how Bendix active satellite radio relay systems, under development for the Department of Defense, will provide direct and positive global communications. In addition, Bendix is developing advanced A-J techniques to relieve aerospace communications from the problems of interference and jamming. Career opportunities for engineering and technical management await your direct communication.

BENDIX SYSTEMS DIVISION
ANN ARBOR, MICHIGAN

THE Bendix CORPORATION

It's the point where men will first meet in space. It could be any point. The big problem is getting two men there at the same moment. How do you do it when they're orbiting at 18,000 miles an hour and moving through three dimensions? In the immensity of space, there are no landmarks, and a miss may be your last chance.

Northrop scientists and engineers are already attacking some of the complexities of this problem such as rendezvous trajectories, spacecraft maneuverability, naviga-



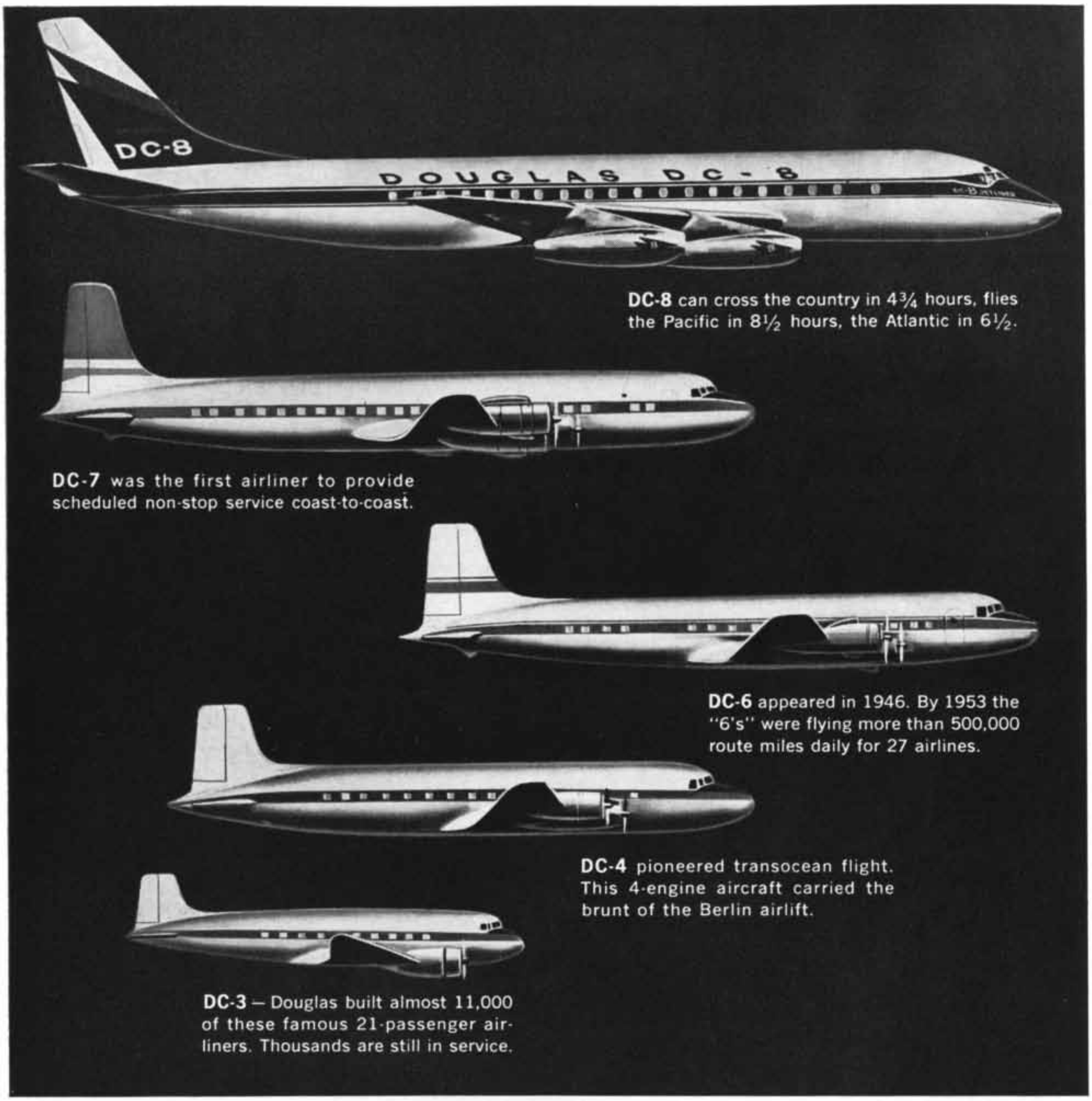
tion and propulsion; in-space rescue, repair and refueling; space medicine and human engineering for crew survival; and re-entry and recovery systems to bring astronauts safely back to earth.

When men move out into space, Northrop equipment and techniques will make the task simpler and safer.

NORTHROP

Northrop Corporation, Beverly Hills, California

One of a series of advertisements showing the breadth of Douglas experience being devoted to commercial, military and space-exploration projects.



Five big steps to a smaller world

How narrow the oceans have become! How small the world! And how quickly the shrinking has occurred!

Within a generation, man has stopped wondering if he would ever fly, and now asks how soon he will land on the moon.

Douglas, builder of the 5 great "DC" airliners that did so much to shrink the world you live in, is now at work on the great rockets and rocket ships which will shrink the solar system.

DOUGLAS

MISSILE AND SPACE SYSTEMS • MILITARY AIRCRAFT • DC-8 JETLINERS • TRANSPORT AIRCRAFT • ANTI-SUBMARINE SYSTEMS • AIRCOMB® • GROUND SUPPORT EQUIPMENT


U.S. AIR FORCE
BLUE SCOUT

LEFT: USAF technicians of 6555th Test Wing under technical supervision of Aeronutronic engineers erect Blue Scout on simplified launch pad prior to successful flight. The development of Blue Scout effectively bridges gap between larger, more expensive ICBM's and smaller sounding rockets in our advanced space research and test programs. The Blue Scout is the largest solid fuel missile ever fired at Cape Canaveral.

OPPOSITE: U. S. Air Force Blue Scout Jr., lifts off launch pad as spin rockets ignite. This unguided 4-stage missile was successfully launched on the first attempt.

U. S. AIR FORCE PHOTOS

The United States Air Force Blue Scout Program provides the Nation with a new and versatile low-cost family of test vehicles to support our military weapons and space systems development programs. It can be used in a variety of deep space probes, orbit missions, boost glide trajectories, and as a rocket and satellite command and control communications system. Blue Scout has already fired a 32-pound scientific payload 16,000 miles into space ...and a 392-pound payload in a controlled trajectory 1400 miles down the Atlantic Missile Range. Aeronutronic is systems engineer, payload and test contractor on this important Air Force program.

AERONUTRONIC DIVISION *Ford Motor Company,* DEFENSE PRODUCTS GROUP

FORD ROAD, NEWPORT BEACH, CALIFORNIA

Write for information about Aeronutronic's capabilities and the career opportunities open for engineers and scientists.

The Blue Scout program, based on modifications of the NASA Scout, is under the executive direction of the U.S. Air Force Ballistic Missile Division, Air Research and Development Command. Above LEFT: Blue Scout is raised to a firing position on simplified launch pad. Because missile requires minimum ground support equipment, it is operable in a number of various field environments at minimum cost. *RIGHT:* Instrument package of Blue Scout is checked by Aeronutronic personnel and Air Force technicians. Accurate guidance system, data recovery system and final stage attitude control make Blue Scout adaptable to a wide variety of applications.

THE AUTHORS

GABRIEL GIANNINI ("Electrical Propulsion in Space") was born in 1905 in Rome. He studied with Enrico Fermi at the Institute of Physics of the University of Rome, where his father and grandfather had been respectively professors of admiralty law and Italian literature. He came to the U. S. in 1930. After working for 10 years on the engineering of loudspeaker systems, he became interested in aviation and developed the aircraft instruments that are now manufactured by the Giannini Controls Corporation. Later he established Giannini Scientific Corporation, a holding company for technological industries. He personally directs the corporate research laboratory in California.

ANTHONY H. ROSE ("New Penicillins") lectures in microbiology at Heriot-Watt College in Edinburgh, where he is also doing research on the metabolic function of the vitamin biotin in yeasts and on the biochemistry of psychrophilic microorganisms. He received a degree in industrial fermentation from the University of Birmingham in 1950 and a Ph.D. in applied biochemistry there in 1954. Rose has done research at the Institute of Microbiology at Rutgers University under a King George VI Fellowship of the English-speaking Union and with the fermentation group of the National Research Council of Canada. He is currently editing a text on the biochemistry of microorganisms in collaboration with Cyril Rainbow; his first book, on industrial microbiology, will be published later this year.

MARTIN F. GLAESSNER ("Pre-Cambrian Animals") is a member of the department of geology at the University of Adelaide in South Australia. After acquiring a degree in paleontology at the University of Vienna, Glaessner did research in the Natural History Department of the British Museum. From 1932 to 1937 he was associated with the U.S.S.R. Academy of Sciences as a Foreign Specialist and participated in several expeditions to the Caucasus for the purpose of studying paleontological problems related to the search for oil. His work for the Anglo-Iranian Oil Company, which he joined in 1938, took him to New Guinea, where he established and directed a laboratory for research in micropaleontology. When the laboratory was transferred to Melbourne in 1942, Glaessner did graduate work at the University of Melbourne, receiving a D.Sc. degree in 1946. He took his present position in 1950. A research associate of the American Museum of Natural History since 1953 and a Fellow of the Australian Academy of Science since 1956, Glaessner is at present engaged in paleontological studies of fossil protozoa and Australian mammals, as well as in research on the historical geology and stratigraphy of Australia and the Indo-Pacific region.

GEORGE GAMOW ("Gravity") is professor of physics at the University of Colorado. After receiving his doctoral degree in nuclear physics from the Leningrad State University in 1928, Gamow continued his studies under Niels Bohr at the University of Copenhagen and later under Ernest Rutherford at the University of Cambridge. He came to the U. S. in 1934 and taught physics at George Washington University until 1956, when he went to the University of Colorado. A prolific popularizer of science, Gamow was awarded the Kalinga Prize in 1956 for his interpretation of science for the layman. He has published a dozen books in 23 languages, with three more going to press. "Gravity" is his 11th article for SCIENTIFIC AMERICAN.

MICHAEL H. JAMESON ("How Themistocles Planned the Battle of Salamis") is associate professor of classical studies at the University of Pennsylvania and a research associate at that institution's University Museum. Born of American parents in London in 1924, Jameson spent much of his childhood in Peking, where his father was a college teacher. He traces his interest in archeology and antiquity to this time. "I was particularly impressed," he writes, "by the work and personality of Père Teilhard de Chardin, the Jesuit paleontologist. At that time he was working on Peking man, and I still have some bone and ash from that cave which Père Teilhard gave me." Jameson acquired a B.A. in Greek at the University of Chicago, served three years in the Navy during World War II, studying and translating Japanese, and then returned to Chicago, where he took his Ph.D. in Greek in 1949. After a year at the American School of Classical Studies in Athens, he went to the University of Missouri to teach Latin and Greek. He joined the faculty at Pennsylvania in 1954.

R. S. SCORER ("Lee Waves in the Atmosphere") is Reader in Applied Mathematics at the Imperial College of

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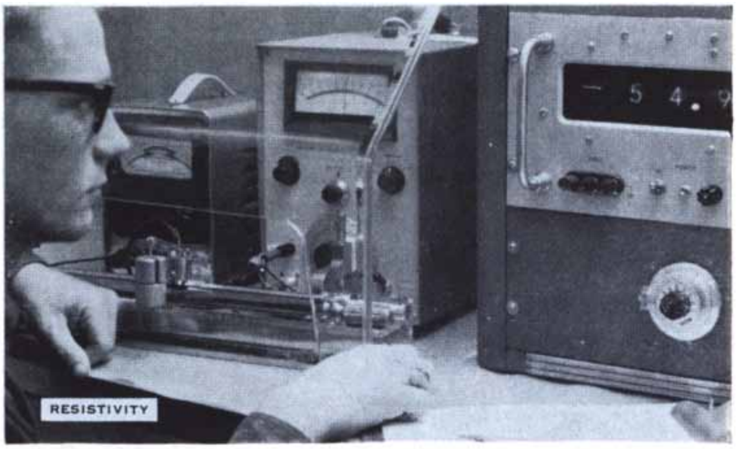

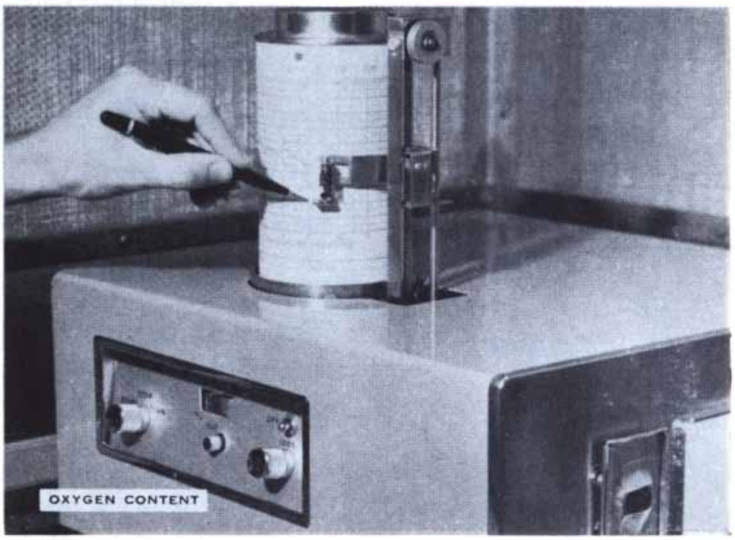

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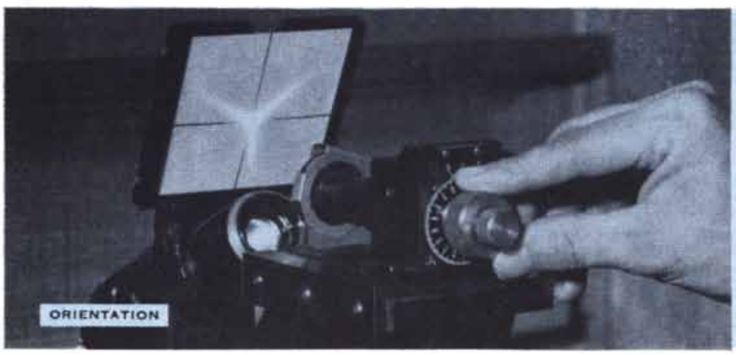

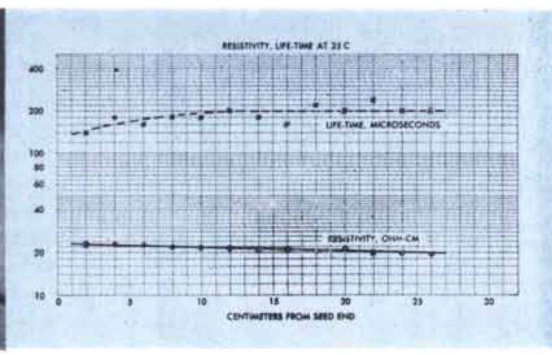

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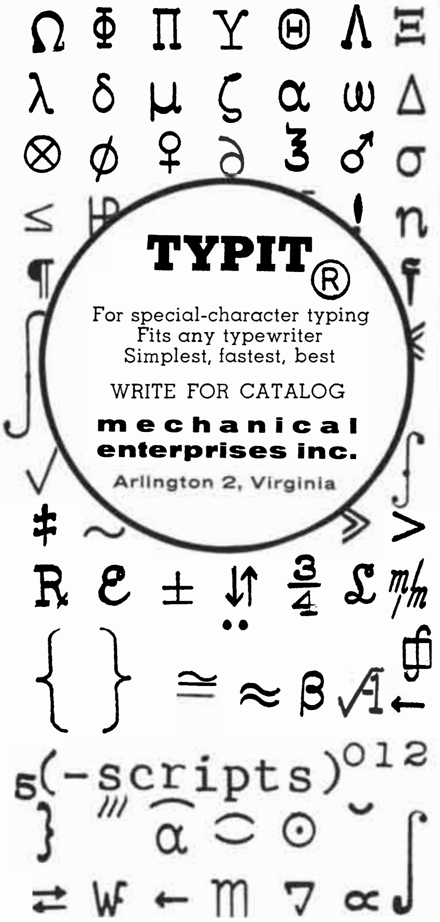

Science and Technology in London. He studied mathematics at the University of Cambridge before joining the British Meteorological Office in 1941. Until the end of 1945 he was engaged in weather forecasting for the Royal Air Force. During this period, which included two years in Gibraltar, he became interested in the effect of mountains on winds and air flow and the causes of different types of cloud formations. He returned to Cambridge to complete his undergraduate work in mathematics in 1946. From 1947 to 1949 he did research under the direction of Sir Geoffrey Taylor on the flow of air over mountain ridges and on the waves in the atmosphere produced by large explosions. Until 1957 Scorer was Lecturer in Meteorology at Imperial College; he assumed his present post later the same year.

ECKHARD H. HESS ("Shadows and Depth Perception") is professor of psychology at the University of Chicago. He was born in Germany in 1916 and came to the U. S. to study at Blue Ridge College, where he acquired a B.A. in 1941. Hess did graduate work at Johns Hopkins University, receiving his Ph.D. in physiological psychology there in 1948. He went to Chicago later that year. His main research interest is the experience of infant animals and the effects of that experience on behavior.

HERMAN E. RIES, JR. ("Monomolecular Films"), is a senior research associate at the Whiting Research Laboratories of the American Oil Company, formerly Standard Oil Company (Indiana). Born in Scranton, Pa., in 1911, Ries acquired a B.S. degree at the University of Chicago in 1933. As a graduate student at Chicago he did research on monomolecular films under the direction of William D. Harkins and received a Ph.D. in physical chemistry in 1936. From 1936 to 1951, when he took his present position, Ries headed the physical chemistry division at the research laboratories of the Sinclair Refining Company, concentrating on low-temperature gas adsorption, the pore structure of solids and the structure and sintering of catalysts. Since then most of his research has centered on monomolecular films and radioactive-tracer studies of adsorption. He wishes to acknowledge the contribution of three of his associates to the work reported in his article. They are Wayne A. Kimball and Norman Isaacs, who performed the electron microscopy, and Joseph Gabor, who assisted Ries throughout the film-balance studies.

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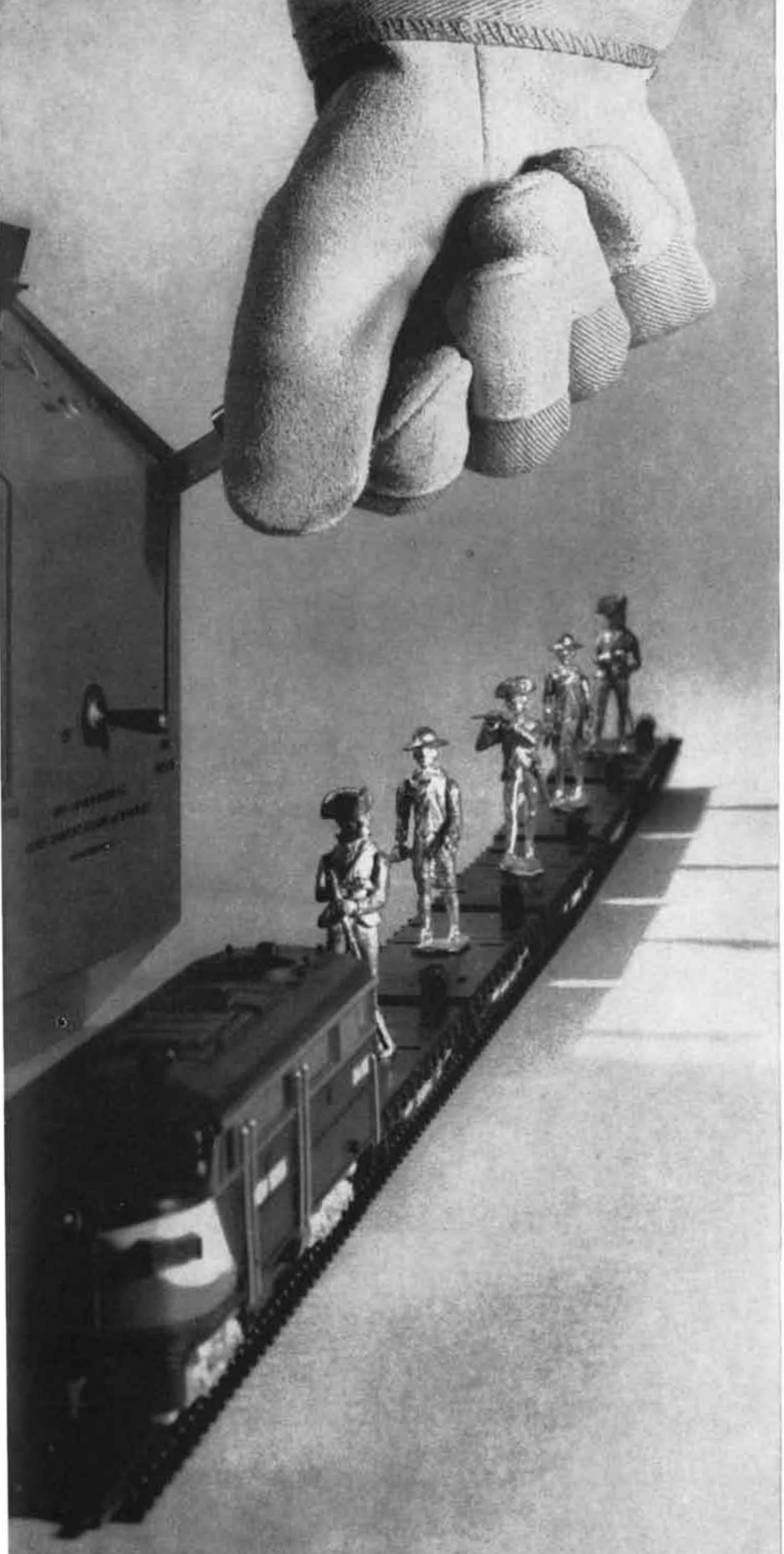

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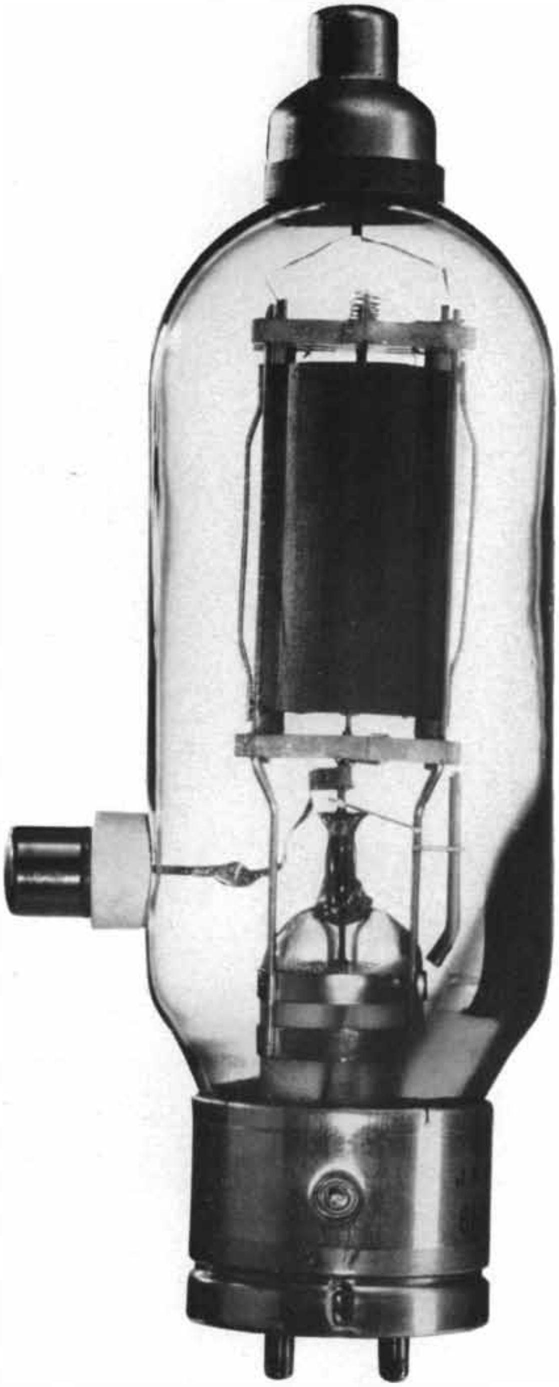

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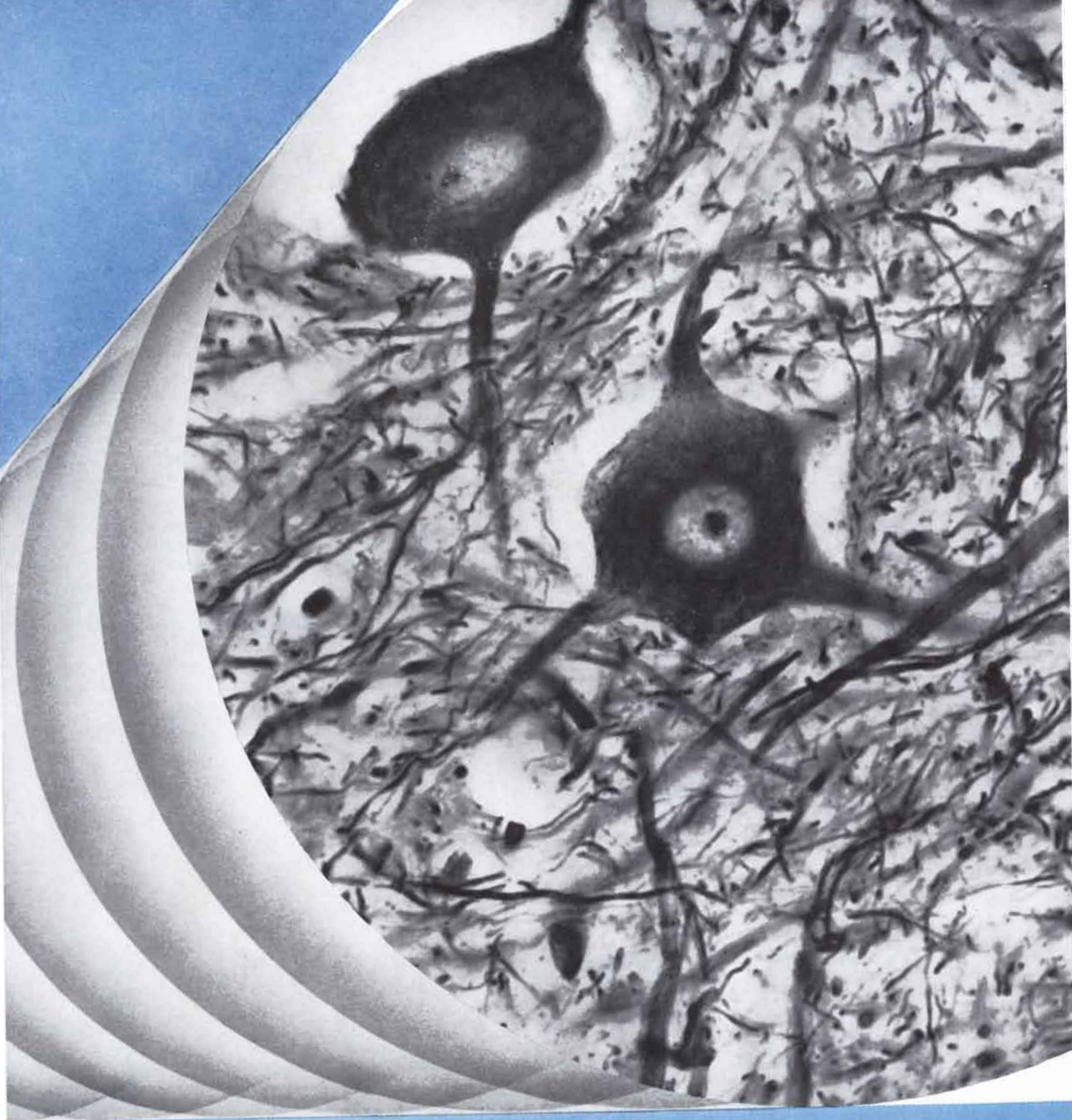

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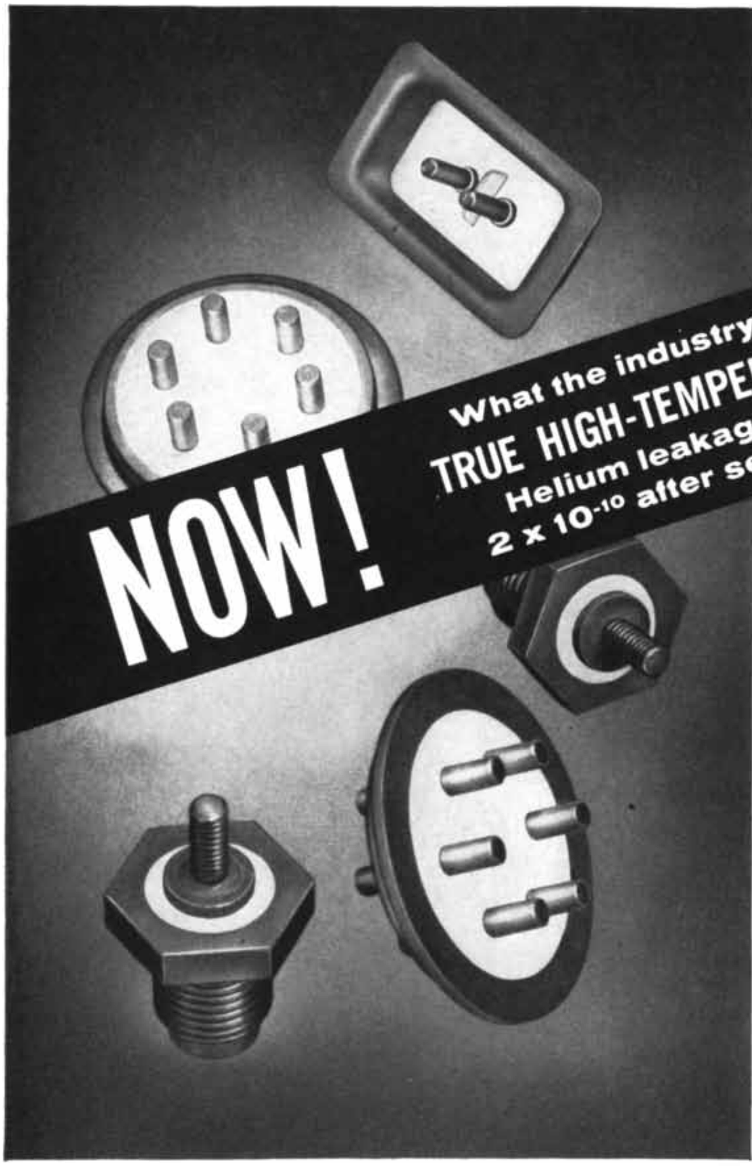

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Electrical Propulsion in Space

Economy of propellant is the chief advantage of electrical rocket engines now being developed. Their low thrust will limit their use to vehicles previously boosted into an orbit by other means

by Gabriel Giannini

This is an article about propulsion engines—primarily electrical ones—for spaceships. Before starting to talk about engines, however, it will be well to decide just what a spaceship is. Opinions may differ on exactly where "space" begins, but most of us would agree that "ship" means something that floats. This means that the engine of the ship does not have to support the ship's weight.

A lighter-than-air ship such as a blimp is held up by the displacement of air; the force of gravity is opposed by a force of buoyancy. A spaceship outside the earth's atmosphere is held up by reason of its motion. As everyone knows, a certain minimum velocity is required for the attainment of "weightlessness." Therefore spaceships will always have to be launched from a planet by means of booster engines capable of exerting extremely large forces; however, the enormous, roaring booster rockets that put artificial satellites into orbit will not be discussed here; the launching problem is solved in principle and to a large extent in practice. Chemical rockets do the job and will probably remain best suited to the purpose for a long time to come. While there is undoubtedly a practical limit to the thrust obtainable from a single assembly of rockets, and thus to the mass that can be launched into space at one time, this need not limit the size of space vehicles. It will surely be possible to launch them piecemeal and assemble them in orbit, much as ordinary ships are assembled in their elevated cradles.

Thus the chief function of a spaceship engine is to act against inertia rather than to support the vehicle. The function of the engine is somewhat comparable to that of a blimp engine except that the latter must overcome the large frictional force of the air as well as inertia.

We are concerned, then, with propulsion in space—an essentially frictionless medium. It is at once apparent that two important considerations must apply. First, just as there is no surrounding mass to offer frictional resistance, so there is none for the engine to push against. A blimp moves forward by thrusting backward a mass of air. A space vehicle has no outside mass to thrust, and so it carries some mass with it for the purpose. It cannot accelerate—that is, alter its motion—unless it ejects a portion of its own substance.

Whether mass is carried internally or is provided by a surrounding fluid, the propulsion system obeys the law of reaction: the forward momentum of the vehicle—that is, its mass times its velocity—equals the momentum of the mass thrown backward by the engine. In other terms, the propulsive force is proportional to the rate of mass flow (the number of pounds thrown backward per second) and to the velocity with which the mass is thrown.

The second general consideration involved in space propulsion is that, with no friction to overcome, the thrust can in theory be as small as one pleases. Any force at all will produce some acceleration and, if applied for a long enough time, could propel a vehicle between any two points in space.

At present only one type of engine is in use in space: the chemical rocket. The mass it ejects is the combustion products of its fuel, which is burned to furnish thermal energy for the ejection. Here mass and energy are stored in the same material. There is, however, no theoretical necessity for the arrangement, and others are now under active investigation at a number of centers. If the propellant gas is to be accelerated not by its own burning but by heating from an outside source, the thermal energy can be obtained from a nuclear reactor [see "Nuclear Rockets," by John J. Newgard and Myron Levoy; SCIENTIFIC AMERICAN, May, 1959] or from an electric arc. The propellant can also be accelerated by nonthermal means, such as electromagnetic or electrostatic fields.

Three electrical engines—the electric-thermal, the electromagnetic and the electrostatic—are the chief concern of this article. They make up a class quite different from the chemical and nuclear types.

To put the different kinds of propulsion devices into proper perspective, let us briefly consider some of the standards by which they must be evaluated. As in any other type of locomotion, there is no engine universally best for space travel. A good engine is one that is well matched to the mission of the vehicle: the distance it must travel, the time available for the journey, the size and the nature of the payload (*e.g.*, instruments, or people and the necessities that people must carry with them to stay alive) and so on. There are several criteria for evaluating engine performance, and their relative importance will vary from one mission to another.

A primary criterion is propellant economy. Chemical-rocket engineers measure it in terms of "specific impulse," defined as the ratio of thrust produced to the rate of mass (fuel) consumed. Since thrust is measured in pounds and mass flow in pounds per second, this ratio turns out to be expressed in seconds. It can be thought of as representing the length of time a pound of propellant would last if expended at a rate that would continuously provide a pound of thrust. For a given thrust the specific impulse is maximized by making the mass flow as small as possible. Because thrust increases with both mass flow and velocity of ejection, the velocity of ejection must be as large as possible.

When mass and energy are supplied by separate sources, the weight of the energy source and the efficiency with which the energy is utilized must be considered individually; in the case of the chemical rocket both factors are included in specific impulse. One more factor may be mentioned: the minimum practical weight of the power source. Chemical rockets can be made smaller than your finger; the smallest conceivable nuclear rocket would be very much bigger.

In classical rocketry the emphasis has always been on maximizing specific impulse or, what amounts to the same thing, exhaust velocity. To this end the fuel is burned in the combustion chamber at the highest possible temperature to extract the most heat from the chemical energy available. Then the heat is converted into mechanical energy at maximum efficiency by proper design of the nozzle through which the hot, high-pressure combustion products leave the engine. The best chemical propellants burn at a temperature of about 7,000 degrees Fahrenheit. They produce an exhaust velocity of some 10,000 feet per second, or a specific impulse of about 300 seconds. To accommodate the high gas-temperature, the chamber and nozzle must be cooled by circulating fuel through their walls.

At 7,000 degrees F. almost all the chemical bonds in any compound are broken open. Hence this temperature is very nearly the highest that can be attained through combustion or any other chemical reaction. It would seem that the chemical rocket has almost reached the limit of its capability.

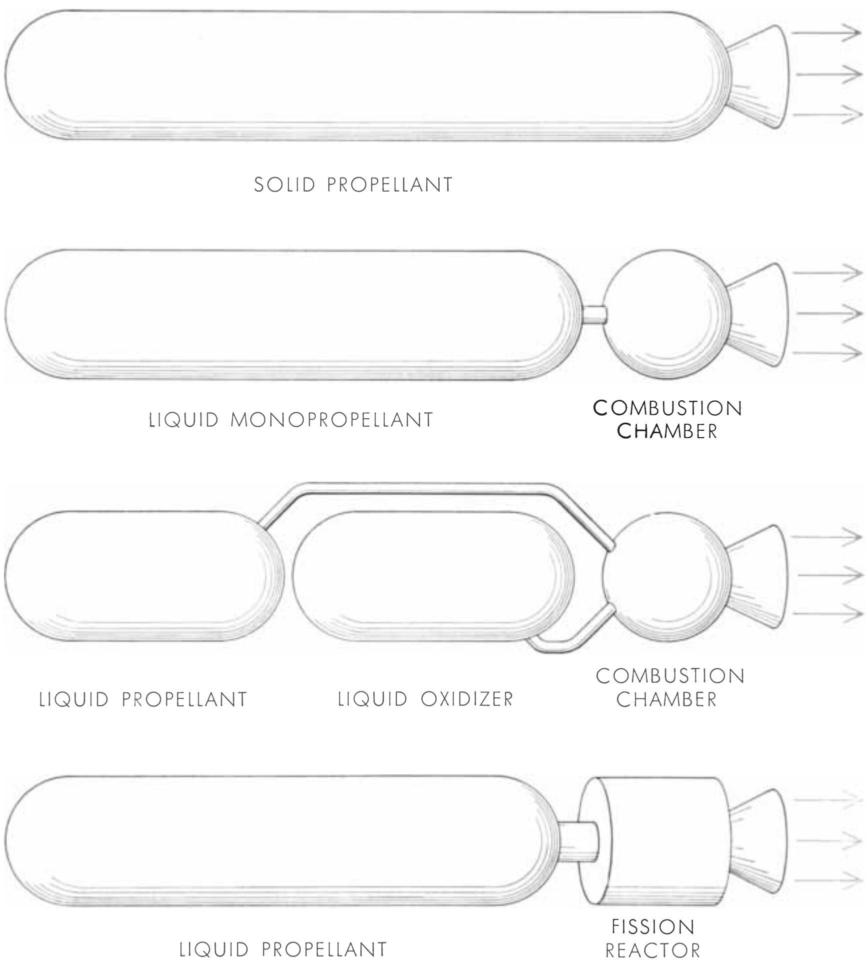
Nuclear-thermal rockets, when they are built, will have approximately the same range of performance as chemical rockets. Their chief advantage will result from the separation of the heat source—the nuclear reactor—and the propellant that it heats, thus permitting the use of hydrogen as propellant. Because of hydrogen's high specific heat, or ability to store thermal energy, its expansion and acceleration are higher than they are in the combustion gases of chemical fuels. This more than compensates for its greater bulk.

Both chemical and nuclear-thermal engines are of the "impulse" type. They produce a large thrust, up to several pounds per pound of weight, for a brief time. And their maximum attainable exhaust velocities yield specific impulses of a few hundred seconds.

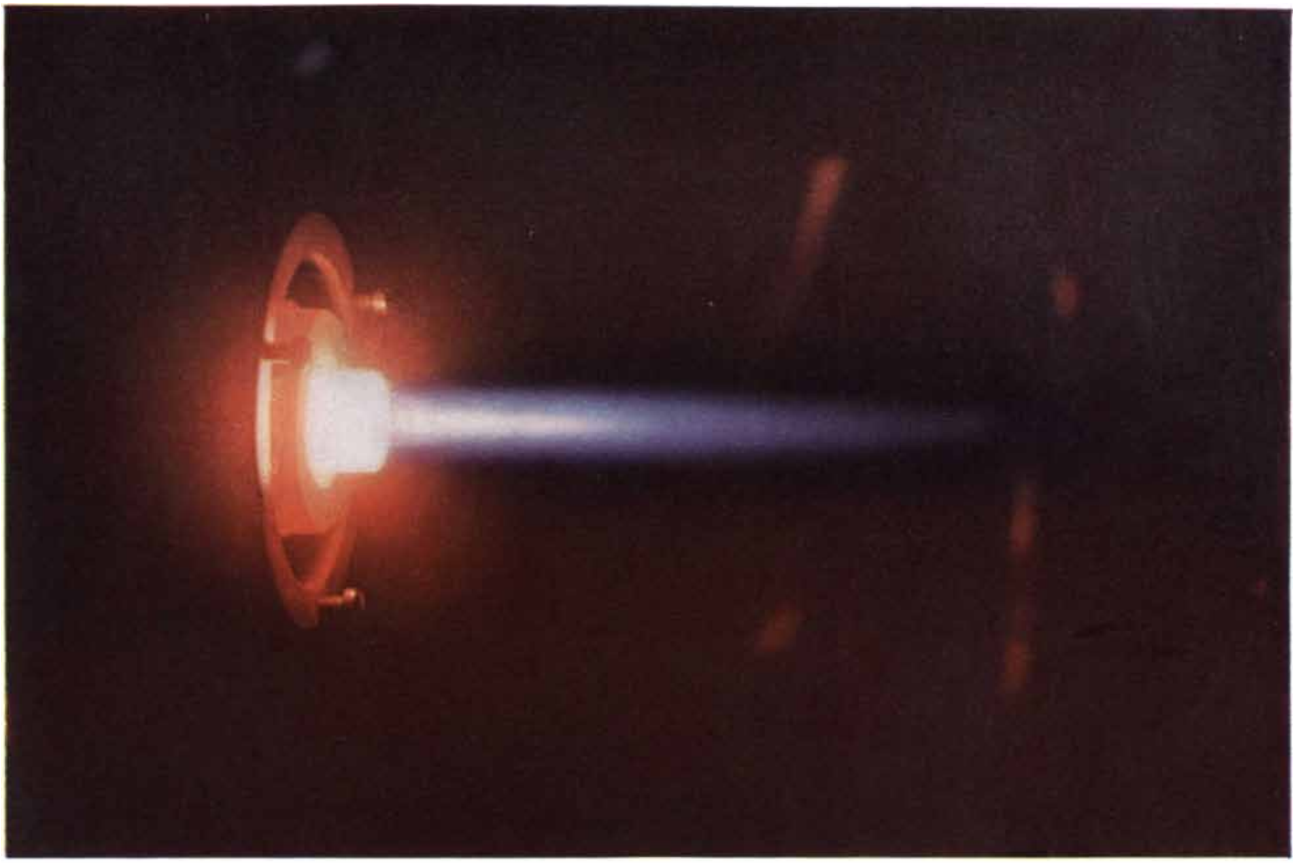
In search of higher specific impulse, designers are turning to electrical propulsion. If their efforts are successful, the result will be engines with much greater propellant economy than that of impulse rockets, but also with radically different operating characteristics. Their thrust will be thousands of times lower, and they will therefore operate over much longer periods. Moreover, their specific impulse can be too high as well as too low. The aim of the designer will be to optimize specific impulse for given missions rather than to make it as large as possible. As we shall see, engines that develop very high exhaust velocities are worth while only if the trip is long enough.

The developers of electrical propulsion systems face two main problems. One is to develop sources of electrical energy that are sufficiently light; the other is to feed the energy into the propellant in such a way as to provide higher exhaust velocities than are now attainable. Let us look at the second problem first. It is the easier of the two and is nearer to solution.

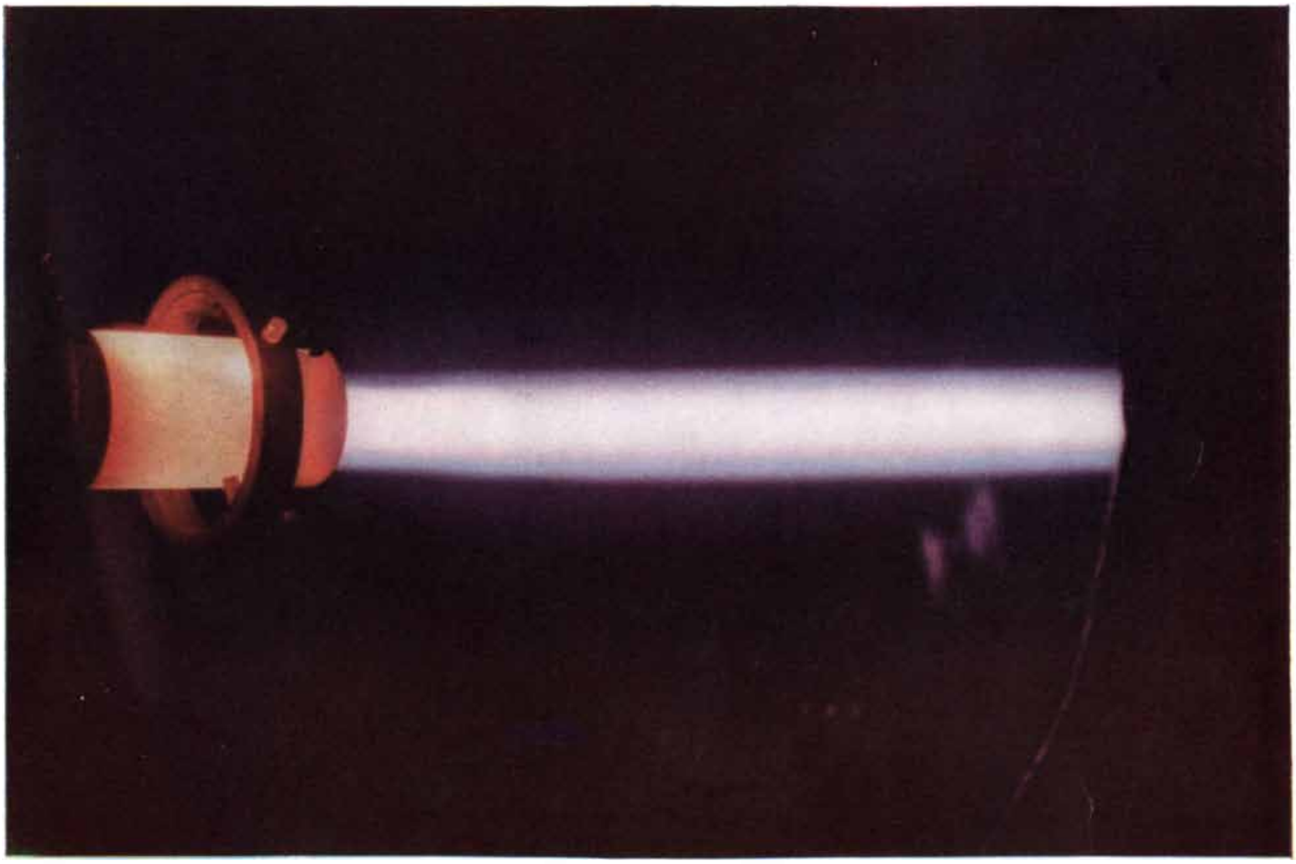
It has long been known that electric arcs produce temperatures well in excess



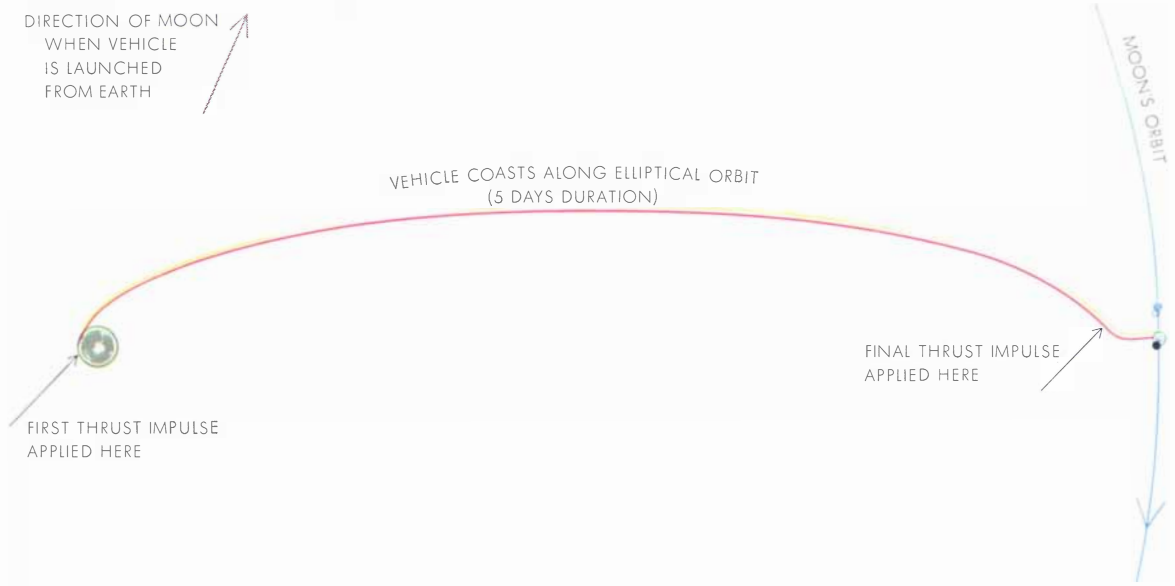
THERMAL ROCKETS drawing energy from combustion of chemical fuel (*top three drawings*) or from nuclear reactor (*bottom*) operate at a temperature of about 7,000 degrees Fahrenheit. This places a low limit on economy with which they expend their propellant.



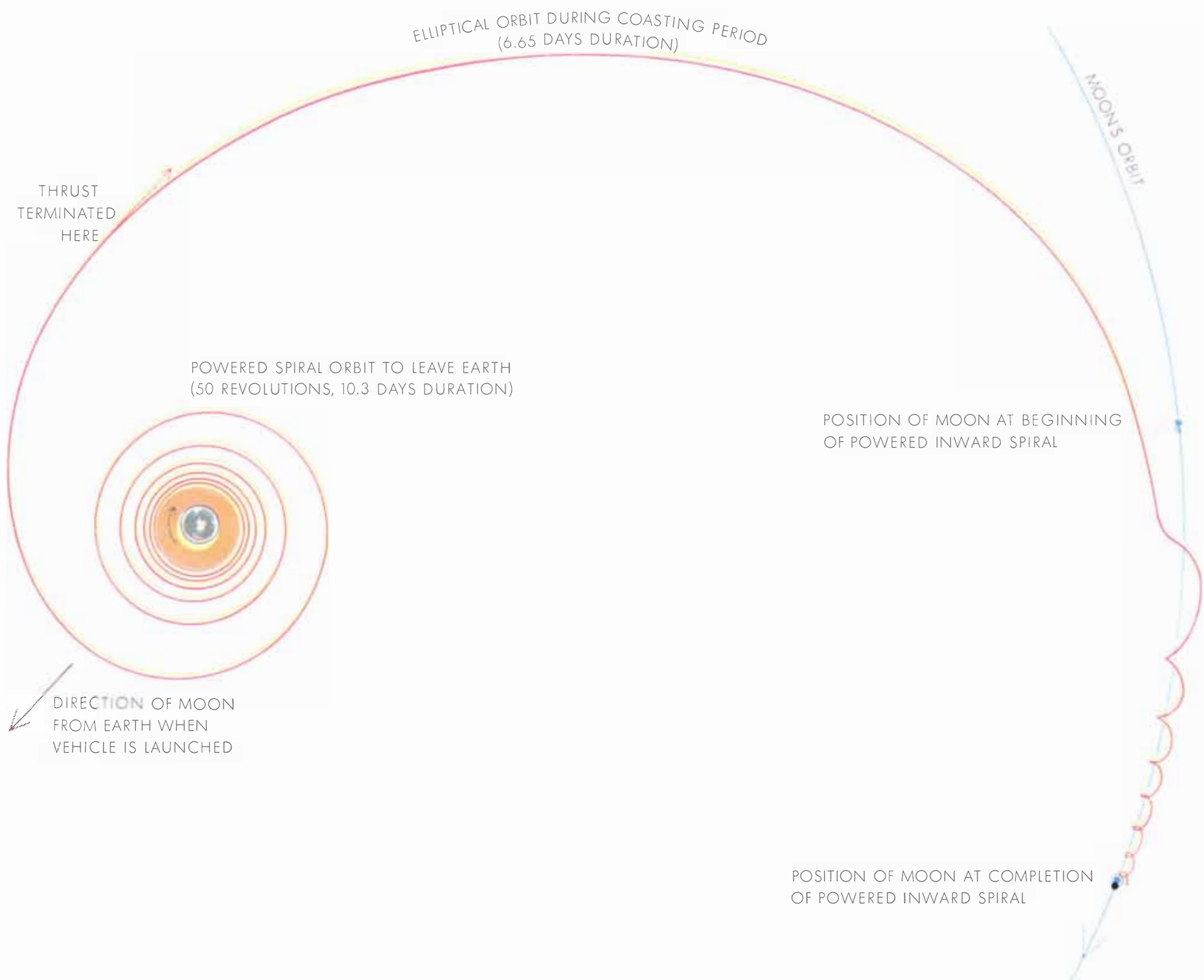
ELECTRIC-THERMAL ENGINE, operating in a laboratory vacuum tank, develops a few tenths of a pound of thrust. Heating is provided by an arc. This prototype was developed by the Plasmadyne Corporation for the National Aeronautics and Space Administration.



LARGER PLASMA-JET PROPULSOR delivers about a pound of thrust. Temperature of emerging jets in these engines is higher than 20,000 degrees F., near the practical limit for thermal rockets. This model was developed by Plasmadyne for the Air Force.



HIGH-THRUST TRAJECTORY for a trip between an orbit around the earth and one around the moon (*green circles*) is shown in red. Chemical rocket engine, which would power such a trip, would operate only about a minute and ship would coast about five days.



LOW-THRUST TRAJECTORY, for trip made with electric-thermal engine, spirals around earth for about 10 days of powered flight. Innermost spirals are indicated by orange tone. These approximate orbits are referred to a co-ordinate system through center of earth.

of those from any chemical reaction. Their heating intensity can be enhanced through techniques such as constricting the arc and increasing the current density in certain regions of it [see "The Plasma Jet," by Gabriel Giannini; SCIENTIFIC AMERICAN, August, 1957]. Neglecting for a moment the weight of the electric-power source, plasma-jet heating makes possible thermal rockets with specific impulses ranging up to 2,000 seconds. The arc requires some 50 kilowatts of electric power per pound of thrust. In the plasma jet the propellant gas (*e.g.*, hydrogen) is heated to between 20,000 and 30,000 degrees F. Now the walls of the chamber must not only be cooled; they must also be insulated by a cushion of cooler gases.

Such temperatures represent the limit for thermal rockets. If the gas gets any hotter, it loses an excessive amount of energy to processes that do not contribute to propulsion. Furthermore, the electrodes and walls can no longer be adequately cooled. To reach higher values of specific impulse it is necessary to turn away from the random particle-velocities produced by heating and look for means of accelerating the propellant in a directed stream.

One method takes advantage of the electrical conductivity of the gas stream produced by an arc. At a temperature of 20,000 degrees or so a gas is partially ionized: electrons separate from some of the atoms and the material becomes a mixture of neutral particles, positively charged atoms and free electrons. This plasma, as it is called, is usually electrically neutral over-all. But because of its high concentration of charged particles it is an excellent conductor of electricity.

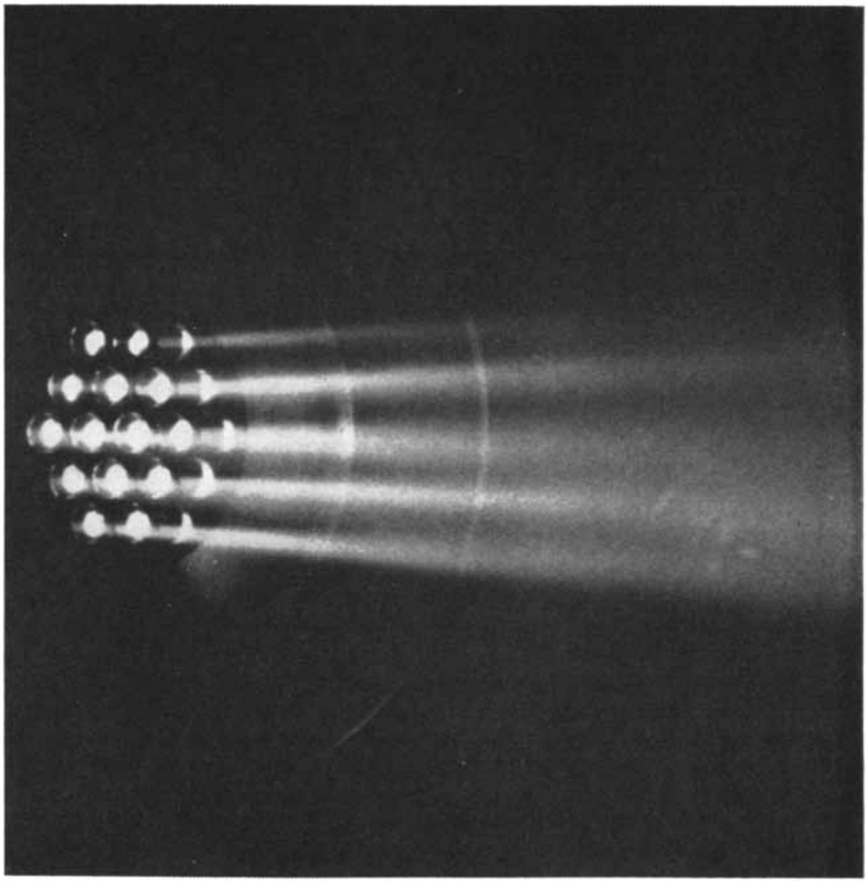
As every high school student of physics knows, a conductor carrying an electric current is accelerated by a magnetic field. That is how an electric motor works. Those who remember the "left-hand motor rule" are aware that the direction of motion is at right angles both to the magnetic field and the flow of current through the conductor.

Imagine a stream of plasma emerging horizontally from an arc chamber, say from left to right [*see middle illustration on page 63*]. If electrodes are placed on opposite sides of the conducting stream, a current will flow across it. A magnetic field perpendicular to both the stream and the current direction will produce a horizontal acceleration of the stream. This is just one example of the many different arrangements for speeding up a plasma stream with a magnetic field. Calculations show that such a "magnetohydrodynamic" propulsor can step up the specific impulses to values of from 2,000 to 4,000. The power requirements are more than 50 kilowatts per pound of thrust, and the devices currently available are heavy.

Another way to accelerate the particles of a gas in a directed stream is through the effect of static electric fields on charged particles. For this purpose a mixture of positive, negative and neutral particles will not do. Only charged particles can take energy from the field, and they must all be of the same sign in order to move in the same direction. Electrons are easily produced and accelerated to high speeds, as they are in television picture tubes, X-ray tubes and similar devices. So far as propulsive force is concerned, however, their extremely small mass more than offsets their large velocity. Accordingly electrostatic engines utilize positive ions. Cesium is employed because it is easily ionized by moderate heating, and an atom of cesium is some 240,000 times heavier than an electron. After the ions have been speeded up by a high-voltage field, they must be restored to electrical neutrality by the addition of their lost electrons. Otherwise the electrons will collect on the vehicle, building up a negative charge that will slow down the positively charged exhaust stream. Neutralization may be accomplished with a hot filament located at the rear of the engine [*see bottom illustration on page 63*]. Ion propulsion systems can develop specific impulses in the range of 5,000 to 100,000. They require 50 kilowatts per pound of thrust.

Prototypes of all these propulsion units have been built. So far only rather crude experimental versions of the electromagnetic engine have been built, but small models of the other two types are nearly ready to fly [*see illustrations on page 59 and on this page*].

Like all energy converters, electrical propulsors are subject to inefficiencies at every point in their operation. For the arc-jet engine, heat loss through direct radiation and through heating of gas chamber walls, electrodes and ejection nozzles constitutes the chief energy thief. The drain is especially large for the small



CESIUM-ION BEAM emerges from prototype ion-engine in a vacuum tank. The thrust produced by this model is in the range of several ten-thousandths of a pound. This device was developed for the Air Force by the firm of Electro-Optical Systems, Inc., of Pasadena, Calif.

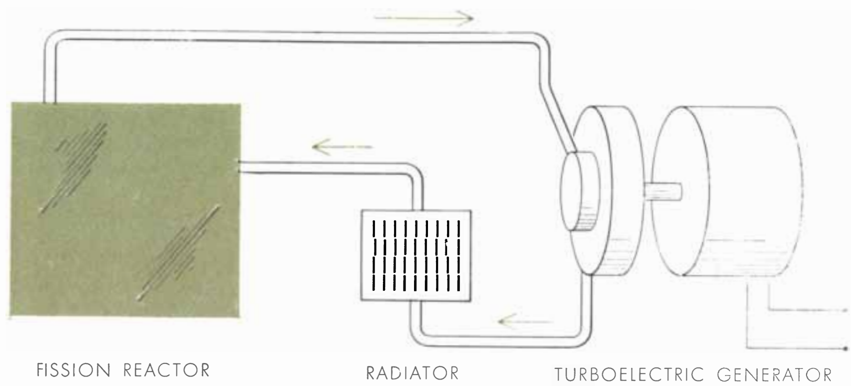
models. The larger the unit—that is, the higher the ratio of volume to surface—the more efficient is the insulating gas layer. In the ion engine incomplete neutralization of the exit beam cuts the available thrust.

We can expect that these difficulties will be steadily reduced through improvements in technique. On the other hand, the thrust obtainable from electric propulsors is inherently small. As exhaust velocities increase, so do the demands on the energy source, which grows much heavier in relation to the mass flow of propellant through the engine. Thus we find the thrust measured in thousandths of a pound per pound of engine weight. Larger engines than those listed in the table on pages 64 and 65 would produce somewhat higher values of thrust per pound of weight, but at most the thrust of plasma-jet and electromagnetic engines might be a few hundred pounds, and of ion engines a few tens of pounds.

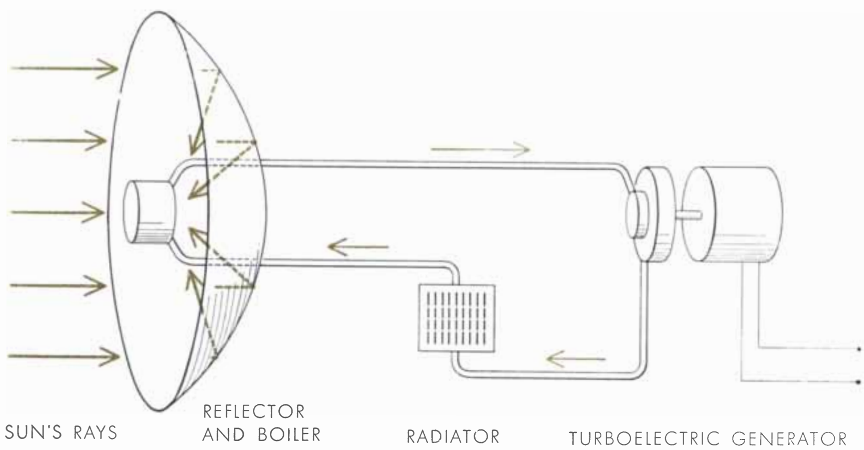
Extensive experimental work remains to be done before all the relative advantages of electric-thermal, electromagnetic and electrostatic propulsors are firmly established. At the moment it appears that electric-thermal methods will be superior at specific impulses up to 2,000 seconds, and that electrostatic methods will be superior above 5,000 seconds, with electromagnetic methods filling the gap.

As to power sources, the picture is much less clear. Chemical batteries would appear to be out of the question as a prime source. The process of converting chemical energy into electrical energy and then into energy of motion is hardly likely to be competitive with the single conversion carried out by chemical rockets.

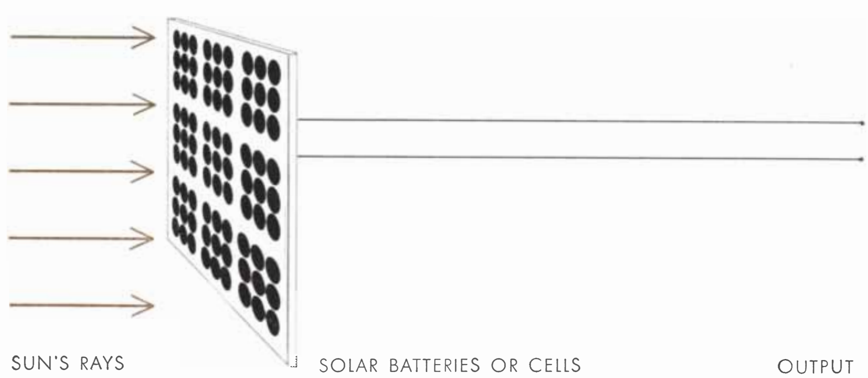
Inevitably, then, the energy will have to come from nuclear reactions. Here there are only a few possibilities. One is a more or less conventional nuclear power plant: a fission reactor driving a turbogenerator. It is a characteristic of these systems that their power output increases faster than their total weight. In order to achieve a sufficiently high power-to-weight ratio they will have to be quite large. Therefore they are suitable only for big vehicles, and vehicles that will remain in space long enough for the fuel economy to compensate for the original investment in the weight of the power plant. This in turn requires that powerful reactor-generator systems be designed to operate unattended for years on end, in a vacuum, bombarded



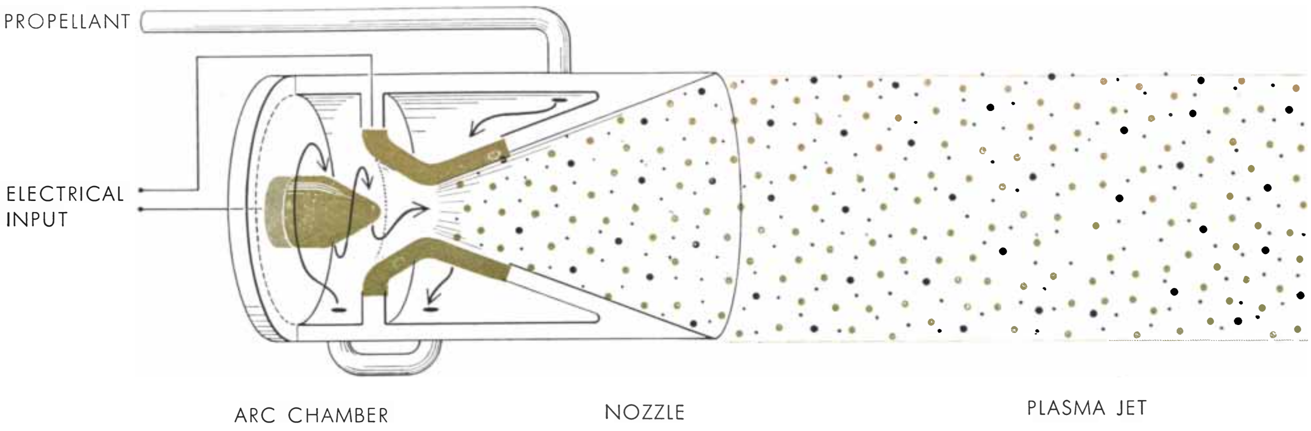
NUCLEAR REACTOR driving a turbogenerator is a possible means of providing power for electrical rocket engines. Inherently heavy, it also presents many problems of design.



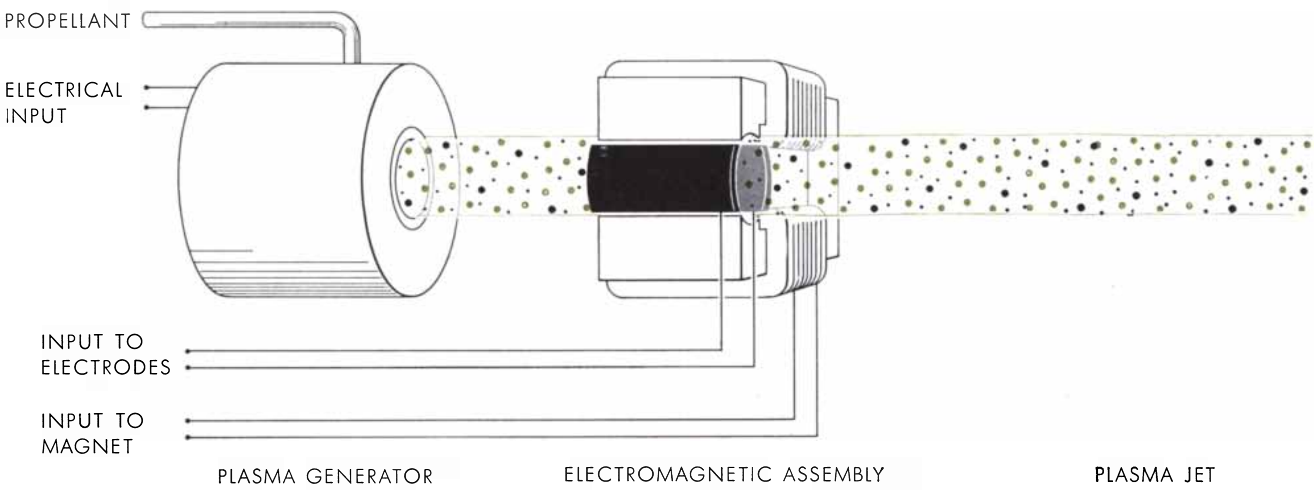
SOLAR FURNACE might also provide heat to run a turbogenerator. Radiator is necessary to dispose of heat not used in turbine before the working fluid is recycled through the boiler.



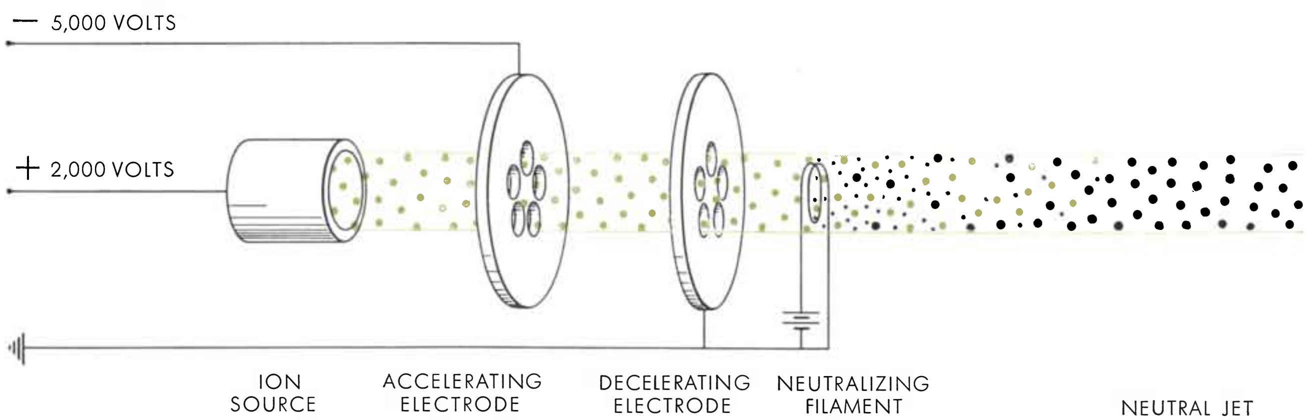
SOLAR BATTERIES convert light directly into electricity. They can be used to charge storage batteries, which in turn could energize small "vernier" electrical rockets.



ELECTRIC-THERMAL ENGINE employs a high-temperature arc to heat propellant. Arc electrodes are shown in color. Arrows indicate direction of propellant flow. Large dots represent atoms, with ionized atoms shown in color; small dots represent electrons.



ELECTROMAGNETIC ENGINE speeds up plasma jet. Electrodes (*black-gray areas*) surrounding plasma beam produce current in it. Magnetic field, set up by poles above and below, exerts a force on the current-carrying plasma, thus accelerating it toward the right.



ELECTROSTATIC ENGINE accelerates a beam of positive ions by means of an electrostatic field. The decelerating electrode acts to focus the beam. The hot filament (*right*) releases electrons to ions, preventing the build-up of negative charge on the vehicle.

by meteorites and exposed to extremes of temperature. This is going to take some doing.

If fusion reactors become practical, they may well prove the ideal source of electrical energy for space vehicles. Meanwhile there is a natural thermonuclear reactor whose energy can be tapped: the sun. Outside the atmosphere it delivers a steady stream of more than one kilowatt per square meter.

This energy can be concentrated at high temperature by mirrors and used to drive a turbogenerator. One can conceive of such a system weighing about 10 pounds per kilowatt of electricity delivered, if it is made large enough. Alternatively, the light energy in the sun's radiation can be converted directly to electrical energy by semiconductor devices. These solar batteries are already in extensive use in satellites. Their efficiency and power, however, are inherently low.

Although it is outside the scope of the present article, one other means of converting solar energy to propulsive force should be mentioned briefly. Light radiation exerts a small but measurable pressure on any surface it strikes. In the frictionless "sea" of space the pressure would be sufficient to power a type of sailing vessel. Calculations show that the

	GROSS WEIGHT (POUNDS)	PROPELLANT WEIGHT (POUNDS)	PROPULSOR WEIGHT (POUNDS)	PAYLOAD (POUNDS)	SPECIFIC IMPULSE (SECONDS)
CHEMICAL-THERMAL 	9,000	5,700	500	2,000	325
NUCLEAR-THERMAL 	8,000	2,600	2,600	2,000	800
ELECTRIC-THERMAL 	7,600	3,000	1,800	2,000	1,200
ELECTROMAGNETIC 	5,000	1,300	900	2,000	2,000
ELECTROSTATIC 	3,500	400	300	2,000	5,000

TRIP TO THE MOON varies in its characteristics (*colored columns in table*), depending on engine type. Areas of schematic drawings are roughly proportional to weight of vehicles. The payload is shown in light gray; propellant and tank in dark gray; propulsion unit in medium gray. Width of jets (*colored areas*) is indicative of amount of thrust; length of jet, of duration. Some of the numerical solar sail would be a practical device for long missions. Indeed, solar radiation has already demonstrated its propulsive power for space vessels by pushing the light *Echo* satellite off course.

Until the problem of the power source is solved, electrical engines cannot take over the main job of propulsion in space vehicles. Before that time electrical engines may find use in low-thrust

THRUST (POUNDS)	THRUST DURATION	TRIP (DAYS)
32,000	ONE MINUTE	5
4,300	SEVERAL MINUTES	5
3.4	12 DAYS	19
1	28 DAYS	35
.15	150 DAYS	150

values in the table have been taken from experimental results; other values represent calculations that are still theoretical.

"vernier" applications for adjusting the attitude or the orbital path of satellites. In the reasonably near future satellites will undoubtedly be in use as relay stations for communication purposes, as weather observatories and so on. These objects will have to stay on a prescribed orbit for several years (and perhaps change orbit from time to time). They may also need to carry out certain maneuvers in attitude, for example turning around their own axes once in each revolution in order to keep an antenna or a camera pointing at the earth.

One way to offset the effects of drift and to change the motion as necessary is to equip the satellites with small thrust units. Some would be mounted so as to produce rotation around various axes, and others to produce thrust through the center of gravity of the vehicle. In those satellites which carry electrical power sources for their main equipment the vernier engines might well be electrical units to which power can be diverted for short intervals as needed. Small chemical rockets could also do the job, but they would be much less convenient. Electrical units are easier to turn on and off, their power output can be readily varied and they are very economical of propellant.

Finally, let us look further ahead, to electrical engines as main propulsion units. As has been pointed out, such engines can deliver a wide range of specific impulses, but the higher the figure, the heavier the engine. When the engine weight begins to bulk larger than that of the total propellant to be carried, economy of propellant ceases to be a controlling consideration. One would not put a diesel engine in a power boat with a 10-gallon fuel tank. To make a heavy engine worth while, a ship must have the capacity for a heavy load of propellant. This means that it is adapted to long journeys. Analysis of the problem indicates that the total weight of propellant and power source is least when the weight of each is approximately the same.

For missions to and from the moon, or between satellites around the earth, the moon and Mars, specific impulses in the range of 2,000 to 5,000 will give maximum economy of energy. In general, as we have seen, the higher the specific impulse, the lower the total thrust and therefore the longer the time required for the journey. If time rather than energy is the primary consideration, lower specific impulses become desirable.

To understand how the various factors interact, consider a trip to the moon [*see illustrations on page 60*]. We are concerned with a true space mission and so we do not start from the surface of the earth but from a close-in orbit, say 400 miles above the earth's surface. Similarly, our terminus at the other end is an orbit 100 miles from the lunar surface. A typical chemical rocket with a specific impulse of 300 could make the trip in about five days, but its payload would be only a fifth of the original weight of the vehicle at the starting orbit. Comparative analysis of typical electrical systems [*see illustration on these two pages*] shows that an engine with a specific impulse of 1,200 can drive a ship to the moon in about 19 days with a payload of a fourth of its starting weight. By raising the specific impulse to 5,000 the payload can be increased to 60 per cent of the initial weight, but only with a consequent lengthening of the trip to five months. Beyond a value of 5,000 the performance actually gets worse, because the weight of the required power source increases to the point where payload must be sacrificed to carry it. Only for a much longer journey, where the ratio of propellant to total weight is substantially greater, does the economy afforded by higher specific impulse begin to pay off. Even for round trips to Mars, requiring a couple of years or more, there is no point in increasing specific impulse much above 5,000.

What is the best engine for a lunar trip? This is like asking what is the best engine for a trip to Chicago. It depends on when you want to arrive, on how much baggage you have or on whether you don't want to go yourself but just want to ship some freight. A party of scientists wishing to minimize their exposure to radiation in space, and being busy men, would probably choose a chemical rocket. Important equipment that cannot be accommodated in the small payload might be transported by plasma jet, arriving two weeks later. Heavy supplies could be sent ahead by "slow freight," in an unmanned vehicle powered by an ion engine, carrying 10 times the payload of the passenger ship but requiring five months for the trip.

Is this a fairy tale? Until adequate energy sources have been developed such an operation must remain highly speculative. But although the problems are difficult, there are no impassable barriers to their solution that we can see. And so far as propulsion units are concerned, we can already build them to perform beyond the requirements of any mission presently envisioned.

NEW PENICILLINS

By altering the groups of atoms that are attached to the "core" of the penicillin molecule, chemists have produced penicillins that are effective against resistant strains of microorganisms

by Anthony H. Rose

With the triumph of the germ theory of disease in the 19th century, physicians, microbiologists and chemists began to seek substances that would destroy infectious organisms within the afflicted human body. Chemists in particular were excited by the idea of specific drugs, each tailor-made to combat a specific disease agent. Paul Ehrlich called such drugs "charmed bullets," and he succeeded early in the 20th century in designing just such a drug—salvarsan—for syphilis.

The vision of the pioneers in chemotherapy was surpassed in the fulfillment that came during the 1930's. First the sulfonamide drugs and then penicillin proved to be effective against not one but several disease organisms. The goal of research now became the development of compounds with even broader effects: a few drugs, or even a single drug, that would control virtually every disease organism. With such a "shotgun" to do the work of many different specific drugs, accurate diagnosis would no longer be essential.

By 1950 about a dozen antibiotics had come into use along with penicillin. Together they appeared to constitute a formidable arsenal against the microbes responsible for diseases in man and animals. Penicillin was the drug of choice against staphylococcal and streptococcal infections and venereal diseases; streptomycin, against tuberculosis and tularemia; chloromycetin, against typhoid and dysentery; the tetracycline family of antibiotics, against a variety of lung infections and diseases of the digestive and urinary tracts.

Almost as soon as the antibiotics came into wide use, however, clinicians discovered that certain pathogenic microbes are capable of developing a resistance to their action. Among the most troublesome are the penicillin-resistant strains of staphylococcus. One of the earliest reports, by Mary Barber and her colleagues at the St. Thomas Hospital Medical School in London in 1949, described an epidemic among newborn infants in a hospital nursery. It was alarming to read that no fewer than 60 per cent of the nursing staff were harboring the resistant bacteria. In the years that followed, similar outbreaks were reported in hospitals throughout the world; they have involved not only the newborn but also nursing mothers, surgical patients and aged or debilitated individuals [see "The Staphylococcus Problem," by Stuart Mudd; SCIENTIFIC AMERICAN, January, 1959]. Apparently by coincidence, the penicillin-resistant staphylococci are among the most virulent strains of their species. They cause a variety of diseases, ranging from rashes and abscesses to fatal pneumonias and blood poisoning. Though penicillin remains one of the safest and most useful clinical antibiotics—retaining its effectiveness against such organisms as the spirochete of syphilis—it has been entirely withdrawn from use for periods of time in many hospitals. The experience with staphylococcal resistance to penicillin has made many physicians fear that the widespread use of antibiotics may engender the development of resistant strains of other pathogenic bacteria, thus negating the entire scheme of chemotherapy. It is now clear, however, that the problem of resistance to antibiotics becomes a serious one only in certain clinical situations.

The situation is undoubtedly most serious with respect to infections caused by staphylococci. Today the resistant strains of this organism are endemic in many hospitals, constantly threatening to break out into epidemics. Moreover, they are widely disseminated in the general population, because normal and otherwise healthy people can become carriers. Some of the newer antibiotics are effective against resistant staphylococci. But unfortunately several of these drugs have serious disadvantages and must be prescribed with the utmost care. Some are made useless by "cross resistance"; that is, the penicillin-resistant staphylococci quickly become resistant to the new drugs as well. A few produce undesirable side effects in some patients, causing rashes and other allergic reactions, kidney damage, blood changes and, in the case of one drug, injury to the auditory nerve. Some success has been reported in the use of two or more antibiotics together in mutual reinforcement against resistant staphylococci. But the urgency of the need for a more positively effective chemotherapeutic agent is indicated by mortality rates as high as 20 per cent among hospital patients stricken by the resistant staphylococci. It became apparent some time ago that a really dependable drug must be found or created—a drug made specifically to control these bacteria.

Within the past year such a drug has come from the laboratory. Strangely enough, it is not a new antibiotic. It is old, established penicillin, modified chemically to neutralize the defenses of the resistant staphylococci. This specially designed penicillin meets all of Ehrlich's requirements for a charmed bullet.

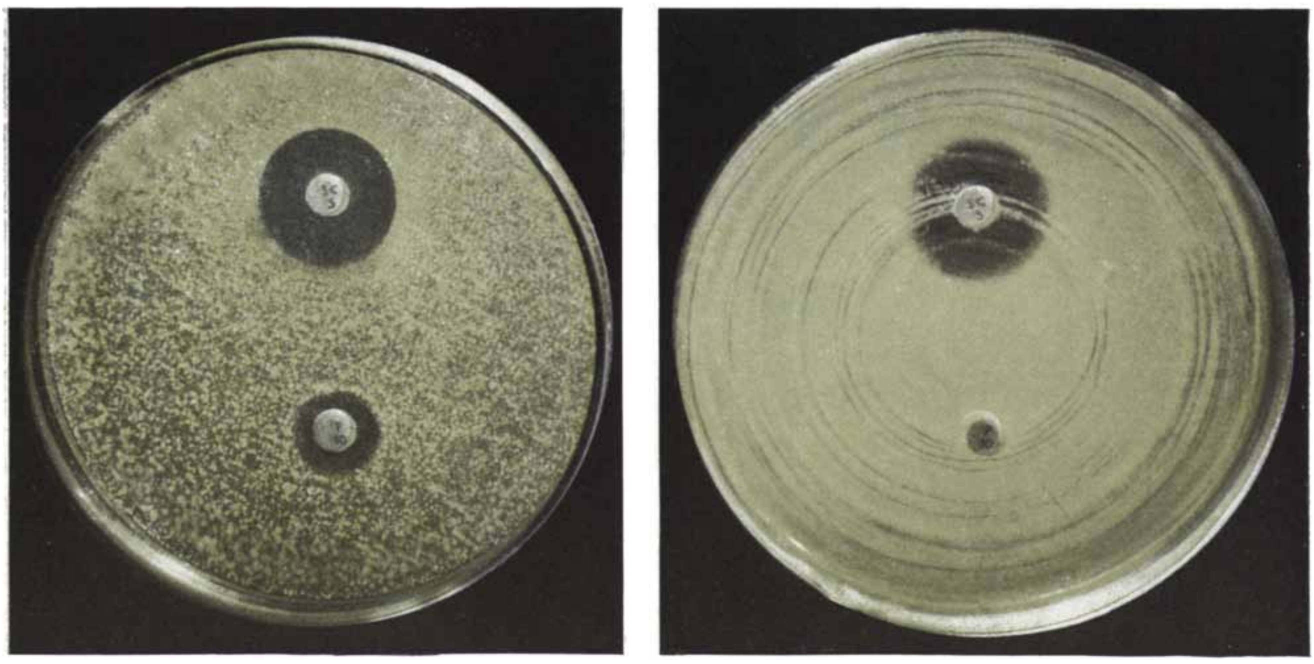
The recent work on penicillin grew out of the effort by microbiologists and biochemists at the U. S. Department of Agriculture laboratory in Peoria, Ill., to achieve large-scale production of penicillin during World War II. Early in the investigation the group found that the name penicillin, given to the antibiotic by Alexander Fleming in 1928, was actually a generic name covering a whole family of related penicillins, all of them the products of the metabolism of *Penicillium* molds. The various penicillins have the same molecular "core," consisting of a fused beta-lactam-thiazolidine ring. They each have a different "tail," or side chain, and it is the chemical structure of this appendage that distinguishes one kind of penicillin molecule from another [*see illustration on next page*]. Grown in a simple laboratory broth, the mold *Penicillium chrysogenum* produces mostly the substances penicillin F, penicillin dihydro F and penicillin K. The side chain of the penicillin F molecule is a 2-pentenyl residue, and the side chain of the penicillin K molecule is an *n*-heptyl residue. Biochemists and bacteriologists have established that both the core and the side chain must be present if the penicillin is to be an effective antibiotic, but they do not know why.

The Peoria workers were looking for nutrient substances that would stimulate the mold to make larger quantities of the antibiotic. They found one of the most effective nutrients is corn-steep liquor—the residue left after starch is extracted from corn. Corn-steep liquor not only increased the yield; it also caused the mold to form benzyl penicillin, or penicillin G, a new substance that turned out to be far more effective than any penicillin previously isolated. Penicillin G is still the type in general use. The Peoria workers then tracked down the substance in the corn-steep liquor that induced the mold to make penicillin G. It proved to be beta-phenylethylamine, a preformed building block for the side chain that distinguishes penicillin G from other penicillins. Nowadays the manufacturer does not rely solely on this precursor as found in corn-steep liquor; he adds pure phenylacetic acid, an even more readily convertible precursor for the side chain, to the mold culture.

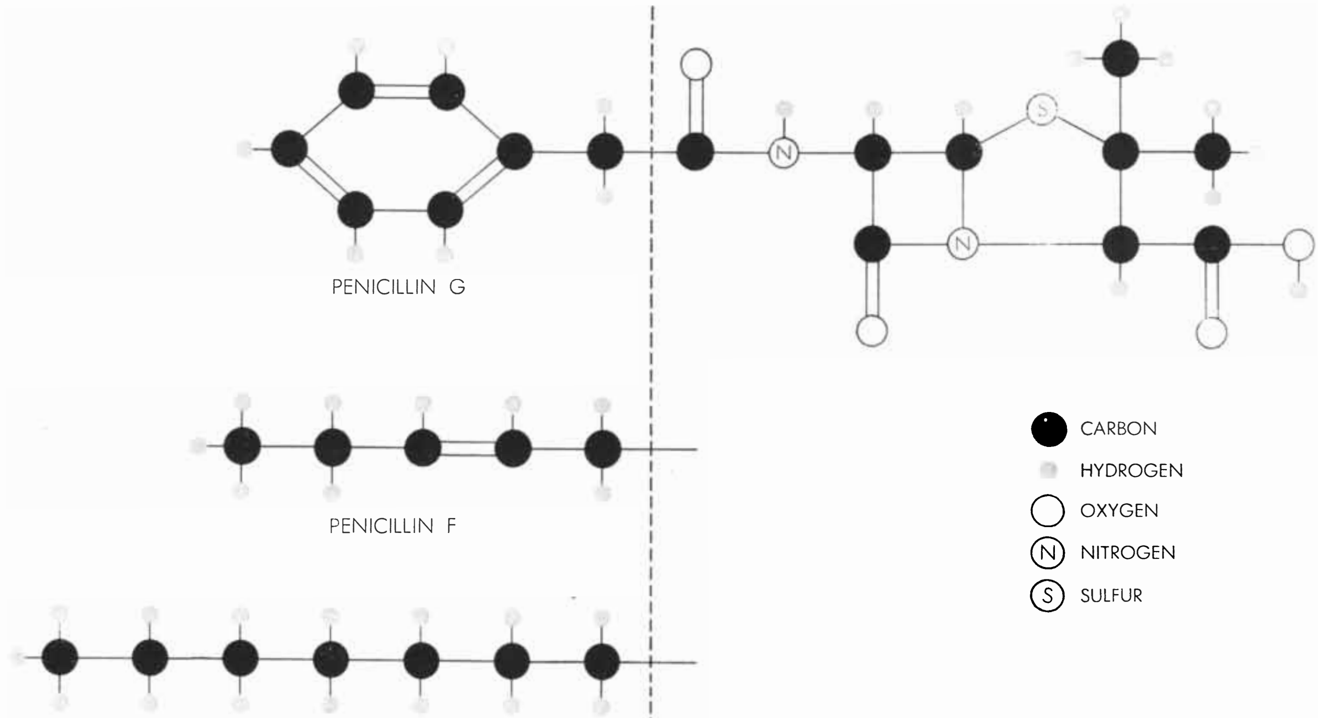
After penicillin G had appeared so unexpectedly, investigators began to feed the mold a variety of potential side-chain precursors in the hope of producing other "semisynthetic" penicillins. The mold responded by making many new penicillins. Only one of these offered any advantages over penicillin G. This was penicillin V (phenoxymethylpenicillin), first produced in 1948 when Otto K. Behrens and his colleagues at the Eli Lilly & Company Research Laboratories added phenoxyacetic acid to the mold culture. It is a good antibiotic for administration through the mouth because it is stable in acid solutions and so, unlike penicillin G, resists destruction by the digestive juices. (Accompanied by suitable buffers, penicillin G can also be administered orally, but some of it is destroyed in the stomach.)

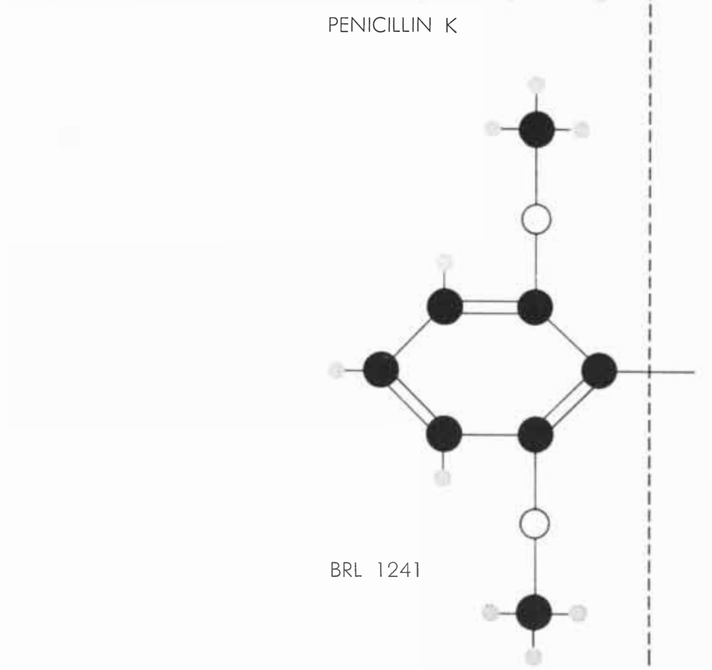
With resistant staphylococci becoming a major problem, some microbiologists and biochemists turned in 1949 from the study of penicillin itself to investigation of the interaction between the antibiotic and the bacterium. They soon learned that resistance to penicillin is a case of genetic adaptation, or "survival of the fittest." In any culture of staphylococci sensitive to penicillin, about one bacterium in 100 million is a mutant that is resistant to the drug. Under normal circumstances the mutation apparently offers no survival advantages; it may even be accompanied by a slower reproduction rate or some other disadvantage. But in an environment containing penicillin such mutants are the only members of the colony that can reproduce. Hence they establish a population of resistant staphylococci.

Biochemical studies of the resistant bacteria revealed that they can thrive in the presence of penicillin because they produced the enzyme penicillinase, which breaks down the penicillin molecule by opening its beta-lactam ring [*see top illustration on page 70*]. The reaction yields penicilloic acid, a compound devoid of antibiotic activity. In-



TWO PENICILLINS ARE TESTED against a light culture (*left*) and a heavy culture (*right*) of penicillin-resistant staphylococci. These microorganisms produce penicillinase, an enzyme that inactivates most penicillins. In each culture dish the upper disk contains dimethoxyphenyl penicillin sodium (marketed under the trade name Staphcillin), a slight modification of the new penicillin BRL 1241, which was designed to combat resistant staphylococci. The lower disk contains the standard penicillin G. The width of the clear areas around the disks shows that the new penicillin acts against resistant strains, and that penicillin G has little or no effect.





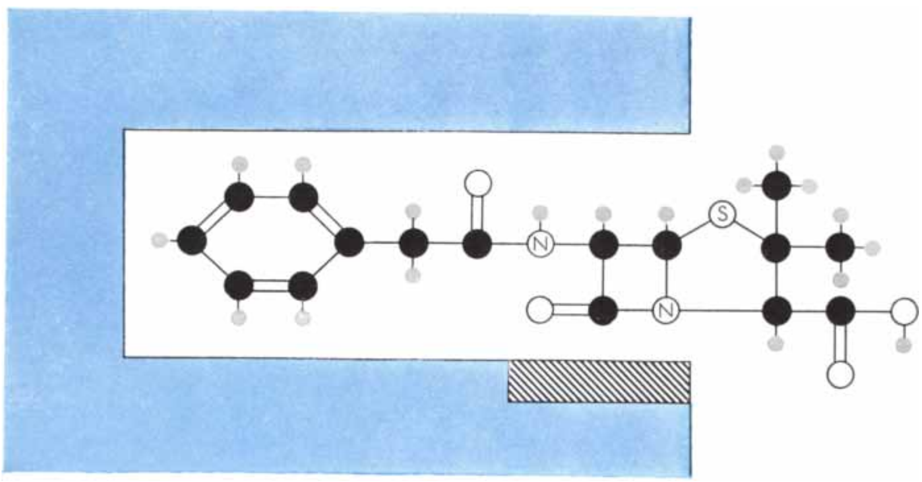
MOLECULES OF FOUR PENICILLINS all have same core: a fused beta-lactam-thiazolidine ring. They are differentiated by their side chains, which appear to left of broken line.

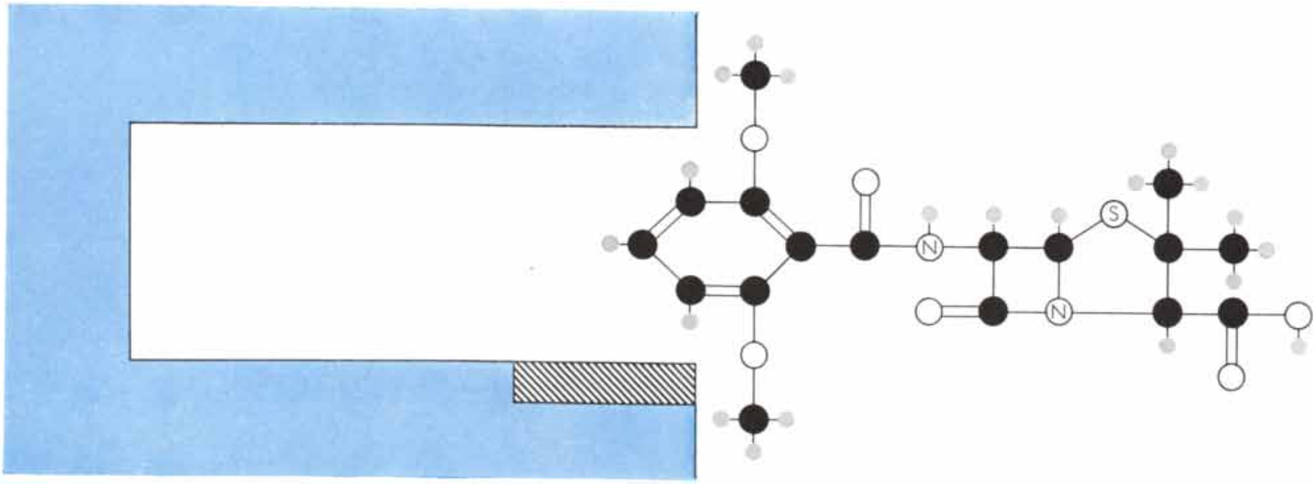
vestigators were at first baffled by the discovery that resistant staphylococci produce hardly any penicillinase when they are isolated and cultivated in a laboratory vessel free of penicillin. But it soon became clear why the bacteria are so strongly resistant: the production of penicillinase increases several hundred times when penicillin is added to the bacterial culture. Thus penicillin itself stimulates the staphylococci to produce greater quantities of the enzyme. Biochemists know this phenomenon as "enzyme induction." Microorganisms are induced to step up their production of many enzymes by the presence of the particular substance upon which the enzyme acts, or by some closely related substance.

Further study of penicillinase revealed a most significant fact about its action: the enzyme breaks down different penicillins at different rates of speed. It destroys penicillin G and penicillin X (*para*-hydroxybenzylpenicillin) far more quickly than it does penicillin F and penicillin K. Biochemists in particular were prepared to appreciate the implications of this finding. Enzymes are often narrowly specific in their activity, mediating only one particular chemical reaction and only in interaction with a specific compound or group of compounds. By slight modification of the chemical structure of a compound it is often possible to insulate it completely from the action of the enzyme. Here was the key to the development of a penicillinase-resistant penicillin. Moreover, since it is the side chain that distinguishes one penicillin from another, it was plainly the differences in their side chains that explained why one penicillin breaks down more slowly than another under the action of penicillinase. The biochemists accordingly set out to make new penicillins with high antibiotic activity and with side chains that would protect them from enzymatic breakdown.

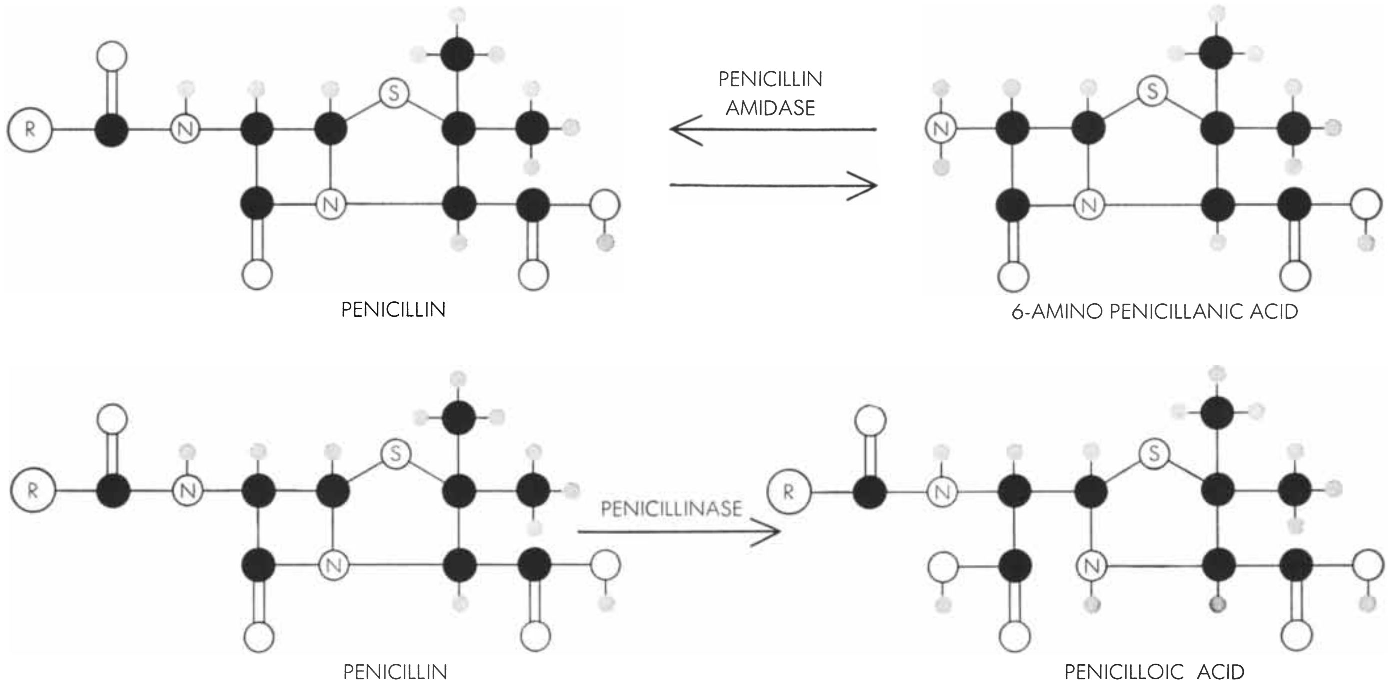
One major route to this objective promised to open up with the impending resolution of the chemical structure of the penicillin molecule. Although penicillin is not a large molecule in comparison with many other organic molecules, it has proved to be remarkably complex. Attempts to synthesize it began during World War II, but success was achieved only during the past few years by John C. Sheehan and his associates at the Massachusetts Institute of Technology. Unfortunately the process is too costly for large-scale production. Sheehan and his group nonetheless made several important discoveries. Above all, they worked out the structure of the core of the penicillin molecule and showed it to be a substance called 6-amino penicillanic acid, or 6-APA. This structure, it turns out, is extremely difficult to synthesize, even when one is able to start with penicilloic acid, the breakdown product of degradation by penicillinase. With the structure of 6-APA established, however, it became possible to visualize the synthesis of entirely new penicillins by attaching suitable side chains to it.

Fortunately investigators engaged in the effort to develop new penicillins were able to enlist the chemical virtuosity of the *Penicillium* mold. The group led by F. R. Batchelor at the Beecham Research Laboratories in Surrey, England, found that *Penicillium* itself could be made to produce 6-APA as an end product. They made this discovery by growing the mold in a broth that contained no side-chain precursors. The product of their experimental cultures seemed to be penicillin when assayed chemically. But it had practically no antibiotic activity. The observation led them to the work done in 1953 by K. Kato in Japan. He had reported that the mold grown in a precursor-free broth produces a compound that induces production of penicillinase by a bacterium and is broken down to penicilloic acid by penicillinase. Kato also found that this compound had no antibiotic activity. Upon analysis, the workers at the Beecham laboratory found that the compound was 6-APA. Isolation of the core molecule from the culture broth provided strong evidence in favor of the idea that the final step in the biosynthesis of a penicillin by the mold is the addition of a side chain to the core. But the





ACTION OF PENICILLINASE in catalyzing breakdown of a penicillin may be visualized as resulting from the "fit" of penicillin molecule into a notch in the surface of enzyme molecule (*color*). Penicillin G (*above*) fits well; contact with active site of penicillinase (*hatched area*) opens beta-lactam ring, producing inactive penicilloic acid. The new penicillin BRL 1241 (*below*) has a different side chain that will not fit into notch. This is a hypothetical explanation; the mechanism is not yet well understood.

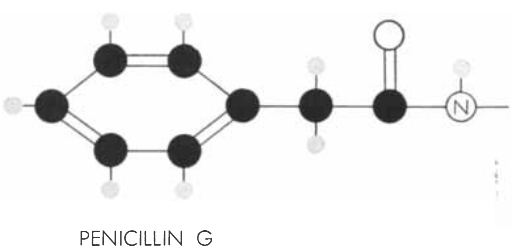


ENZYME ACTIVITY can destroy, construct and inactivate penicillins. Amidase (*above*) can build up or break down the molecule by adding or removing the side chain. Penicillinase (*below*) causes a water molecule to join penicillin, thereby breaking a bond between a nitrogen atom and a carbon atom and opening the beta-lactam ring. This yields penicilloic acid, which is not an antibiotic.

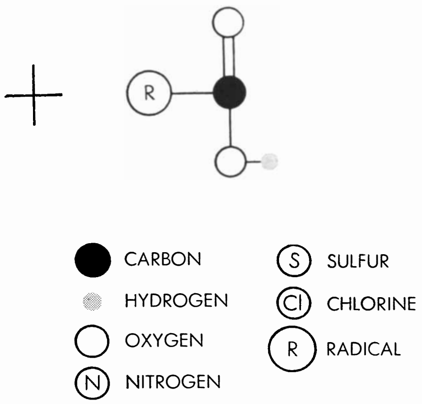
discovery had the further practical importance of showing that 6-APA can be manufactured cheaply by a microbiological process.

Meanwhile the Beecham group had been approaching the production of 6-APA by an entirely different route: the microbiological breakdown of a whole penicillin molecule to 6-APA. In this effort they were collaborating with workers at the Bristol Laboratories in Syracuse, N.Y., and another group at the International Research Center for Chemical Microbiology in Rome under the leadership of Ernst Boris Chain. With Howard Florey, Chain had developed Fleming's curious discovery into a drug suitable for clinical use during World War II. The three groups of investigators were attracted by the possibility of breaking down penicillin G with amidase enzymes. Many types of microorganisms, including various fungi and bacteria, produce these enzymes. Comparative studies isolated the bacterial species and strains that produce the amidase with the highest affinity for penicillin G. For production-control purposes the bacteria are prevented from multiplying while they are fed penicillin. Such cultures will produce five or six batches of 6-APA without appreciable decline in amidase activity.

With 6-APA obtained in abundance from interrupted biosynthesis by the mold or from the breakdown of penicillin G by amidase enzymes, the Beecham and Bristol workers turned to the task of attaching new side chains to the core molecule. The amidase enzymes will function during the addition as well as the subtraction of a side chain from 6-APA, and this is the method that has proved commercially efficient [*see illustration above*]. Several of the new penicillins resist acids. One of them,



SYNTHESIS OF A PENICILLIN, in technique devised by John C. Sheehan and his associates at the Massachusetts Institute of Technology, begins with penicillin G. Triethylamine methanolic hydrochloride removes the side chain and also opens the beta-lactam ring.



6-(alpha-phenoxypropionamido)-penicillanic acid, is an excellent oral antibiotic. It gives levels of penicillin in the blood two or three times higher than those obtained with oral penicillin V and equal to the level reached with an injection of penicillin G. The new oral compound will be welcomed by anyone who has had to endure a series of injections of penicillin G.

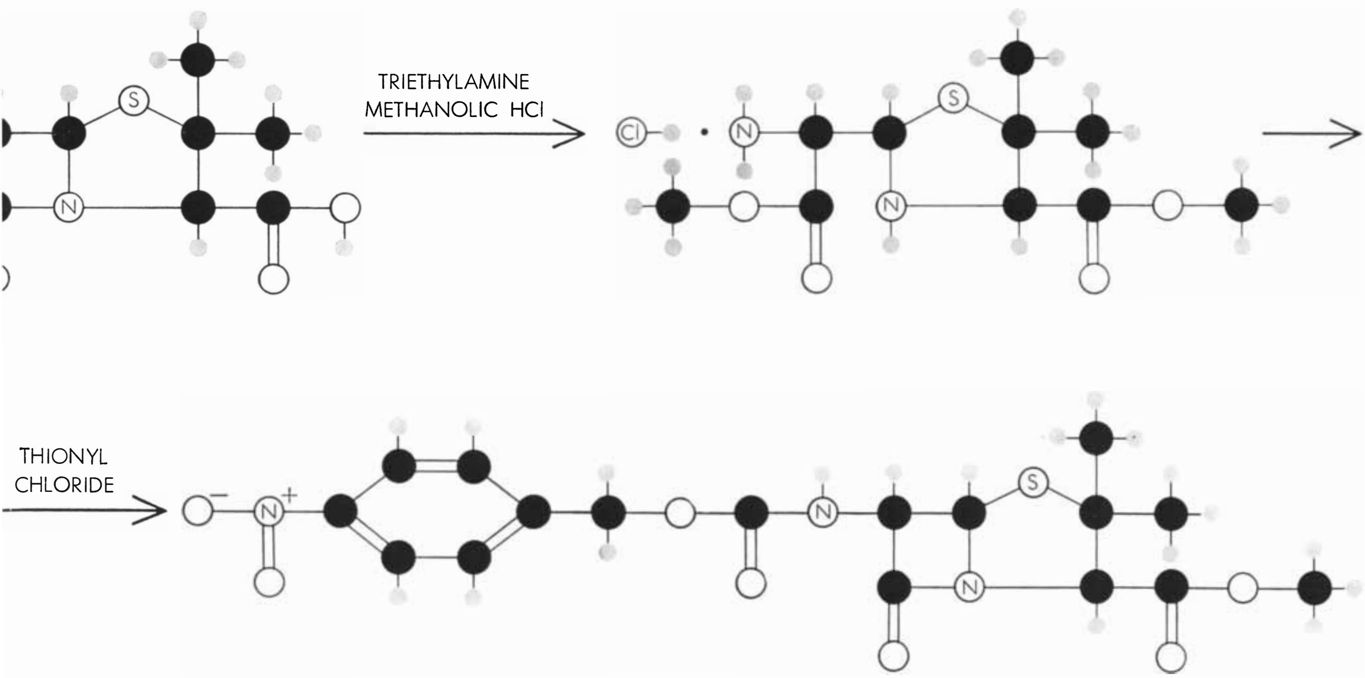
Finally, in 1960, F. P. Doyle at the Beecham Laboratories succeeded in synthesizing a penicillin that combines high antibiotic activity with immunity to penicillinase. The side chain is 2,6-dimethoxybenzoic acid, a rather simple structure, and the penicillin itself is called (2,6-dimethoxybenzamido)-penicillanic acid. It was given the code name of BRL 1241 at the Beecham Laboratories and X 1497 at the Bristol Laboratories. Like other penicillins, it induces staphylococci to produce penicillinase. But the structure of its side chain apparently prevents it from making close enough contact with penicillinase to be destroyed [*see illustration on page 69*].

The new penicillin does not exhibit exactly the same range of antibacterial activity as penicillin G and so cannot be used in all cases where penicillin G would be effective. Furthermore, it is not so potent as penicillin G and must be administered more frequently in larger doses. It is effective, however, against the penicillin-resistant staphylococci that have caused so much trouble around the world. At Guy's Hospital Medical School in London, Robert Knox has found that this penicillin causes one resistant strain of staphylococcus to lose its ability to produce penicillinase and makes it revert to the penicillin-sensitive state. It is too early to say whether this holds true for other resistant strains.

Clinical trials of the new antibiotic have produced spectacular results. Recently the *British Medical Journal* carried seven papers on tests carried out in a London hospital. These and trials elsewhere in England and in the U. S. indicate that 90 per cent of patients suffering from resistant staphylococcal infections are either cured or greatly helped. Furthermore, aside from the occasional allergies caused by all penicillins, the new antibiotic has had no untoward side effects.

Prospects for the further development of new penicillins from 6-APA are excellent and promise significant improvements in chemotherapy. Even the best penicillins have their drawbacks. Penicillin tends to be excreted rather rapidly in the urine, and some patients develop serious and even dangerous allergies to it. New penicillins that can overcome these problems and still retain activity against penicillinase-producing bacteria may very well be developed. In addition, synthetic penicillins could be designed to combat pathogenic bacteria not now sensitive to any antibiotic.

It seems that the old goal of a tailor-made drug for every type of disease is still a worthy one. Success is still some way off, however, and before it comes a great deal more will have to be learned about the mechanism by which antibiotics exert their effects on microbes. Meanwhile the control already achieved over the staphylococcal infections has shown how the penicillins and perhaps other antibiotics can be fashioned into truly charmed bullets.



PARA-NITROBENZYLPENICILLIN

***Para*-nitrobenzyl chloroformate then provides a new side chain. Finally, thionyl chloride removes a water molecule, which permits the beta-lactam ring to close once more. The final product is a new penicillin which has chemical label *para*-nitrobenzylpenicillin.**

Pre-Cambrian Animals

Until recently the fossils of organisms that lived earlier than the Cambrian period of 500 to 600 million years ago were rare. Now a wealth of such fossils has been found in South Australia

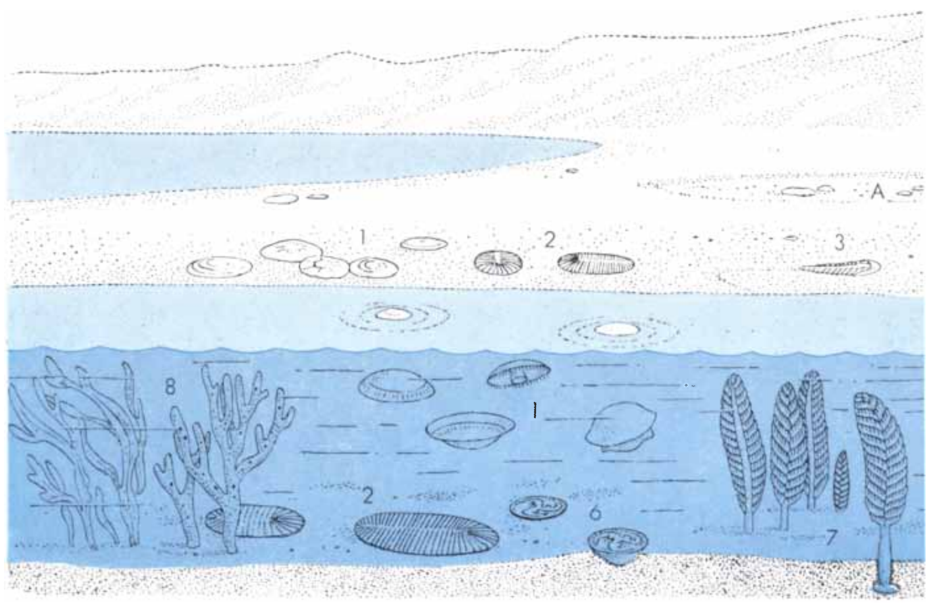
by Martin F. Glaessner

The successive strata of sedimentary rock laid down on the earth's crust in the course of geologic time preserve a rich record of the succession of living organisms. Fossils embedded in these rocks set apart the last 60 million years as the Cenozoic era—the age of mammals. The next lower strata contain the 150-million-year history of the Mesozoic—the age of reptiles. Before that comes the still longer record of the Paleozoic, which leads backward through the age of amphibians and the age of fishes to the age of the invertebrates. Then, suddenly and inexplicably, in the lowest layers of the Paleozoic the record of life is very nearly blotted out. The strata laid down 500 to 600 million years ago in the Cambrian period of the Paleozoic era show a diversity of primitive marine life: snails, worms, sponges and the first animals with segmented legs, the trilobites and their relatives. But the record fades at the bottom of the Cambrian. The greater part of the journey to the beginning of sedimentation, at least another 2,000 million years, still lies ahead. Yet apart from algae and a few faint traces of other forms, the Pre-Cambrian strata have yielded almost no fossils and have offered no clues to the origin of the Cambrian invertebrates.

The geological record necessarily becomes more obscure the further back it goes. The older rocks have been more deeply buried and more strongly deformed than the younger rocks. They have undergone longer exposure to the heat and pressure and the mineralizing solutions by which fossils are commonly destroyed. One can find fossils, however, in greatly deformed younger sediments, including metamorphic rocks, which have been even more thoroughly reworked by geologic processes than some older rocks. What is more, no rock-deforming process affects the entire surface of the globe. Some Pre-Cambrian formations have escaped extreme alteration, just as the lower Cambrian rocks are altered in some places and not in others.

The abrupt termination of the fossil record at the boundary between the Cambrian and the Pre-Cambrian has appeared to many observers as a fact or paradox of decisive importance. They have advanced many different explanations for the mystery, from cosmic catastrophes to the postulate of an interval of time without sedimentation; from the assumption of a lifeless ocean to the thought that all Pre-Cambrian organisms may have lived at the surface of the sea and none on its bottom, or all in the deep sea and none on its shores.

The need for such speculation has at last been obviated by the discovery in the Ediacara Hills in South Australia of a rich deposit of Pre-Cambrian fossils. The first finds at this site were made in 1947 by the Australian geologist R. C. Sprigg. In sandstones that were thought to belong to the lowest strata of the Cambrian he came upon varieties of fossil jellyfish. Sprigg's find was followed up by other geologists and by students under the leadership of Sir Douglas Mawson, who found some



PRE-CAMBRIAN SEASHORE AREA, reconstructed from fossils found in South Australia, supported several types of animal. Some are shown stranded in dried-up mudholes (*A*) and on sand of beach, where they were fossilized. Others appear (*lower left*) in sand and

plantlike impressions that appeared to be algae. Some time later two private collectors, Ben Flounders and Hans Mincham, brought to light not only large numbers of presumed fossil jellyfish but also segmented worms, worm tracks and the impressions of two different animals that bear no resemblance to any known organism, living or fossil. These discoveries prompted the South Australian Museum and the University of Adelaide to undertake a joint investigation of the region. Re-examination of the geology now showed that the fossil-bearing rocks lie well below the oldest Cambrian strata. This finding, taken together with the nature of the fauna represented in the fossils and their evident relationship to certain fossils discovered in South Africa before World War I and more recently in England, established that all these fossils date from the Pre-Cambrian era.

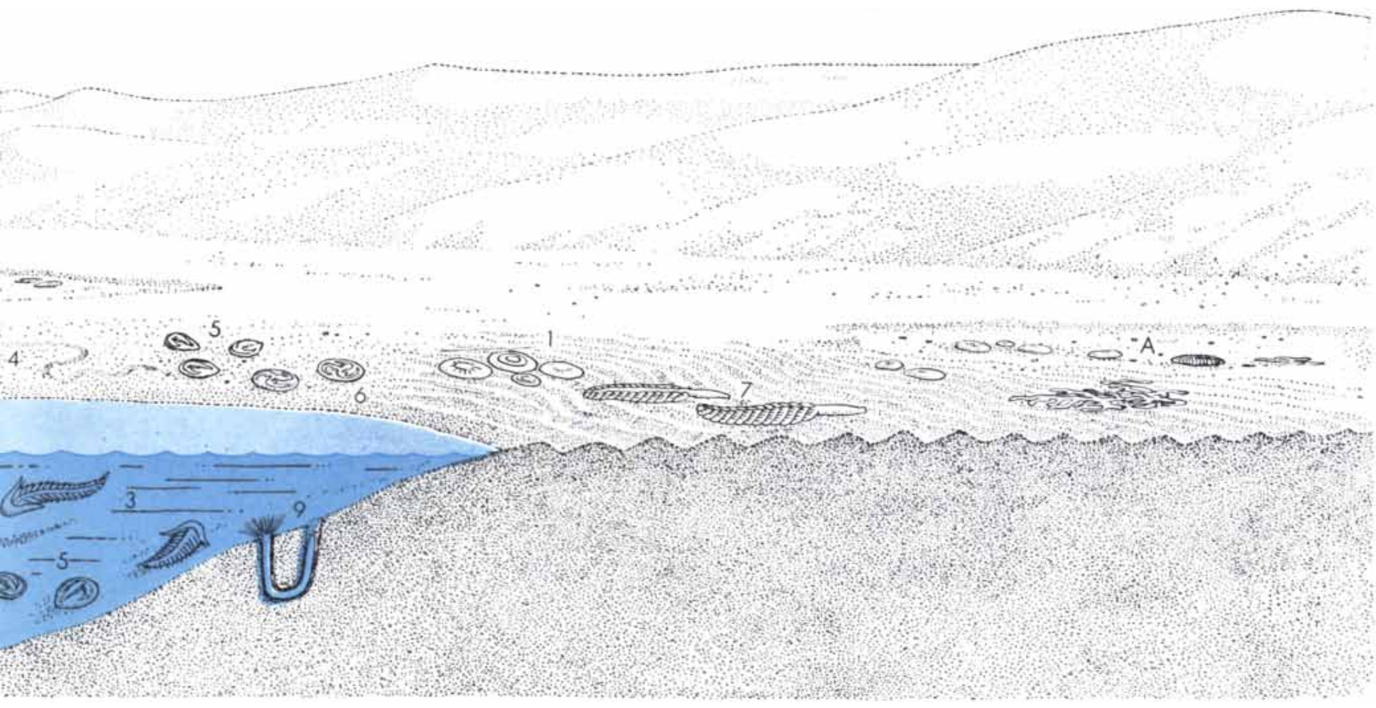
To date some 600 specimens have been collected in the Ediacara Hills. The fauna include not only jellyfish representing at least six and probably more extinct genera but also soft corals related to the living sea pens; segmented worms with strong head shields; odd bilaterally symmetrical animals resembling certain other types of living worm; and the two animals that look like no other living thing.

All the Ediacara animals were soft-bodied; none had hard shells, and their soft tissues were strengthened by nothing more than spicules: needles of calcium carbonate that served as a primitive support. All, of course, lived in the sea, some fixed to the bottom, some crawling and others free-floating or swimming. Their preservation is due to rather unusual, though not unique, conditions. The animals lived or were stranded in mud flats in shallow waters. Their impressions or their bodies were molded in the shifting sands that washed over the flats and were preserved as molds or casts in sandstone, mostly on the lower surfaces of sandstone beds. The resulting rich and varied assemblage of fossil animals gives the first glimpse of the marine life of the Pre-Cambrian era. It is a glimpse not merely of several types of animal but also of an association of creatures living together in the sea.

The soft-bodied nature of these fossils justifies the characterization of the Pre-Cambrian as the "age of the jellyfish." The term jellyfish, however, applies to a number of highly diverse and only remotely related forms, of which the most common belong to the coelenterate phylum. These are animals that alternately take the free-swimming medusoid, or jellyfish, form and the sedentary polyp form. Sprigg concentrated on the medusoid jellyfish among his finds. He arranged some of them in two classes and four orders that have living representatives and placed the more commonly occurring specimens, which he called *Dickinsonia,* in a more problematic position with respect to living forms. But further study has indicated that none of the Pre-Cambrian medusae can be tied with any confidence to living orders, suborders or families.

Greater interest perhaps attaches to the leaf- or frondlike stalked fossils that Sprigg apparently took to be algae. The stalk is some 12 inches long and three-quarters of an inch wide. The body measures up to nine inches long and four and a half inches wide; it is characterized by transverse ridges branching off from either a tapering median field or a median zigzag groove and divided in turn by longitudinal grooves [*see bottom illustrations on page 75*]. No living algae display such structures. The true nature of these fossils appears in specimens that show the impressions of spicules in the stalk and along the lower edges of the side branches. These suggest the spicules of otherwise soft alcyonarian corals living today and identify the fossil fronds as animals of the coelenterate phylum rather than as plants.

One group of modern corals—the sea pens (*Pennatulacea*)—has a similar arrangement of spicules, along with the stalk and side branches. Thus the fossils

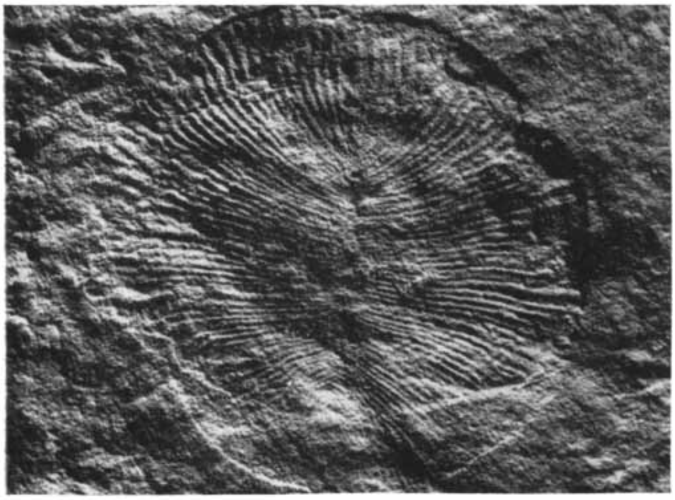


water as though seen in an aquarium. They are jellyfish-like creatures (*1*); the wormlike *Dickinsonia* (*2*); the segmented worm *Spriggina floundersi* (*3*) and worm trails (*4*); *Parvancorina* (*5*), which resembles no other known animal; *Tribrachidium* (*6*), another unknown type; the sea pens *Rangea* and *Charnia* (*7*); hypothetical algae and sponges (*8*), and a worm in a sand burrow (*9*).

appear to be sea pens, which are normally rare in the geological record. The differences between the Pre-Cambrian sea pens and the modern animals are remarkably small, considering the 600 million years of evolution that separate them. In the living sea pens the frond is either deeply dissected into movable side branches or it forms an entire platelike body. In the fossil the lateral ridges are separated by furrows and not by open slits. Coral polyps that occupy the surfaces of the fronds and stalks in modern sea pens are so small that they would not be apparent in the rather coarse sandstone casts of the fossils.

The Australian frond fossils are similar to those discovered before World War I by German geologists in Southwest Africa. Those fossils were named *Rangea* and *Pteridinium*. The Pre-Cambrian fossil discovered recently in England and named *Charnia masoni* also resembles certain of the fossil Australian sea pens. The English fossil seems to possess a circular disk with concentric ribs at the end of the stalk opposite the frond. Although the connection between these two structures is uncertain, it may be that this fossil represents the two alternating coelenterate forms, that is, the free-swimming medusa and the branching colony of small polyps that remains fixed to the ocean bottom. In this case one might speculate that the Pre-Cambrian sea pens grew from free-swimming, solitary medusae. But this is as yet pure guesswork about the reproductive processes of long-dead organisms. Further discoveries may prove or disprove the connection between fronds, stalks and disks.

The most spectacular finds in the Pre-Cambrian strata of South Australia were small annelid worms named *Spriggina floundersi* after their discoverers, Sprigg and Flounders. They had a narrow, perfectly flexible body up to one and three-quarter inches long, a stout horseshoe-shaped head shield and as many as 40 pairs of lateral projections (parapodia) ending in needle-like spines. A pair of fine threads projected backward along the sides of the body from the lateral horns of the head shield, and another thread probably grew from the segment behind it [*see illustration at top right below*]. Although such worms no longer exist, they resemble the living marine *Tomopteridae*, which have similar but wider heads, transparent narrow bodies and parapodia ending in flat paddles [*see illustration on page 76*]. These modern worms, because of their special paddle adaptation to the free-swimming life,



PRE-CAMBRIAN FOSSILS preserved in sandstone are seen in these eight photographs. This is *Dickinsonia costata*, shown actual size.

SEGMENTED WORM *Spriggina floundersi*, shown about twice actual size, resembles certain segmented worms living today.

JELLYFISH *Spriggia annulata* is one of the many types of this organism that have been found. The fossil is very slightly enlarged here.

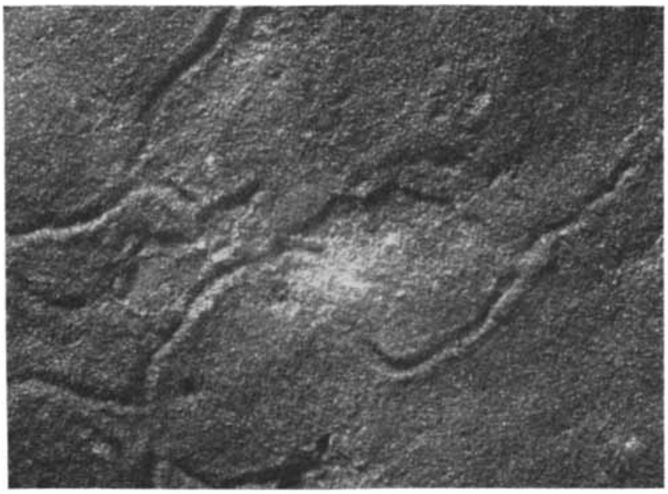
ANOTHER JELLYFISH, *Medusina mawsoni*, is shown nearly three times actual size. Jellyfish were the first fossils found.

had not been considered primitive or of ancient origin. It now appears, however, that they are directly descended from extremely ancient forms. The shape of the head of the Pre-Cambrian worms suggests the possibility of a relationship between them and the arthropods, such as the now extinct trilobites, which first appear in large numbers in the Cambrian. All of these later animals represent a considerable advance over the primitive anatomical organization of the coelenterates.

The most common fossil at the Ediacara site, the *Dickinsonia,* represented by more than 100 specimens, may also be related to living worms. The fossilized bodies are quite remarkable. They are more or less elliptical in outline, bilaterally symmetrical and are covered with transverse ridges and grooves in a distinctive pattern. The size of the bodies and the number of ridges vary so much that Sprigg attempted to distinguish species by counting the ridges. One recently discovered specimen has some 20 ridges; a larger one may have had as many as 550. The animals range in length from a quarter of an inch up to two feet. The numerous impressions of wrinkled and folded-over specimens indicate that all were soft-bodied, for there are none of the fractures that would be apparent if the creatures had possessed shells. These animals vaguely resemble certain flatworms living today. There is also one genus of annelid worm with a strikingly similar pattern of ridges formed by extensions of its parapodia. This similarity proves little or nothing, especially since no traces of eyes, legs or intestines are preserved in the fossils, but it provides some hope of finding out what these strange creatures were.

There is possibly less hope of placing in the family tree of the animal kingdom the two completely novel forms discovered in the Ediacara Hills. One had a shield- or kite-shaped body with a ridge that looked like an anchor. It was named *Parvancorina minchami* [*see illustration at top right below*]. The first specimen was tiny, but others found later measure up to one inch in length. Some show faint oblique markings within the shield on both sides of the mid-ridge, as if the animal had had legs or gills underneath. Here again folded and distorted specimens occur, proving that their bodies were soft.

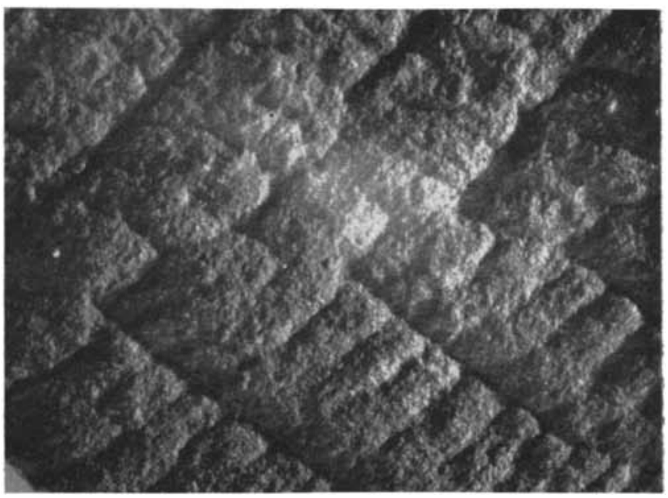
The other entirely new creature is even stranger. Named *Tribrachidium,* it has three equal, radiating, hooked and tentacle-fringed arms [*see illustration on the cover of this issue*]. Nothing like it has ever been seen among the known



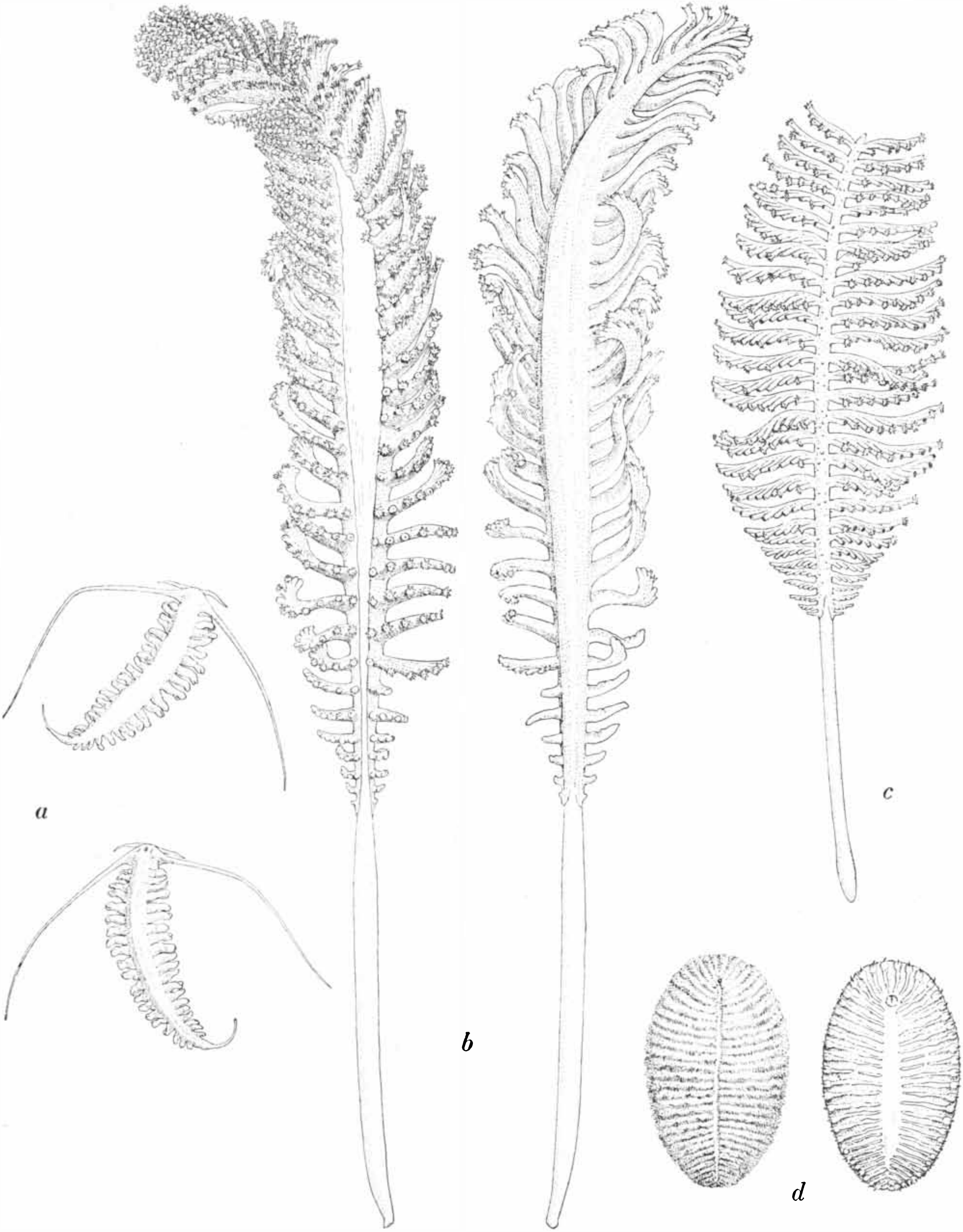
WORM TRAILS, approximately actual size, provide proof that fossilized worms lived in the area where they were preserved.

UNKNOWN TYPE OF ANIMAL, *Parvancorina minchami*, here enlarged nearly three diameters, resembles no other known organism.

SEA PEN *Rangea arborea* left this imprint, shown here twice actual size. The fossil resembles some of the living sea pens.



ANOTHER SEA PEN, *Charnia*, is shown actual size. Viewing photographs upside down may give fuller idea of animals' appearance.



FOUR LIVING ANIMALS that resemble some of the Pre-Cambrian fossils from South Australia are a segmented worm, *Tomopteris longisetis* (*a*), seen in dorsal and ventral views; sea pens *Pennatula rubra* (*b*), shown front and back, and *Pennatula aculeata* (*c*); and the worm *Spinther citrinus* (*d*), which looks like the many specimens of *Dickinsonia* in the Pre-Cambrian rocks.

millions of species of animals. It recalls nothing but the three bent legs forming the coat of arms of the Isle of Man.

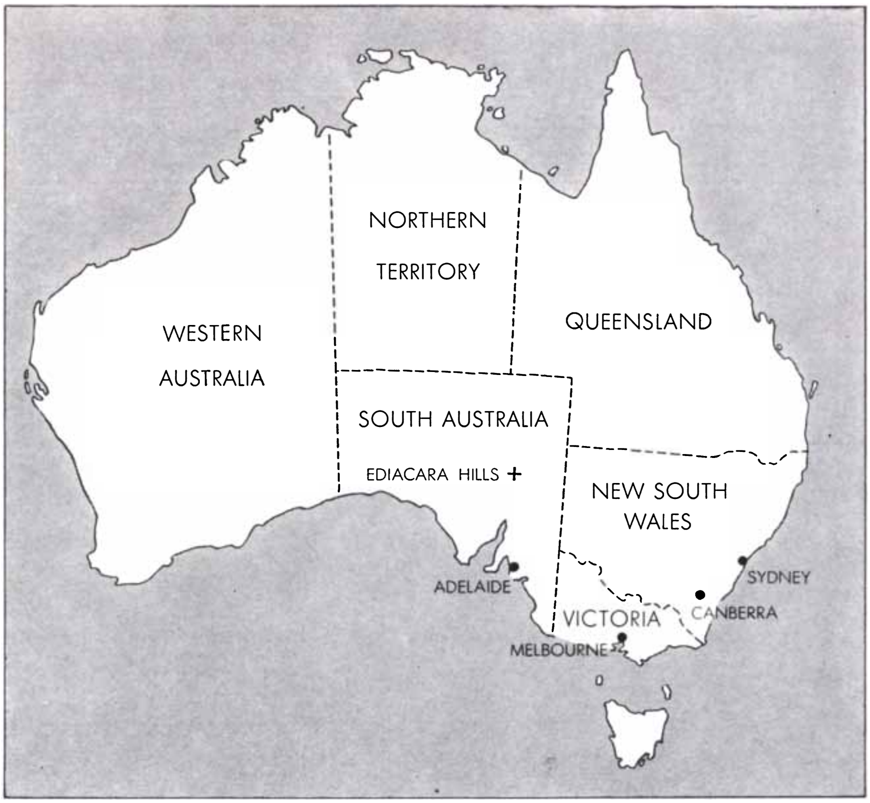
Considered together, the South Australian fossils suggest a rough and incomplete picture of conditions in the late Pre-Cambrian. Of course, such a group of fossils constitutes no more than a small, biased sample of the life of the time. Animals buried together in slabs of sandstone did not necessarily live together. Some, if they really are medusae, were floating in the sea. Others, like the annelid worm *Spriggina,* with its numerous legs and sinuously curving body, were free-swimming. *Dickinsonia* was probably also a free-swimming form, apparently along with *Parvancorina.* Scattered miniature treelike stands of sea pens, waving their flexible fronds, must have covered parts of the shallow sea floor. Elsewhere earthworm-like annelids, which have left only their tracks, crawled over and through the sediment, feeding on the decaying organic matter in it. Other worms inhabited the U-shaped burrows that have been found, consuming tiny creatures in the sediment and possibly also marine plankton, which left no traces in the rock. The fixed, three-rayed spread of tentacles of the strange *Tribrachidium* may be similar to the plankton-fishing structures around the mouth of the living brachiopods (lamp shells), bryozoa (lace corals) and some worms. If that is correct, *Tribrachidium* may have been a bottom dweller, possibly occupying low, conical, ridged cups, of which a few impressions have been found.

Bundles of impressions of needle-shaped spicules also occur in the Ediacara strata. Since spicules are characteristic of sponges, these sessile, bottom-dwelling animals may have been present. Snails and small crustaceans, as well as various protozoa (radiolarians and foraminifera), may also have existed at that time, but they would have been too small or too fragile to be preserved. Plant life likewise left no traces here.

The worm tracks are the only fossils indicating without doubt that the animals lived where their remains are found. Thus the *Spriggina* worms, the *Dickinsonia* and *Parvancorina* may have lived near or on the sedimentary beds. They are represented by individuals varying in size and growth stage, which indicates accidental death rather than transport from afar and later burial. On the other hand, the jellyfishes were probably stranded and the soft corals torn from their anchorage before they came to rest on the bottom.

The sandstone in which the fossils are found shows ripple marks and other evidences of currents, which would have had to be rather strong to transport the coarse grains of sand. Thus it is difficult at first to see how imprints of delicate, soft-bodied creatures could have been preserved. Careful study of the fossils has yielded an explanation. Only a very few of the animals came to rest on the shifting sand. Most of them came down on mud flats or on patches of fine clay that settled out of the water during calmer periods. Some of the mud patches dried out, possibly between tides, and developed deep cracks. The next high tide or shifting current covered them with a layer of sand. The lower surfaces of such sandy layers preserved the clay surfaces in the form of perfect casts, showing the wrinkles in the clay and the cracks formed by drying as well as the shapes of the animals stuck in the clay. The sand grains were cemented by silica solutions and turned to quartzite in the transformation from soft sediment to hard rock. The clay changed to thin slatelike streaks of the mineral sericite and was compacted almost beyond recognition. Since the sericite inclusions are small and irregular, the rock does not split along their surfaces as slate would. Only the slow, natural weathering in the arid climate of South Australia can open up the rock along the vital sericitic partings where the fossils occur. Slabs of quartzite of all sizes remain in place, projecting from the hillsides until they break off. They often turn over when moving downhill and their lower surfaces become exposed to the infrequent rain. Then the weathering causes them to reveal their wonderful riches of Pre-Cambrian animals. But if the rocks are not collected, the fossils are ultimately worn away by the weather and by the sand drifting in on the wind from the adjoining desert plains.

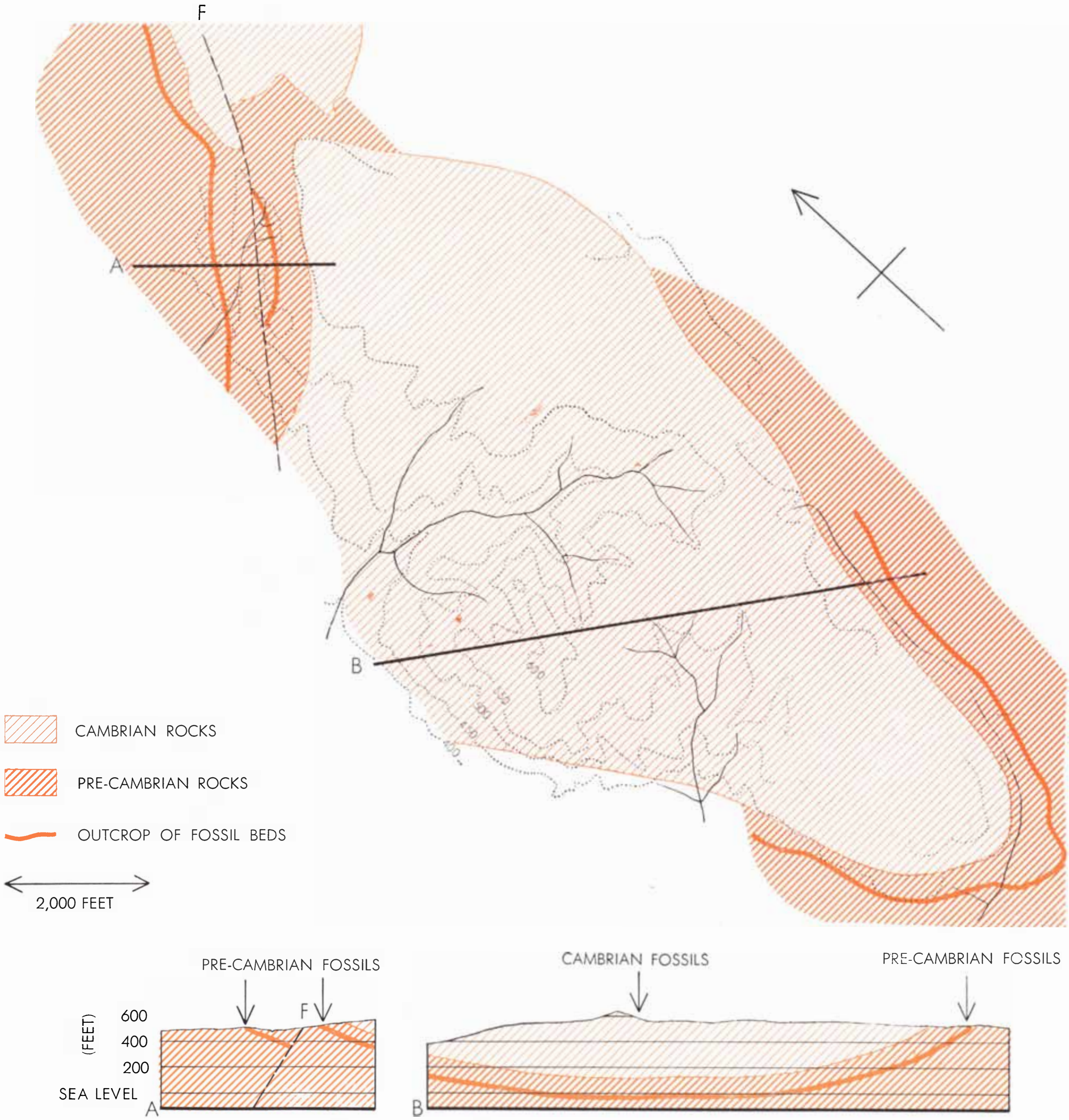
The age of the fossil-containing rocks cannot be determined directly in years because it does not contain radioactive minerals suitable for dating. Fortunately in the Ediacara Hills one can follow the stratification in unbroken sequence upward until the first undoubtedly Cambrian fossils are reached in dolomitic limestone 500 feet above the Pre-Cambrian level. These fossils in the limestone are typical of the lowest Cambrian strata elsewhere and are quite unlike the strange fossil organisms in the quartzite



LOCATION OF PRE-CAMBRIAN FOSSIL BED is in the Ediacara Hills (*cross*), some 300 miles north of Adelaide. The geologist R. C. Sprigg made the first discoveries there in 1947.

below. The quartzites higher up in the Cambrian strata do not contain any fossils of the type now known from the Pre-Cambrian, and the dolomites and limestones lower down contain no Cambrian fossils. From this distribution of fossils in the rocks it can be judged that the lack of shells and hard skeletons (other than the spicules) in the Pre-Cambrian animals was not due to any factors in the physical environment. The development of shells in the Cambrian was not a result of a sudden change in the habits or habitats of the animals. Rather, shells appeared as a step forward in biochemical evolution. Calcium metabolism underwent a change that produced hard shells and other skeletal material, providing the protection and mechanical support so important to the more advanced animals.

This is as far as the paleontologist and geologist can take the story today. The biochemist and physiologist may see in it a lead to experimentation that could well open a new chapter in the story of fundamental research in evolution.



MAP AND CROSS SECTIONS OF SITE where fossils are found show relative positions of Cambrian and Pre-Cambrian rocks. Lines *A* and *B* indicate locations of cross sections *A* and *B* (*below map*). Broken line *F* is a fault that has caused part of Pre-Cambrian fossil bed to move, creating two outcrops (*left*). Pre-Cambrian bed is under Cambrian rocks, except where its edges come to surface at periphery of Cambrian area. Dotted lines indicate contours. Part of the region shown here has been included in a fossil reserve.

Kodak reports on:

fish, raisins, chicken, bananas, and distilled acetylated monoglycerides...a mask for glass, switched by light...a book for those who plan to change worlds

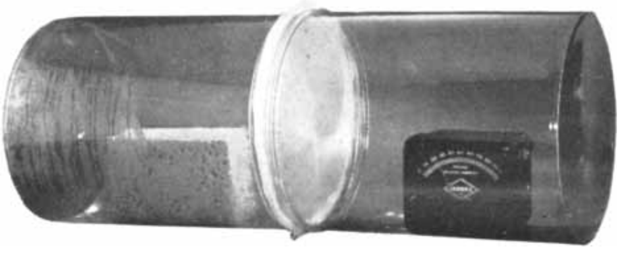
New and edible

The general public doesn't realize that we produce edible products with calories in them that a person can grow on and do pushups with. The newest of them, bearing the colorless designation "distilled acetylated monoglycerides," will win few gold medals for flavor because they are not supposed to have any flavor but what they do have are: 1) a most unfoodlike resistance to oxidative deterioration, and 2) very interesting physical properties.

We shall probably never advertise the product on television. We do stick in front of the ungainly generic name the trademark "Myvacet," which is easier to remember and shows we mean business. So far the business is confined to operating a small pilot plant and sending out technical salesmen to get food laboratories to accept samples with which to play and plan.

First the salesmen establish the distinction from *un*acetylated monoglycerides, another and equally real food which we have been producing by the ton for years as a texture-improver for fat-based foods and more recently for starch-based ones.

Then the salesmen undertake their mission of inspiration. They show this picture to fix in mind that "Myvacet" makes



a most effective barrier to water vapor. It also bars oxygen but not carbon dioxide. The solid "Myvacet, Type 5-00"* is far more flexible when cold than paraffin wax, which it resembles in feel and appearance but not in chemical nature.

The liquid "Myvacet, Type 9-40"** is a better gear and bearing lubricant, even under high pressures, than many petroleum-based products, yet, like the solid, it is unquestionably and officially *** edible and at the same time outlasts previously known edible oils against the forces of rancidity. As an intentional ingredient of shortening and table spreads, it makes their consistency almost independent of temperature. (As man inhabits more and more of the globe, he will need quite a few such ideas to keep himself in a good frame of mind.)

To send for our salesman and his samples, write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company.) Let him hint at new frontiers in fish-dipping, raisin-spraying, chicken-plucking, meat-freezing, and sealing the cut end of a hand of bananas so that the stalk can be left back at the plantation.

An invitation to engrave

To etch glass, you can draw up the pattern nice and big and black, reduce it photographically onto a *Kodalith* material and use the resulting photograph as a mask which determines where the resist comes off and exposes the naked glass to HF.

Think a moment what you are asking of any photosensitive resist. It must be capable of being switched by a reasonable amount of light from one to the other of two conditions: a) tenacious adherence to the particular material you wish to etch and impenetrability to agents which rapidly attack that material; b) abject submission to attack by agents which do not affect the substrate, or alternatively, full permeability to appropriate etchants for the substrate.

Obviously, *we* have given this matter much more than a moment's thought. Our researches have now brought forth a photosensitive resist for glass and silicate ceramics to join our previously announced *Kodak Photo Resist* ("KPR," for copper, clear anodized aluminum, and high-copper alloys) and *Kodak Metal-Etch Resist* ("KMER," for other metals). We would be justified in trying to recover all that thinking expense by selecting a similar proprietary name to imply the discovery of a new chemical compound. But no. We shall merely tell you how to convert KMER to a glass-etch resist by the use of those two arcane compounds, technical-grade aluminum stearate and sulfur-free xylene.

For details, write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y. If you don't want to bother stating your problem, just say "photosensitive resists."

The student who took advice

So much buy, buy, buy on all sides! Many a scientific man says the clamor is too overwhelming. Perhaps it is unwise to irk him further by suggesting that his own kind bears no small part of the credit for having caused the din to be set up.

In the early 1900s Sir William Ramsay, the physical chemist who discovered the noble gases, strongly advised a student of his named Mees to get a job in industry instead of following the traditional scientist's livelihood of teaching. The young fellow therefore went to work for Wratten & Wainwright, a small firm that made photographic plates. Actually, until not so long before, Mrs. Wratten, the senior partner's wife, had been making them in her kitchen, quite successfully flowing the emulsion from a teakettle onto glass.

But young Mees brought science into the operation. The union of science and industry was blessed with new products for Wratten & Wainwright. They attracted the attention of Mr. Eastman, of Kodak, who decided it would be good for *his* business, too, to apply some science to it. Instead of emulating Wratten & Wainwright, he bought their business and brought Mees to Rochester, N. Y., U.S.A., as Kodak's research director. This happened in 1912.

After 43 years in the job, Mees retired and wrote a book about his experiences in nurturing the chemistry and physics of one industry to churn out the stuff that has to be bought, bought, bought. His long, happy, and fruitful life ended last year. This month the book will be coming out under the title "From Dry Plates to Ektachrome Film" (Ziff-Davis Publishing Co., New York, $5.95 at many camera shops). It is recommended to those who want a very grown-up viewpoint on photography and its technology. It may also prove instructive to scientists in general who have made or are contemplating a switch from the world of scholarship to the world of commerce.

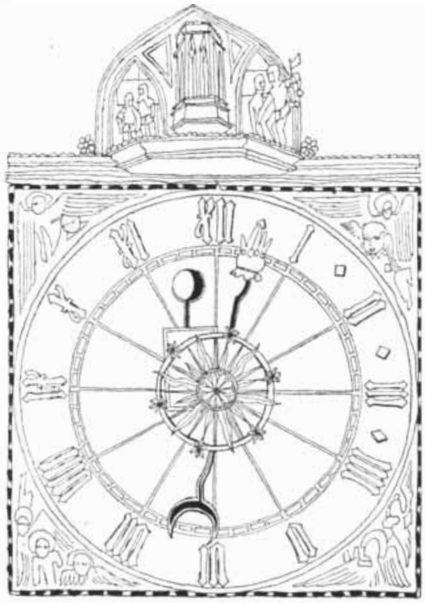
Like the other great founding fathers of industrial scientific research, Mees never needed advance warning to deliver an hour's lecture on almost any subject, accurately and wittily. Readers with fairly broad scientific educations will get the most out of his book. By going into considerable technical detail about the origins of products of ours, the book may even find new customers for them. Of necessity, the details are old enough to be told.

Price quoted is subject to change without notice.

*A distilled monoglyceride of fully hydrogenated lard or cottonseed oil, with about half the glyceryl hydroxyls replaced by acetyl groups.
**A distilled monoglyceride of partially hydrogenated lard or cottonseed oil, with nearly all the glyceryl hydroxyls replaced by acetyl groups.
***United States Food and Drug Regulations, Sec. 121.1018.

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

Kodak
TRADEMARK



SCIENCE AND

The New Administration

In naming nuclear chemist Glenn T. Seaborg to be chairman of the Atomic Energy Commission, President Kennedy has placed the first scientist in that position. Now 48, Seaborg has been chancellor of the University of California at Berkeley since 1958. In 1951 he shared the Nobel prize in chemistry with Edwin M. McMillan for discovering the fissionable isotopes uranium 233 and plutonium 239. Seaborg is codiscoverer of the synthetic elements 94 through 102.

Jerome B. Wiesner, 45, professor of electrical engineering at the Massachusetts Institute of Technology, has been appointed special assistant to the President for science and technology. Reportedly Kennedy's closest science adviser for several years, he has also been a member of President Eisenhower's Science Advisory Committee since 1957. In his new post he will serve as ex officio chairman of that committee as well as of the Federal Council on Science and Technology. Wiesner has long been interested in problems connected with disarmament.

Massy Electron

Among the 30 so-called elementary particles known to physicists the most baffling of all is the mu meson, or muon. A delicate experiment conducted at CERN (European Organization for Nuclear Research) in Geneva and reported in *Physical Review Letters* makes the muon more mystifying than ever. Not only does it seem to lack a useful role in subnuclear affairs (other particles share this lack) but also, as the CERN experiment confirms with new precision, it seems "nothing but" a heavy electron.

The muon weighs about 207 electron masses and has only a fleeting existence; its half-life is two-millionths of a second, and it decays into an electron and a pair of neutrinos. Like the electron, the muon exists in just two forms: as a negative particle and as a positive antiparticle. Thus electron and positron (or antielectron) are matched by negative muon and positive muon. In all experiments so far devised, whatever the electron will do the muon will do also, the only difference in behavior being attributable to the muon's greater mass.

The CERN experiment, performed by an international team made up of G. Charpak and T. Muller (France), A. Zichichi (Italy), J. C. Sens (Netherlands), F. J. M. Farley (United Kingdom), and R. L. Garwin and V. L. Telegdi (U. S.), involved an extremely precise determination of the behavior of the muon in a magnetic field.

Every charged particle will describe an orbit in a magnetic field. A muon, like an electron, makes a magnetic precession (a rotation of its own magnetic axis) of almost precisely one revolution in the time it is describing one revolution in orbit. The predicted (and previously verified) departure from unity for the electron is .001160; the predicted departure for the muon, assuming it differs from the electron only in its mass, is .001165. This is called the anomalous magnetic moment. If the deviation were zero, the axis of the muon would revolve exactly once in the time needed for one orbital revolution, just as the moon revolves once in circling the earth once. If a low-energy muon is forced to make 880 orbits, it will make 881 revolutions of magnetic rotation (880×1.001165). In the experiment a beam of muons was directed through a magnetic field in which the particle made about 1,000 revolutions. When they emerged, their magnetic axes no longer coincided with their axis of momentum (direction of flight). The disparity was a measure of the anomalous magnetic moment.

At decay the muon reveals the direction of its magnetic axis by sending an electron off in the same direction (but preferentially backward). The CERN experimenters determined the direction of electron flight by particle counters. After making 60 hours of observations, the CERN group obtained an experimental value for the muon's anomalous magnetic moment of $.001145 \pm .000022$. Thus theory and experiment agree in the fifth decimal place, within the limits of accuracy of the experiment.

Several important deductions follow from this remarkable agreement: (1) the laws of quantum electrodynamics are valid for distances as small as .7 fermi ($.7 \times 10^{-13}$ centimeter), confirming the previous verification with the electron; (2) the muon incorporates its great mass in a pointlike source no bigger than .3 fermi, or about the same maximum size placed on the electron, and about half that for the proton; (3) there is no evidence yet of a fundamental or "shortest" unit of length at which the known laws of physics might begin to fail—any such unit would have to be less than .2 fermi; (4) there is no evidence for particles, still unknown, with which the muon might interact.

The experiment leaves the mass of the muon totally unaccounted for. Said one physicist: "It's as if an equation of nature permits two solutions, one with the mass of an electron, the other with the mass of a muon."

The Return of Jack Frost

The frigid winter now ending may be, unhappily, no fluke. The warming trend that has dominated world climate through most of the years since 1880 seems to have come to an end. At a symposium sponsored by the American Meteorological Society and the New York Academy of Sciences, J. Murray Mitchell, Jr., of the U. S. Weather Bureau reported that mean annual temperatures have dropped in both Northern and Southern hemispheres by .2 degree Fahrenheit and mean winter temperatures by .4 degree since the early 1940's. Even greater declines have occurred in high northern latitudes. In many areas climatic conditions have already returned to those prevailing in the 1920's.

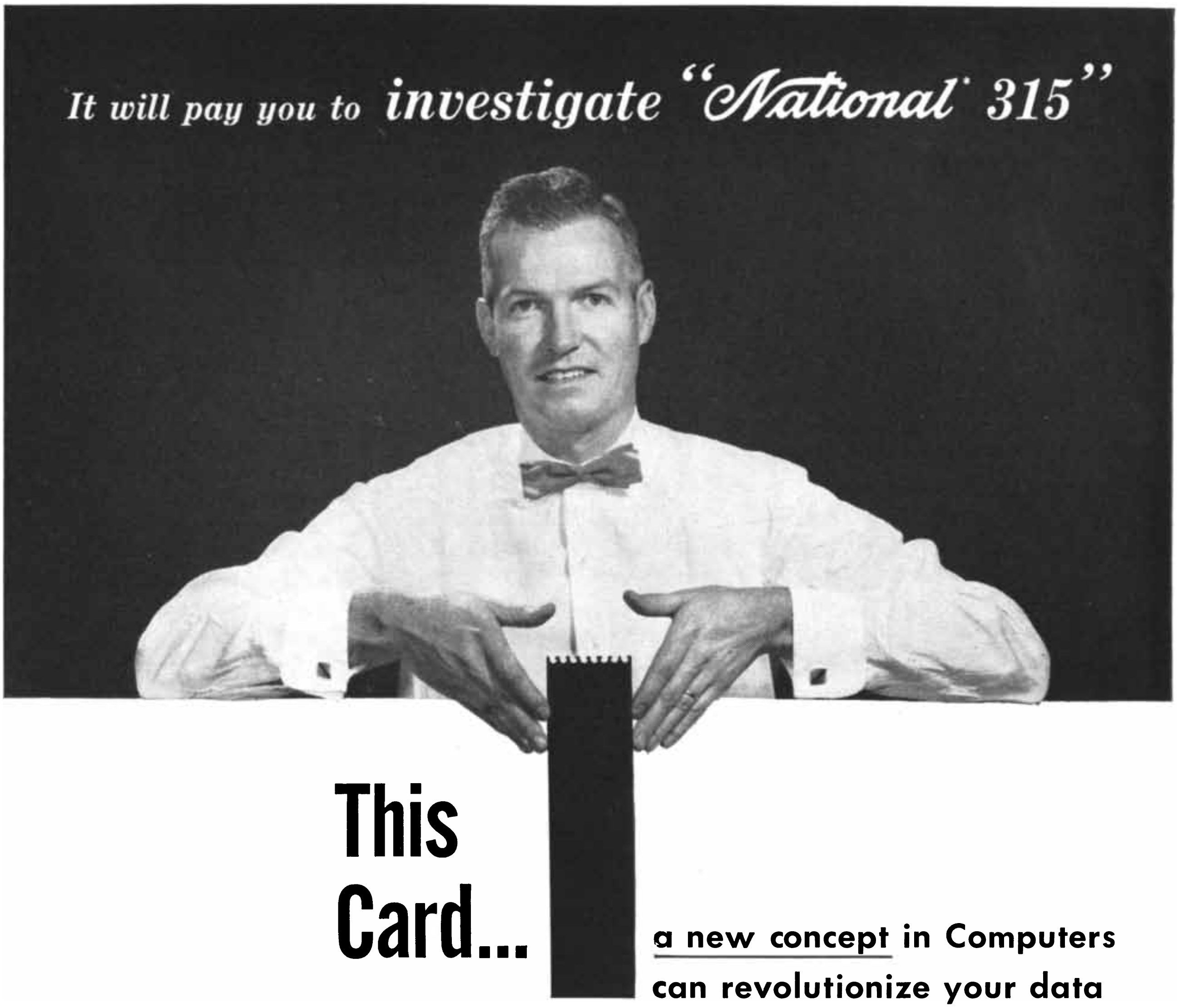
The downturn has allayed fears about the "greenhouse effect," in which a rising concentration of carbon dioxide in the atmosphere, due to increased use of fossil fuels, was supposed to be trapping more and more solar energy, formerly reradiated by the earth. But the reasons for the cooling are unknown. Possible explanations advanced during the symposium—attendance at which was reduced by heavy snowfalls—included variations in solar activity and output, an increase in the volume of volcanic ash in the atmosphere, a decrease in ozone concentration and changes in atmospheric circulation. Whatever the answer, it was agreed that the current cooling trend might last half a century or more, as have similar cycles in the past. And Rhodes W. Fairbridge of Columbia University predicted that the cycle would soon halt the melting of the Arctic Ocean's cover of ice and the 1.2-millimeter-a-year rise in sea level that has been occurring since 1900 as a result of the melting of mountain glaciers.

Atomic Power: The Long View

"As of today, nuclear energy for large power stations is uneconomical. Hence it makes little difference whether it is very uneconomical. The large-scale use of money and of scientific manpower for the development of nuclear energy cannot be justified on the basis that it leads only to a small economic disadvantage. It can be justified only if it is directed toward the use of nuclear energy when it will be needed, and if the use of nuclear energy will indeed satisfy the need which will arise." So concluded Alvin M. Weinberg, director of the Oak Ridge National Laboratory, and Eugene P. Wigner, professor of physics at Princeton University, in an article in *Bulletin of the Atomic Scientists*.

When fossil fuels run out, say the authors, the only way to meet the need will be through breeder reactors (reactors that create more fissionable material than they consume in their chain reaction). If breeder reactors are not developed, even a steep rise in uranium prices will not produce enough fissionable material to meet U. S. energy needs for much more than a generation. By making it possible to utilize the entire energy content of uranium and thorium, on the other hand, breeding will provide a supply of energy "ample for many hundreds of years."

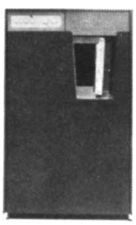
More work on breeders is needed now, Weinberg and Wigner point out, because "it is quite uncertain whether the problems of the breeder will be solved by a frontal assault, or by successive improvements on burner [reactors]." Moreover, "several generations of breeders fueled by materials produced by earlier breeders will be necessary to produce



a new concept in Computers can revolutionize your data processing procedures.

This magnetic card is the heart of the National 315 Card Random Access Memory (CRAM) . . . an unequalled advance in economical magnetic file processing.

In effect, a reel of magnetic tape—3¼ inches wide—has been cut into 256 strips forming addressable magnetic cards. A single card is capable of storing 21,700 alpha-numeric characters. Each card contains seven recording tracks that can be addressed electronically by the central processor.



The 256 cards (5,555,200 alpha-numeric characters) are housed in a removable cartridge that can be changed in less time than it takes to change a reel of magnetic tape. Up to 16 CRAM files can be operated on-line with the National 315 . . . providing 88,883,200 alpha-numeric characters . . . an unprecedented range of random accessible memory.

This unique system combines all the advantages of random and sequential processing . . . eliminates rewind time . . . requires fewer files . . . speeds sorting, up-dating, and reporting routines.

INVESTIGATE THE NATIONAL 315 for economical price performance • For unusual expansibility • For high-speed, balanced processing • For economy of programming • For ease of operation.

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the inventories [of fuel] for the critical period." In addition, many difficulties will arise in the storage and disposal of the vast amounts of radioactive material generated by large-scale use of nuclear energy; adequate handling of the difficulties "will have to be based on protracted practical experience." For the solution of these and numerous other problems there may well be less than the 100 years indicated by the apparent size of present fossil fuel reserves. Some fossil fuels will have to be reserved for nonfuel purposes, and severe local fuel shortages can be expected to develop in many areas in much less than 100 years.

Celestial Supermagnet

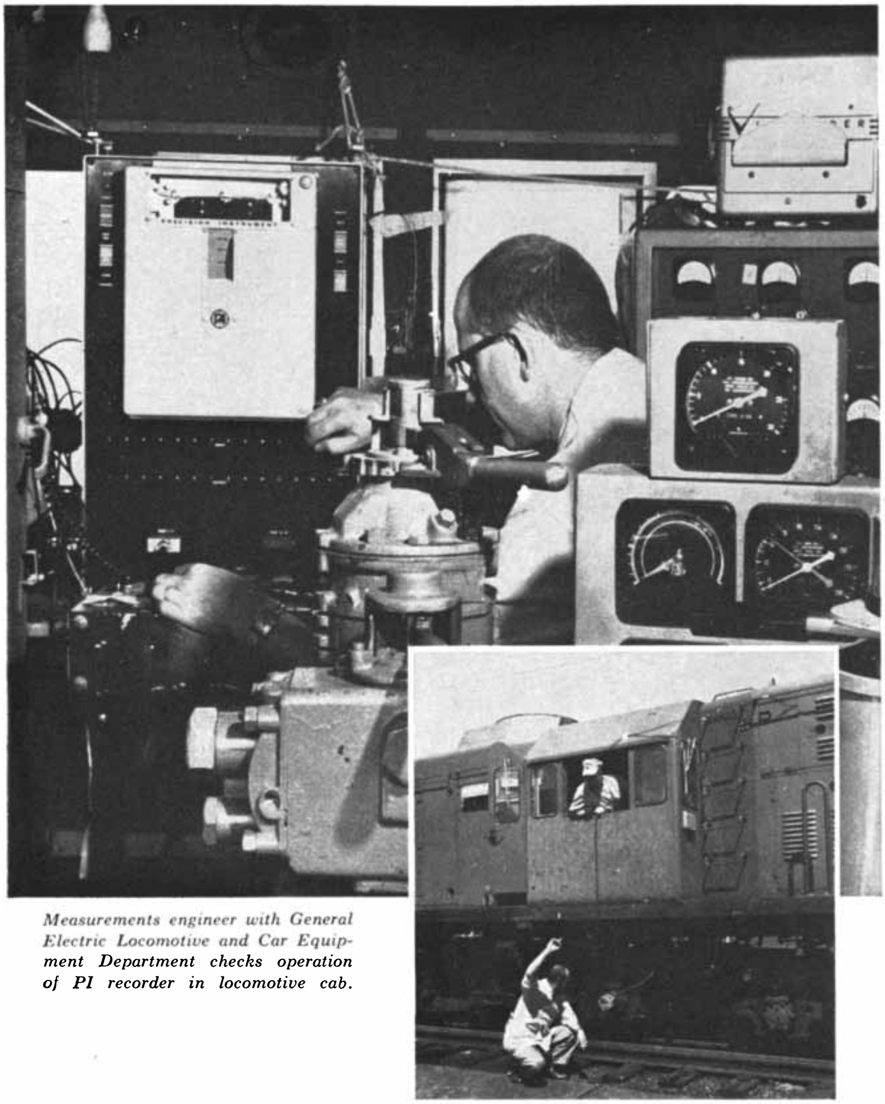
An otherwise undistinguished star in the northern constellation Lacerta has been found to have a magnetic field that sometimes exceeds 34,000 gausses—by far the strongest magnetic field yet discovered in nature. Since July, 1959, when the magnetism was first discovered, the irregularly fluctuating field has never been observed to drop below 4,000 gausses, according to a recent report in *The Astrophysical Journal.* Most magnetic stars have fields of 1,000 to 2,000 gausses. In its quiet areas the sun's field is one or two gausses; the average magnetic field at the surface of the earth is .6 gauss.

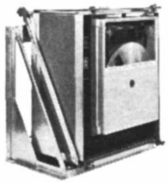
Known only by its catalogue number, HD 215441, the star attracted the attention of Horace W. Babcock of the Mount Wilson and Palomar Observatories because its surface temperature and certain lines in its spectrum were typical of magnetic stars. A spectrogram made with the 200-inch telescope showed a degree of "Zeeman splitting" and polarization in the spectral lines that indicated a very strong magnetic field. On further observation the star proved to be an unusually lucky find in another respect. Almost every strongly magnetic star, including this one, is in rapid rotation. Usually the motion produces Doppler effects that smear out the spectral lines and mask the Zeeman splitting. HD 215441, however, happens to face the earth pole on, so there is no motion along the line of sight and no Doppler shift.

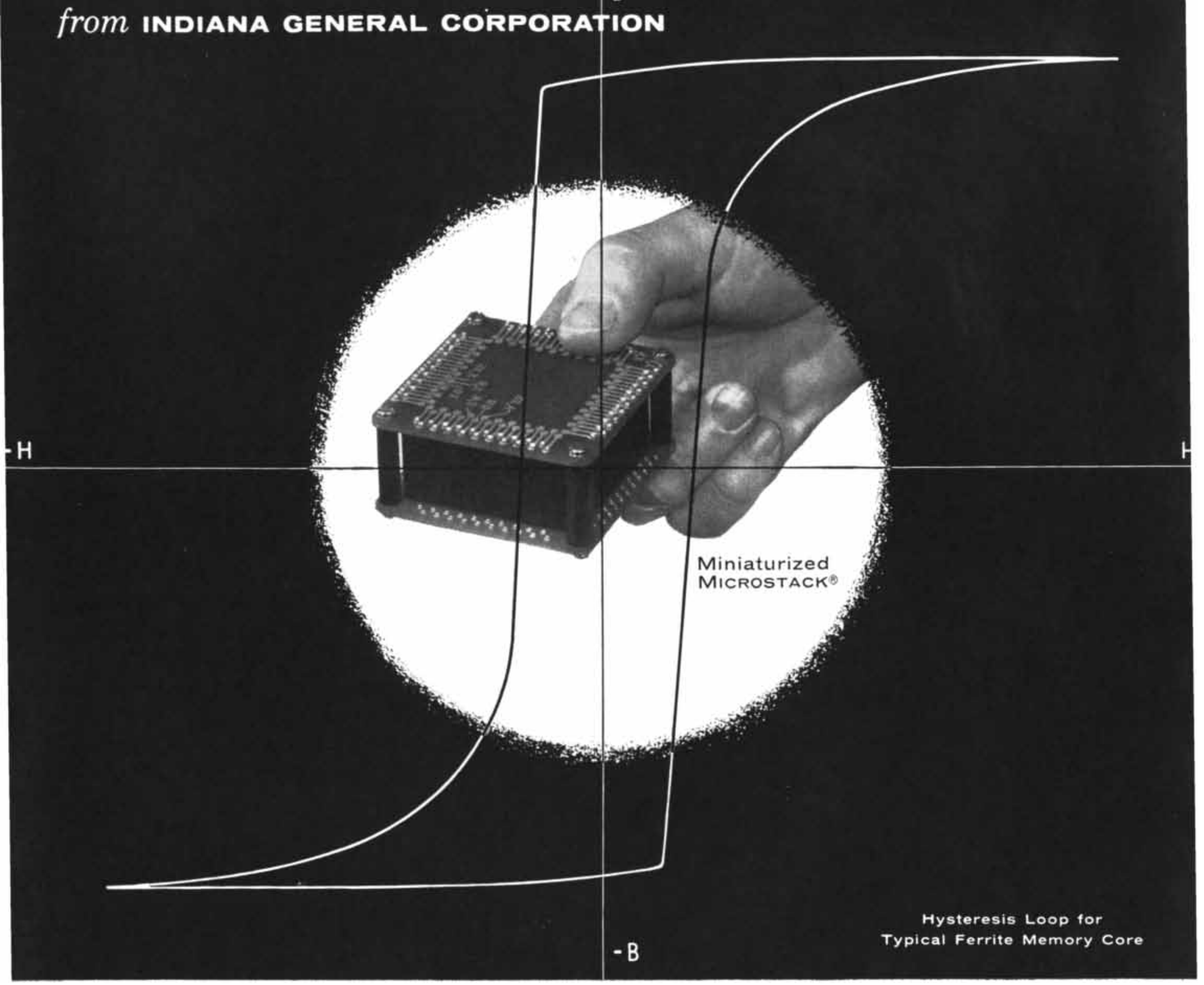
Old and Isolated

Do aged recluses really fill their rooms with rubbish and their mattresses with money? According to a recent psychosociological study—apparently the first one ever made—many of them do.

As the authors of the study, New York physician Frederic D. Zeman and Co-







CREATIVE MAGNETICS

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Rectangular hysteresis loop ferrite cores pioneered by our General Ceramics Division have opened a new era of accuracy and practicality in data processing.

Indiana General's ferrite cores are the brain cells in the memory units of today's highly complex computer machines. These tiny, magnetically bi-stable cores, which reverse their polarity in one microsecond or less by minute electrical impulses, have proved to be the ultimate in reliability.

Research by our General Ceramics Division has produced a number of important advances. One is the company's newest packaging concept for memory planes, the miniaturized MICROSTACK which is 90% smaller than conventional arrays. Another is the special temperature-controlled unit that operates efficiently between −55° C. and 125° C. This new type of memory matrix is compact, durable, and much more reliable than older frame-type memory arrays because of a drastic reduction in soldered connections.

Indiana General also furnishes customized buffer or random access memories using standardized plug-in modules mounted in standard 19-inch relay racks. These are not only up to 80% smaller than competitive units, but offer increased reliability and simplified maintenance. Standard, in-stock memories are available with word capacities of 32 to 32,000 (any bit length), with sequential cycle times down to 3.3 microseconds, random access cycle times down to 6 microseconds, and data access times down to 2 microseconds.

Let us prove our leadership in the memory field — write today outlining your requirements to General Ceramics Division, Applied Logics Department, Keasbey, New Jersey. Ask for Bulletins 25 and 26.

INDIANA GENERAL CORPORATION VALPARAISO, INDIANA

Permanent Magnets • Ferrites • Technical Ceramics • Memory Products • Magnetic Separation and Handling Equipment lumbia University sociologist Ruth Granick, point out, many aged recluses constitute a danger to their communities. Their homes are fire hazards; the numerous dogs and cats they often keep are foci of vermin; their proverbial hidden wealth is an invitation to violence. Moreover, these aberrant individuals are worthy of attention in their own right and as extreme examples of social isolation in the aged.

Yet they do not seem to have received attention, except from newspapers. Zeman and Granick checked the index of *Psychological Abstracts* back to 1927 without finding a single entry under "recluse," "hermit" or similar names. Their own survey is based on clippings from newspapers over a period of 17 years.

The portrait of the aged recluse to emerge from the data is sketched in the *Journal of Chronic Diseases*. He or she (women are as likely as men to become recluses) is generally in his 70's or 80's and usually lives in a house or apartment that is ill-kept and filled with an impenetrable clutter of junk. While a majority live alone, a surprising proportion—more than a third—live with a relative or friend. These "joint recluses," as the authors call them, are likely to be even more isolated from outside contact than those who live alone. Most recluses have substantial funds. Of the 105 individuals studied, nearly half had hoards of cash hidden at home. Sixty-five per cent of them died possessed of fortunes ranging from $30,000 to $5,000,000. Murder, accidents and starvation were prominent as causes of death. Many exhibited signs of withdrawal—such as failure to marry—early in life. Zeman and Granick feel that some recluses may be latent schizophrenics whose disease becomes overt only with the onset of senility.

Zeman and Granick hope their report will stimulate more careful studies. As sources of data on old people who live and die alone but do not get into the newspapers, they suggest welfare agencies, medical examiners' offices, police departments and city morgues.

The Color of Radio Stars

Radio astronomers are beginning to apply one of the most powerful tools of visual astronomy—the diagram that plots absolute magnitude against color. An analysis of the radio emissions from a number of visible galaxies shows that they fall into two groups. One, comparable to the "main sequence" of stars, consists of sources of fairly uniform intensity ("magnitude") but with a wide

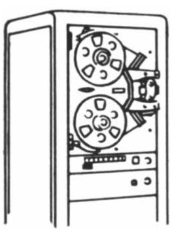
A WORD OF WARNING ABOUT THE NEW ALLUREMENTS OF RECOMP II [and a modest word about price]

Could you be enticed by a computer? Surprisingly, there *are* businessmen and scientists who have allowed their emotions to get quite out of control regarding Recomp II.

And now there is more reason than ever for becoming enamored with this amazing computer. *Three* reasons, to be exact, and all of them new. Hence, our warning to you.

The first reason is, in itself, enough to steal your heart away: it is Recomp II's new reduced lease price. Always the darling of the medium-scale computer user, Recomp II has been so well accepted that it can now be offered at significantly lower terms. And it *still* provides the identical quality, solid-state performance, and features that can't be found on computers costing three times what Recomp II *used* to cost.

This is heady stuff—but even more enticements lie in wait. You can now add an optional modification to your Recomp II to enlarge its capacity by using magnetic tape. Here you see the new Recomp Magnetic Tape Transport unit.



Naturally it's superbly designed, solid state throughout. But don't let its quietly well-bred air fool you; it has a memory that would stagger an elephant—over 600,000 words. And up to eight of the Transport units can be connected to Recomp II, giving you a computer with a total memory capacity of over 5,000,000 words. Steady there, Mr. Simpson!

The speed of this new magnetic tape control is something to applaud, too: read and write speed is 1850 characters a second; bidirectional search speed is 55 inches per second. Do you begin to see why we warned you about these new allurements of Recomp?

Below you see another new optional feature for your Recomp II: the Facitape tape punch and reader console. It punches 150 characters a second, reads 600 characters a second, and stops on a character. It adjusts to read and punch from 5

through 8 channels. It is versatile, accurate, fast, simple-to-operate, economical, reliable. And it has perfect manners: the mechanical components are completely enclosed in a soundproof housing.

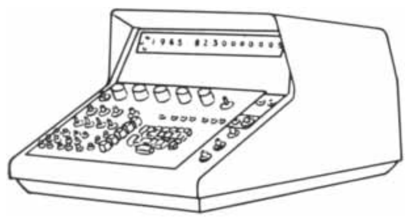
But lest we harp too much on the *new* features of Recomp II, perhaps we had better remind you of some of the extraordinary features that Recomp II *already had*. Features that have always made it the finest computer in the low-priced field.

1] Recomp II is the *only* compact computer with built-in floating point arithmetic. It defies being hemmed in on a problem. With its large capacity it obviates computer-claustrophobia.

2] Recomp II was the first solid-state computer on the market. As you can see by the new features above, Recomp II's scrupulous engineers have seen to it that it remains the *finest* solid-state computer on the market.

3] Recomp II seems to have more built-in features than a dream home kitchen. It has built-in square root command. Built-in automatic conversion from decimal to binary.

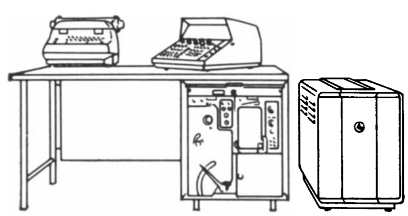
Here you see Recomp II's distinctive keyboard. It looks easy enough to operate—and it *is!* And because Recomp II



requires no specialized talents, anyone with computer problems can be taught to use it.

One look at Recomp II leaves little wonder that even practical people have allowed their hearts to influence them in choosing Recomp II. Without being showy, it is an object of beauty that reflects its supreme precision of performance. Its distinguished exterior bespeaks the ultimate of excellence; *c'est sans pareil.*

But if you want to avoid being captivated by a computer you should know how strong your emotions will run. May we suggest a *test?* Expose yourself to Recomp II. See it in action. Touch it. Feed problems into it. This is the only way to know how you will react to this extraordinary computer. Make a date to see Recomp II right away.



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The Autonetics Division of North American Aviation, Inc.

variety in the relative proportion of wavelengths ("color"). The second is like the visible "red giant" stars in having more or less the same color but varying in intensity. Some giant radio galaxies are a million or more times brighter than those in the "main" radio-galaxy sequence.

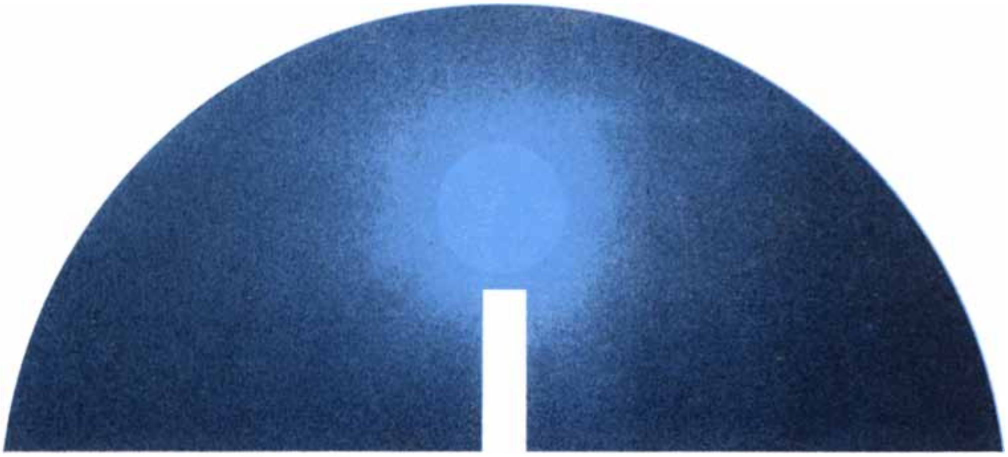
The existence of the two classes was discovered by David S. Heeschen of the National Radio Astronomy Observatory, who described his findings in *Publications of the Astronomical Society of the Pacific*. As an index of absolute radio magnitude, Heeschen uses the observed intensity of emission at a wavelength of 68.2 centimeters, and corrects it for the distance of the galaxy. For the "color" scale, he compares the emissions at 21.4 and 68.2 centimeters. On this scale a source emitting radio waves of equal intensity at 21.4 and 68.2 centimeters would have a color index of zero. A "redder" radio source (one with more of the long radiation) would have a color index greater than zero; the redder the source, the higher the index number. A "blue" radio galaxy, with greater emission at 21.4 than at 68.2 (if such exists —none has actually been found), would have a negative color index.

When the absolute magnitude and color values for 18 radio galaxies were plotted on the chart, the galaxies were found to fall into the two distinct groups, with none in an intermediate position. The groupings were associated, moreover, with differences in the visual appearance and visible-light spectra of the galaxies. Those belonging to the "main" type of sequence are optically normal galaxies. Those in the giant class, on the other hand, exhibit visual and spectral peculiarities. What the radio sequences signify, however, and whether they extend to other types of radio source such as luminous gas clouds and exploding supernovae, remains to be seen.

Leukemia and Chromosomes

Investigators in Great Britain have discovered an abnormal chromosome in the white blood cells of patients suffering from a form of leukemia. The chromosome is either No. 21 or No. 22 in the standard classification, both of which are normally small, three-lobed bodies. The abnormal form is even smaller, apparently having lost one of its lobes.

The anomaly was discovered with the aid of a procedure, originated in Britain more than a year ago, for culturing white cells collected from circulating blood. Seen first in two men with chronic



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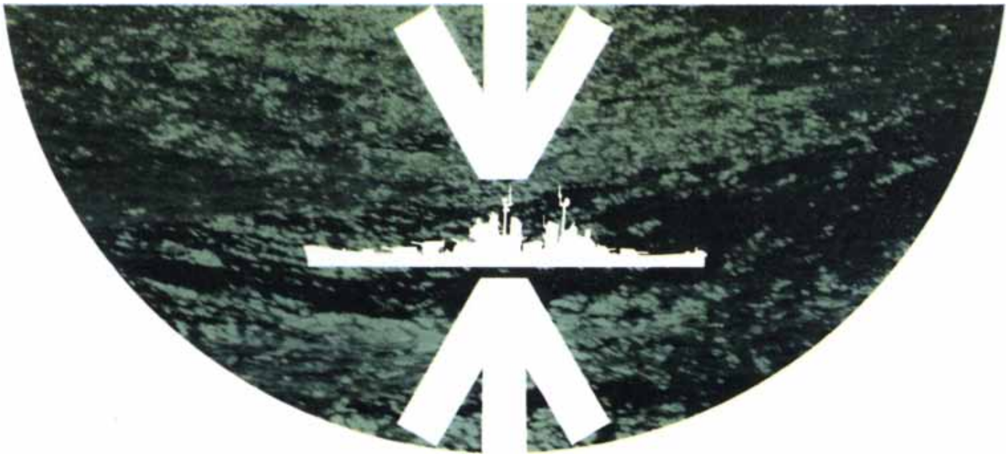

New Data Interchange System Tightens Naval Fleet Coordination The new Naval Tactical Data System will permit a task force, dispersed over a 300 mile area, to be operated by its commander with the same flexibility and tactical control he exercises over his flagship. Information from radar, sonar and other sensing sources gathered by all surface and airborne elements of the task force will be continuously displayed, providing intelligence for directing missile-launching functions, reconnaissance operations and tactical maneuvers.

Alpha is providing system engineering and management for the channeling of the intelligence data from each unit's computer and the transmitting by single sideband radio to like computers in each other unit of the force. This computer-to-computer instant sharing of intelligence is the heart of NTDS.

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myeloid leukemia, the chromosome was thought to be an unusually small "Y" sex chromosome, which is found in the cells of males but not females. Soon afterward, however, A. G. Baikie and his colleagues at the Western General Hospital in Edinburgh found it in cells from women patients as well.

In recent years chromosome aberrations have also turned up in mongoloid children and in people suffering from a variety of disorders of sexual development. Curiously, the same chromosome may be involved in mongolism and chronic myeloid leukemia. In a report to *Nature* the Baikie group points out that mongoloids not only have an extra chromosome No. 21 (giving them a total of 47 chromosomes instead of the standard human complement of 46) but also are often found to have white-cell abnormalities. The chronic myeloid leukemia and mongolism chromosome aberrations differ, however, in two striking respects. In mongolism the extra chromosome is found in all tissues and is present from birth. In chronic myeloid leukemia, the preliminary studies suggest, the defective chromosome is present in leukemic white cells only and it may appear only at or shortly before the development of the disease.

Talking Maser

A maser producing a continuous and coherent beam of light that can carry a large number of messages has been developed by Bell Telephone Laboratories. The first masers amplified microwaves, hence the acronym meaning "microwave amplification by stimulated emission of radiation." Recently the device has been adapted to suit visible light, but only in short bursts. To be useful for carrying signals (and not just amplifying them) a light maser must produce a continuous beam that can be modulated as a radio beam is modulated. Moreover, the beam must be coherent, meaning that all the waves must be in phase and not jumbled.

The new maser, invented by Ali Javan, meets all these requirements. It achieves amplification by the interaction of helium and neon and uses only about 25 watts of power. Previous optical masers, employing ruby crystals, required thousands of watts of power to produce their short bursts. Javan's maser produces a steady beam of infrared light slightly under half an inch wide that spreads no more than a foot over a distance of a mile. With a telescope as a transmitting antenna the beam could be sent 100 miles with the same one-foot dispersion.

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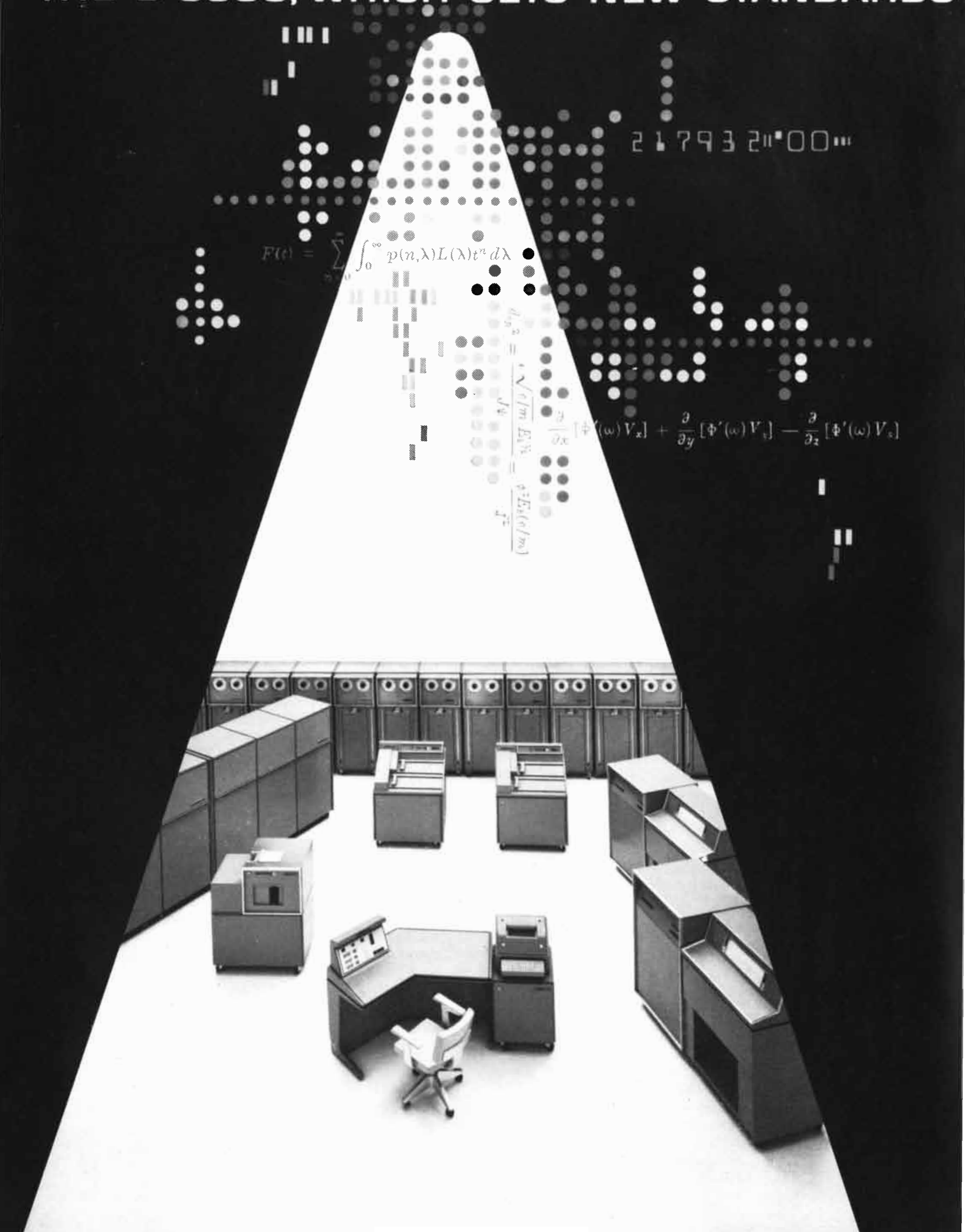


GRAVITY

Albert Einstein showed that gravitation can be interpreted as a geometrical property of space-time. His further hope, of relating gravity and electromagnetism, is still unfulfilled

by George Gamow

In the days when civilized men believed that the world was flat they had no reason to think about gravity. There was "up" and "down." All material things tended naturally to move downward, or to fall, and no one thought to ask why. The notion of absolute up and down directions persisted into the Middle Ages, when it was still invoked to prove that the earth could not be round.

The first ray of light to pierce the mist of scholastic ideas about falling bodies issued from the work of Galileo Galilei. Since free fall was too fast to measure directly, Galileo decided to dilute the motion by studying bodies placed on an inclined plane. He argued —and at the time it was a novel argument—that since a ball resting on a horizontal surface does not move at all, and since a ball falling parallel to a vertical surface moves as fast as it would if the surface were not there, a ball on an inclined surface should roll with an intermediate speed depending on the angle of inclination. Letting balls roll down planes tilted at various angles, he observed their rates of travel and the distances covered in different time intervals, which he measured with a water clock. The experiments showed that at any angle the speed increases in direct proportion to time (counted from the moment of release) and that the distance covered increases in proportion to the square of the time. Galileo also observed that a massive iron ball and a much lighter wooden ball roll down side by side if released simultaneously from the same height on the same inclined plane.

As another way to dilute free fall he employed simple pendulums—weights suspended by thin strings. Here the steepness of the arc along which the weight travels is adjusted by changing the length of the string. Pendulums of the same length proved to have the same period of oscillation even when the weight was varied, a result in agreement with the outcome of the inclined-plane experiments. From all these observations Galileo was led to infer that in free fall all material bodies, light or heavy, also move in exactly the same way. This idea directly contradicted the opinion of the then prevailing Aristotelian school of philosophy, which held that heavier bodies fall faster than light ones. According to the celebrated legend, which may or may not be true, Galileo climbed the leaning tower of Pisa and dropped a light and a heavy ball, which hit the ground simultaneously, to the consternation of contemporary philosophers.

Newton's Law of Gravity

These studies laid the foundation for the science of mechanics. The main structure was erected by Isaac Newton, who was born the year Galileo died. With his laws of motion Newton introduced the notions of force and of inertial mass. When a force is applied to material bodies, it changes their speed or direction of motion or both. Their inertial mass opposes these changes. Newton stated that the rate of change of velocity (acceleration) of an object is directly proportional to the force acting on it and inversely proportional to its mass. Doubling the force doubles the acceleration; doubling the mass cuts the acceleration in half; if both force and mass are doubled, the acceleration is unchanged.

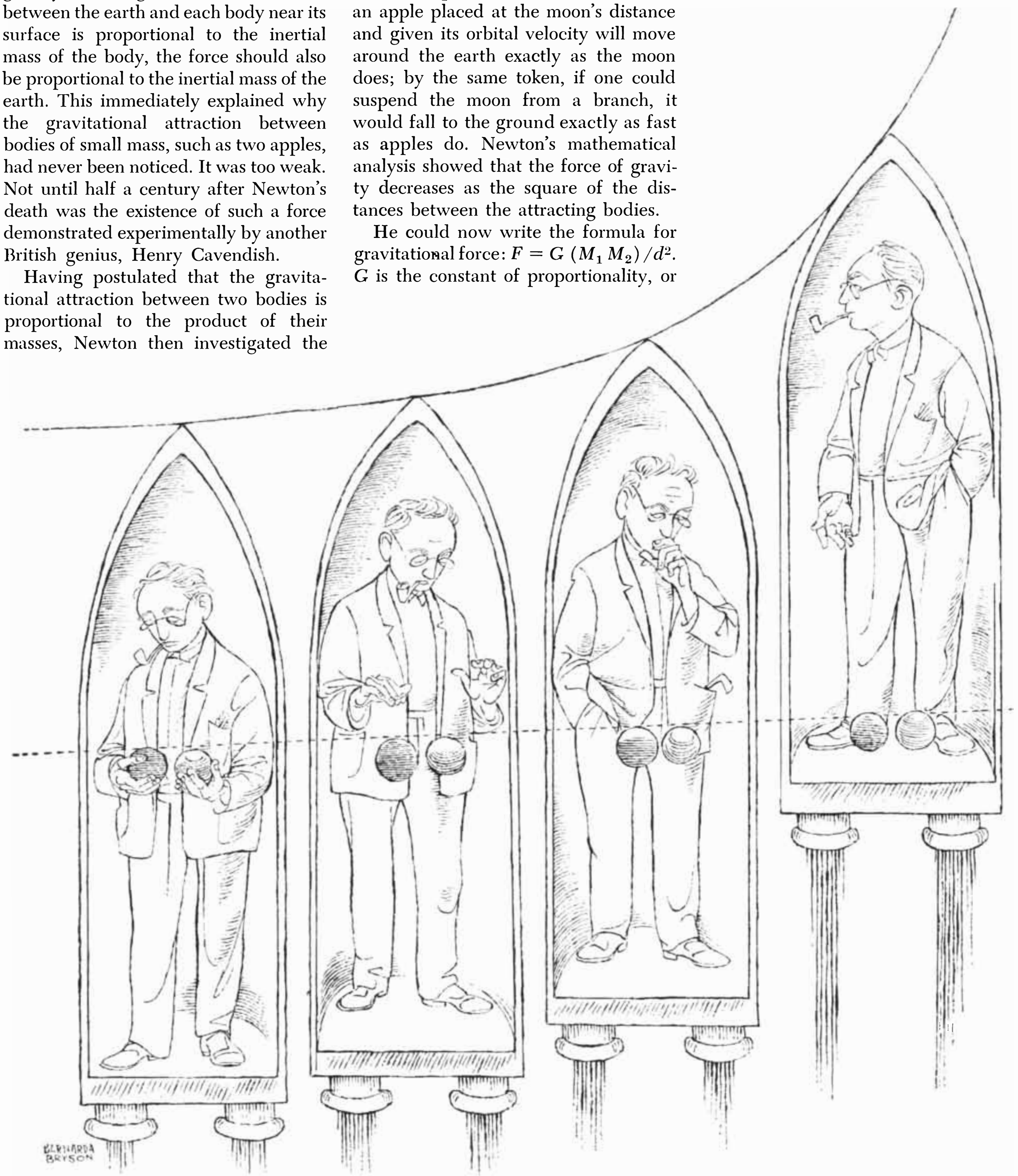
In the light of this law Galileo's conclusion about free-falling bodies implies a fact that is usually taken for granted, but which is actually very curious; namely, the weight of a body (that is, the gravitational pull of the earth upon it) is strictly proportional to its inertial mass. Otherwise an iron and a wooden ball of the same size would not fall at the same rate. If the two objects have the same acceleration when they are dropped, the inertial mass opposing a change of motion in the iron ball must be greater than that in the wooden ball in exactly the same proportion that the downward force on the iron ball is greater. This proportionality is far from trivial; in fact, it holds true only for gravity and not for other familiar forces such as those of electricity and magnetism. Thus while an electron and a proton would fall with equal acceleration in a gravitational field, when these particles are placed in an electric field the electron is accelerated 1,836 times faster.

From his analysis of balls (or apples) that fall toward the earth Newton went on to consider gravitation in wider terms. His line of thought is demonstrated by a very interesting discussion in his *Principia*. Suppose, he said, we shoot a bullet horizontally from the top of a mountain so high that it rises above the atmosphere [*see illustration on page 96*]. The bullet will follow a curved trajectory and hit the surface of the earth some distance away from the base of the mountain. The greater the muzzle velocity, the farther away from the mountain the bullet will land. At a sufficiently high initial velocity the bullet will come to earth at a point directly opposite the mountain; at still higher velocity it will never hit the ground but will continue to revolve around the earth like a little moon. If, Newton argued, it is possible in this way to make an artificial satellite, why not assume that the motion of the natural moon is also a free fall? And if the moon revolves around the earth because of the earth's gravitational attraction, is it not logical to assume that the earth itself is held in orbit around the sun by the force of the sun's gravity? Then is this not also true for all the other planets and their satellites? So originated the profoundly important idea of universal gravitation, which states that all material bodies in the universe attract one another with forces determined by their masses and mutual distances.

To establish the exact relation of force to mass and distance, Newton began by assuming that, since the force between the earth and each body near its surface is proportional to the inertial mass of the body, the force should also be proportional to the inertial mass of the earth. This immediately explained why the gravitational attraction between bodies of small mass, such as two apples, had never been noticed. It was too weak. Not until half a century after Newton's death was the existence of such a force demonstrated experimentally by another British genius, Henry Cavendish.

Having postulated that the gravitational attraction between two bodies is proportional to the product of their masses, Newton then investigated the dependence on distance. He compared the force necessary to hold the moon in its orbit at the distance of 60 earth radii with the force on an apple at the distance of only one radius from the center of the earth. It is important to realize here that the great difference in mass between the two bodies does not affect the validity of the comparison. As a matter of fact, an apple placed at the moon's distance and given its orbital velocity will move around the earth exactly as the moon does; by the same token, if one could suspend the moon from a branch, it would fall to the ground exactly as fast as apples do. Newton's mathematical analysis showed that the force of gravity decreases as the square of the distances between the attracting bodies.

He could now write the formula for gravitational force: $F = G\,(M_1 M_2)/d^2$. G is the constant of proportionality, or the gravitational constant. It is a very small number; if the masses are measured in grams and the distance in centimeters, G is approximately .000000066. This means that a pair of one-gram weights separated by one centimeter attract each other with a force a little



PRINCIPLE OF EQUIVALENCE enunciated by Einstein states that accelerated motion produces effects indistinguishable from those of a gravitational field. If an observer in a uniformly accelerating spaceship simultaneously releases two balls of different weight, he will see them fall toward the floor at the same rate. An outside observer would say that the balls continue to move upward (*broken line*) with the speed of the ship at the moment of release, while the floor, moving up at an accelerating rate, overtakes them.

more than six hundred-millionths of a dyne, or about six hundred-billionths of the weight of a gram.

Combining the law of gravitation with his laws of motion, Newton was able to derive mathematically the rules governing planetary motion that had been discovered by Johannes Kepler. In the memorable era that followed, Newton and his successors explained the motions of celestial bodies down to the most minute details. But the nature of gravitational interaction, and in particular the reason for the mysterious proportionality between gravitational mass and inertial mass, remained completely hidden for more than 200 years.

Einstein's Law of Gravity

Then, in 1914, Albert Einstein lifted the veil. The ideas he put forward grew out of his formulation of the special theory of relativity a decade earlier. That theory is based on the postulate that no observations made inside an enclosed chamber can answer the question of whether the chamber is at rest or moving along a straight line at constant speed. Thus a person in the situation of the author as he writes these lines—in an inside cabin of the S.S. *Queen Elizabeth* sailing on a smooth sea—can perform no experiment, mechanical, optical or any other kind, that will tell him whether the ship is really moving or still in port. But let a storm come up and the situation changes painfully; the deviation from uniform motion is all too apparent.

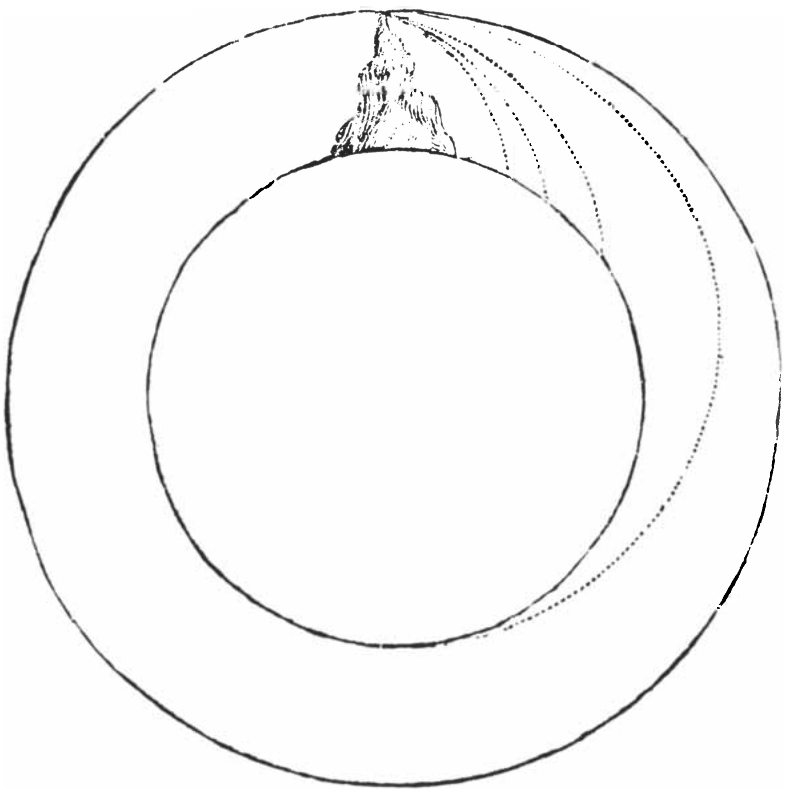
In order to deal with the problem of nonuniform motion Einstein imagined a laboratory in a spaceship located far from any large gravitating masses. If the vehicle is at rest, or in uniform motion with respect to distant stars, the observers inside, and all their instruments that are not secured to the walls, will float freely. There will be no up and no down. As soon as the rocket motors are started and the ship accelerates, however, instruments and people will be pressed to the wall opposite the direction of motion. This wall will become the floor, the opposite wall will become the ceiling and the people will be able to stand up and move about much as they do on the ground. In fact, if the acceleration is equal to the acceleration of gravity on the surface of the earth, the passengers may well believe that their ship is still standing on its launching pad.

Suppose one of the passengers simultaneously releases two spheres, one of iron and one of wood, which he has been holding next to each other in his hands. What "actually" happens can be described as follows: While the spheres were held they were undergoing accelerated motion, along with the observer and the whole ship. When they are released, they are no longer driven by the rocket engines. Now they will move side by side, each with a velocity equal to that of the spaceship at the moment of release. The ship itself, however, will continuously gain speed and the "floor" of the ship will quickly overtake the two spheres and hit them simultaneously.

To the observer inside the ship the experiment will look different. He will see the balls drop and hit the "floor" at the same time. Recalling Galileo's demonstration from the leaning tower of Pisa, he will be persuaded that an ordinary gravitational field exists in his space laboratory.

Both descriptions of the observed event are correct; the equivalence of the two points of view is the foundation of Einstein's relativistic theory of gravity. This so-called principle of equivalence between observations carried out in an accelerated chamber and in a "real" gravitational field would be trivial, however, if it applied only to mechanical phenomena. Einstein's deep insight was that the principle is quite general and holds also for optical and other electromagnetic phenomena.

Imagine a beam of light propagating across the space laboratory in a "horizontal" direction. Its path can be traced by means of a series of vertical fluorescent glass plates spaced at equal distances [*see illustration on page 98*]. Again what actually happens is that the beam travels in a straight line at constant speed, while the glass plates move across its path at an ever increasing speed. The beam takes the same time to travel from each plate to the next, but the plates move farther during each successive interval. Hence the pattern of fluorescent spots shows the floor approaching the light beam at an increasing rate. If the observer inside the chamber draws a line through the spots, it will look to him like



ARTIFICIAL SATELLITE was envisaged as a thought experiment by Isaac Newton in his *Principia*, from which this diagram is reproduced. Bullet fired horizontally from a mountaintop falls farther from base as its muzzle velocity is increased. At sufficiently high speed it circles the earth, suggesting that the moon is also falling in the earth's gravitational field.

a parabola bending toward the floor. Since he considers acceleration phenomena as being caused by gravity, he will say that a light ray is bent when propagating through a gravitational field.

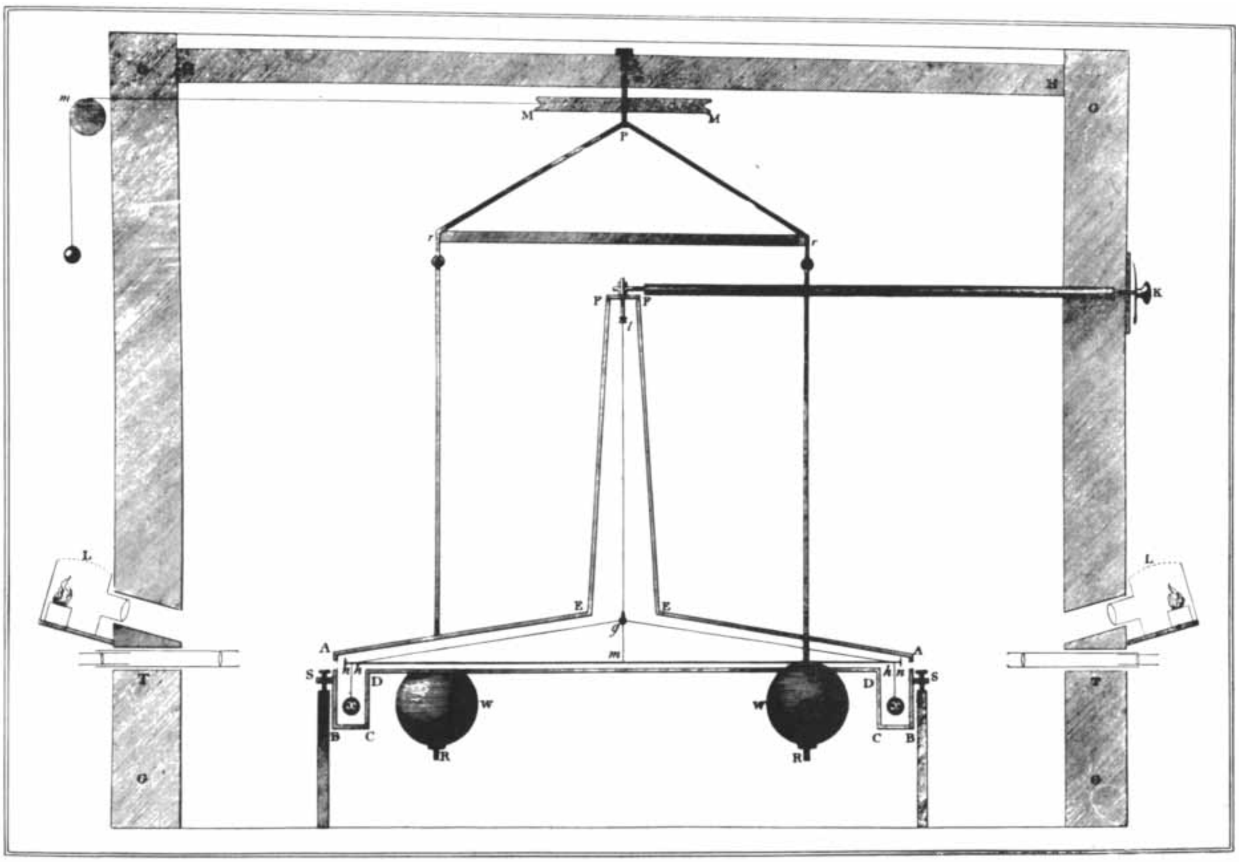
Thus, concluded Einstein, if the principle of equivalence holds in all of physics, light rays from distant stars that pass close to the sun on their way to the earth should bend toward the sun. This prediction was brilliantly confirmed in 1919 by a party of British astronomers observing a total solar eclipse in Africa. With the obscuring sunlight extinguished by the moon, stars near the edge of the solar disk were seen to be displaced about 1.75 seconds of arc away from the sun.

Relativistic Merry-Go-Round

Let us next consider another type of accelerated motion—uniform rotation. (A body moving at constant speed on a circular path is accelerated because of its continuous change of direction.) Imagine a merry-go-round with a curtain around it so that people inside cannot tell by looking at the surroundings that it is rotating. If the merry-go-round is turning, the observers will be aware of centrifugal force, which pushes them out toward the rim. A ball placed on the platform will roll away from the center. The centrifugal force acting on any object on the platform will be proportional to the inertial mass of the object, so that here again the effect of accelerated motion can be considered as equivalent to that of a gravitational field. It is a peculiar field, to be sure; it is quite different from the field on the surface of the earth or of any other spherical body. The force is directed away from the center of the system, not toward it; and instead of decreasing as the square of the distance from the center, it increases proportionately to that distance. Moreover, the field has cylindrical symmetry around a central axis rather than spherical symmetry around a central point. Nevertheless, the equivalence principle holds, and the field can be interpreted as being caused by gravitating mass distributed at large distances all around the symmetry axis.

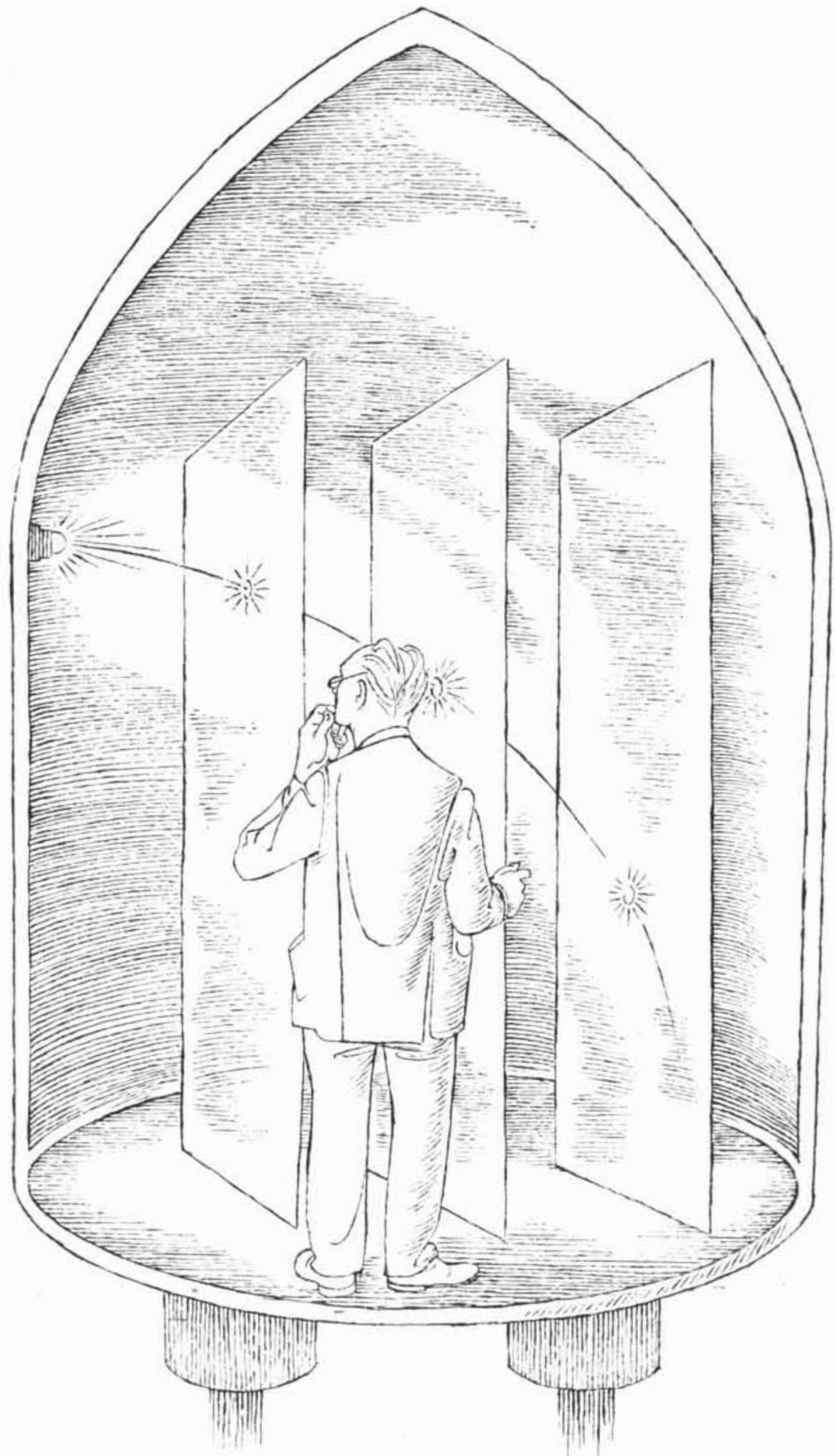
How will light propagate through this field? Suppose a light source that sends out rays in all directions is located at a point, *A*, on the periphery of the rotating disk, and is observed at a second point, *B*, also on the periphery. According to the basic law of optics, light always propagates along the shortest path. But what is the shortest path between *A* and *B*? To measure the length of various lines connecting the points *A* and *B* the observer uses the old-fashioned but always safe method of counting the number of yardsticks that can be placed end to end along the line [*see illustration on page 99*].

As we watch the experiment from outside, we recall the special theory of relativity, which tells us that moving yardsticks shrink in the direction of their motion. Therefore we see that if the observer measures along the "true" straight



TORSION BALANCE was used by the British physicist Henry Cavendish to measure gravitational attraction between small masses. In this diagram, reproduced from his paper in the *Philosophical Transactions of the Royal Society*, two-inch lead spheres (*x*) are attached to beam suspended by torsion wire (*lg*). Twelve-inch spheres (*W*) are placed so as to twist the beam first in one direction and then in the other. Turning is observed through system of lenses at each side. Total rotation is measure of attractive force.

line from A to B, his sticks will contract and he will need more of them to measure that line than if the platform were not moving. Now an interesting point arises. The closer a yardstick is to the center of the merry-go-round, the less its linear velocity and therefore the smaller its contraction. By bending the line of yardsticks toward the center the observer decreases the number he needs to go from A to B. Although the "actual" distance is somewhat longer, the increase is more than compensated for by the smaller shrinkage of each yardstick. A light ray following this shortest path, heading inward at the start of its journey and then bending outward, can be considered to be deflected by the apparent gravitational field, which is directed radially outward.



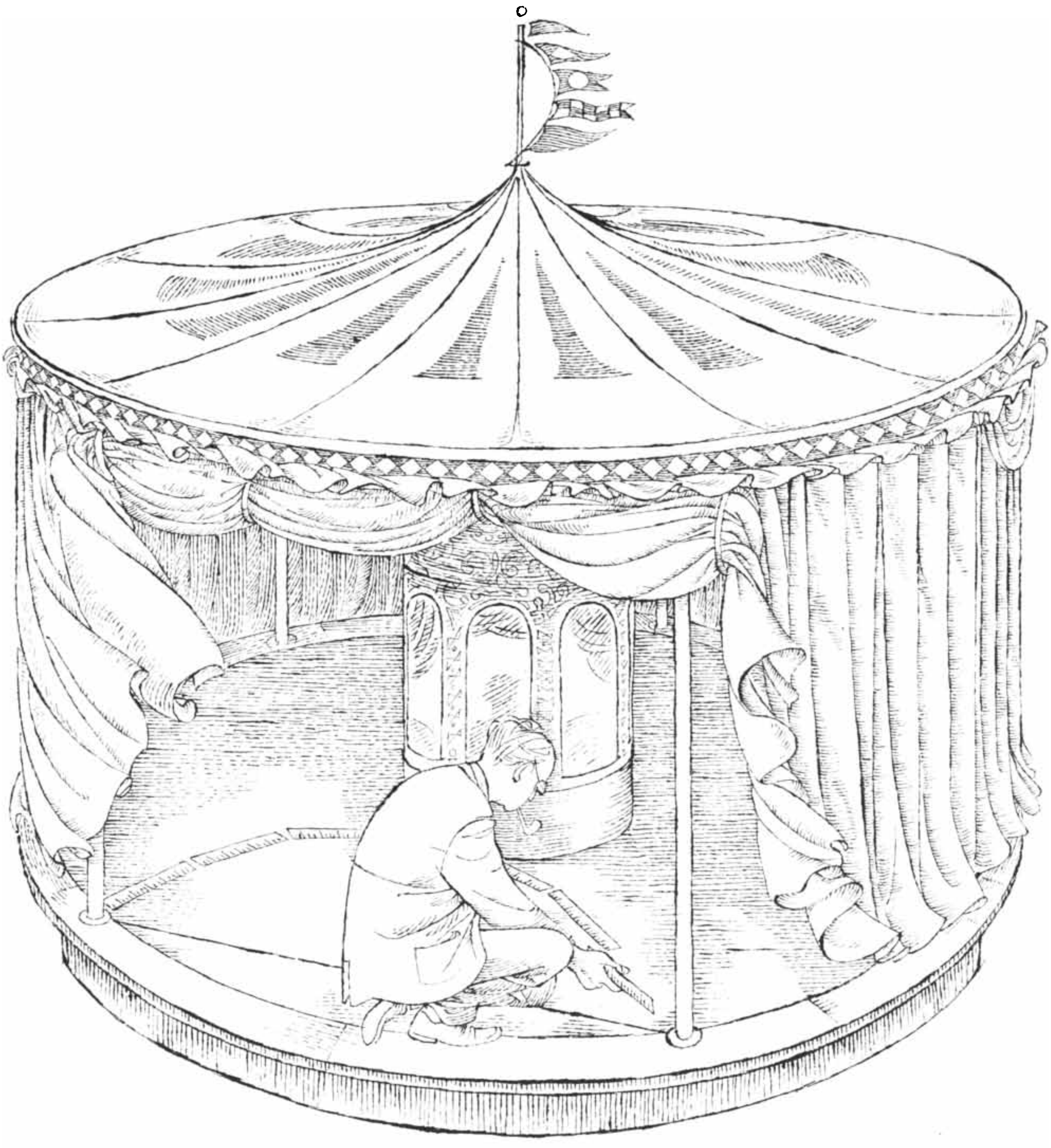
CURVATURE OF LIGHT is detected by observer in accelerating rocket. To an observer outside, the light beam travels along a straight, horizontal path and crosses each successive plate of glass at a point nearer the floor because of the upward acceleration of the plates.

Before leaving the merry-go-round let us consider one more experiment. A pair of identical clocks are placed on the platform, one near the center and the other at the edge. As in the case of the yardsticks, the outer clock is moving faster than the inner one, and again special relativity predicts a difference in their behavior. In addition to causing yardsticks to contract, motion makes clocks run slow. Therefore the outer clock will lose time with respect to the inner one. Now the observer who interprets the acceleration effects in terms of a gravitational field will say that the clock placed in the higher gravitational potential (that is, in the direction in which gravitational force acts) runs slower.

Although we cannot go into details here, Einstein's argument shows that the same effect is expected in a normal gravitational field such as that on the earth. Here the field is directed downward, so that a clock at sea level runs slower than one on top of a mountain. The slowing down applies equally to all other physical, chemical and biological phenomena, and a typist working on the first floor of the Empire State Building will age slower than her twin sister working on the top floor. Stronger fields produce greater retardation. A clock on the surface of the sun would run .0001 per cent slower than a terrestrial clock.

Obviously we cannot put a clock on the sun, but we can watch the rate of atomic vibrations that produce the various lines in the solar spectrum. If these natural clocks are slowed down, the light they emit should be shifted toward the low-frequency, or red, end of the spectrum. This "gravitational red shift" was predicted by Einstein. Such a shift is indeed found in the lines of the solar spectrum, but it is so small as to be almost at the limit of observational precision. Spectra of the much denser white-dwarf stars, where the red shift is expected to be 40 times larger than on the sun, agree quite well with the theory.

Astronomical evidence is not so satisfying as experiments that can be performed in a terrestrial laboratory. Until a couple of years ago, however, there seemed to be no hope of measuring the minute difference predicted between clocks at different heights in the earth's gravitational field. Then R. L. Mössbauer, working at the University of



CENTRIFUGAL FIELD OF FORCE, such as the one on a rotating merry-go-round, can also be interpreted in terms of gravitating mass. As explained in the text, an observer on the platform would find that a curved line is the shortest distance between points on the periphery. Since light rays travel along the shortest path, or geodesic, they are expected to curve in this type of field.

Munich, found a way to produce nuclear gamma rays of very pure frequency and to measure extremely small changes in their frequency [see "The Mössbauer Effect," by Sergio De Benedetti; SCIENTIFIC AMERICAN, April, 1960]. Seizing on the new opportunity, several workers proceeded to show that two nuclear "clocks" separated by only a few tens of feet in the earth's field run at measurably different rates, and the difference is exactly that predicted by Einstein, within the limits of experimental error. Still another verification, if any more are needed, will almost certainly be obtained when an atomic clock in an artificial satellite is compared with one on the ground.

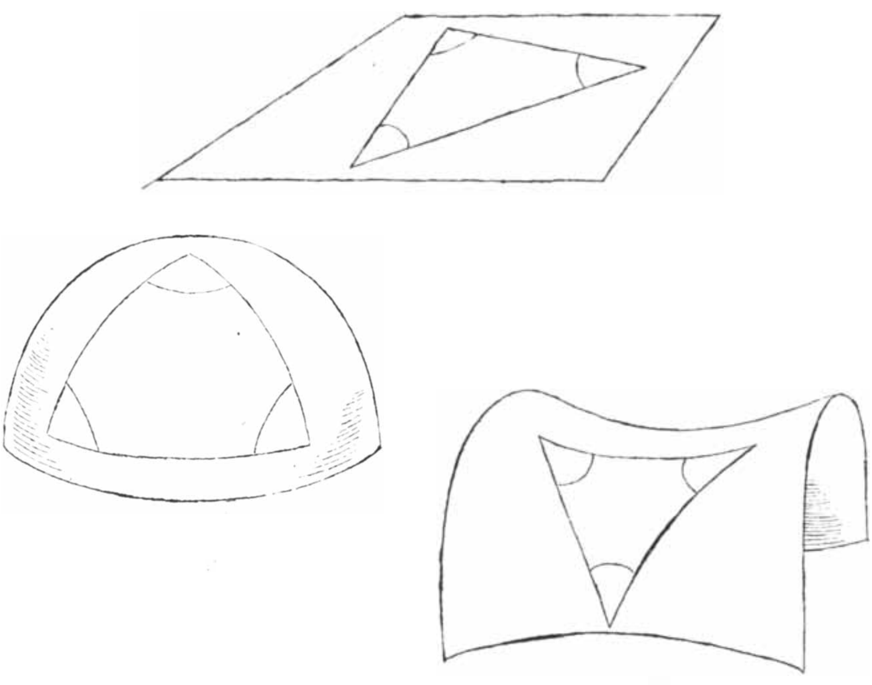
So we see that in a gravitational field clocks run slow, light rays bend in the direction of the field and a straight line is not the shortest distance between two points. Yet how can one define "straight line" other than as the path of light in a vacuum, or the shortest distance between two points? Einstein's idea was to retain this definition. Instead of saying that light rays and shortest distances are curved, he suggested that space itself (more accurately space-time) is curved. It is difficult to conceive of a curved three-dimensional space, let alone a curved four-dimensional space-time, but some idea of what it means can be gained from an analogy with two-dimensional surfaces. The Euclidean geometry we all learned at school pertains to figures that can be drawn on a plane. If geometrical figures are drawn on curved surfaces, for example a sphere or a surface shaped like a saddle [*see illustration on this page*], many of the Euclidean theorems do not hold.

In particular, the sum of the angles of a plane triangle is equal to 180 degrees. In a spherical triangle the sum of the angles is greater than 180 degrees, and in a triangle drawn on a saddle surface it is less. True, the lines forming triangles on spherical and saddle surfaces are not straight from the three-dimensional point of view, but they are the "straightest" (*i.e.*, shortest) lines between the points if one is confined to the surface in question. Mathematicians call such lines geodesic lines, or simply geodesics.

In three-dimensional space a geodesic line is by definition the path along which a light ray would propagate. Consider a triangle formed by three such geodesics. If the sum of the angles is equal to 180 degrees, the space is said to be flat. If the sum is more than 180 degrees, we say that the space is spherelike, or positively curved; if it is less than 180 degrees, we say that it is saddle-like, or negatively curved. Because of the bending of light toward the sun, astronomers located on earth, Mars and Venus would measure more than 180 degrees in the angles of the triangle formed by light rays traveling between the planets [*see illustration on page 102*]. Hence we can say that the space around the sun is positively curved. On the other hand, in the merry-go-round type of gravitational field, the sum of angles of a triangle is less than 180 degrees, and this space is curved in the negative sense.

The foregoing arguments represent the foundation of Einstein's theory of gravity. In the Newtonian view the sun produces in the space around it a field of force that makes the planets move along curved trajectories instead of straight lines. In Einstein's picture space itself becomes curved and the planets move along the straightest (geodesic) lines in that curved space. Here we are speaking of geodesics in the four-dimensional space-time continuum [*see illustration on page 104*]. It would, of course, be wrong to say that the orbits themselves are geodesic lines in three-dimensional space.

Einstein's interpretation of gravity as the curvature of space-time does not lead to exactly the same results as those of the classical Newtonian theory. We have already mentioned the bending of light. The relativistic theory also gives slightly different answers for the motions of material bodies. For example, it explained the difference between the calculated and observed rates of precession of the major axis of Mercury's orbit, which represented a long-standing mystery of classical celestial mechanics.



SPACE CURVATURE is illustrated in two dimensions. In flat space (*top*) the angles of a triangle total 180 degrees; in spherelike or positively curved space (*middle*), more than 180 degrees; in saddle-like or negatively curved space (*bottom*), less than 180 degrees.

Gravity Waves

Newton's law of gravitational interaction between masses is quite similar to the law of electrostatic interaction between charges, and Einstein's theory of the gravitational field has many common elements with James Clerk Maxwell's theory of the electromagnetic field. So it is natural to expect that an oscillating mass should give rise to gravitational waves just as an oscillating electric charge produces electromagnetic waves. In a famous article published in 1918 Einstein indeed obtained solutions of his basic equation of general relativity that represent such gravitational disturbances propagating through space with the velocity of light. If they exist, gravitational waves must carry energy; but their intensity, or the amount of energy they transport, is extremely small. For example, the earth, in its orbital motion around the sun, should emit about .001 watt, which would result in its falling a millionth of a centimeter toward the sun in a billion years!

No one has yet thought of a way to detect waves so weak. In fact, some theorists, among them Sir Arthur Eddington, have suggested that gravitational waves do not represent any physical reality at all but are simply a mathematical fiction that can be eliminated from the equation by a suitable choice of space-time co-ordinates. More thorough analysis indicates, however, that this is not the case and that gravitational waves, weak though they may be, are real.

Are gravitational waves divided into discrete energy packets, or quanta, as electromagnetic waves are? This question, which is as old as the quantum theory, was finally answered two years ago by the British physicist P. A. M. Dirac. He succeeded in quantizing the gravitational-field equation and showed that the energy of gravity quanta, or "gravitons," is equal to Planck's constant, h, times their frequency—the same expression that gives the energy of light quanta or photons. The spin of the graviton, however, is twice the spin of the photon.

Because of their weakness gravitational waves are of no importance in celestial mechanics. But might not gravitons play some role in the physics of elementary particles? These ultimate bits of matter interact in a variety of ways, by means of the emission or absorption of appropriate "field quanta." Thus electromag-

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A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

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Now we learn that the first of the astronauts will have a window in his capsule, that he will peer *down* at the spinning earth and *out* at the wheeling stars.

We are producing these unique, spacegoing viewports for McDonnell Aircraft Corporation, prime contractor for the National Aeronautics and Space Administration's Project Mercury capsule.

The window is an excellent piece of engineering. Not just because we made it, but because it *has* to be.

It will take the slams and whams, the blistering heat, and the embrittling cold of blast-off, orbitation, re-entry, and a soak in the briny. All during this it must remain transparent, intact, and sealed tight.

There are four panes to the window. The outer two are VYCOR® 96% silica glass. The inner two are aluminosilicate glass specially tempered to phenomenal strength.

Each pane is ground and polished to the precision finish of a telescope mirror. The outermost panel curves to the contour of the capsule, so it trapezoids from an 11″ base to a 7½″ top along a 21″ height.

The glasses present a delicate balance of optical qualities, thermal shock resistance, and low weight. The last is vital when you consider that it takes about 100 gm of fuel to orbit 1 gm of payload.

So, remember, when you see the first astronaut smiling quietly, confidently from his capsule, you are looking at him through Corning glass.

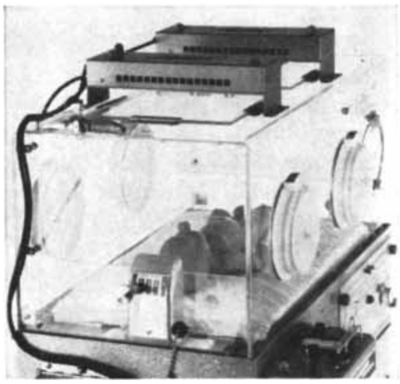
HOW ABOUT A DEGREE IN MEDICAL ENGINEERING?

The mechanics of modern medicine are fast maturing to the point where some engineers are specializing in the building of machines like this Infant Servo-Controller for the Isolette, manufactured by Air-Shields, Inc., Hatboro, Pennsylvania.

This particular machine is used with prematurely born infants who must keep their body temperature at a constant level, but lack a well-developed thermal regulatory device.

You attach a thermistor to the babe's abdomen and let him work as his own thermostat. He automatically requests heat from infrared lamps whenever his skin temperature drops below 97°F. When things are just right again, he switches off the lamps and takes a rest, with the odds for survival more in his favor.

If you've ever tried to unbulb an infrared lamp, you know that it gives off *direct* heat as well as IR energy.

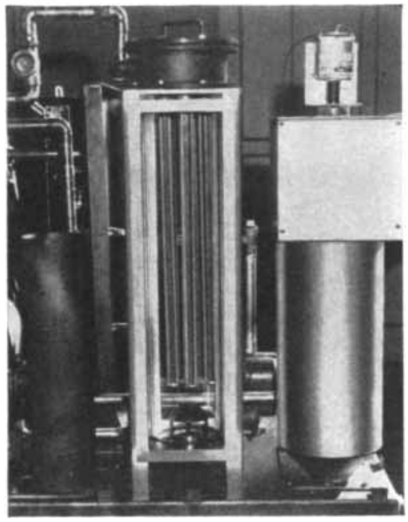


That's why there are two PYREX No. 7740 glass plates sitting on top of the plastic chamber in the picture. You can see them, if you look closely. The PYREX plates are heat resistant and will also dissipate the *direct* thermal output of the lamps. So, the plastic forgets the lamps are there.

As far as the IR energy is concerned, the PYREX plates don't exist either, so practically all the IR gets through to the baby.

The over-all relationship between IR and glass is an odd one. We can give you glass which transmits as much as 92% of the IR or a glass which transmits as little as 8% of the IR.

Happily for our product specialists, there is demand for both situations. We've prepared some bulletins on many of these IR characteristics, a copy of which you may have by sending the coupon.



SOMETIMES GLASS IS SO OBVIOUS

Leafing our way through the 4th Annual Shirt Issue of "Cleaning Laundry World" (April 1960), we took note of an advertisement which concerned a machine which displayed a feature which we consider the soul of genius.

The machine is a dry cleaner manufactured by Detrex Chemical Industries, Inc. The feature is a glass-enclosed filter which keeps the dry-cleaning solvent cycling unpolluted. The soul of genius, to our minds, consists of intelligent manipulation of the obvious . . . in this case, an application of the first known and longest respected of the myriad properties of glass . . . to wit, its *transparency*.

When you locate such a place, it doesn't necessarily take a lot of redesigning of custom fabrication to put glass to work, either. We checked and found that Detrex, for example, simply orders standard 6″ O.D. PYREX brand Heavy Duty Tube for its filter wall.

The result is that the operator of the Detrex Cleaner can watch the filter at work. He can spot trouble while it's still potential, determine its cause exactly should it occur . . . all without any dismantling or shutdown.

Is there anything you're working on that you wish you could watch working? If there is, and you want to put glass to work, you can start by sending the coupon for a copy of Bulletin IZ-1, "Designing with Glass for Industrial, Commercial, and Consumer Applications."

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Street..

City........................ Zone.......... State..............

netic interactions (for example the attraction of oppositely charged bodies) involve the emission or absorption of photons; presumably gravitational interactions are similarly related to gravitons. In the past few years it has become clear that the interactions of matter fall into distinct classes: (1) strong interactions, which include electromagnetic forces; (2) weak interactions such as the "beta decay" of a radioactive nucleus, in which an electron and a neutrino are emitted; (3) gravitational interactions, which are vastly weaker than the ones called "weak."

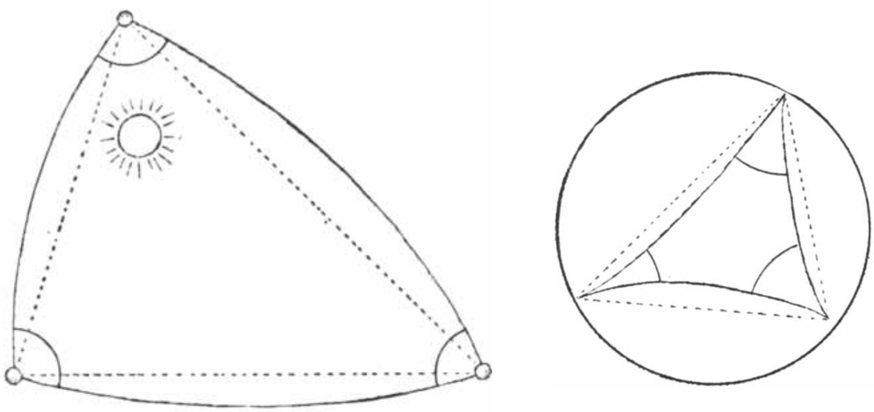
The strength of an interaction is related to the rate, or probability, of the emission or absorption of its quantum. For example, a nucleus takes about 10^{-12} second (a millionth of a billionth of a second) to emit a photon. In comparison the beta decay of a neutron takes 12 minutes—about 10^{14} times longer. It can be calculated that the time necessary for the emission of a graviton by a nucleus is 10^{60} seconds, or 10^{53} years! This is slower than the weak interaction by a factor of 10^{58}.

Now, neutrinos are themselves particles with an extremely low probability of absorption, that is, interaction, with other types of matter [see "The Neutrino," by Philip Morrison; SCIENTIFIC AMERICAN, January, 1956]. They have no charge and no mass. As long ago as 1933 Niels Bohr inquired: "What is the difference between [neutrinos] and the quanta of gravitational waves?" In the so-called weak interactions neutrinos are emitted together with other particles. What about processes involving only neutrinos—say, the emission of a neutrino-antineutrino pair by an excited nucleus? No one has detected such events, but they may occur, perhaps on the same time scale as the gravitational interaction. A pair of neutrinos would furnish a spin of two, the value calculated for the graviton by Dirac. All this is, of course, the sheerest speculation, but a connection between neutrinos and gravity is an exciting theoretical possibility.

Gravity and Electromagnetism

In the laboratory diary of Michael Faraday appears the following entry in 1849: "Gravity. Surely this force must be capable of an experimental relation to electricity, magnetism and other forces, so as to build it up with them in reciprocal action and equivalent effect. Consider for a moment how to set about touching this matter by facts and trial." The numerous experiments he undertook to discover such a relation were fruitless, and he concludes that part of his diary with the words: "Here end my trials for the present. The results are negative. They do not shake my strong feeling of the existence of a relation between gravity and electricity, though they give no proof that such a relation exists." Subsequent experimental efforts have not been any more successful.

A theoretical attack aimed at bringing the electromagnetic field into line with the gravitational field was undertaken by Einstein. Having reduced gravity to the geometrical properties of a space-time continuum, he became convinced that the electromagnetic field must also have some purely geometrical interpretation. However, the "unified field" theory, which grew out of this conviction, had hard going, and Einstein died without producing anything so simple, elegant and convincing as his earlier work. Today fewer and fewer physicists are working at unified-field theory; most are persuaded that the effort to geometrize the electromagnetic field is futile. It seems, at least to the author, that the true relation between gravitational and

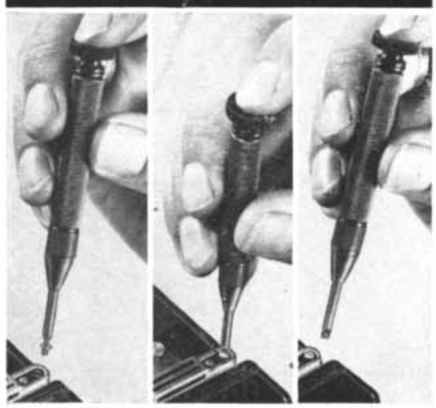


SIGN OF SPACE CURVATURE depends on type of gravitational field. Observers on three planets (*left*) would detect positive curvature because of deflection of light rays by the sun. Observers on periphery of merry-go-round (*right*) would detect negative curvature.

electromagnetic forces is to be found only through an understanding of the nature of elementary particles—an understanding of why there exist particles with just certain inertial masses and not others—and of the relation between the masses and the electric and magnetic properties of the particles.

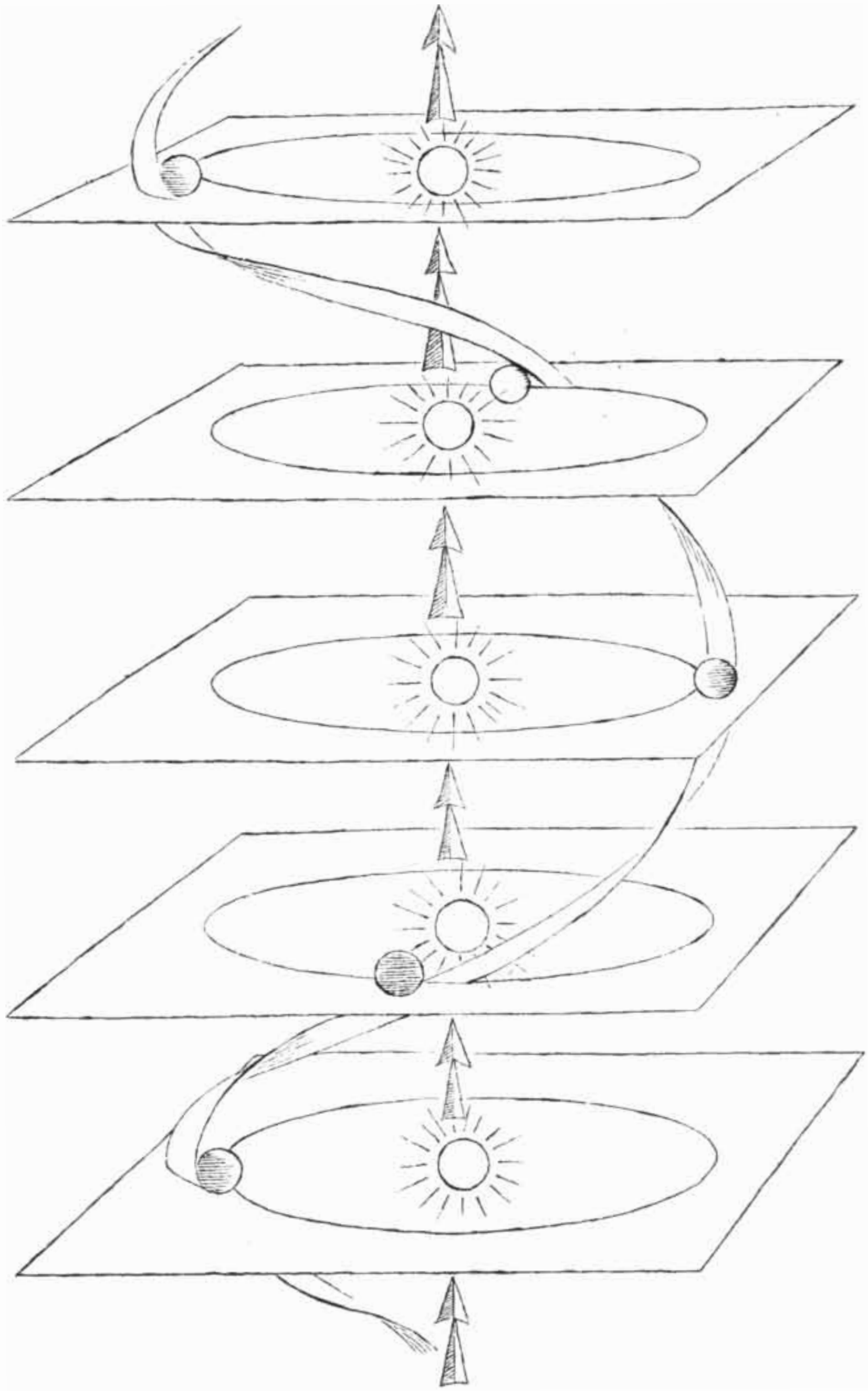
As a sample of one of the basic questions in this field, consider again the relative strength of gravitational and electromagnetic interactions. Instead of comparing the times required for emission of quanta, let us compare the actual strength of the electrostatic and gravitational forces between a pair of middleweight particles, say pi mesons. Computation shows that the ratio of electrostatic to gravitational force equals the square of the charge on an electron divided by the square of the mass of the particles times the gravitational constant: $e^2 / M^2 G$. For two pi mesons the value is 10^{40}. Any theory that claims to describe the relation between electromagnetism and gravity must explain this ratio. It should be pointed out that the ratio is a pure number, one that remains unchanged no matter what system of units is used for measuring the various physical quantities. Such dimensionless constants, which can be derived in a purely mathematical way, often turn up in theoretical formulas, but they are usually small numbers such as 2π, 5/3 and the like.

How can one derive mathematically a constant as large as 10^{40}? Some 20 years ago Dirac made an interesting proposal. He suggested that the figure 10^{40} is in fact not a constant, but a variable that changes with time and is connected with the age of the universe. According to the evolutionary cosmology, which holds that the universe originated with a "big bang," the universe is now about 5×10^9 years, or 10^{17} seconds, old. Of course, a year or a second is an arbitrary unit, and we would prefer an elementary time interval that can be derived from the basic properties of matter and light. A reasonable one is the length of time required by light to travel a distance equal to the radius of an elementary particle. Since all the particles have radii of about 3×10^{-13} centimeter, and since the velocity of light is 3×10^{10} centimeters per second, this elementary time unit is 3×10^{-13} divided by 3×10^{10}, or 10^{-23} second. To express the age of the universe in this elementary time unit we divide its age in seconds, 10^{17}, by 10^{-23} and obtain the number 10^{40}! Thus, said Dirac, the large ratio of electric to gravitational forces is characteristic of the present age of the universe. When



the universe was half as old as it is now, this ratio was also half of its present value. Since there are good reasons to assume that the elementary electric charge does not change with time, Dirac concluded that the gravitational constant must be decreasing, and that this decrease may be associated with the expansion of the universe and the steady rarefaction of the material that fills it.

If the gravitational constant really has been decreasing, or in other words if the force of gravity has been growing weaker, then our solar system must have been expanding along with the universe. In earlier times the earth would have been nearer the sun and therefore hotter than it is now. When Dirac put forward the idea, the solar system was thought to be about three billion years old. Edward Teller, now at the University of California, pointed out that on such a time scale the earth would have been 50 degrees hotter than the boiling point of water during the Cambrian era, when well-developed marine life existed. Now it seems that the solar system may be five billion or more years old, in which case the Cambrian oceans, though hot, would not have been vaporized. So the objection loses its force, provided that Cambrian plants and animals could live in very hot water.



FOUR-DIMENSIONAL PATH (*spiral*) of a planet in space-time is a geodesic. It is rendered schematically by showing space in two dimensions and measuring time vertically.

Antigravity

In one of his stories H. G. Wells describes a British inventor, Mr. Cavor, who found a material, called cavorite, that was impenetrable to the force of gravity. Just as sheet copper can shield an object against electric forces and sheet iron can shield against magnetism, a sheet of cavorite placed under a material body would shield it from the gravitational pull of the earth. Mr. Cavor built a large gondola surrounded by cavorite shutters. One night when the moon was high, he got into the ship, closed the shutters facing the ground and opened those facing the moon. Cut off from terrestrial gravity and subjected only to the attraction of the moon, the gondola soared into space and eventually deposited Mr. Cavor on the surface of our satellite.

Why is such an invention impossible? Or is it? There is a profound similarity between Newton's law of universal gravity and the laws that govern the interactions of electric charges and magnetic poles. If one can shield electric and magnetic forces, why not gravity? To answer this question we must consider the mechanism of electric and magnetic shielding. Each atom or molecule in any piece of matter is a system of positive and negative electric charges; in conducting metals there are numbers of negative electrons that are free to move through the crystal lattice of positively charged ions. When a metal is placed in an electric field, the free electrons move to one side of the material, giving it a negative charge and leaving the opposite side positive. This polarization produces a new electric field, which is directed opposite to the original field. Thus the two can cancel each other. Similarly, magnetic shielding depends on the fact that the atoms of magnetic materials are tiny magnets, with north and south poles that line up so as to produce a field that opposes an external magnetic field. Here also the shielding effect arises from polarization of atomic particles.

Gravitational polarization, which

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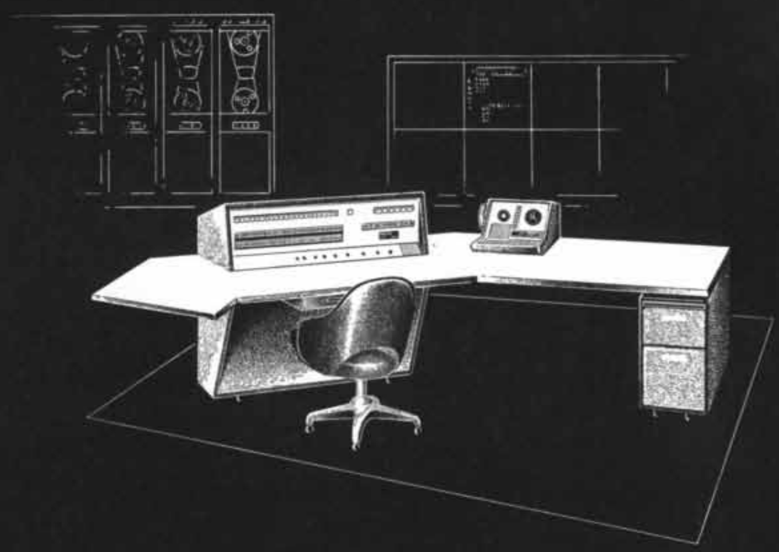

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could make possible shielding against the force of gravity, requires that matter be constituted of two kinds of particles: some with positive gravitational mass, which are attracted by the earth, and some with negative gravitational mass, which are repelled. Positive and negative electric charges and north and south magnetic poles are equally abundant in nature, but particles with negative gravitational mass are as yet unknown, at least within the structure of ordinary atoms and molecules. Therefore ordinary matter cannot be gravitationally polarized and cannot act as a gravity shield.

There is, however, another kind of matter—antimatter—that in many ways is the reverse of ordinary matter, including its electric and magnetic properties. Perhaps antiparticles also have negative mass. At first sight this might seem an easy point to decide. One has only to watch a horizontal beam of antineutrons, say, emerging from an accelerator and see whether the beam bends down or up in the gravitational field of the earth. In practice the experiment cannot be done. The particles produced by accelerators move almost at the speed of light; in a kilometer of horizontal travel gravity would bend them, whether up or down, only about 10^{-12} centimeter, the diameter of an atomic nucleus. Nor can they be slowed down by letting them collide with the nuclei of a "moderator" material, as neutrons are slowed in atomic piles. If antiparticles collide with their ordinary counterparts, both disappear in material annihilation. Thus from the experimental point of view the question as to the sign of the gravitational mass of antiparticles remains painfully open.

From the theoretical point of view it is open too, since we do not have a theory that relates gravitational and electromagnetic interactions. If a future experiment should demonstrate that antiparticles do have a negative gravitational mass, it will deliver a mortal blow to the entire relativistic theory of gravity by disproving the principle of equivalence. An antiapple might fall up in a true gravitational field, but it could hardly do so in Einstein's accelerated spaceship. If it did, an outside observer would see it moving at twice the acceleration of the ship, with no force at all acting on it. The discovery of antigravity would therefore force upon us a choice between Newton's law of inertia and Einstein's equivalence principle. The author earnestly hopes that this will not come to pass.

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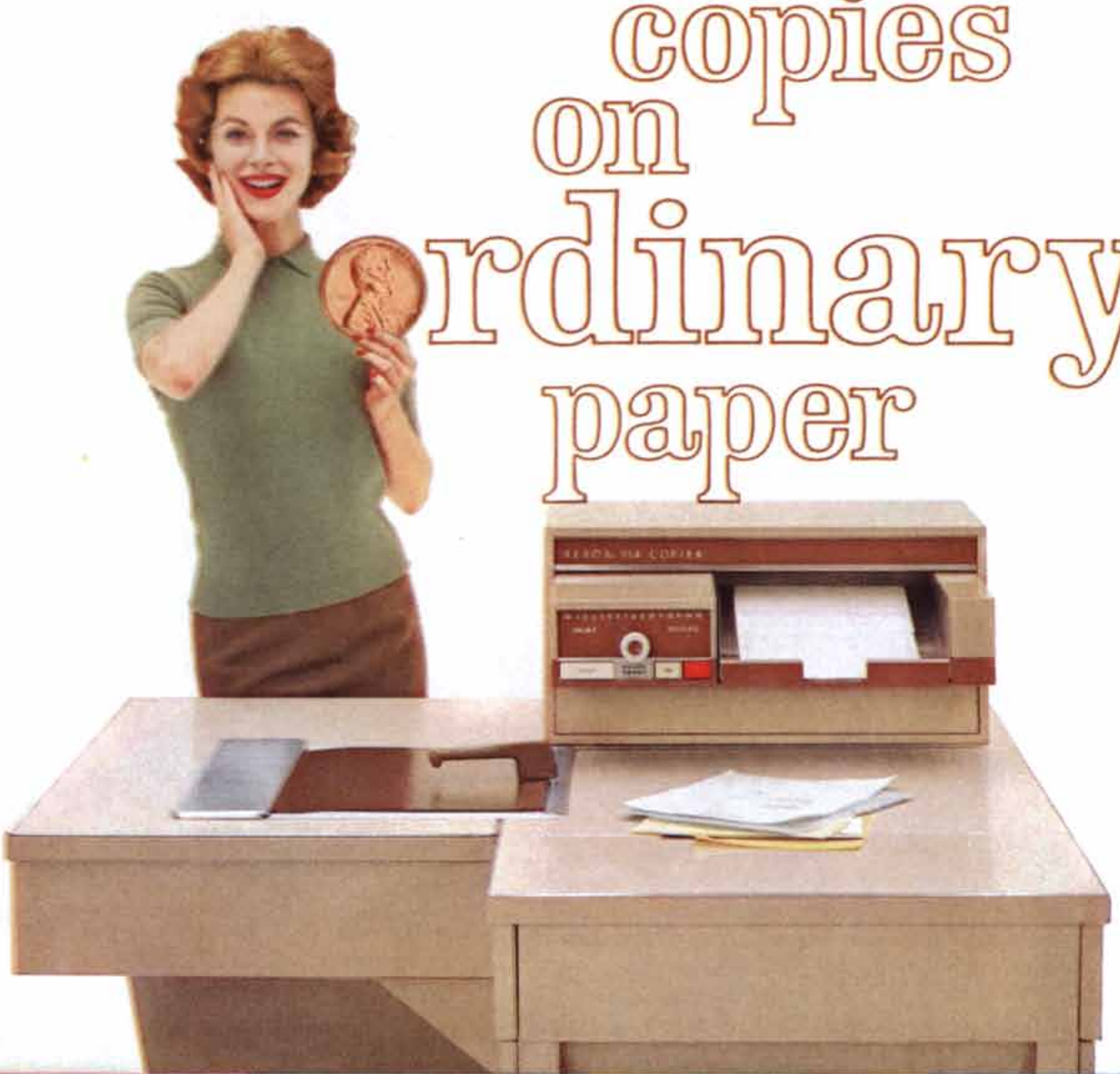

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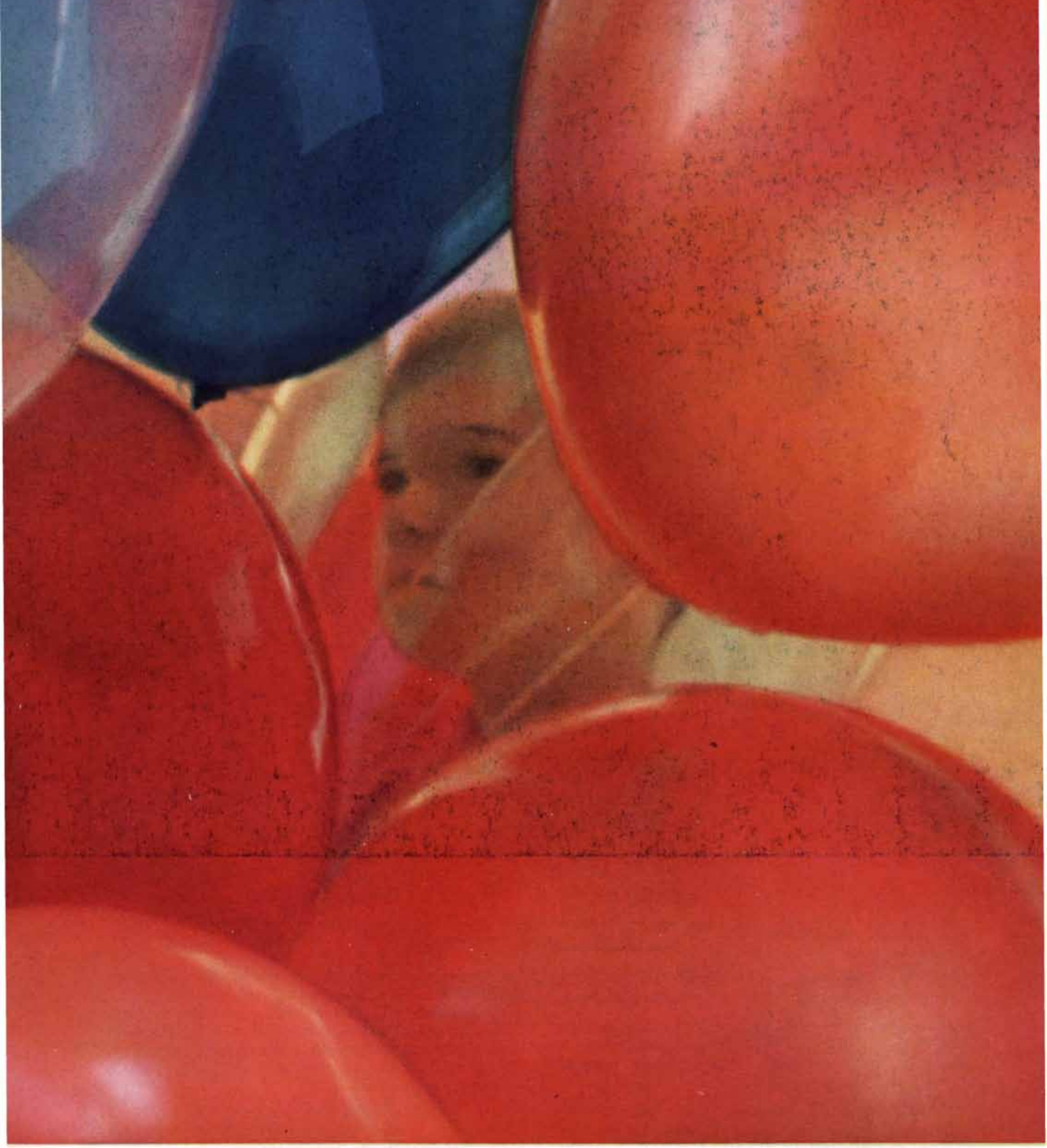

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How Themistocles Planned the Battle of Salamis

A newly discovered tablet is the great general's decree on the eve of the battle. It reveals that he called for an orderly evacuation of Athens and deliberately chose to meet the Persians in a strait

by Michael H. Jameson

Early on a September morning in the year 480 B.C. Xerxes, king of the Medes and Persians, ruler of an empire that stretched from India to the Aegean Sea, sent his fleet of 1,000 ships into the narrow strait between the island of Salamis and the coast of Attica. The great king himself sat watching from an eminence on the mainland near the city of Athens, which had been captured and sacked by his enormous army. There in the strait he could see 300 Greek ships waiting for the onslaught of his fleet. Ship after ship of the Persians rowed in, only to be rammed and boarded by the outnumbered Greeks. In the mile-wide waters of the strait only a few ships of the vast Persian fleet could engage the enemy at one time; as those in the van attempted to backwater under the Greek counterattack they became entangled with their own ships pressing in from the rear. The Greek victory at sea was decisive. Xerxes left for home

STRAIT OF SALAMIS is viewed from the island of Salamis. Across the strait is the Attic mainland. The Persian fleet of 1,000 ships entered the strait from the right and was met by 300 Greek ships. In the narrow waters of the strait the Persians were routed.

DECREE OF THEMISTOCLES is this scarred slab found in 1959 in Troizen, a village in the Peloponnesus across the Saronic Gulf from Athens. The slab is about two feet high, 15 inches wide and three inches thick. It is now in the National Museum in Athens.

almost at once, taking a large part of his army with him. The rest wintered in Greece, but the next year the Greeks had the confidence and strength to rout them on land as well. The Persian invasion of Greece was over.

The battle of Salamis is one of the turning points of history. It enabled the Greeks in the following century and a half of their independence to make their finest and most lasting contributions to Western culture—and most of these were made by the Athenians who had manned the majority of the Greek ships and fought in sight of their own ravaged homes and fields. The Athenian poet Aeschylus, who was himself at Salamis, has given us their rallying cry: "O sons of the Greeks, come, free your fatherland, free your children and your wives, the seats of your ancestral gods, the graves of your forefathers. Now the fight is for everything."

How did the Greeks manage to win? The events leading up to the Persian invasion and the facts of the victory are well known to history. But until 1960 the record provided no clear picture of how the Greeks prepared to face the Persian threat. It was known that Salamis was fought after the Greek land forces had failed to stop the enemy. The Athenians, it was thought, had evacuated their women and children at the last moment, abandoning their country to "the Barbarian," and had taken to their ships in the forlorn hope that they might stand off the Persians at sea. Except for memorial poems a few lines long and Aeschylus' patriotic drama *The Persians* there had been no historical sources for the war dating from less than 50 years after the events themselves.

About 30 years ago, however, a farmer of Troizen, a village in the Peloponnesus across the Saronic Gulf from Athens, unearthed a small marble slab [*see illustration on opposite page*]. One side was covered with small engraved letters, but they meant nothing to the farmer. For some years he used the stone as a doorstep. In the spring of 1959 an enterprising schoolteacher from the nearby town of Poros learned of the stone and persuaded the farmer to contribute it to a collection of inscriptions, coins and pottery from the ancient city of Troizen that he had on exhibition in a local coffeehouse. There it rested when, in the summer of that year, my wife and I visited the village in search of inscriptions and other evidence bearing on the history of the area.

The inscription was badly damaged on one side, but close examination established that the letters had been inscribed not earlier than the latter part of the fourth century B.C., or about 150 years after the Persian Wars. As usual, there were no spaces and no dividers between words, and no punctuation, except for an empty space, equivalent in length to two letters, occurring at the end of two sentences. But like many inscriptions of that period, this one was engraved on an exact grid that allowed the same amount of space for each letter. This fact had important consequences in the eventual reading of the text, because it meant that even where the stone was badly damaged the precise number of missing letters could be determined.

Something of the nature of the document was also apparent. It must have been a decree, a resolution passed by a public body. "The Council and the People" was quite clear at the end of a line near the beginning of the inscription, in a form that suggested the common formula: Resolved by the Council and the People. . . . A decree of even an insignificant independent state such as Troizen had been would still be valuable, and here were more than 40 lines of text.

But further examination showed it was not a decree of Troizen. After the reference to the council and the people came another formula: So-and-so, son

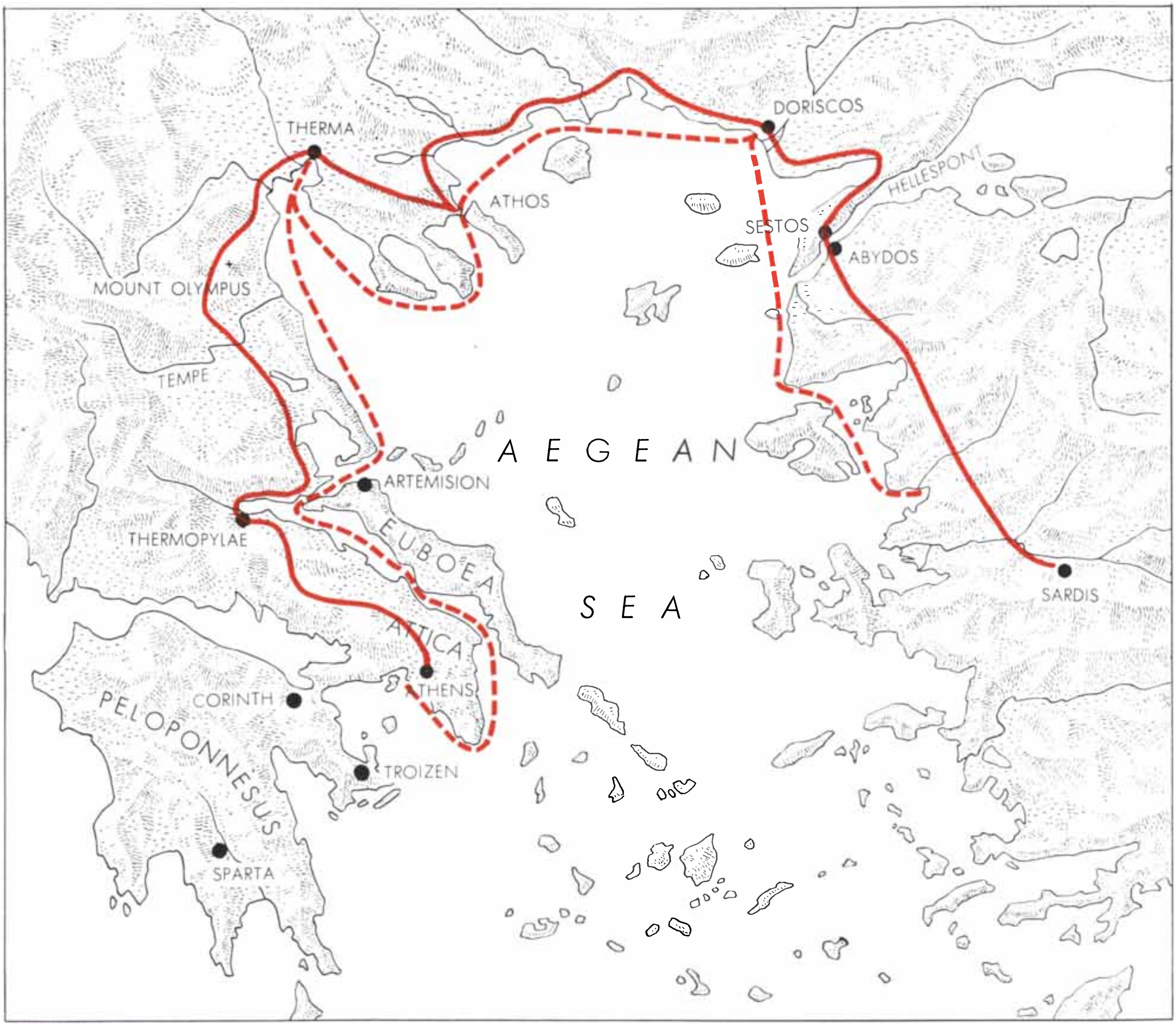
BUST OF THEMISTOCLES was found at Ostia, near Rome. This bust was copied from an original that was made about 470 B.C., only 10 years after the Greeks defeated the Persians.

of so-and-so, *Phrearrios*, made the motion. *Phrearrios* identified the originator of the decree as coming from a particular township of Athens, so the text was a decree of Athens and not of Troizen. This was confirmed by the spelling of such words as I could make out; it was perfectly normal fourth-century Athenian. What, I wondered, was the inscription doing here?

I could see references to "Salamis" and "the Barbarian," and I remembered that when the Athenians had evacuated their women and children in 480 B.C. they had sent them to Troizen and safety behind the narrow, defensible Isthmus of Corinth, which protected the Peloponnesian peninsula against invasion from the mainland. Perhaps, then, this was a fourth-century Athenian decree recalling the past kindness of the people of Troizen and set up in Troizen for that reason. In the latter part of the fourth century, when Greek independence was again under threat—this time from Philip and Alexander of Macedon—Troizen and Athens had renewed their ties. Even the name of the mover of the decree, when I made it out, seemed to be a link with the great days of the past. It proved to be Themistocles, the name not only of the Athenian general of the Persian Wars but also of one of his descendants in fourth-century Athens.

Not until I was back at the University of Pennsylvania did I have a chance to study the text with due care. It then became clear that although the inscription could not have been cut in the stone before the fourth century, the text itself belonged to the time of the Persian Wars.

I had a photograph, made just before sunset with the light at an oblique angle to the inscribed face and so putting most of the incisions in shadow; I had a "squeeze," an impression made by pounding wet filter paper onto the stone and removing it when dry; and I had a transcription of all the legible letters plus notes on more doubtful traces, the result of repeatedly working a wash of rubbed charcoal and water over the damaged surface. (The grains of charcoal would wash into the otherwise invisible grooves for a fraction of a second and permit a reading.) The readings from these combined sources were plotted on graph paper with spaces left



ROUTE OF THE PERSIAN ARMY (*solid colored line*) and that of the Persian navy (*broken line*) are traced in the map at left. The map at right shows the routes in the vicinity of Athens. Sardis was the capital of Xerxes, king of the Persians.

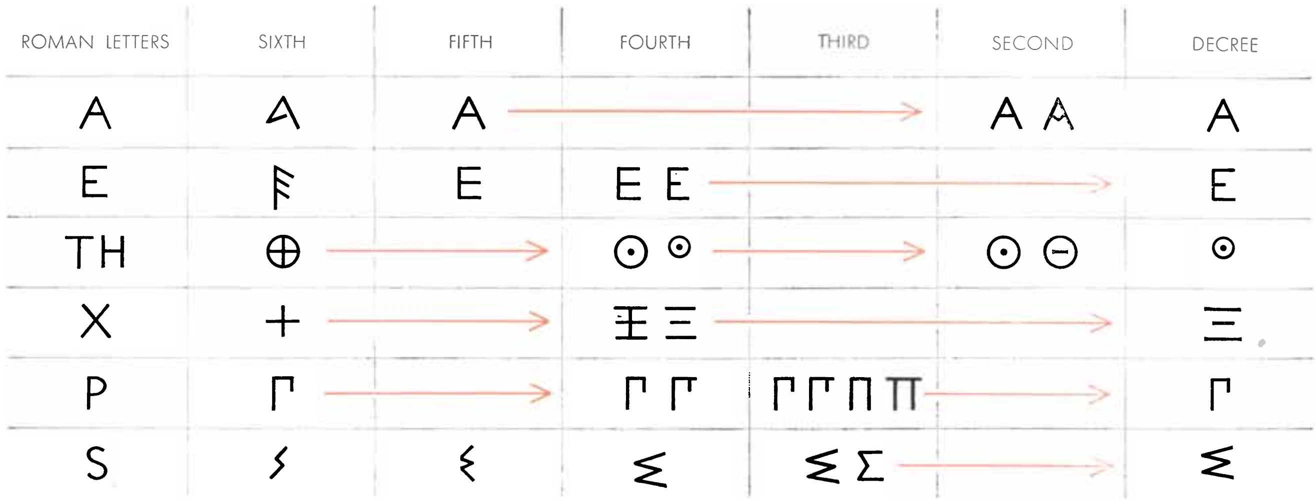
for the missing letters. To fill in these gaps was a matter of catching the sense of the legible portions and completing the sentences in correct Greek of exactly the right number of letters. Thus, although a third of more than 1,900 letters in the surviving portion of the text have had to be restored, the reading is really doubtful only for a gap of 21 letters.

As I began this task I decided to test a suspicion that had been forming in my mind. Plutarch's biography of Themistocles, written in the second century A.D., tells how in 480 B.C. Themistocles moved the decree for the evacuation of the women and children of Athens to Troizen. In fact, Plutarch even seems to quote from such a decree. I plotted his words on the graph paper at the beginning of the text of the supposed fourth-century decree. The first 10 words agreed exactly: "To entrust the city to Athena the Mistress of Athens." As the restoration proceeded it became clear that this was the very decree moved by the general Themistocles, which the Athenians had voted as Xerxes advanced upon them in 480 B.C. Here, in fact, was the first contemporary document of the Persian Wars—a large page from the war plan for one of the most critical battles in Western history. It proved to be full of surprises.

In a few weeks of intensive work, in co-operation with Benjamin D. Meritt and other specialists in Greek inscriptions at the Institute for Advanced Study in Princeton, N.J., the text was restored. The decree probably began with an invocation to the gods, though the letters are no longer legible. Except for the gap of 21 letters occurring later in the text, the reconstruction is otherwise complete. A translation (with some explanations in brackets) follows:

"Resolved by the Council [of 500 members representing all the townships of Attica and selected by lot for one year] and by the People [all free men meeting in assembly], on the motion of Themistocles, son of Neocles, of the township Phrearri: to entrust the city to Athena the Mistress of Athens and to all the other gods to guard and defend from the Barbarian [the term meant only non-Greek, in this case the Persians, and was not necessarily derogatory] for the sake of the land. The Athenians themselves and the foreigners who live in Athens are to remove the

The Persians first met resistance from the Spartans at Thermopylae, and from the Greek navy near Artemision. The Persians then took Athens, which had been evacuated. The women and children of Athens were sent to Troizen, where the tablet was found.



TABLET IS DATED to the fourth century B.C. by the character of the letters on it. This table shows how six letters of the Greek alphabet used at Troizen changed from sixth century B.C. to the second. Column at right shows letters that appear in decree.

women and children to Troizen [gap of 21 letters] the founding hero of the land. The older men [over 50] and the movable possessions are to be removed to Salamis [the island off the coast of Attica]. The treasurers [of the gods' possessions] and the priestesses are to remain on the Acropolis [the ancient citadel and holy place of Athens] and protect the possessions of the gods.

"All the other Athenians and foreigners of military age are to embark [as oarsmen and marines] on the 200 ships that lie ready [the rest of the 300 ships were manned by non-Athenian Greeks] and defend against the Barbarian for the sake of their own freedom and that of the rest of the Greeks, along with the Spartans, the Corinthians, the Aeginetans [the Athenians' bitterest enemy] and all others who wish to share the danger.

"The generals [10 in number, elected from each of the 10 tribes] are to appoint, starting tomorrow, 200 ship commanders, one to a ship, from among those who have land in Athens and legitimate children and who are not older than 50; to these men the ships are to be assigned by lot [to avoid any charges of favoritism by the generals]. The generals are also to enlist marines, 20 to a ship, from men between the ages of 20 and 30, and four archers to a ship. They are also to assign the petty officers [the skilled seamen] to the ships at the same time that they allot the ship commanders. The generals are also to write up the names of the crews of the ships on white boards, taking the names of the Athenians from the registers kept in each township [for electoral purposes] and the foreigners from those registered with the war officer. They are to write up the names, assigning the whole number to 200 equal divisions, and to write above each division the name of the ship and the commander and the names of the petty officers so that each division may know on which ship it is to embark. When all the divisions have been composed and allotted to the ships, the Council and the generals are to complete the manning and outfitting of the 200 ships, after sacrificing a placatory offering to Zeus the Almighty [the chief god of the Greeks], Athena, the goddess Victory and Poseidon the Securer [god of the sea].

"When the manning of the ships has been completed, with 100 of them they are to meet the enemy at Artemision in Euboea [the sanctuary of the goddess Artemis at the northern tip of the island of Euboea], and with the other 100 of them they are to lie off Salamis and the rest of Attica and guard the land.

"In order that all Athenians may be united in their defense against the Barbarian, those who have been sent into exile for 10 years are to go to Salamis and to stay there until the People come to some further decision about them, while those who have been deprived of citizen rights are to have them restored [with the probable exception of those who were religiously tainted]."

To entrust their city to the goddess Athena was in fact to abandon all hope for a human defense against the vastly superior Persian land force (half a million men by the lowest of the ancient sets of figures). Athens at this time probably had not many more than 30,000 male citizens between the ages of 18 and 50. But the Athenians were not prepared to surrender. All men under 50 were to row the war galleys, and even the men over 50 were to serve as a home guard on the island of Salamis. They would sacrifice their city and their land for a chance to defend their freedom at sea.

Only one provision seems inconsistent with this plan: the requirement that the treasurers and priestesses stay on the Acropolis. Later historians tell us that the leaders of Athens had quarreled over defense policy and had consulted the oracle of Apollo at Delphi. In replies that were generally defeatist, the oracle had recommended that the Athenians rely on "wooden walls." Themistocles insisted that this referred to the 200 ships he had got the Athenians to build with surplus revenue from the state's silver mines. But more conservative voices claimed that the god was recommending a wooden stockade on the old citadel. Here we seem to have a concession to this faction. Perhaps it was hoped that the barbarian would respect the sacred officials and the sacred places. As things turned out the Persians sacked and burned the Acropolis and killed everyone they found upon it.

The decree bears no explicit date, as appears to have been the rule in early Athenian public documents. But the decision that half the fleet was "to meet the enemy at Artemision in Euboea" establishes the significant fact that the decree was adopted before the great naval battle off that point. To develop the full impact of this vital piece of information, the progress of Xerxes' huge army and navy must be traced.

The Athenians had first come to the notice of the Persians some 20 years before, when they had sent token support across the Aegean Sea to Greek cities on the west coast of Asia Minor that were rebelling against the Persians. Athens' part in the revolt gave Darius, Xerxes' father, the excuse to plan a conquest of the Greek islands and mainland. In 490 B.C. he sent an exploratory force by sea to Marathon, on the east coast of Attica. There Athenian infantry caught the Persians half in and half out of their ships and won a famous victory.

Xerxes inherited from his father not only the Persian empire but the determination to punish the Athenians and to conquer Greece. He realized he must send a larger force than could be transported by ship across the Aegean. His preparations, delayed by a revolt in Egypt, took several years. They included two bridges of boats across the Hellespont, the swift-running channel dividing Europe from Asia; a ship canal cut through the base of the mountainous peninsula of Mount Athos in northeastern Greece, off which an earlier Persian expedition had lost its fleet in a storm; and numerous depots of stores along the route. Xerxes himself accompanied his army from Sardis in Asia Minor in April of 480 B.C. It took a whole month (May) to cross the Hellespont. By late July he was at Therma in Macedonia and there received tokens of submission from a number of Greek states.

Meanwhile the Athenians had joined with other Greeks under the leadership of Sparta. They first met the invader in force at Thermopylae, a narrow passage between the mountains and the sea that was the chief entrance into central Greece. Xerxes' fleet, gathered nearby at the entrance to the channel between the long island of Euboea and the mainland, also found itself opposed by Greek ships based on the island, at Artemision.

At Thermopylae the Spartan king Leonidas and a handful of men fought to the death when they were overwhelmed by vast numbers before them and outflanked by picked Persian troops led down a mountain path to their rear. The epitaph of the Spartans has been preserved: "Stranger, tell them in Sparta that we lie here, obedient to their word." Nearby the Greek fleet, despite heavy losses, held the Persians off until the news came from Thermopylae, whereupon the Greeks withdrew to Salamis, near Athens.

Both ancient and modern historians have always said or implied that it was only then that the Athenians decided to abandon their city and take to their ships. With the Persians streaming through central Greece toward Athens, and with no sign of a Spartan-led army

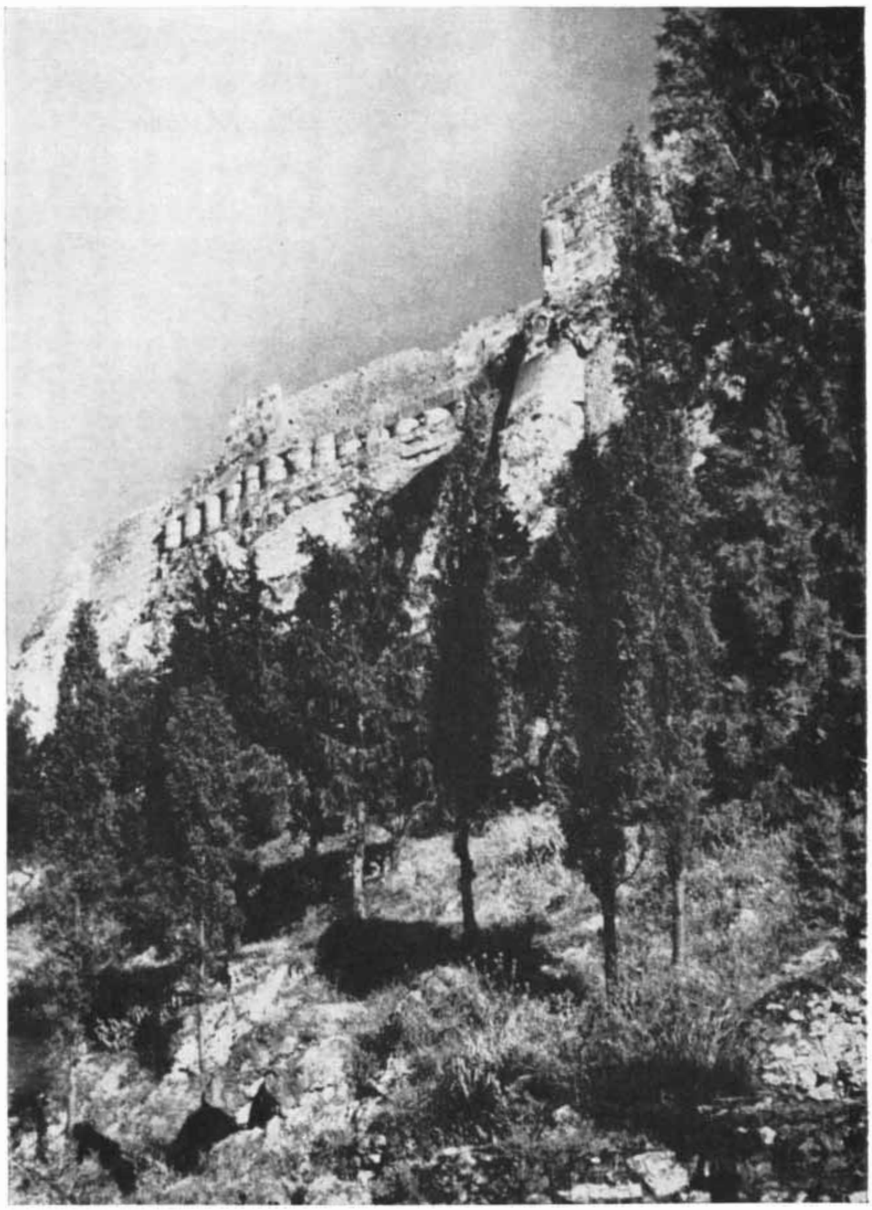
ANCIENT TROIZEN lay beyond the tower at right, the base of which was built in the third century B.C. In the distance is the harbor where the Greek fleet assembled before Salamis.

BATTLE OF MARATHON was fought on this site. Here the Greeks defeated the Persians during the reign of Darius, father of Xerxes. The battle was fought 10 years before Salamis.

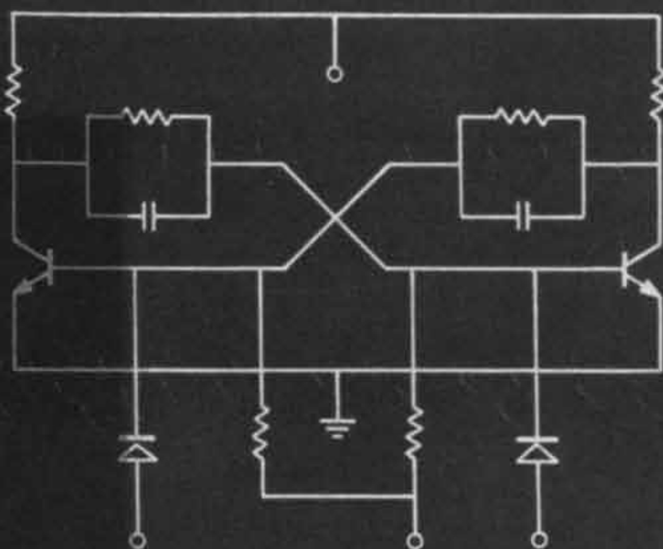
on the mainland side of the Isthmus of Corinth, the decision was supposedly taken in desperation and haste. It is now clear from the inscription found at Troizen that this was not the case.

The decree was passed before Artemision and so also before Thermopylae. It was not the result of last-minute panic but a magnificently cool and courageous decision made before Xerxes had even entered Greece. The fact that the Athenians decided to send only half of their 200 ships to Artemision shows they did not intend that action to be an all-out effort any more than the Spartans intended to risk everything on the defense of Thermopylae. Both were meant to be delaying actions: one to hold off the Persian army while the Peloponnesian cities strengthened their fortifications on the Isthmus of Corinth; the other to stall the Persian navy until reinforcements came up to Salamis from the west. Salamis was the key to Themistocles' plan of defense from the very beginning. It was no accident that in its waters the Persians met their defeat.

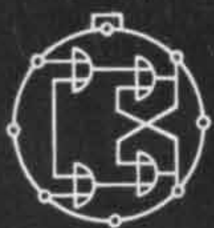
Themistocles had not been blinded by the remarkable victory at Marathon 10 years earlier, won by the heavy infantry. He saw that when the Persians came again, as they certainly would, Athens could not hope to face the full force of the Persian army. On her ships, however, she could use all her citizens—even those



WALL OF THE ACROPOLIS of Athens is set with sections of columns from a temple that was a predecessor of the Parthenon. This temple was destroyed by the Persians, and the columns may have been built into the wall by the Athenians to commemorate Persian defeat.



A NEW SYMBOL



The symbol represents a microminiature "flip-flop." It is a solid-state integrated circuit incorporating all the functions shown in the equivalent conventional circuit. Yet it occupies one transistor package. It makes a 95% saving in space.

The symbol is one of six. There is a series of these functional micrologic elements: flip-flop, gate, buffer, half adder, half-shift register and counter adapter. Entire computer logic systems can be built wholly from combinations of these six building blocks. They are directly interconnectable. Design time is minimal.

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who could not afford a suit of armor. In the narrow waters between Salamis and the coast of Attica the greater numbers and speed of the Persian fleet would be neutralized. Furthermore, the Persian fleet was not Persian at all but was manned by Phoenicians, Egyptians and—most important—reluctant Greeks of Cyprus and Asia Minor pressed into Persian service. When the moment came, the Athenians—with their fathers on the shores of the island and their homes before their eyes—could be counted on for a supreme effort.

In the end, according to the ancient writers, Themistocles had to threaten wholesale emigration of the Athenians to Italy in order to keep his allies at Salamis; it is even said that he lured Xerxes into attack with a secret message saying that the Greeks were about to flee. Whether these embellishments of the story are true or not, the plan worked. Athens not only won Salamis but emerged at the end of the war as the strongest naval power in Greece. Her navy was in turn the foundation of her democracy, since the navy was manned by the people.

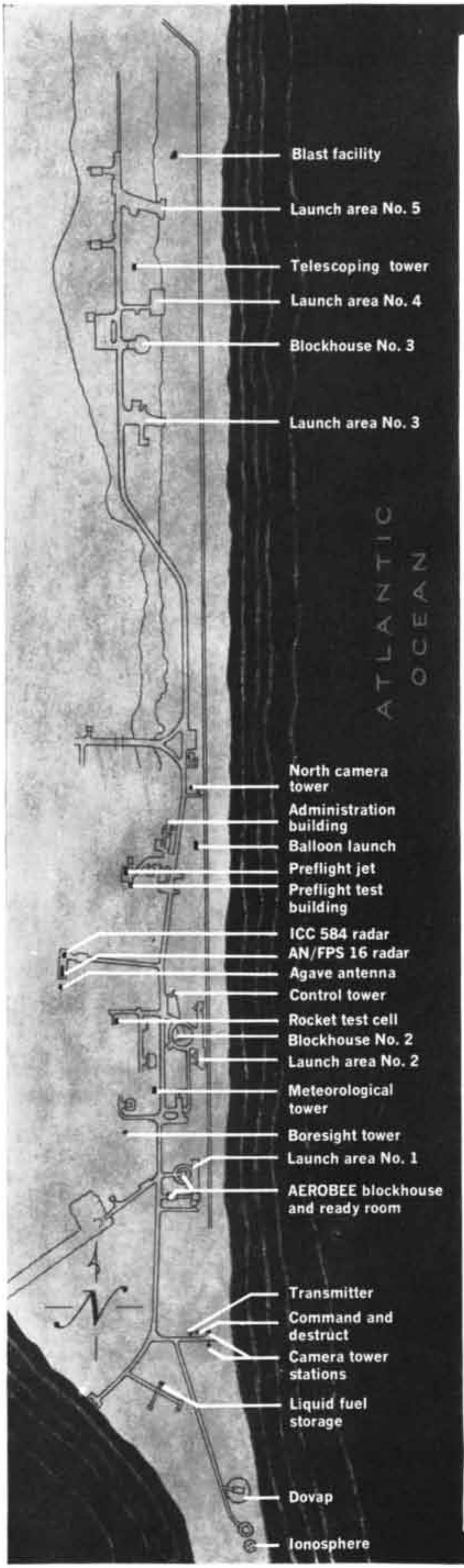
It may seem strange that this heroic version of the evacuation of Athens and the victory at Salamis has not survived in the historical sources. This is partly because the chief ancient source—Herodotus—gathered much of his material in Athens at a time when the people were bitterly hostile to the Spartans and preferred to think of themselves as having been forced to leave their country because the Spartans had withdrawn their land forces. Later, when the decree of Themistocles was circulated more widely, to judge by references and quotations, it was only the first patriotic paragraphs that were cited and not the details of mobilization, nor the revealing mention of Artemision.

This raises a final puzzle. How is it that the only text comes from a fourth-century inscription at Troizen? Some scholars have suggested that our text is not a true copy of the original of 480 B.C. but a patriotic reconstruction or, to put it bluntly, a forgery of the fourth century. This view fails to explain the marked differences between the decree and the accepted tradition. A reconstruction or forgery can be expected to follow tradition as much as possible. The problem really is: How did the text survive, despite the Persian destruction of Athens and an undeveloped system of state archives in the fifth century?

The explanation is probably to be found in the later career of that brilliant but difficult leader Themistocles and in the history of his descendants. He himself, as chairman of the board of generals who supervised the mobilization, is sure to have had a copy of the decree, and later he was not likely to let the Athenians forget that he had been the author of their salvation. For nearly a decade after the victory over Persia he dominated the political scene at Athens, fighting to strengthen her against her former ally, Sparta. But then he was exiled by the Athenians, accused of collusion with the Persians and hunted out of Greece. Not surprisingly, he took refuge with the Persian court, learned the language and won great favor. He was made governor of three Greek cities in Asia Minor and there he died.

His sons were eventually restored to Athens and kept his memory alive with various public dedications. The family continued to flourish in fourth-century Athens (and, as a matter of fact, on into at least the first century A.D.). In this period, as the kingdom of Macedon in the north grew in power and threatened to dominate Greece, there was a revival of patriotic sentiment in Athens and a renewed interest in the stirring texts of its glorious past. No doubt with the encouragement of the descendants of Themistocles, his decree took on the function of a Declaration of Independence or a Gettysburg Address. Even after the conquest of Greece by Macedon and then by Rome the decree continued to be read and declaimed.

Troizen had close ties with Athens at the time of the Macedonian threat. After the Greek defeat at Chaeronea in 338 B.C. the pro-Athenians in Troizen were exiled. They were given citizenship at Athens precisely because their city had sheltered the Athenian refugees in 480 B.C. When they were able to return home, they doubtless saw to it that their city was friendly to Athens. They would have made the most of their city's common cause with Athens 150 years earlier. What better testimonial of this than Themistocles' decree? It may even be surmised that the stone inscribed with the decree was displayed in a portico of the market place, where the Athenians had dedicated statues of the women and children who had taken refuge at Troizen. Most probably the stone was no longer in its original location when found. Only thorough excavation of the area will tell. One cannot help wondering what other documents lie hidden in the ruins of the lesser cities of ancient Greece, which have been neglected so far in favor of more famous sites.


Blast facility
Launch area No. 5
Telescoping tower
Launch area No. 4
Blockhouse No. 3
Launch area No. 3
ATLANTIC OCEAN
North camera tower
Administration building
Balloon launch
Preflight jet
Preflight test building
ICC 584 radar
AN/FPS 16 radar
Agave antenna
Control tower
Rocket test cell
Blockhouse No. 2
Launch area No. 2
Meteorological tower
Boresight tower
Launch area No. 1
AEROBEE blockhouse and ready room
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Command and destruct
Camera tower stations
Liquid fuel storage
Dovap
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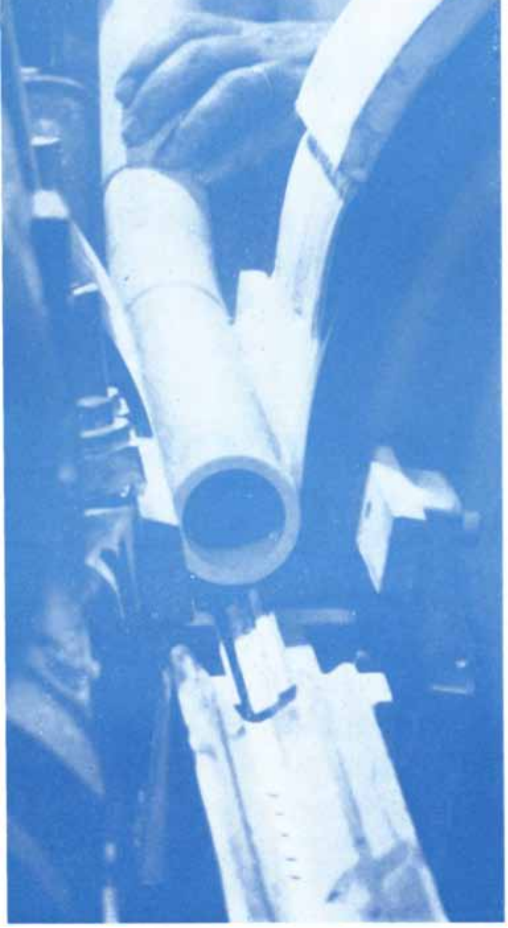

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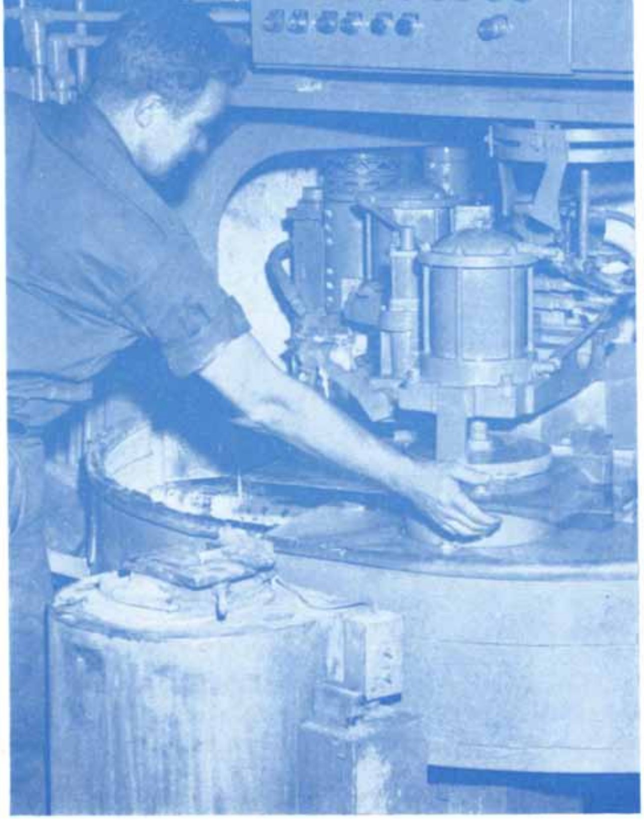

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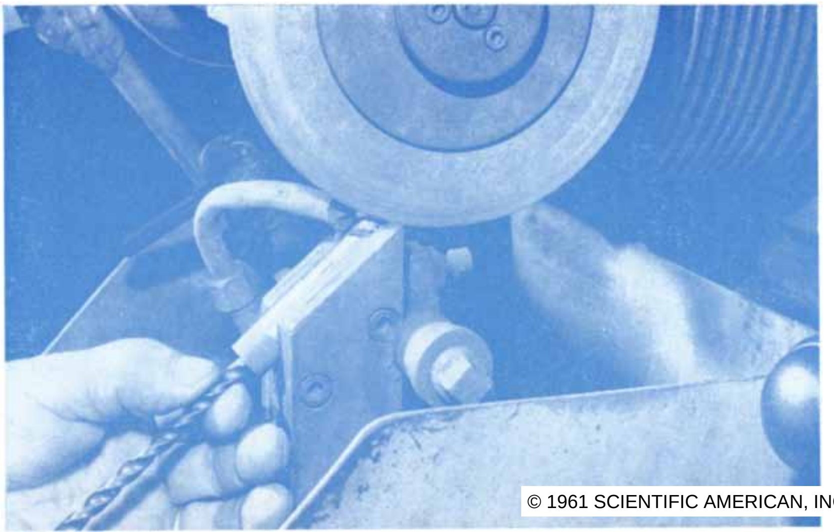

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LEE WAVES IN THE ATMOSPHERE

Formed downwind from hills and mountains, the waves create many strange and beautiful cloud types. Meteorologists neglected lee waves until sailplane pilots began exploiting them to reach great altitudes

by R. S. Scorer

When the wind blows over hills or mountains, it often sets up large but invisible waves in the atmosphere. Because these waves extend downwind from the high ground they are called lee waves. Aircraft flying into them may be carried swiftly upward or downward with disastrous consequences. Fortunately this hazard has largely been removed in the last decade as meteorologists and others have learned how to recognize the presence of lee waves and can warn pilots when to watch for them. Today pilots of light aircraft often save fuel by riding the waves in the right way. Many have learned this technique as sailplane pilots; in fact, sailplane pilots were the first to investigate lee waves.

The waves frequently reveal their presence in characteristic cloud forms. Some of the most spectacular lee-wave clouds can be seen along the eastern slopes of the Sierra Nevada, the mountain range that parallels the Pacific Coast in California. But almost any ridge of hills will produce striking lee-wave clouds from time to time.

It is curious that meteorologists were so slow to appreciate and to study lee waves, because waves of some sort are produced in almost all matter—solid, liquid or gas—when it is subject to a disturbing force. We are familiar in everyday life with sound waves in air, waves on the surface of water and tides in the ocean. Such waves are called gravity waves when gravity provides the force that returns the medium to its original position after it has been disturbed. [They are not to be confused, however, with the hypothetical gravitational waves that travel through space with the speed of light. These are discussed in the article "Gravity," by George Gamow, beginning on page 94.]

The lee waves that concern us here are gravity waves of a special type. They are analogous to the standing waves created when a stream of water passes over an obstacle. The water does not hump upward, as one might naïvely think, but actually starts to dip downward slightly ahead of the obstacle and reaches a low point just beyond it [*see top illustration on page 126*]. The key to this seeming paradox is that the obstacle has the effect of reducing the size of the channel; if the same amount of water is to pass the obstacle as flows down the unobstructed channel, it must momentarily speed up. To be speeded up the water must on the whole flow downhill in order to gain the additional energy of motion required. One's first thought, that the water humps upward over the obstacle in order to get by, is ruled out because there is no source for the additional energy required to lift the water. This is in accordance with the famous Bernoulli principle, which states that if a liquid is speeded up it must at the same time flow toward a region of low pressure in order to acquire the additional energy. When the surface dips down, the pressure due to the weight of water above is of course reduced.

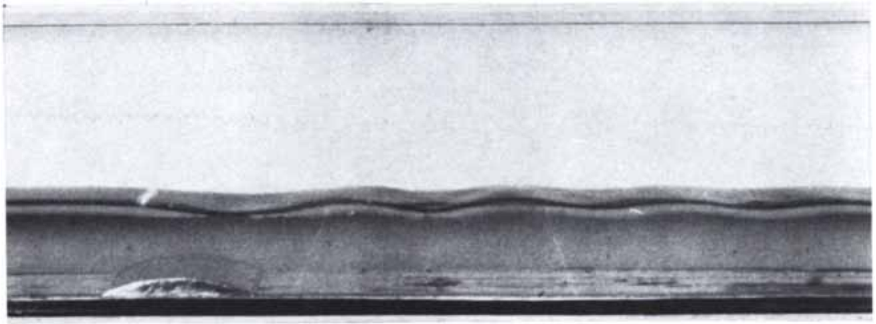
Air flowing over a hill or mountain obeys the same rules, except that now we are concerned with the flow patterns inside the stream rather than with the flow at the surface. The atmosphere has no definite upper surface, and there is an added complication: the air decreases in density with increasing altitude. Moreover, the decrease seldom proceeds at a constant rate. The rate may vary with altitude and it may vary from one hour to the next. The closest analogy to the atmosphere is a fluid consisting of a series of layers of different density, sometimes merging together imperceptibly, at other times remaining quite distinct. Such a fluid is said to be stratified. The stratification is stable because gravity tends to return the layers to their original horizontal position. We are now ready to consider the problem of analyzing the flow of air, stratified in complex fashion, over an obstacle of complex shape.

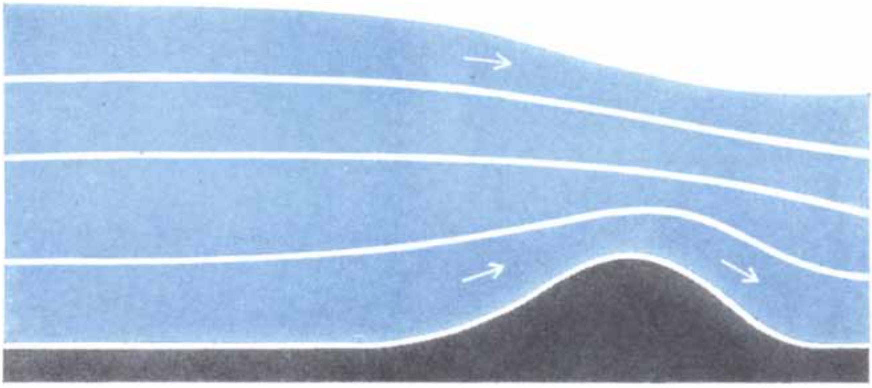
As the stratified air flows over a hill or mountain it first dips downward and then enters into the series of equally spaced undulations called lee waves [*see bottom illustration on page 128*]. The time required to execute one complete wave oscillation is determined by the degree of stratification of the air. In stratified air of considerable stability, the density of which drops rapidly with altitude, the time for one oscillation may be only about 20 seconds. When the stratification is less intense, the time may run as high as five minutes.

In other words, a steep density gradient produces a strong restoring force; a smaller density gradient, a weaker force. The distance travelled by the air in the time required for one oscillation depends on the wind speed, so that the wavelength is determined by two factors: the stability and the wind speed of the airstream. Typical wavelengths are between one and 10 miles. The longest wavelengths are produced by strong winds and low degrees of stability.

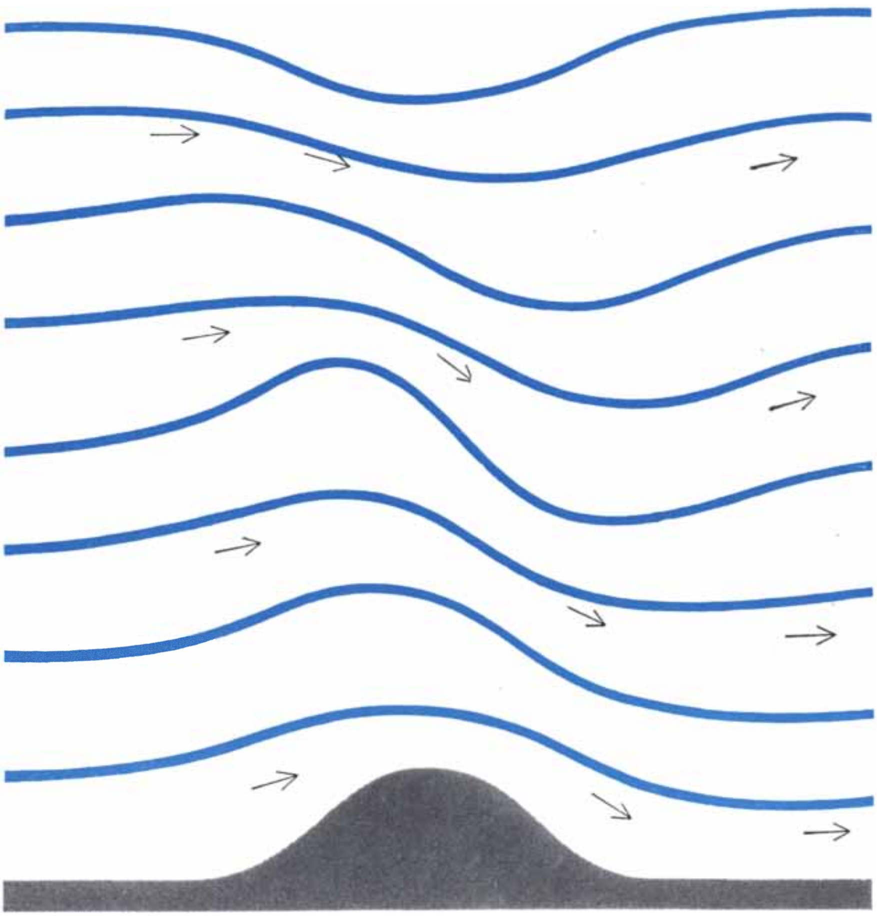
Unlike the gravity waves that would be produced in the atmosphere by a large explosion, lee waves are standing waves. So long as atmospheric conditions remain constant, their crests and troughs remain fixed in one place. Yet lee waves are actually traveling. They are traveling through the air against the wind with a speed exactly equal and opposite to that of the airstream. There is a simple explanation for their unique wavelength. Waves of different length travel at different speeds; the shorter the wave, the slower its speed. Thus short

LEE WAVES CREATED BY MOUNT COOK in New Zealand carried Philip Wills to a British soaring record of 30,400 feet in December, 1954. He made this photograph at 20,000 feet as his sailplane seemed to be hanging almost motionless in the strong wind (blowing from the right), but was actually being lofted at 20 feet a second by a mountainous lee wave. When the plastic cockpit cover of his sailplane began to splinter in the sub-zero air, Wills, dressed only in light summer clothes, was forced to turn back. Mount Cook lies shrouded under the cap cloud to the right. The line of smaller clouds to the left marks a cresting of the first lee wave.





LEE WAVES IN WATER ripple downstream from a submerged obstacle, as shown in the photograph at top. The diagram illustrates the origin of the waves; the water must speed up to pass the obstacle obstructing the channel, and to do so it must briefly flow downhill.



LEE WAVES IN AIR have the same origin as those in water (*top of page*). The obstacle obstructs the passageway; the air must speed up to maintain a constant flow rate; the same net downhill flow occurs. The flow pattern illustrated is only one of many that are possible.

waves will be carried away downwind, while longer ones will race away upstream, leaving behind, motionless in space, the waves whose speed exactly matches that of the airstream. The length of lee waves, therefore, is mainly a property of the airstream.

It is another matter when we come to amplitude: the height of the waves from trough to crest. Here the shape of the obstacle plays a major role. This does not mean that a high ridge or a mountain necessarily produces high waves, and a small hill low waves. The relationship is more subtle and requires complicated mathematics for its explanation.

One result of the computations is to confirm what one would expect intuitively. If the obstacles are regularly shaped—or, better yet, wave-shaped—the highest amplitudes will be produced by those that have a width of about one wavelength [*see illustration at top left on page 130*]. A symmetrical ridge about three miles wide will produce high waves when the airstream executes waves three miles long, and relatively shallow waves when the natural wavelength is shorter or longer than three miles. Moreover, as one might suspect, wavelengths that are simple multiples of the width of the obstacle (six and nine miles for the example just cited) will have greater amplitudes than waves that are not simple multiples.

Most natural obstacles are not regularly shaped, however, and it turns out that the precise shape of the hill has a great bearing on amplitude. To use the kind of argument that delights mathematicians, we can imagine two ridges so shaped that they produce two sets of lee waves of the same amplitude. If we now construct a range of hills from these ridges, placing them half a wavelength apart, their two wave trains will exactly cancel each other, because the crests of one will coincide with the troughs of the other [*see middle illustration at top of pages 130 and 131*]. If the ridges are placed a full wavelength apart, the lee waves will coincide and reinforce each other, producing waves of increased amplitude.

This argument has further ramifications. If an obstacle, such as the range of hills just constructed, produces no lee waves, we can assume that it could be chopped in two (at random) and that each piece standing alone would necessarily produce waves of the same amplitude as the other but exactly out of phase. But if we now cut the air speed in half we get waves of reinforced amplitude where previously the waves had

SIERRA WAVE CLOUDS form on the lee (eastern) slope of the Sierra Nevada in California. The clouds mark the presence of lee waves formed in the atmosphere when the wind blows over obstacles.

CLOUDS IN HILL COUNTRY can blanket the sky for miles, as do these clouds in North Wales. They can be identified as wave clouds because they appear to stand more or less motionless.

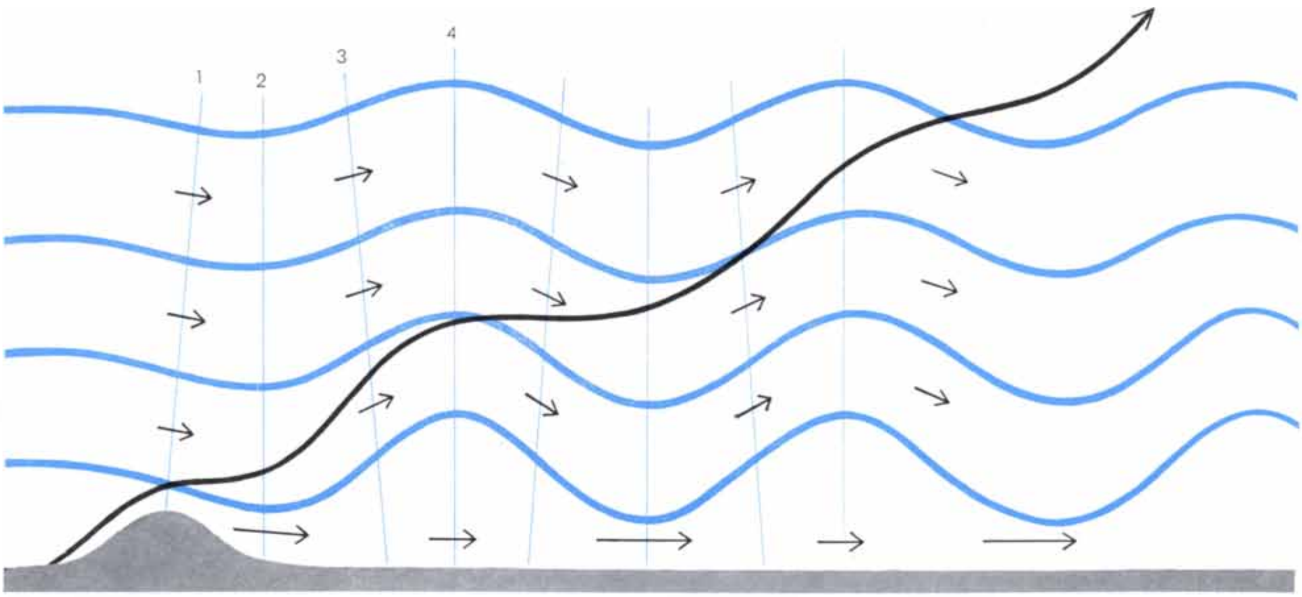
IRIDESCENT CLOUD is a fairly common type of wave cloud in which water droplets, smoothly graded in size across the cloud, diffract light of different wavelengths through different angles.

ICE TRAILS form in long streamers downwind from wave clouds when water droplets freeze inside a cloud and fail to evaporate on being carried out of it. This scene is near Loch Ness in Scotland.

LAYERS OF WAVE CLOUDS stack up three deep in the lee wave of the Sierra Nevada. The low, puffy clouds are extremely turbulent, but the air above is smooth. The view is to the south.

UNE PILE D'ASSIETTES is the name the French have given to wave clouds so neatly stacked they resemble a pile of plates. These plates appeared near the Maritime Alps northeast of Marseilles.

WAVE CLOUDS OVER THE ALPS dramatically outline the undulations of lee waves formed in the stable air currents flowing from right to left (roughly, west to east) over the 13,600-foot Jungfrau in Switzerland. In the foreground is part of the great Aletsch Glacier.



ANALYSIS OF LEE WAVES shows successive positions of a vertical column of air as it is carried downstream by the wind. At position *1* the air at various levels has started to dip downward, causing the column of air to tip forward. At *2* the air at the lowest level is moving faster than the air above it, causing the air column to rotate counterclockwise and tip backward at *3*. After the column of air reaches *4* the whole cycle repeats. The air speed at the base of the columns is proportional to the length of the horizontal arrows. If a weather balloon were released into the lee waves, it would describe the sinuous path indicated.

canceled out. This is so because halving the air speed would halve the lengths of the lee waves contributed by the obstacle's two components, which we have imagined to constitute the mountain. The shorter waves now fall in phase and reinforce each other.

To sum up, the amplitude of lee waves depends on two factors: the shape and size of the obstacle, and the natural wavelength of the airstream. The latter, in turn, is determined mainly by the airstream profile—a composite graph showing how the density and speed of the airstream vary from the ground upward. Mathematical examination of the two variables shows that a weakening of the wind has the same effect as intensifying the stability. Thus many different airstreams may be equivalent.

One might expect that if the airstream profile were very complicated, the wavelength could not be the same at all altitudes, but this is not the case. By having various amplitudes at various levels the layers interact with one another and end up with the same wavelength. The waves of greatest practical and meteorological interest are those having a large amplitude at an altitude somewhere between 1,000 and 20,000 feet, where there are clouds and where most aircraft fly. Waves of this kind occur, for example, when there is a large degree of stability with moderate winds below 10,000 feet, and lesser stability and stronger winds higher up—between 15,000 and 40,000 feet. Such conditions are fairly common, and weather forecasters can predict them with reasonable accuracy. Of course, the amplitude of the waves still depends very much on the shape of the mountain.

When the winds at 25,000 feet are blowing at 50 to 120 miles per hour, the inclination of the flow in the wave can be as steep as 10 to 15 degrees to the horizontal. The upward or downward component of the air's motion may be as much as 20 m.p.h., or nearly 2,000 feet per minute. Vertical speeds of 1,000 feet per minute are very common, and speeds five times as great must occasionally be reckoned with.

In the 1930's, when flying at night or in clouds became commonplace, these fast-moving currents caused many accidents. The pilots evidently did not perceive that they were being swept downward because the drop began insidiously and without any warning bumpiness.

Most of the earliest knowledge of lee waves was contributed by sailplane pilots, who discovered to their surprise that the air currents on the lee side of hills and mountains were often more favorable for soaring than those to windward. In the early days of sailplane flying it was customary to soar where the wind blew up the face of a hill. This was called hill soaring, or soaring in hill lift. But as we have seen, a height is soon reached where the airflow is inclined downward instead of upward above the face of a hill. Thus hill soaring seldom carried a sailplane more than a few hundred feet above the hilltop.

By soaring in wave lift, or wave soaring, sailplane pilots can often exceed the height of the hill many times over. The reason is simply that the upslope flow in lee waves usually extends higher and is more inclined than the flow up the face of the hill. At Dunstable, in southern England, the members of the London Gliding Club soared for years in the lift from a modest 230-foot hill, seldom being carried above 800 feet. But by exploiting the lee wave one sailplane pilot has now soared to nearly 3,000 feet above the foot of the hill, an ascent of 13 times the height of the hill producing the wave.

Historically the exploration and exploitation of lee waves began in Germany. Here as in some other places wave clouds formed by lee waves have long been known by folk names. The Moazagotl, for example, was named after Gottlieb Motz, a farmer who watched this stationary cloud over the Reisen Gebirge and was fascinated because the strong wind did not bring it down from the mountain toward his field. It was near the Moazagotl that Wolf Hirth made the first recorded wave flight in 1933, and by 1939 flights up to 28,200 feet had been achieved there. In 1940 E. Klöckner was towed to 20,000 feet and then soared to 37,400 feet in the lee waves formed by the Grossglockner in the Austrian Alps.

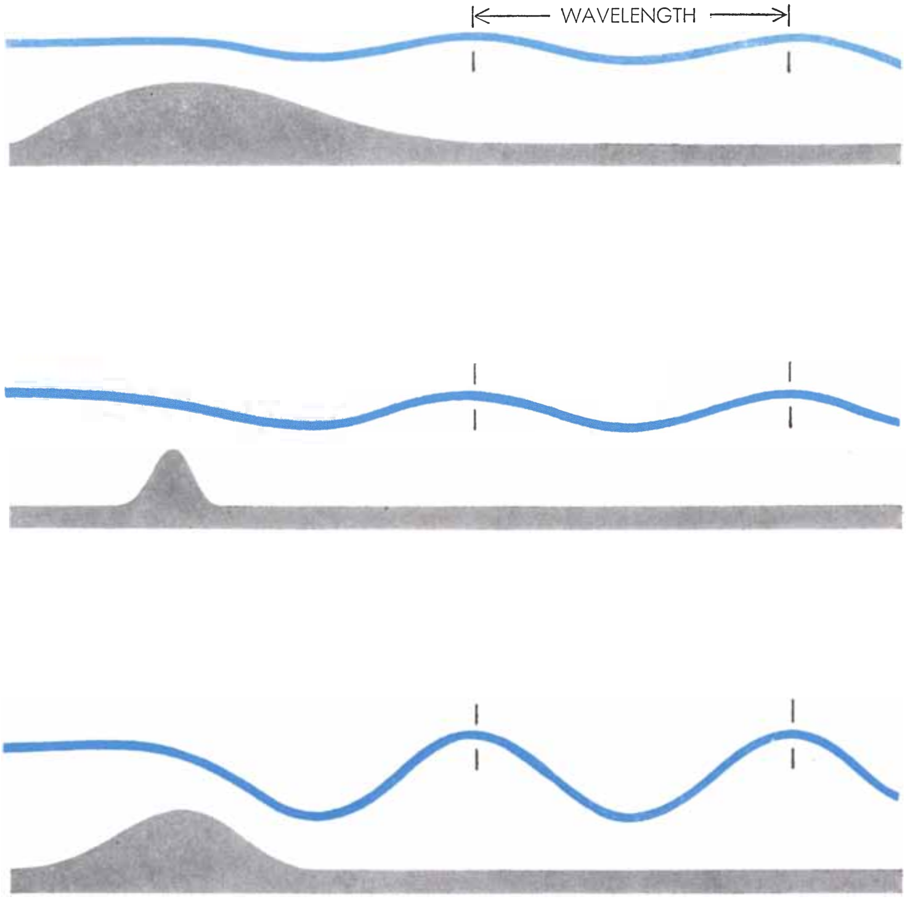
This and many other flights were made by members of the D.F.S. (Deutsche Förschungsinstitut für Segelflug—the German Research Institute for Soaring), who were the first to use wave clouds to detect the location of lee waves. D.F.S. flights also led to the first serious analysis of lee waves by competent mathematicians. The work of Gerhard Lyra in 1943 was the first to point to a proper theory.

It was a number of years before sailplane pilots outside Germany developed a good understanding of lee waves, especially where the ground contours were complex. For example, at Camphill in central England, where the 1954 World Gliding Championships were held, the ridge where hill soaring is done stands to the east of another parallel ridge. When the wind blows from the west, the hill lift normally used may coincide with the upslope of the lee wave formed by the hill to the west; when the wave and the hill lift thus reinforce each other, they produce fine soaring conditions. At other times the two waves may fall out of phase, canceling each other and spoiling the fun [*see illustrations on page 132*]. These queer goings on were not properly understood until 1953, some 20 years after they were first observed. The explanation was finally provided by Derek Roper, who had often soared at Camphill.

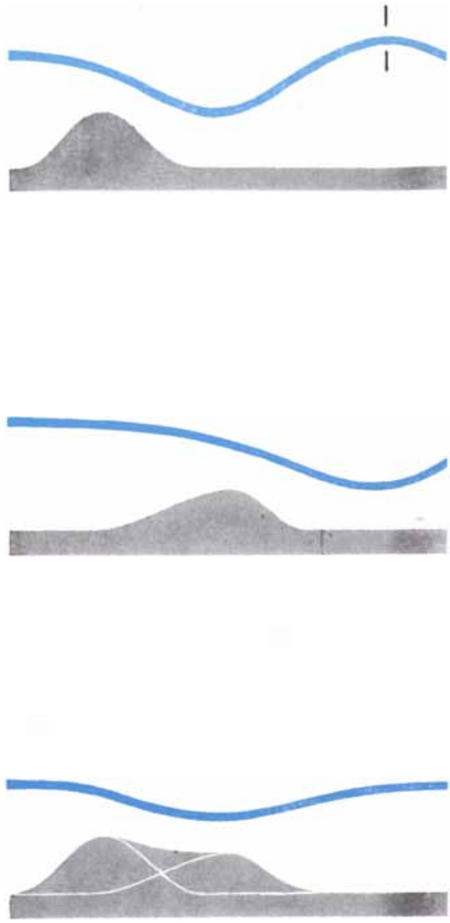
Since then many complicated lee-wave patterns have been explored and exploited in hundreds of sailplane flights in many parts of the world. For example, during the 1954 World Gliding Championships, Philip Wills (then the world champion) made a remarkable ascent through a cloud layer whose upper structure, shaped into great ridges and valleys stretching as far as the eye could see, showed him the exact position of the waves. He was thereby enabled to travel many miles by soaring in a swift hop from the upslope side of one wave to the next, where he gained enough height for the next hop across the down current.

Wills made a still more remarkable flight in the Mackenzie Basin of New Zealand in December, 1954. After being launched by a winch he flew to the lift of a little hill, then circled upward in a thermal current the sun had generated over the hot ground. This gave him sufficient altitude to find the lee waves produced by the flow of air over the main range of the Southern Alps in the vicinity of Mount Cook [*see top illustration on page 134*]. Wills's unplanned flight, made in shirt sleeves in a third-hand prewar German sailplane, carried him to 30,400 feet. Since he was equipped with oxygen and was kept reasonably comfortable by the intense sunshine, he could have soared even higher, but the cold outside air cracked his cockpit cover, obliging him to descend.

The world's altitude record for sailplanes is 44,255 feet. The record was made in March, 1952, by Larry Edgar and Harold E. Klieforth, who utilized the lift provided by the lee wave of the Sierra Nevada, probably the most powerful lee wave in the world. The Sierra Wave owes its gigantic proportions partly to the altitude of the Sierra, which



AMPLITUDE OF LEE WAVES depends on the shape of the obstacle. Under a given set of atmospheric conditions (which establish the natural wavelength) the amplitude will be greatest when the wavelength most nearly matches the shape of the obstacle (*bottom illustration*).

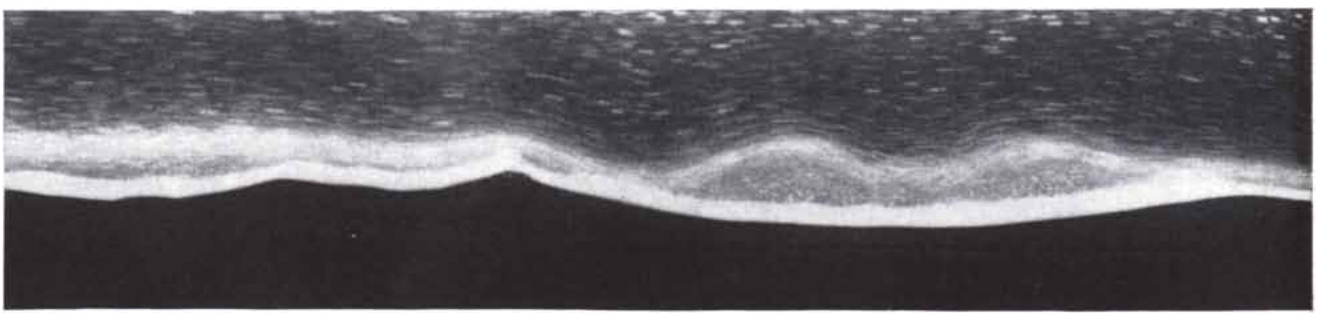


LEE-WAVE CANCELLATION occurs if two ridges that produce lee-wave trains of the same wavelength (*top and*

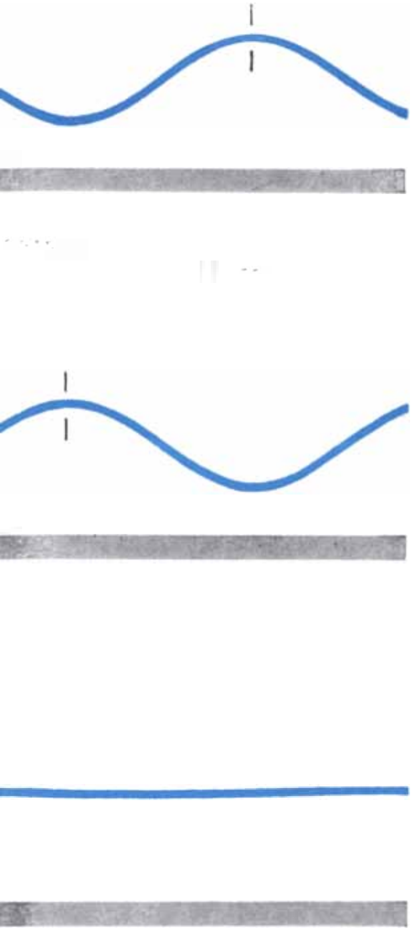
rises almost 9,000 feet above the floor of the Owens Valley, and partly to the extremely clean shape of the Sierra's lee slope. Although the Sierra Wave can certainly carry a sailplane higher than 44,255 feet, it will have to be a sailplane with a pressurized cabin, and none has yet been built.

At times the Sierra Wave produces spectacular stationary clouds. Now that we understand lee waves, wave clouds are easily explained. If taken to a sufficient height in the atmosphere, every small volume, or parcel, of air will condense out some of its water vapor in the form of a cloud. The height at which a given parcel of air first begins to form water droplets is called the condensation level. Wave clouds form when the undulating currents of a lee wave carry air parcels above this critical level for a short distance. If the air is too dry, of course, no clouds will form. If only a thin layer of air contains enough water vapor to condense, only thin, arched clouds will be formed. At other times holes will appear in a wave-cloud layer where the air is swept below its condensation level.

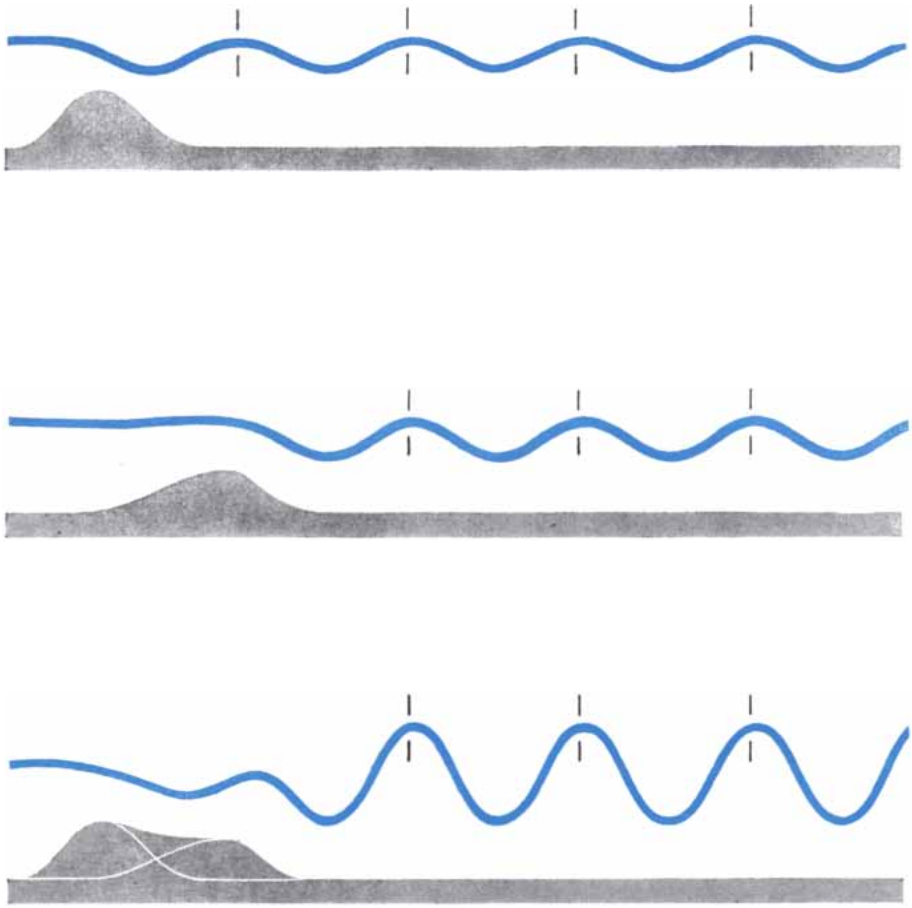
If, as commonly happens, the bottom layers of air up to about 3,000 feet are well mixed and more humid than the air above, a lens-shaped cloud will appear in each wave. The top of each cloud will have roughly the shape of the crest of a wave, the bottom will be quite horizontal, coinciding with the condensation



SIMULATED SIERRA WAVE is created in a laboratory channel using a salt solution that decreases in density from bottom to top. Aluminum powder suspended in the solution reveals how the lee waves change in length and amplitude as the flow rate is varied. The flow is from left to right over a model of the Sierra Nevada, down the lee slope (*left of center*) and into the Owens Valley.



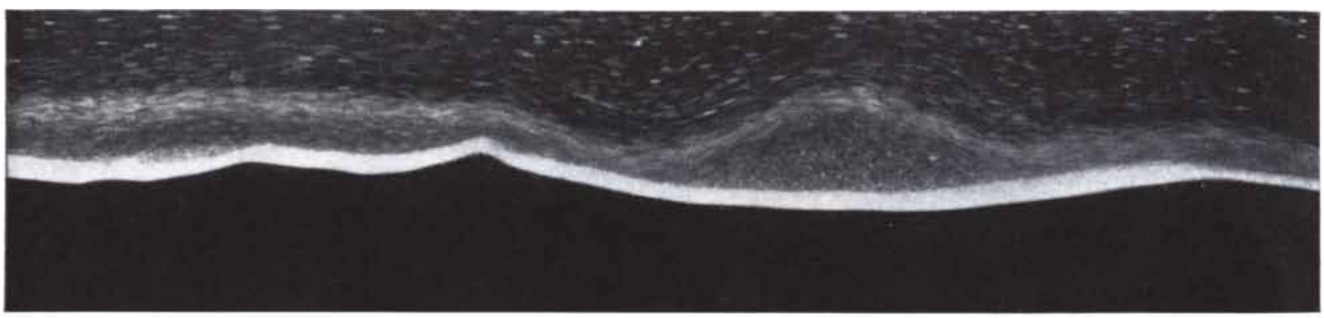
middle) are assembled half a wavelength apart to form single ridge (*bottom*). The two wave trains now cancel.



LEE-WAVE REINFORCEMENT occurs if the speed of the wind blowing over the same composite ridge (*bottom*) is cut in half. With lessened air speed, the lee waves created by the two ridge components (*top and middle*) would be halved and thus fall in phase.

level for the moist air lying below. Wave clouds move only in response to changes in humidity or to changes in the wave pattern. They can be identified by the appearance and growth of cloud elements on the windward side and by the disappearance of cloud elements on the lee side. This is in contrast to cumulus, cirrus and most other clouds, which move along bodily with the air in which they are embedded.

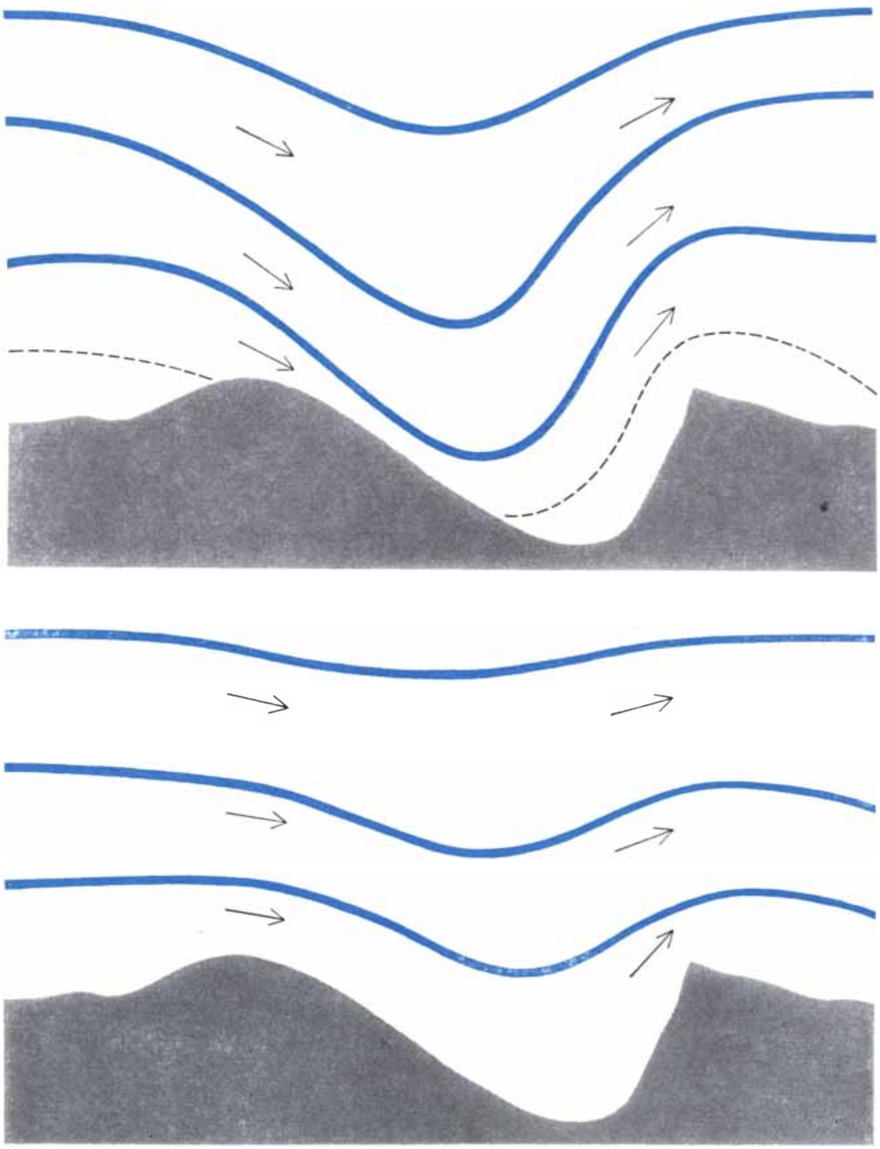
Wave clouds are usually free from turbulence. As a result, in shallow arched or thin lenticular wave clouds the size of water droplets will vary from the windward edge, where they have just been formed and are very small, to the center, where they have grown larger and fairly uniform in size in just a minute or two. In most other kinds of cloud, turbulence or other mixing processes jumble together cloud particles of all sizes. But wave clouds, in which the small size range is preserved, may display a spectrum of delicate iridescent colors, especially within an angle of about 20 degrees from the sun. If the cloud is small the colors may fill the whole cloud [*see illustration at middle left on page 127*]. In large clouds covering the sun the colors may lie more nearly in concentric rings around the sun. Although iridescent clouds are common, their colors can usually be seen only if dark glasses are worn to reduce the sun's brightness.



In the experiment at left two waves with a scale wavelength of 10 miles appear over the valley. In the experiment at right the flow rate has been increased about 50 per cent, resulting in a single large wave about 15 scale miles from trough to trough and with a scale amplitude of about 6,000 feet. These wave experiments were performed by Robert R. Long of the Johns Hopkins University.

Much less common are the ice clouds, which may stream for many miles from the downwind edge of a wave cloud. Usually the water particles that condense out in a wave cloud remain unfrozen even though the cloud temperature is many degrees below freezing. When the supercooled droplets are carried out of the cloud, they evaporate. If, however, the cloud is at or below 40 degrees below zero centigrade, the water droplets will freeze spontaneously [see "The Growth of Snow Crystals," by B. J. Mason; SCIENTIFIC AMERICAN, January]. Since ice crystals evaporate less readily than water droplets they may form long ice trails when they are swept out of the cloud.

Perhaps the most beautiful of all wave cloud formations are those sometimes seen in the Maritime Alps, and occasionally elsewhere. The French call these formations *une pile d'assiettes*—a pile of plates. They consist of a group of thin, arched clouds stacked neatly one above the other [*see illustration at bottom right on page 127*]. Evidently they are formed when the air is arranged in thin alternating layers of high and low humidity; the layers of high humidity cause the plates to appear in the wave crests. The reason for the layering is something of a mystery. A plausible explanation is one that invokes the action of a swift-moving, high-altitude current of air called the jet stream. The air in the jet stream is usually moist. If the jet should encounter a large mass of slower-moving, drier air, some layers of the jet would probably penetrate the mass farther than others, creating tongues of moist air interleaved with drier air.



LEE WAVES AT CAMPHILL, a British soaring center, had sailplane pilots mystified for years. Camphill, the usual launching point, is the ridge at the right. At times (*top*) when it is calm on the hill face (*area under dotted line*), the lee wave from the ridge to the left will create fine soaring conditions aloft. At other times (*bottom*) there will be plenty of wind on the hill face for launching, but there will be no good waves for soaring.

Once in a great while the gently undulating lee wave will set in motion a remarkable—and sometimes fearsome—air current called a rotor. This is a horizontal rotating cylinder of air that forms directly under the crest of a lee wave. Although certain curious cloud formations had suggested the existence of rotors, they seemed so improbable that many meteorologists, including the author, were skeptical. The skeptics were silenced by some observations of dust that revealed the air motion. A striking photograph made in the lee of the Sierra Nevada shows a massive wall of dust rising almost vertically from the floor of the Owens Valley to a height of 16,000 feet [*see illustration on opposite page*]. The wall of dust could have been raised only by a huge rotor.

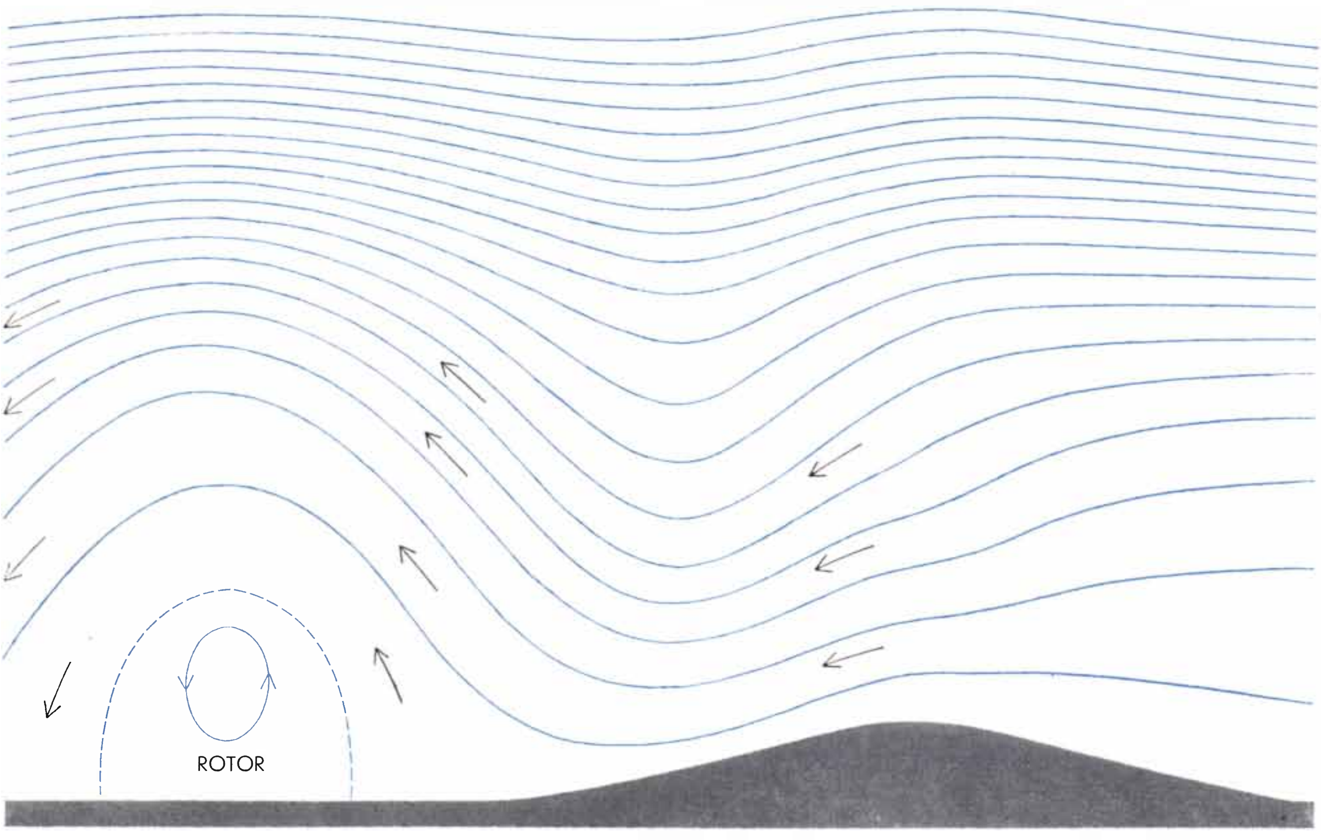
Meteorologists thereupon cracked their heads trying to explain the rotor's origin. Finally, in 1953, Robert R. Long of the Johns Hopkins University solved the problem. He calculated that when the amplitude of the waves was sufficiently large, the air under the crests (and sometimes above the troughs) could be set into rotary motion, while the main airstream passed around outside.

Sailplane pilots, accustomed to smooth sailing in lee waves, were totally unprepared for the rotor's violent turbulence. One sailplane was torn apart when it encountered a fragment of cloud in a rotor in the Sierra Wave. The pilot, Larry Edgar, was ejected with great force, and as he parachuted down half-conscious he was carried first to the east and then back westward again in the lower half of the rotor, finally coming to earth not far from the wreckage of his sailplane.

A still more insidious type of turbulence sometimes arises in lee waves. Since it is unaccompanied by clouds of any kind it is called clear-air turbulence. It appears in the transition region between a layer of strong winds and an overlying layer of lighter wind. Clear-air turbulence has been blamed for a number of otherwise inexplicable air crashes.

The standard instrument for charting winds aloft is the radiosonde balloon, which sends back temperature, pressure and humidity readings. When a radiosonde balloon is seen to follow a sinuous path, it is often because it is passing through lee waves [*see bottom illustration on page 128*].

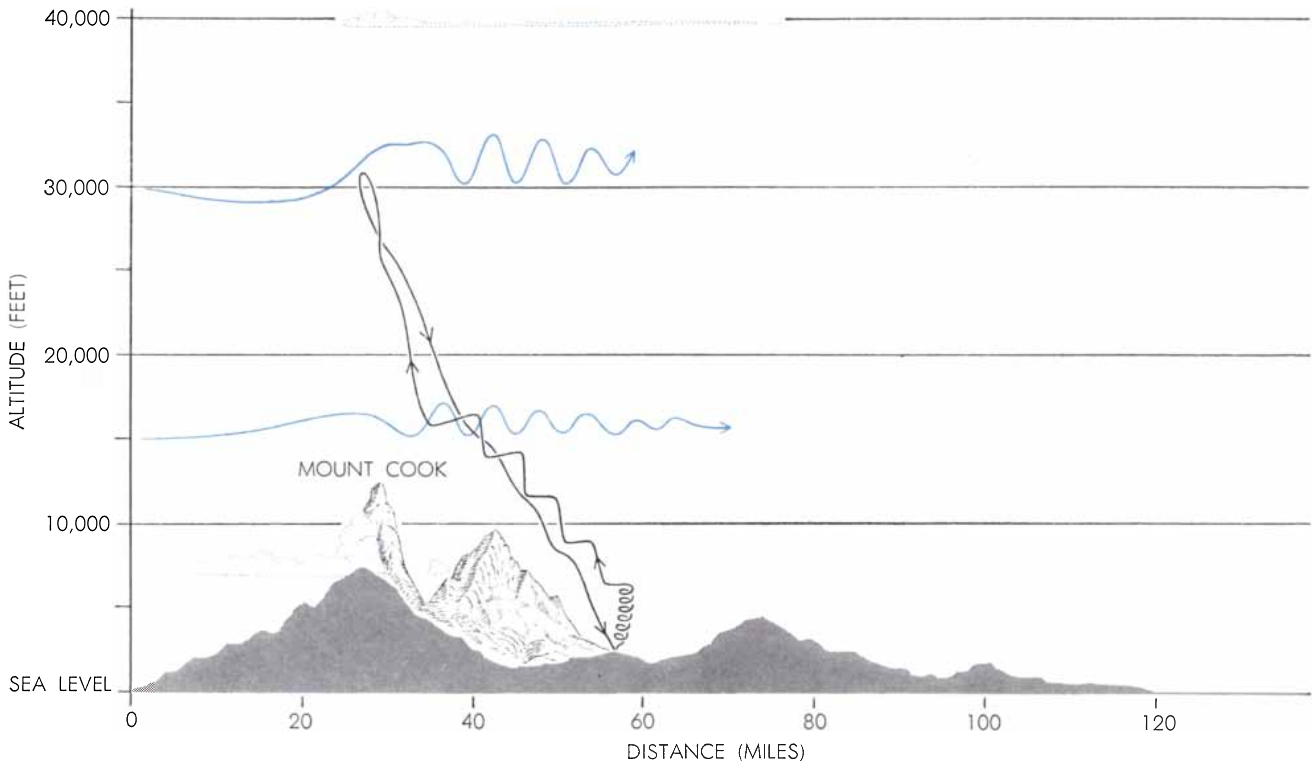
A much better way to study lee waves



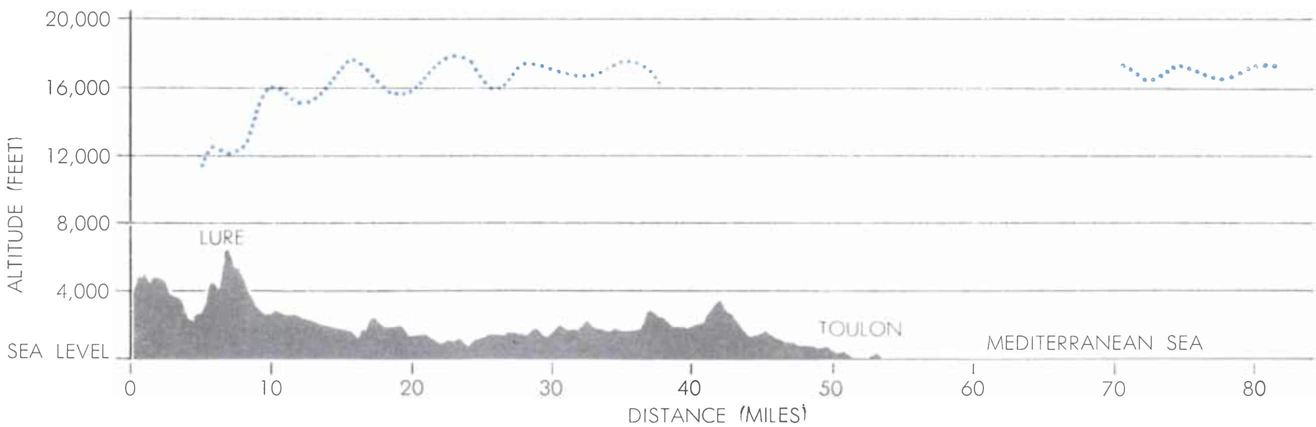
"ROTOR" IN THE SIERRA WAVE is vividly depicted in this rare photograph looking south along the lee slope of the Sierra Nevada. The westerly air currents are being warped into huge lee waves, giving rise to a line of wave clouds with almost perfectly flat lower surfaces. Beneath the clouds is the rotor, a swirling mass of air that is whipping dust from the floor of the Owens Valley and carrying it more than 16,000 feet straight up. The diagram shows how a rotor can develop under a lee wave of great amplitude.

is with the so-called constant-level balloon. This is a balloon encased in a tight silk or nylon envelope, which limits the balloon's expansion and thus fixes its density. Such a balloon will level off where the surrounding air density matches its own, and it will therefore follow the undulating path of lee waves. Meteorologists under Norbert Gerbier have used radio and radar to track many constant-level balloons released into the lee waves of the Maritime Alps. One spectacular flight revealed lee waves extending far over the Mediterranean [*see bottom illustration on this page*]. These waves—sometimes as many as 100 in succession—have also been detected by airline pilots. A pilot can count the waves by noting how many times he has to adjust the trim of his plane to maintain level flight.

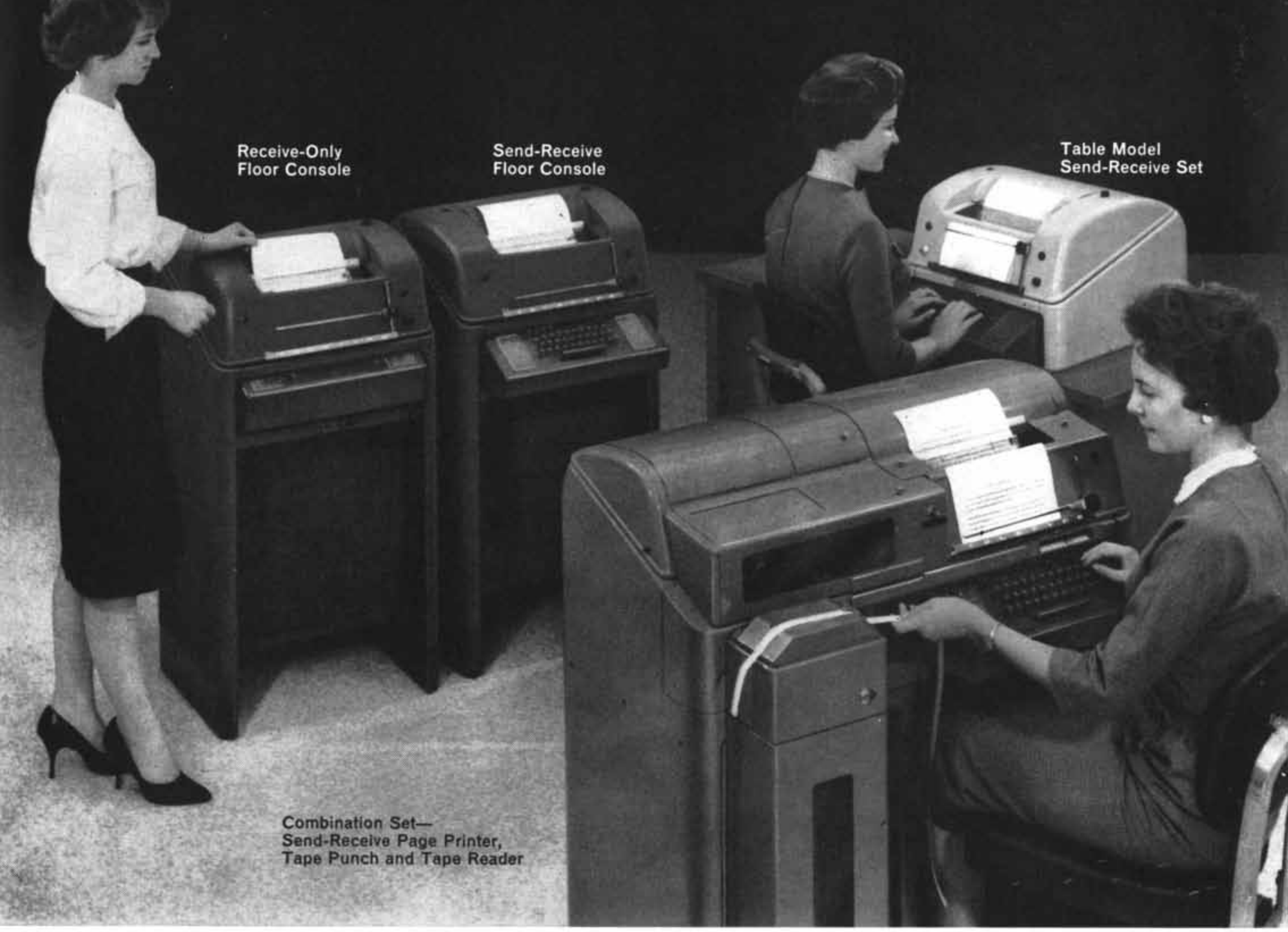
The history of our understanding of lee waves has been spasmodic. First noticed by cloud observers, the waves were almost forgotten for a generation until sailplane pilots recognized their possibilities. During the 1930's and 1940's, as air travel increased rapidly, the still mysterious lee waves caused many air disasters. Now, after a decade of close study, we believe we understand the waves quite well. Sailplane pilots the world over have learned to exploit them, airline pilots befriend them, and we have new insight into the geometry and color of cloudscapes.



MEMORABLE LEE-WAVE FLIGHT carried Philip Wills and his sailplane to 30,400 feet over Mount Cook. After being launched by a winch in the Mackenzie Basin, Wills circled upward in thermal currents until he felt the lift of the lee waves. He then soared toward Mount Cook in a series of hops from one wave to the next. When he reached the foremost and strongest wave he kept his sailplane headed into the wind and ascended almost vertically. Recalling the flight later, Wills described himself as "a very dusty middle-aged gentleman, in light summer clothes, nursing an uncomfortably bloated and borborygmal stomach. . . ."



LEE WAVES CREATED BY THE MARITIME ALPS have been tracked, with the aid of balloons, well out over the Mediterranean. In this flight the balloon was lost from radar view but was still undulating strongly when picked up again some 15 miles at sea. The special balloons used for these studies are designed to stay embedded in the air mass as it travels through a train of lee waves.



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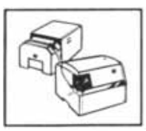
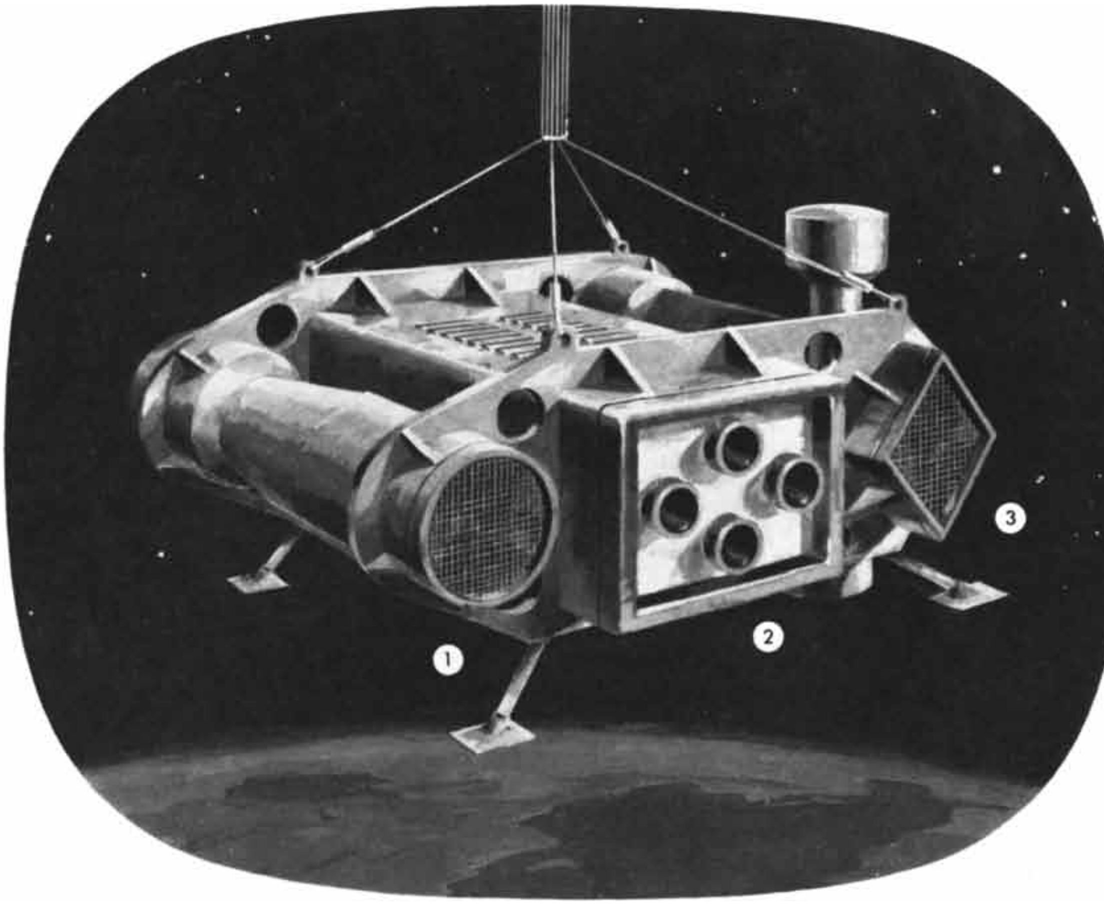

Tape Reader and Typing Tape Punch


Send-Receive Page Printer


Automatic Send-Receive Set

Opportunity report from General Mills Industrial Group



Stylized drawing of (1) large volume filter sampler, (2) four-barrel cascade particle sampler, (3) gas adsorption sampler.

What is present in the Upper Atmosphere? General Mills Research goes aloft for answers

Life as we know it exists in a delicately balanced environment surrounded and protected by the ocean of air which is the Earth's atmosphere. This "ocean" is the laboratory for scientists who believe that small, almost imperceptible changes in its composition may have a marked effect upon the various life forms currently occupying this planet.

At General Mills, basic and applied research studies in the fields of fine particle filtration and gas adsorption have led to the development of sophisticated high altitude probes. These sample large volumes of stratospheric air for trace gases and sub-micron particulate matter. One phase of this work dealing with man-made radioactive debris from nuclear tests has yielded a better understanding of the global fallout problem and atmospheric circulation patterns. Another aspect of interest involves the study of constituents that are of natural origin: meteor dust (elements and compounds produced by the action of sunlight and cosmic rays) and biological life in the form of micro-organisms.

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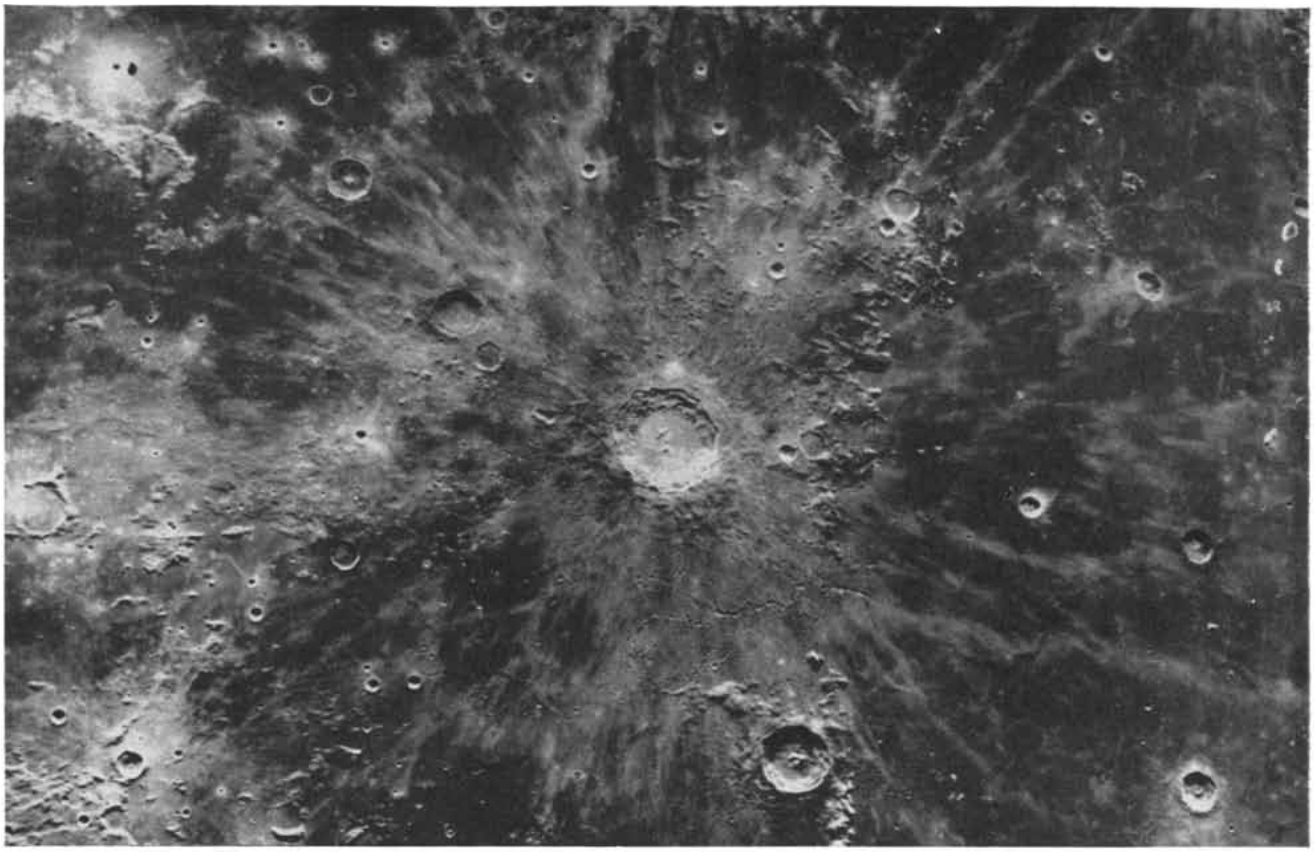


LUNAR CRATERS in the region around Copernicus (*large crater in center*) provide example of apparent reversal of depth that attends reversal of light-and-shadow relationships. When they are viewed upside down, the craters appear to be flat-topped mounds.

AERIAL VIEW of part of Los Angeles shows city sprawling at foot of hills, roads running through ravines. When photograph is inverted, the roads seem to wind along crests of the ridges, part of city (*top center when inverted*) seems to border on a chasm.

Shadows and Depth Perception

The ability to see that a surface curves toward or away from us depends upon how light and shadow are distributed. Investigators have undertaken to determine if the ability is innate or learned

by Eckhard H. Hess

The pictures on the opposite page present a familiar optical illusion. Viewed right side up, the craters of the moon are clearly craters, and the city sprawling at the foot of the hills in the bottom picture is clearly at the foot of the hills. But when the pictures are viewed upside down, the craters of the moon become curious flat-topped mountains, and part of the city seems to border on a chasm. [The cover of this issue of SCIENTIFIC AMERICAN presents the same illusion: viewed right side up, the Pre-Cambrian fossil impression appears in relief; upside down, the fossil sinks into intaglio.]

From common experience one knows that a bulge in a surface usually casts a shadow below it, whereas a depression in a surface usually has a shadow inside its upper edge. When these relationships are reversed, depressions appear as raised surfaces and raised surfaces appear as depressions. The illusion demonstrates our dependence upon the cues provided by light and shadow in seeing whether a surface curves toward us or away from us.

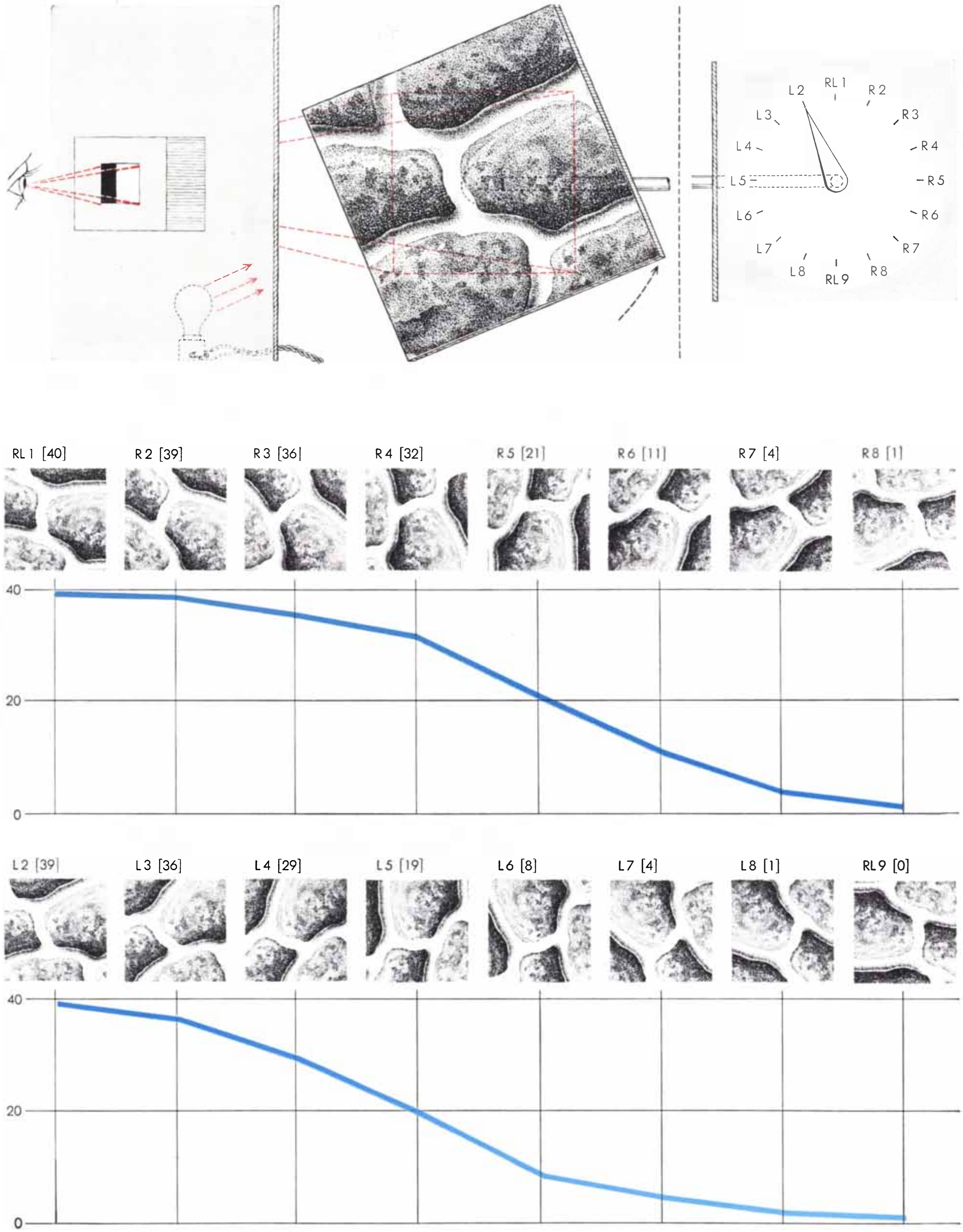
Probably the earliest report of this kind of optical illusion was made in 1613 by François d'Aguillon, a Flemish philosopher and mathematician. D'Aguillon observed that when buildings are viewed from a distance on overcast days, their sunken surfaces seem to protrude. Others reported similar instances of the illusion: objects viewed through optical instruments such as the microscope sometimes undergo apparent reversals of depth—what appears now in relief may appear again in intaglio. David Rittenhouse, an American mathematician and astronomer, suggested in 1786 that the reversal occurs because the observer is aware of the direction of the actual light source and takes this knowledge into account in his interpretation of the shaded and lighted areas in the inverted image presented by the microscope. Rittenhouse's explanation received support from Moritz Wilhelm Drobisch, a German scholar, who in 1842 postulated that experience engenders a "preference for relief," which makes it difficult to see in intaglio objects that are normally seen in relief.

In their explanations of the phenomenon both Rittenhouse and Drobisch assumed that learning and experience play the dominant role in determining the response to the cues of light and shadow. Modern psychologists tend to take this viewpoint but in general have failed to show how such learning takes place. Recent investigations of visual space perception have been developing evidence that some aspects of the faculty depend upon innate mechanisms. This finding is perhaps not so surprising in the case of cues furnished by the physiology of vision. Such cues include lens accommodation, in which the curvature of the lens of the eye adjusts to bring an object into focus; and the convergence (or the divergence) of the eyes, which fuses their separate images of a near (or distant) object. But the experimental evidence has also been pointing to the same conclusion in the case of psychological cues of depth, of which the light-and-shadow cue is one. Among the other psychological cues are interposition (the overlapping of a distant object by a nearer one), linear perspective (the converging of parallel lines), aerial perspective (the haziness of distant objects) and motion parallax (which causes near objects to appear to move faster than distant ones).

A group of investigators at Cornell University has shown, for example, that space perception by the use of motion parallax is clearly innate in rats, cats, sheep and human infants. They placed their subjects on a "visual cliff," a pane of clear glass bridging a sunken surface, and found that the young animals avoided the glass-covered pit as soon as they were able to see and move about on their own [see "The 'Visual Cliff,'" by Eleanor J. Gibson and Richard D. Walk; SCIENTIFIC AMERICAN, April, 1960].

In our work at the University of Chicago we have shown that in the chick at least one physiological cue of space perception is innate. We placed prisms over the eyes of newly hatched chicks before they had had any significant visual experience. The prisms displaced the visual field of the chicks to the right or left. We then observed their success in pecking at kernels of wheat and other objects. Had they adjusted to the skewing of their spatial perception and become able to strike what they pecked at, this would have been clear evidence of learning. As it was, they invariably missed their targets and did not learn to allow for the displacement of their visual field.

There was not sufficient experimental evidence, however, to determine that the response to the light-and-shadow cue is innate. As recently as 1936 Wolfgang Metzger, a psychologist at the University of Münster in Germany, suggested that the reversal of depth attending the reversal of light and shadow arises from the habit of reading with light over the left shoulder. The habit, he argued, causes one to "assume" a light source at the upper left when the source of the light is in fact not apparent. On the other hand, Kai von Fieandt, a Finnish child psychologist, had observed in 1938 that such illusory reversals of depth are no less frequent among preschool children, in spite of the fact that they have had little reading experience. Von Fieandt postulated instead that an innate mechanism makes ambiguous images appear



APPARATUS TO TEST DEPTH PERCEPTION cued by light and shadow consists of picture of flagstones (*top center*) mounted on shaft in viewing box. Subject (*top left*) could not see edges of picture or light source. Movement of lever (*top right*) rotates picture, presents subject with views shown in small pictures (*middle and bottom*). First numbers above small pictures correspond to settings on lever dial; bracketed numbers give subjects' responses, which are also plotted on graphs. All subjects saw upright picture (*RL1*) in relief. As picture occupied positions up to 90 degrees away from *RL1*, progressively fewer saw it in relief. At *R5* or *L5* (halfway to inversion) approximately half saw picture in relief and half saw it in intaglio. As picture approached inversion, intaglio responses increased. All subjects saw inverted picture (*RL9*) in intaglio. Graph on page 142 gives subjects' impressions of direction of light.

as though they are illuminated from above. Neither Metzger nor Von Fieandt, however, systematically investigated the problem, so the question of innateness or learning was not settled.

Our first experiment inquired into Metzger's contention that the observer assumes a light source at the upper left. Our testing apparatus was built around a picture of flagstones set in a bed of mortar. As the reader can see for himself, the stones seem to protrude from the mortar when the picture is presented in one orientation and seem to recede into the mortar when the picture is inverted [*see illustration on opposite page*]. The picture was mounted on a rod so that we could rotate it through any angle, and the assembly was placed at the rear of a viewing box. The subject peered into the box through a small hole surrounded by a baffle, which restricted his field of view so that he could not see either the edges of the picture or the light bulb, which threw a flat illumination on the picture from the bottom of the box. Each of 20 subjects looked through the peephole and reported whether he saw the stones in relief or in intaglio and from which direction he thought the light was coming for each of 16 around-the-clock positions of the picture.

All the subjects were able to decide quickly whether they saw the stones sunk in the mortar or protruding from it, and all had clear impressions about what they saw each time they looked at the picture. But they had some difficulty in deciding where the light was coming from. When the picture was presented right side up all the subjects agreed that the stones appeared in relief. If the picture was presented to the viewer in any of several positions up to 90 degrees to the right or left of upright, the illusion of relief again occurred. In most cases the light source was reported to coincide with the angle at which the picture was tilted. If the picture was presented in positions that were beyond 90 degrees to the left or right of upright, most subjects saw it in intaglio. The reported direction of the light source no longer coincided with the angle at which the picture was tilted but appeared to be 180 degrees away. Apparently the subjects assumed most often that the source of the light was above the horizon, and the reversal of the picture into intaglio resulted from their continued assumption of the same location for the light.

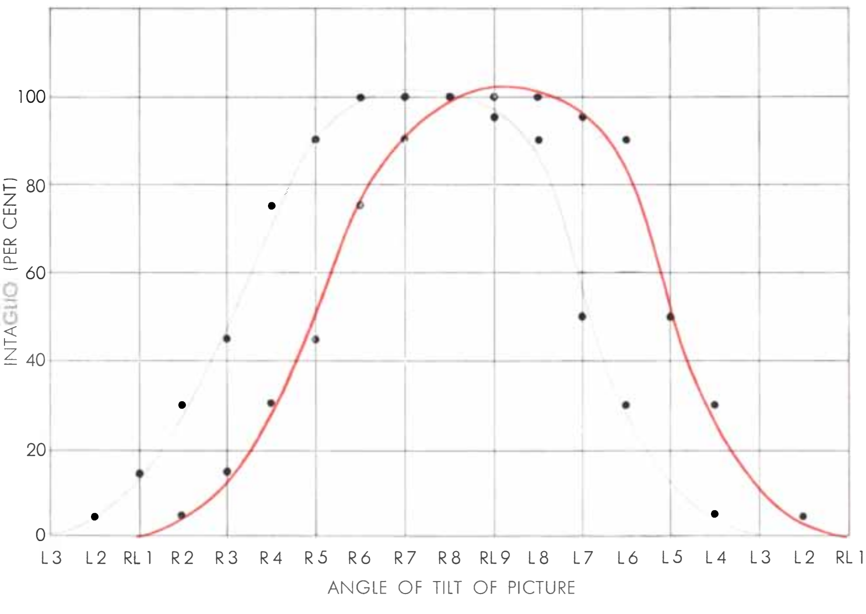
There were a few who reported the light as coming from below the horizon; no one, however, reported it as coming from directly below the picture. The colored curve in the illustration at the bottom of this page shows the percentage of "intaglio" responses made to each position of the picture. The gray curve shows the percentage of intaglio responses that would be expected on the basis of Metzger's hypothesis that the light is assumed to come from the upper left. Obviously our results do not support his hypothesis; rather, the light is assumed to come from above.

The location of the bulb that illuminated the interior of the box seemed of no consequence; although it rested at the bottom of the box, no one thought the light in the picture came from there. Nor did moving the bulb to other parts of the box affect the results. The subjects' perception of depth was obviously not the result of their deliberately analyzing how light and shadow were distributed in the picture but was a spontaneous impression, corresponding in almost every case to the angle at which the picture was tilted. (If the reader tries to reconstruct the direction of the light in the photographs on page 138 when they are inverted, he will find that his effort has little effect upon what he sees.)

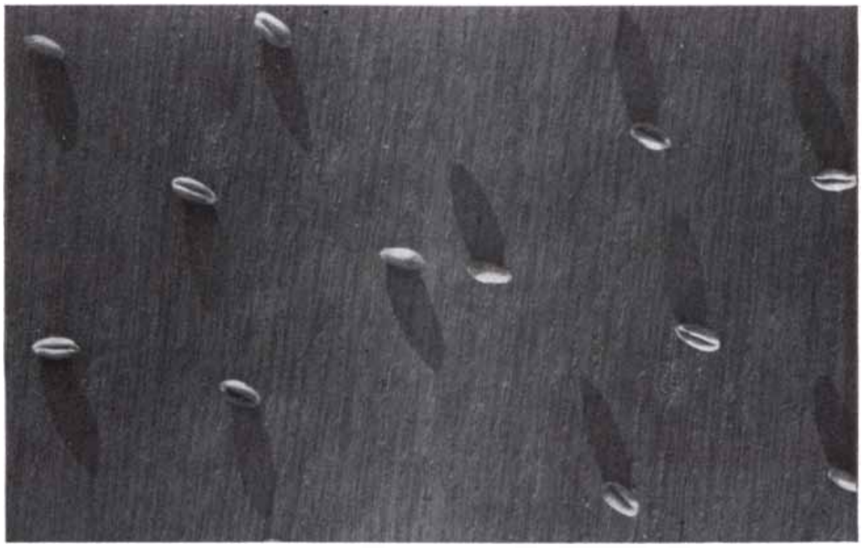
The results of this experiment could be interpreted in one of two ways. Since the light in normal visual experience must often come from above—sunlight, for example, is always above and never below the horizon—one may learn to tell depth by means of experience with light-and-shadow patterns. On the other hand, it could still be argued from our experiment that people have an innate perceptual mechanism that makes them see the light as coming from particular directions when its source is uncertain. In either case the tendency is so ingrained that most people see a "strange" quality in human faces and other objects when they are lighted from below.

Our problem now was to determine whether learning or some innate faculty is involved in the interpretation of the light-and-shadow cue. We again used chicks because we could easily control their visual environment from the moment of hatching. Our idea was to raise chicks in cages in which all the light came from below and then see how their depth perception functioned as a consequence of this experience.

We submitted several chicks to preliminary tests in order to ascertain their normal preferences. A naturally colored photograph of wheat kernels illuminated from above was placed side by side with an identical but inverted photograph [*see top illustration on page 144*]. Only the shadows on the photographs gave any clue of depth; all other depth cues were absent. The chicks pecked far more



PERCEPTION OF INTAGLIO in experiment illustrated on page 140 is plotted (*colored curve*). Horizontal scale is angle to which picture is tilted; vertical scale, percentage of intaglio responses at each angle. In positions *L4* through *R4* (within 90 degrees of upright) picture was seen in relief; light source was generally assumed to coincide with angle to which picture was tilted. From *R5* through *L5* (beyond 90 degrees) picture was increasingly seen in intaglio; light source was assumed to be 180 degrees away. Black curve plots responses that would have occurred had subjects assumed light source at upper left. Wolfgang Metzger, an early investigator, suggested depth perception depended on this assumption.



CHICKS' CHOICE of photograph of grain lighted from above (*left*) or from below (*right*) was affected by their early experience. Pictures were used in experiment illustrated below.

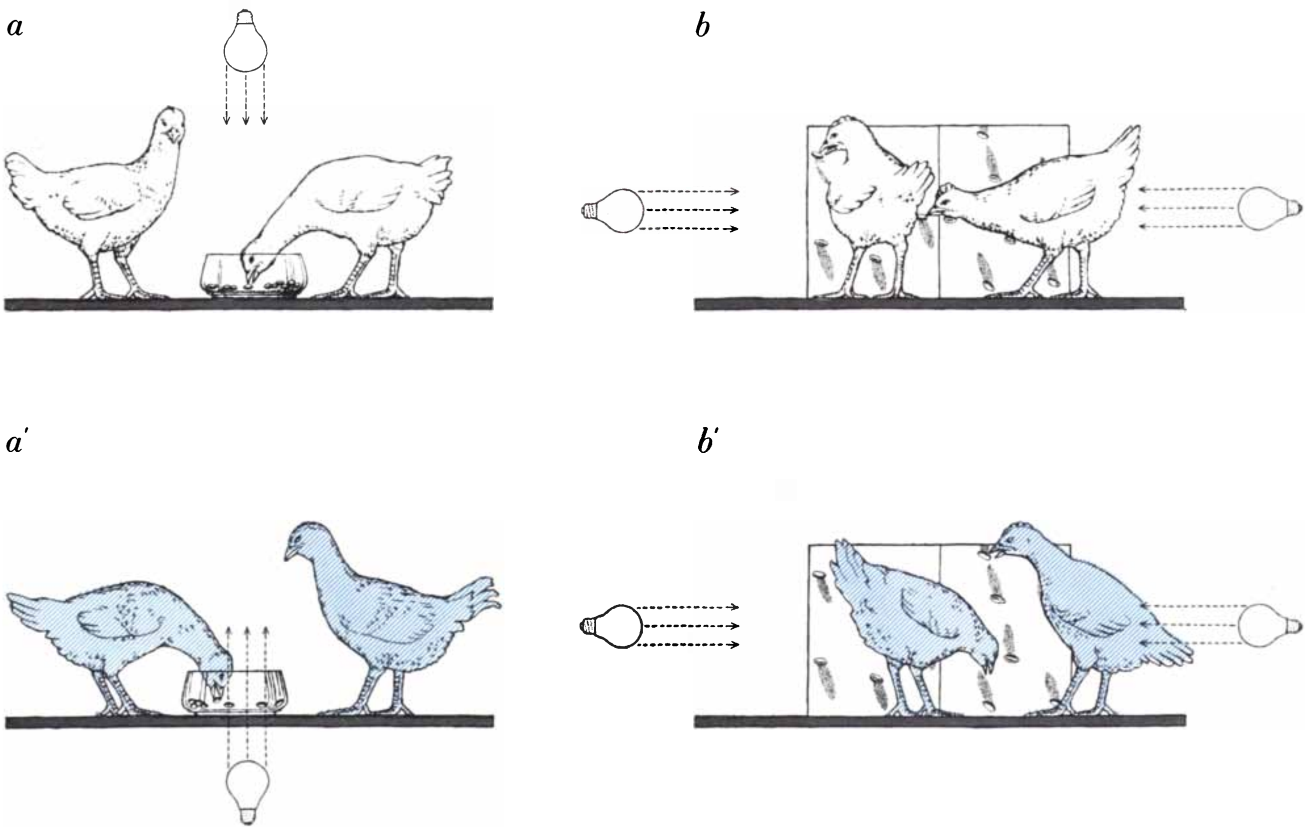
frequently at the picture of the toplighted grain. We then proceeded with the experiment.

One group of 42 chicks lived from the time of hatching in cages lighted from below and draped at the top to eliminate stray light; they ate from glass or wire containers so that their grain was lighted from below. A control group of 41 chicks was raised, also for seven weeks from the time of hatching, in identical cages lighted from above and opaque at the bottom.

When the chicks were seven weeks old we began our tests. We deprived them of food for six hours in order to motivate them to peck, and placed them two at a time in an enclosure where the right-side-up and inverted pictures of grain were evenly illuminated by bulbs at the left and right.

Out of the 25 control chicks that responded at all, 24 pecked first at the photograph of grain illuminated from above; out of the 22 chicks from the bottom-lighted cage that responded, 22 made their first peck at the photograph of grain apparently lighted from below. The chicks' over-all performance was equally decisive: in terms of total pecks at the two pictures, half of the control chicks delivered 80 per cent or more (median percentage) of all their pecks to the right-side-up photograph, whereas half of the experimental chicks delivered all of their pecks to the inverted photograph. This was persuasive evidence that the response to the cue of light and shadow is the product of learning and experience.

In order to eliminate any question that the general illumination of the test cage affected the results, we repeated the test a week later. This time we exposed both groups of chicks to reversal of their early visual experience. For the control group the test cage containing

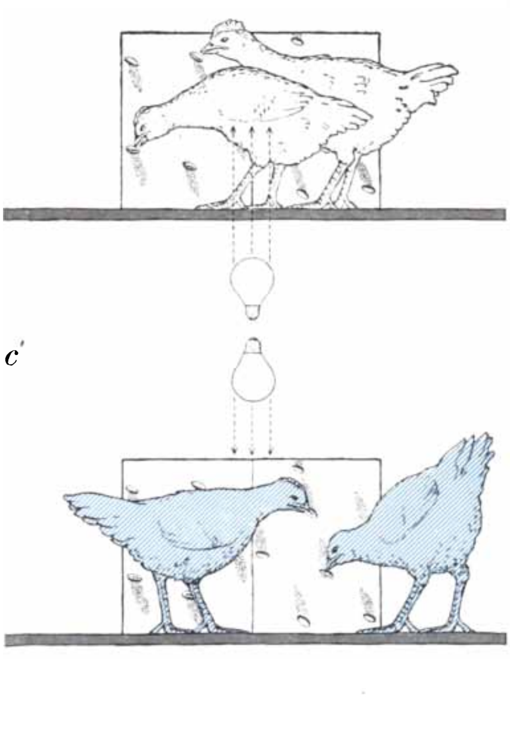


EFFECT OF EARLY EXPERIENCE on perception of depth by means of light-and-shadow cues was investigated by raising chicks in cages in which all light came from below (*a′*). In chicks' seventh week they were exposed to flatly illuminated photograph shown in illustration at top of this page. Chicks delivered most pecks to photograph of grain lighted from below (*b′*). Control group raised in identical but toplighted cages (*a*) delivered most pecks to photograph of grain lighted from above (*b*). In second part of test photographs were illuminated by sources opposite to those under which chicks grew up. Chicks from toplighted cages, now eight the photographs was illuminated from below; for the experimental chicks the cage was lighted from above. This change did not affect the chicks' preferences any more than shifting the illumination in the experiment with humans had affected theirs. Of 30 control chicks that responded, 28 first pecked at the toplighted photograph; of 33 experimental chicks that responded, only two made that choice. Half of the control chicks delivered 80 per cent or more of their total pecks to the toplighted photograph, while half of the experimental chicks delivered 86 per cent or more (median percentage) of their pecks to the bottom-lighted photograph. Reversal of the test illumination had little or no effect on the chicks' perception of depth by means of light-and-shadow cues. Early conditioning to these cues would therefore seem to be so strong that it overrides the effect of the actual light source in any given instance.

The demonstration that the response is learned raised the question of how and when this learning occurs. We tested 13 chicks as soon as possible after hatching, before they had had any visual experience. They showed no preference for either photograph, thus confirming

c

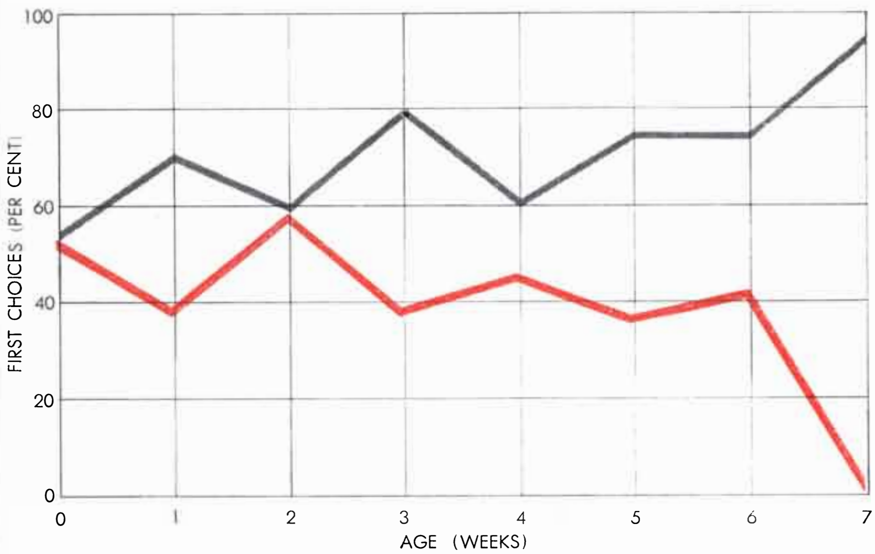
c′



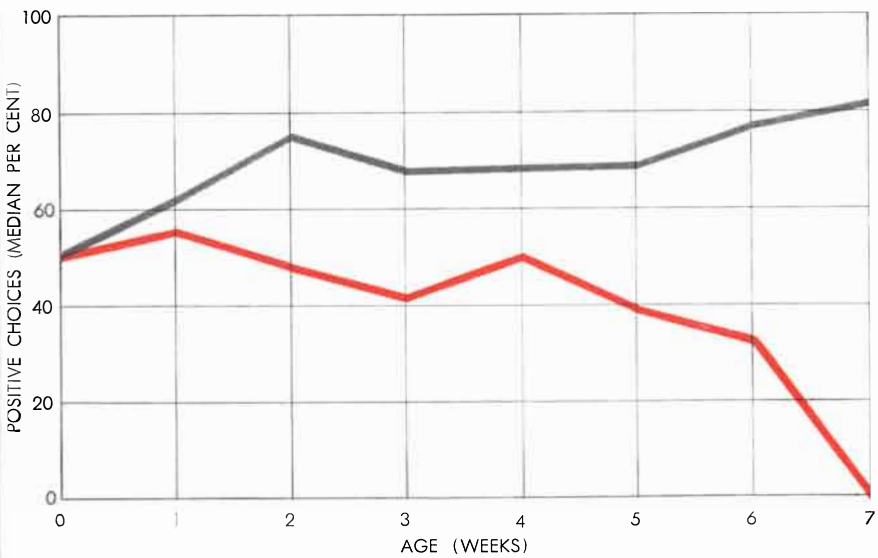
weeks old, still chose photograph of grain lighted from above (*c*) ; chicks from bottom-lighted cages still chose photograph of grain lighted from below (*c′*). Detailed results of experiment appear in graphs on page 146.

that the response is not innate. We then submitted separate groups of about 10 newly hatched chicks—for periods of one, two, three, four, five and six weeks—to the routines of our first experiment, after which they were tested in the same manner. The control chicks in each age group usually delivered their first pecks to the toplighted photograph, and those from the bottom-lighted cages usually pecked first at the bottom-lighted photograph. But although the trend of their preferences was apparent from the age of three weeks on, statistically significant preferences did not emerge until the fifth week for the normal chicks and the seventh week for both groups [*see illustrations on this page*].

The reasons for the sharp divergence in preference between the control and



FIRST PECKS of chicks of various ages at photograph of toplighted grain reproduced on page 144 show effect of early visual experience. No preference was shown by newly hatched chicks, but effect of environment began to emerge in three-week-old chicks. Those from toplighted cages (*gray curve*) increasingly chose photograph of grain lighted from above; those from bottom-lighted cages (*colored curve*) increasingly avoided toplighted photograph, chose bottom-lighted one instead. Difference was decisive among seven-week-old chicks.

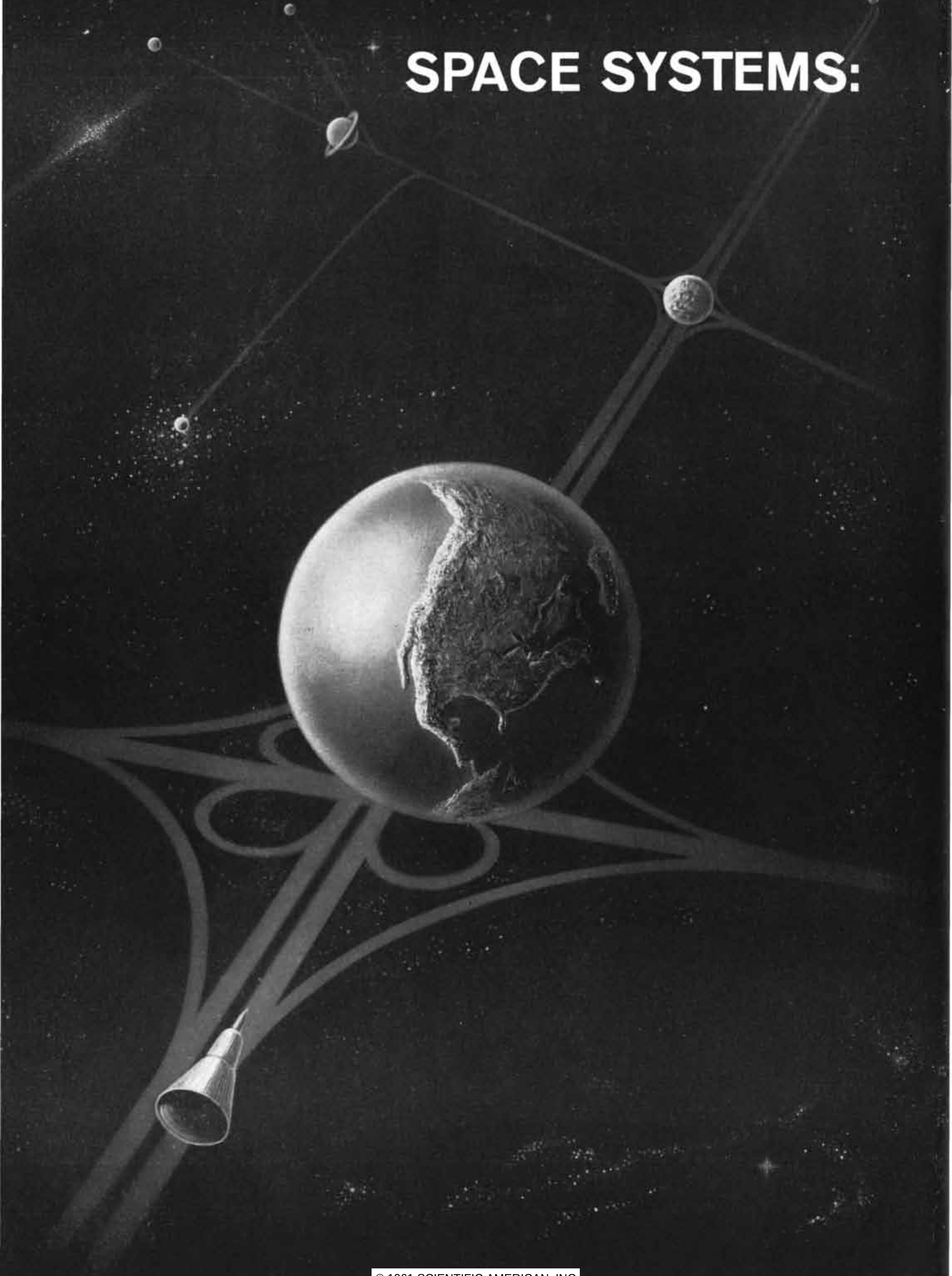


TOTAL PECKS delivered by chicks bear out results expressed by first pecks plotted in top graph. Gray curve shows that half the chicks from toplighted environment deliver most of their pecks to photograph of grain lighted from above. Colored curve shows that half of chicks from the bottom-lighted environment avoided the photograph of grain lighted from above and delivered most of their pecks to the photograph of grain lighted from below.

experimental chicks during the seventh week are not clear. It may be attributable entirely to unavoidable differences in the conditions of the two experiments—the seven-week-old chicks in the first experiment were not so tame as those in the second experiment. The latter had experienced the weekly removal of small numbers of chicks. The sudden emergence of preference in the chicks in their seventh week suggests, however, that their neurosensory organization may be going through a critical period of maturation at that time. That the control chicks responded to the light-and-shadow cues somewhat sooner than the experimental chicks leaves some ground for arguing in favor of the presence of an innate preference for toplighted objects—a possibility that might be tested by rearing chicks in a shadowless environment or an environment in which the light source is placed alternately at the top and bottom. Such experiments might also test the possibility of reversing what the chicks had previously learned.

It is evident that experience alone can be decisive in influencing responses to the distribution of light and shadow in objects. In the case of chicks the response apparently reaches an adequate stage of development as early as five weeks. Taking this information together with what is known about human behavior in this respect, it appears that experience plays the determining role in the development of this mode of perception in humans as well.

The finding that depth perception from light-and-shadow cues is not innate seems eminently reasonable. Nature is, by and large, lighted from above and rarely presents these cues in ambiguous arrangements. Moreover, in the life history of most animals there is little need to make this kind of discrimination immediately after birth. On the other hand, some types of visual depth perception seem to require innate mechanisms. The response to motion parallax (as in the visual cliff, for example) must be in functioning order as soon as a young animal can walk, if it is to avoid falling from an actual cliff. In addition, the ability to locate food objects in space is needed by the chick as early as three days after hatching. In any case the perception of depth by means of light-and-shadow cues comes along quickly enough with experience. During the first few weeks of life, preference in the interpretation of the cues begins to go in the direction that is demanded by the environment.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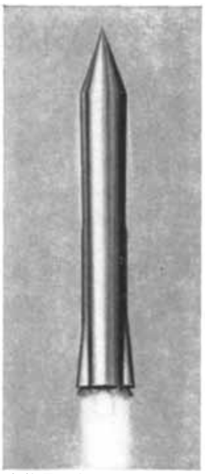
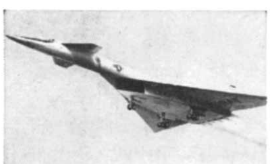

CENTAUR


BOMARC-B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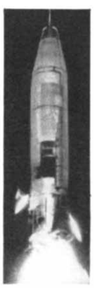
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MONOMOLECULAR FILMS

Many physical, chemical and biological processes involve thin films of material at surfaces. In these processes the most important role is played by a film just one molecule thick

by Herman E. Ries, Jr.

In nature and in the laboratory many of the most interesting events take place at the surfaces of substances. Surfaces are invariably interfaces; that is, at every surface two material systems are always in contact and interacting. Matter in its three states forms five interfaces: solid-solid, solid-liquid, solid-gas, liquid-liquid and liquid-gas. At almost all interfaces the interaction between the systems is mediated by thin films.

Thin films fully warrant the careful attention that has made investigation of them an important discipline of physics and chemistry. At the solid-liquid interface of a bearing and its lubricant a thin film reduces friction and wear. Thin films at the solid-gas interface between the catalyst particles and the reactant stream in a chemical reactor are the site at which the chemical reactions take place. A thin film of a long-chain alcohol spread on the surface of a reservoir reduces evaporation at the liquid-gas interface of water and air and serves as a highly effective means of water conservation. Living systems abound in interfaces; at many of these interfaces thin films containing proteins, cholesterol and related substances make up the biological membranes that organize and control the complex chemistry of living matter.

In every case the ultimate film—the one actually in contact with the surface—is one molecule thick. This monomolecular film, or monolayer, is bound more strongly to the surface than any succeeding layer above it. In almost every physical, chemical and biological process that involves thin films, the monolayer plays the most important role.

Present knowledge of monolayers comes mostly from the study of the oily or soapy films that are formed on the surface of water by relatively large insoluble molecules. Such films were the subject of early investigations in this field by Irving Langmuir and William D. Harkins in the U. S. and by N. K. Adam and Eric K. Rideal in England. Over the past 40 years the work has shown the way to the design of useful films and the control of surface phenomena. It has also contributed to a clearer visualization of the individual molecules of film-forming substances, of their size and shape and the location of their "charged" active groups.

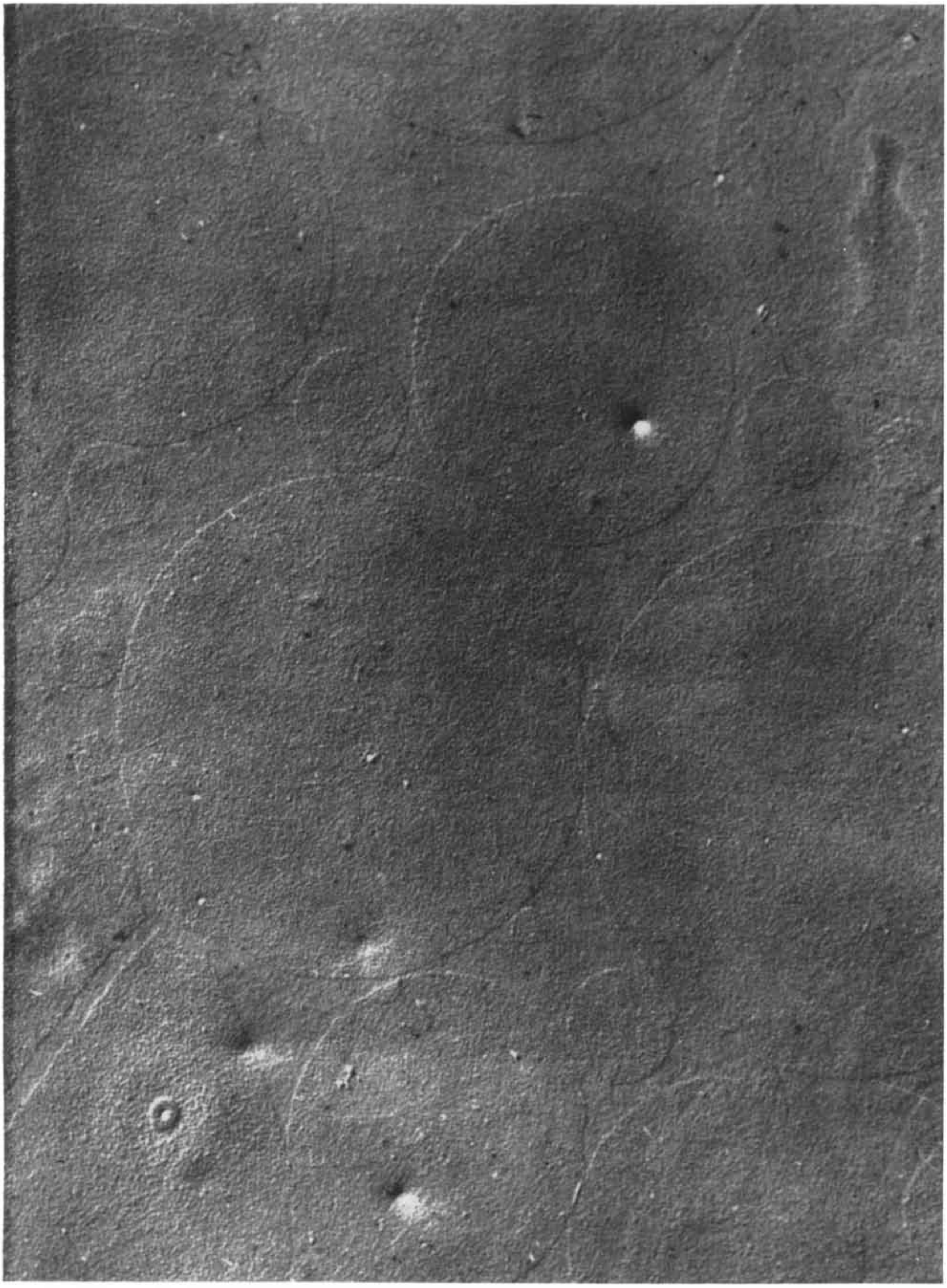
The so-called film balance, devised by Langmuir in 1917, remains the principal instrument for the study of monomolecular films. Its range has recently been extended by the electron microscope and the use of radioactive isotopes. But the basic work is done with the film balance. This is one of those very few classically simple devices—comparable to the centrifuge, the viscometer, the osmotic column and the light-scattering tank [see "How Giant Molecules Are Measured," by Peter J. W. Debye; Scientific American, September, 1957]—by which one can make primary measurements of the properties of individual molecules.

Essentially the film balance consists of a small, shallow trough filled with water, on which the monolayer is spread. A bar or barrier laid across the trough behind the monolayer is driven by a high-precision screw and made to push the leading edge of the film against a delicately suspended floating barrier (the "float"), which measures the pressure exerted by the film as it is compressed [*see illustration on page 156*].

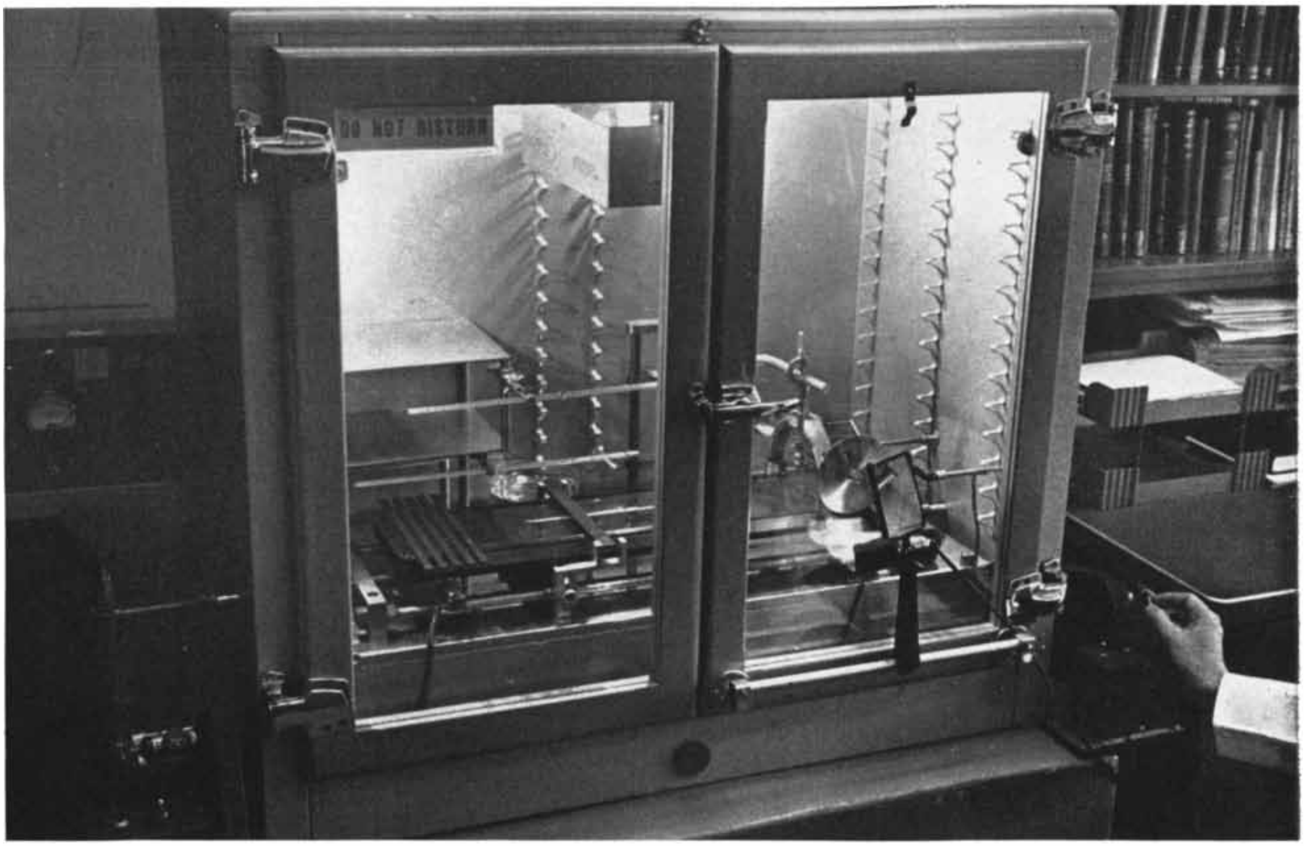
Because temperature affects the behavior of the film the entire apparatus is housed in a thermostatted cabinet. Great care is taken to avoid contamination; a single dust particle in the monolayer could cause major errors in the film-balance measurements. Before each experiment the entire apparatus is thoroughly cleaned. Small brass bars are used to sweep the water surface clear of contaminating material before the monolayer is spread on the surface. Vibration is minimized by mounting the entire apparatus on a heavy concrete base. In order to obtain a water surface higher than the edges of the trough, the trough itself and all the working parts are coated with a paraffin wax, or with Teflon, a fluorocarbon. The water does not wet such a coating; where the water meets the coating, therefore, its surface has a positive meniscus (that is, it curves downward) and can be raised high enough to interpose the monolayer between the barrier and the float.

The film is spread on the water surface as follows. A few drops of a dilute solution, containing about .01 milligram of the film-forming compound in a volatile solvent such as benzene or hexane, are deposited. The amount of compound to be deposited is precisely measured (in a special weighing pipette) so that the number of molecules present can be computed from the known molecular weight of the material. Upon evaporation of the solvent the compound forms a film just one molecule thick on the area between the barrier and the float. This area is large enough (usually more than 500 square centimeters) to allow the molecules in the "two-dimensional fluid" of the film ample room to move freely on the surface.

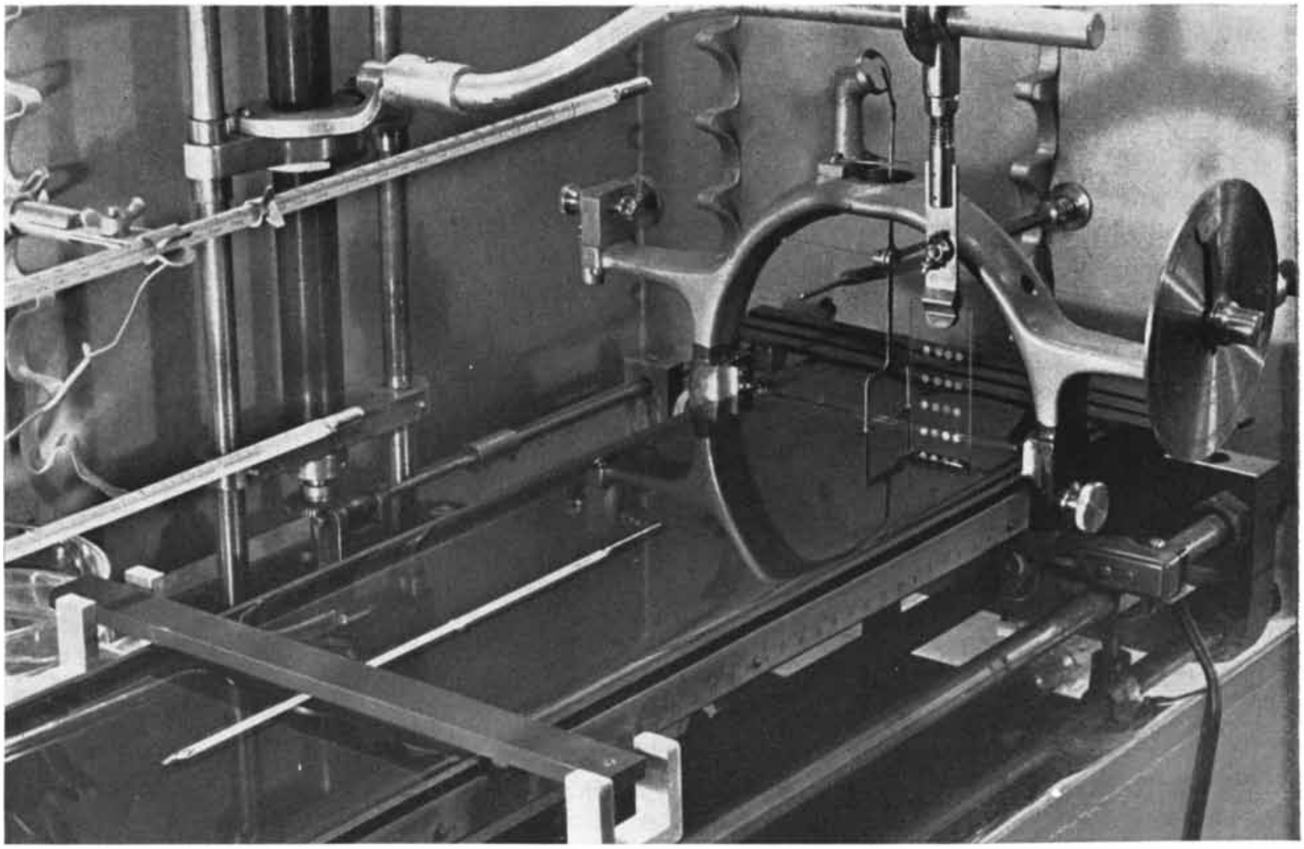
The compound traditionally used to form monolayers is stearic acid, a fatty acid. Consisting of a long, straight hydrocarbon chain with a charged, or polar, group at one end, the stearic acid molecule is among the simplest film-forming molecules. As in the case of some oil molecules, the polar group is strongly



"ISLANDS," or aggregates of molecules, in monomolecular film of stearic acid are circular at surface pressure of 10 dynes per centimeter. Film (enlarged 19,000 diameters in this electron micrograph) rests on collodion support. Wayne A. Kimball and Norman Isaacs of the Whiting Research Laboratories of the American Oil Company made this micrograph and those on page 164.



THERMOSTATTED CABINET houses film balance, maintaining constant temperature during experiments. Surface-pressure data on the indicator dial (*small disk at lower right*) is read through the magnifying glass. The cabinet rests on a heavy concrete base.



FILM BALANCE is basically a water-filled trough, with a compression barrier (*bar at lower left*) and a mica float (*thin strip across other end of trough*). Samples of the film are removed on small screens attached to vertical glass plate in front of float.

attracted to the polar water molecules, whereas the nonpolar chain is only weakly attracted. As a result many of the molecules tend to stand straight up on the water surface. At the beginning of the experiment, however, with ample space between the barrier and float, some tend to lie down. As the barrier moves toward the float, reducing the surface area in small decrements, all the molecules begin to be oriented vertically under the increased compression. The random horizontal motion and the electrical repulsion of the molecules in the film resist this compression and thus generate a surface pressure.

Area and pressure readings are taken simultaneously throughout the experiment. A linear scale at the side of the trough provides the area data. The pressure of the film against the float is balanced by twisting the torsion wire to which the float is attached. The degree of twisting that is required to keep the float stationary is a measure of the surface pressure, which is expressed in dynes per centimeter. Compression is increased until the pressure remains constant or falls, that is, until the film "collapses."

The single simple plot of pressure against area yields a surprising amount of significant information. Among other things, one may derive the cross section and length of the molecule, the approximate location and strength of its polar groups and the approximate strength of the cohesive forces between the molecules.

The slope of the curve shows the decrease in area with increase in surface pressure and so measures the compressibility of the monolayer. The curve for stearic acid, for example, has a steep slope, which indicates that increase in pressure brings only a small decrease in area. Low compressibility is a sign that the molecules pack rather tightly even at low pressure, and that the cohesive forces between the stearic acid molecules are considerable.

Because the number of molecules present in the monolayer is known, the average area in which each molecule is free to move at different successive points on the pressure-area curve is easily calculated. Extension of a line from the steepest part of the curve to zero pressure gives the cross-sectional dimension of the molecule, or strictly speaking the area the molecule would occupy if it were under no compression at all [*see top illustration on page 161*]. For stearic acid the area is 20 square angstrom units

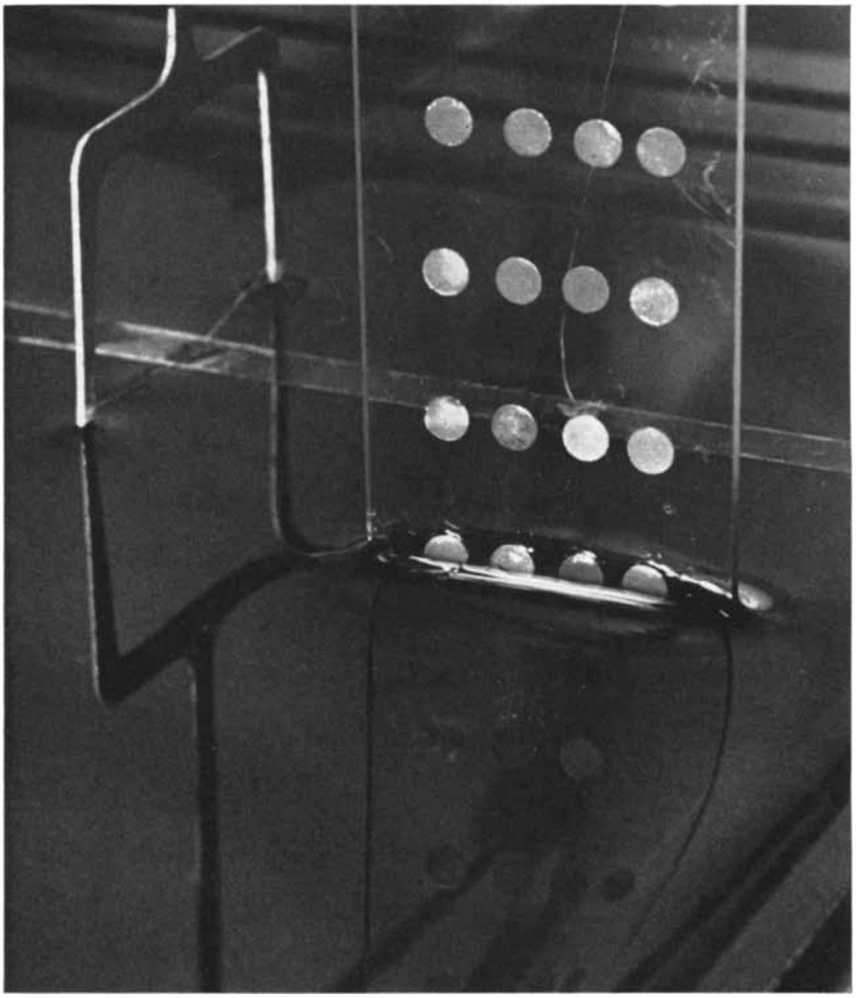
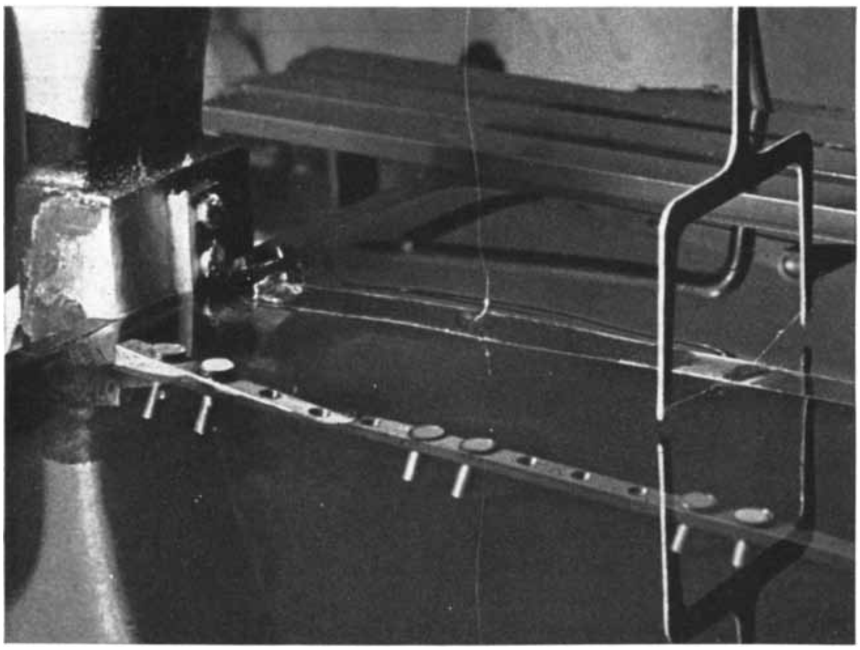
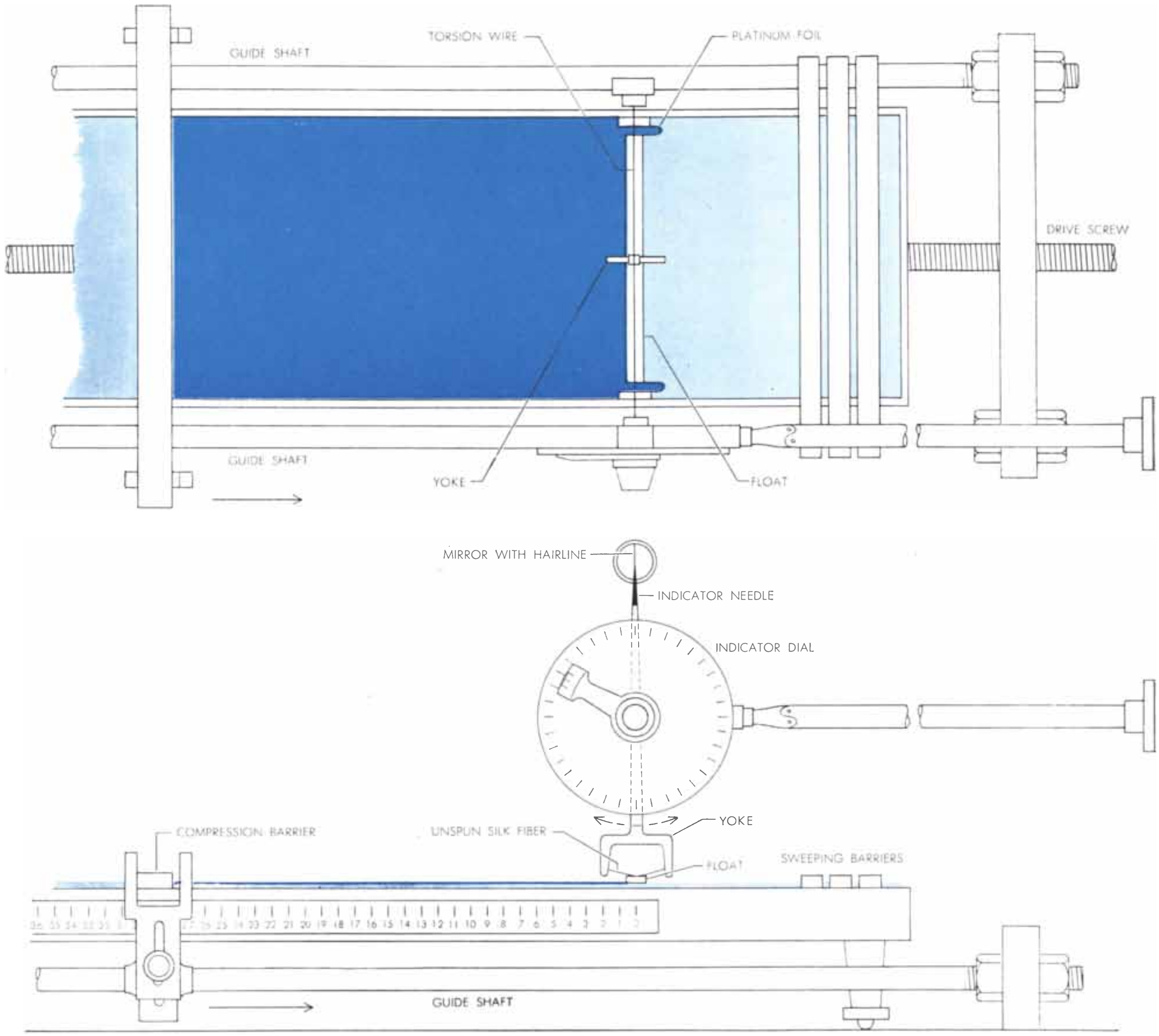


PLATE METHOD of removing film samples at different stages of compression involves raising a glass plate vertically through the film. Film adheres to small screens attached to plate. Positive meniscus of film at side of trough causes a highly distorted reflection.



CUP METHOD of removing film samples requires a bar in which one or more shallow cups can be inserted. Bar (*shown here with six cups*) is slowly raised through the film by an extension arm (*not shown*). Each cup contains a coated screen to support the sample.



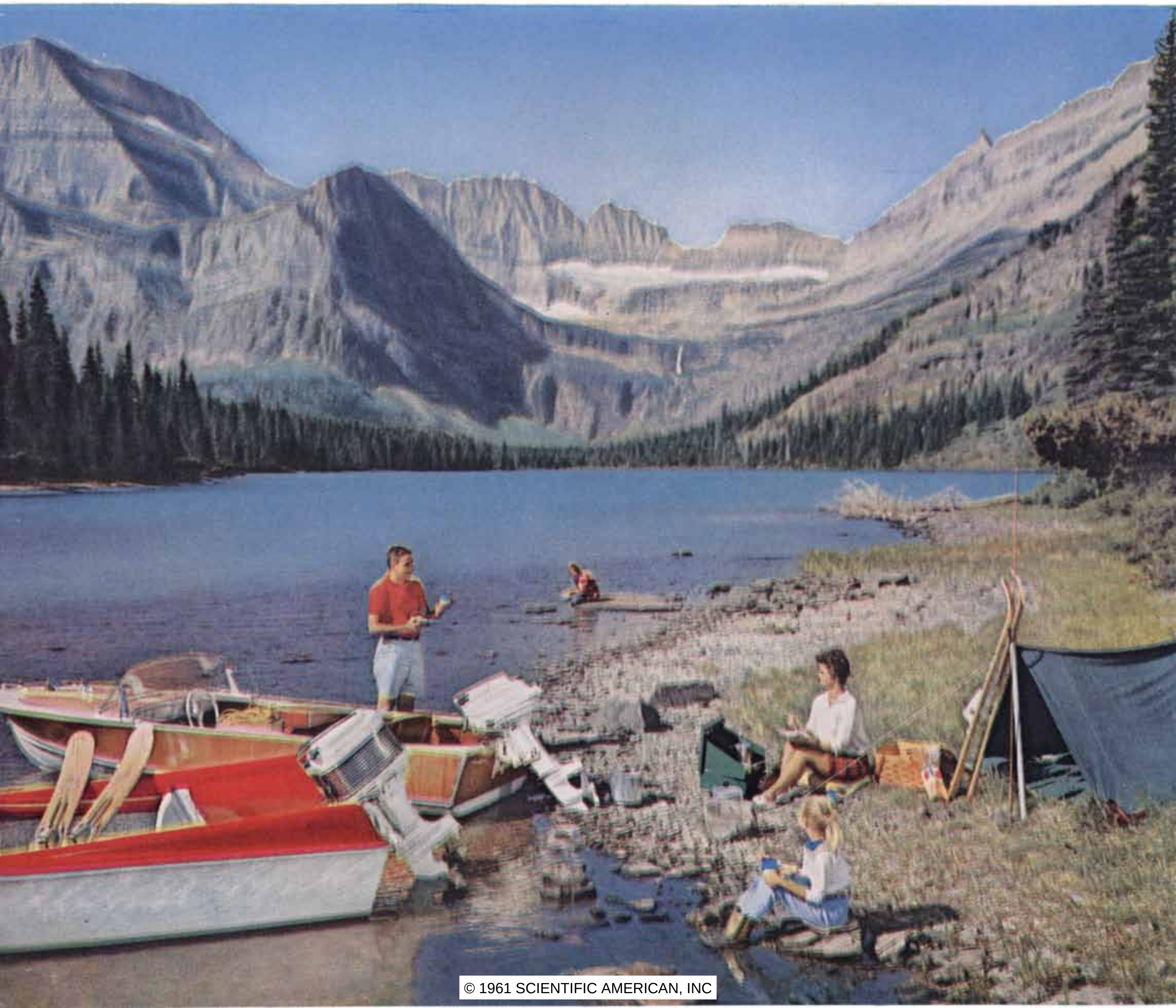
FILM BALANCE is depicted schematically in view from above (*top*) and from side (*bottom*). Float is attached to sides of film balance by flexible platinum foils; yoke is fixed to torsion wire, which can be twisted by turning rod at right of indicator dial. During experiment variable-speed drive-screw moves compression barrier toward float, compressing monomolecular film (*heavy colored area and line*) on surface of water (*light colored areas*). Degree to which torsion wire must be twisted to keep float stationary is a measure of the pressure of film against float. Simultaneous readings of film area and pressure are taken from linear centimeter scale and from indicator dial respectively. Sweeping barriers clear the water surface of contaminating material before experiment.

(an angstrom unit is a hundred-millionth of a centimeter).

The length of the molecule in a monolayer of vertically oriented molecules is given by the thickness of the film. To establish the thickness one first computes the volume of the film by dividing its weight by the known density of the material. (The density of the film at, or near, the collapse pressure is very close to the density of the bulk material.) The volume thus computed can be divided by the surface area of the compressed film to yield the thickness. For stearic acid monolayers the thickness is close to 25 angstrom units, in good agreement with the length of the molecule as determined by other means.

The collapse pressure reflects both the strength with which the film adheres to the surface of the water (*i.e.*, the strength of the polar group) and the strength of the cohesive forces. The stronger the polar group, the more tightly it adheres to the surface of the water; the greater the cohesive forces, the stronger the film. Stearic acid molecules, with their strong polar groups and high cohesive forces, adhere to the surface up to a surface pressure of 42 dynes per centimeter.

Comparison of the pressure-area curves of three polar compounds—isostearic acid, tri-*para*-cresyl phosphate and *n*-hexatriacontanoic acid—with the pressure-area curve of stearic acid will illustrate the insights developed by the film balance. Isostearic acid is an isomer of stearic acid, containing the same number and kind of atoms. Its slightly different structure, however, gives an isostearic acid molecule a 50 per cent larger cross-sectional area: 32 square



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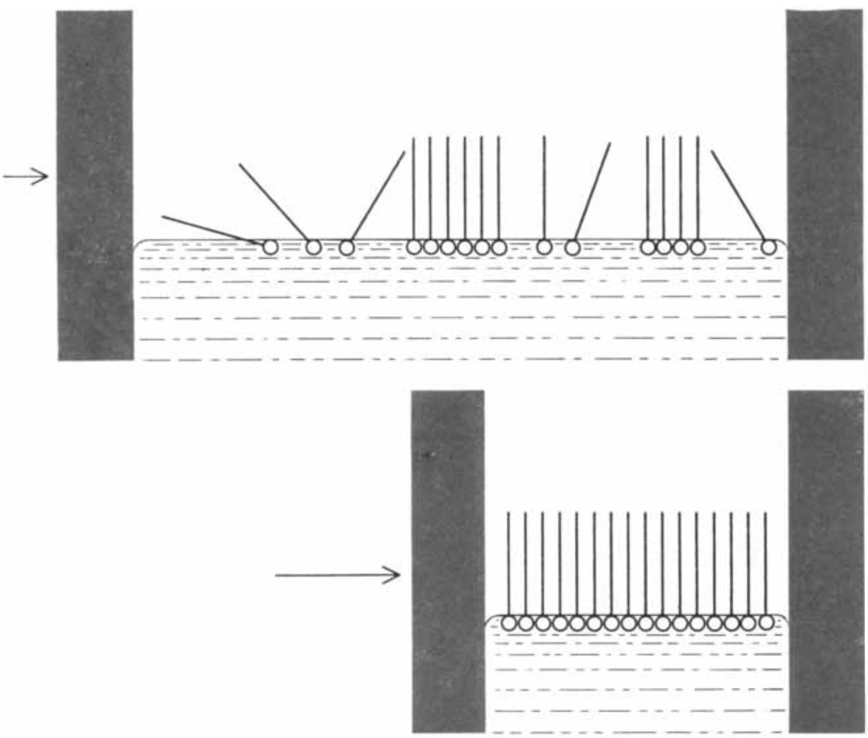
angstrom units as compared with 20 for stearic acid. The collapse pressure of an isostearic acid film is 14 dynes per centimeter—only one-third that of stearic acid. The film balance thus develops striking differences between two molecules that are difficult to distinguish by chemical methods.

The discriminatory power of the film balance is even more strikingly illustrated in the case of tri-*para*-cresyl phosphate. This molecule has a bulky three-ring hydrocarbon portion attached to a strongly polar phosphate group. The pressure-area curve reflects its markedly different molecular structure. Measurement of the molecule's cross-sectional area shows it to be 95 square angstroms, in keeping with the bulky configuration of its three-ring structure. In contrast with monolayers of stearic and isostearic acid, which behave like rigid sheets, tri-*para*-cresyl phosphate behaves like a liquid, collapsing only gradually. The gradual slope of the curve, indicating high compressibility, shows that the molecules are not tightly packed. Finally, the low collapse pressure of nine dynes per centimeter indicates the weakness of such a film. Bulky hydrocarbon structures are of little use as protective films.

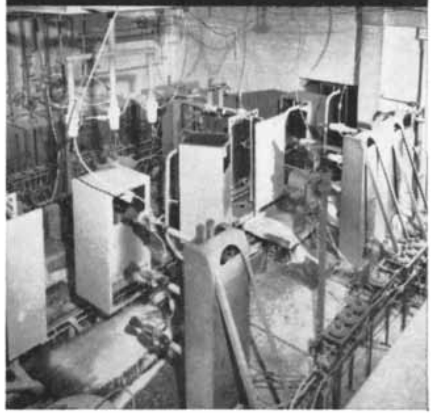
Another straight-chain fatty acid similar to stearic acid, but containing 36 carbon atoms instead of 18, is *n*-hexatriacontanoic acid. It has the same cross-sectional area (20 square angstroms) as stearic acid. This measurement clearly indicates that the molecules are oriented vertically. The compound should therefore form a monolayer twice the thickness of a stearic acid monolayer, and it does. The high collapse pressure of 58 dynes per centimeter, 16 dynes greater than that of stearic acid, reflects the increased cohesion, and hence greater film strength, that comes with increased length.

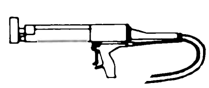
Once the over-all geometry of the molecule is established, one can figure out the location of the polar group or groups. For instance, it is clear that a vertically orienting molecule—one with a small cross-sectional area and a relatively great length—has its polar groups located at one end. A large area and a short length, on the other hand, would indicate that the polar groups are distributed along the molecule or are located at both ends of the molecule.

For many years investigators assumed the monolayers to be homogeneous at all stages of compression, that is, uniformly distributed over the available surface.



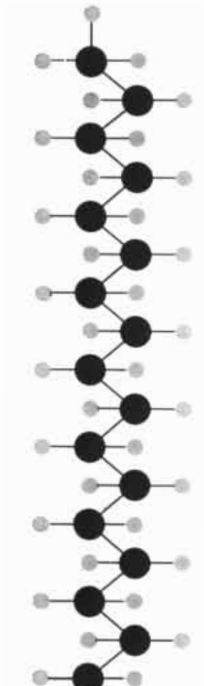
MONOMOLECULAR FILM AT INTERFACE between water (*broken lines*) and air is shown schematically at two stages of compression. At low compression (*top*) molecules are oriented at different angles or form tightly packed aggregates. At high compression (*bottom*) molecules are tightly packed and approach vertical orientation. Circles represent polar (water-attracting) groups of the molecules; straight lines, nonpolar hydrocarbon chains.

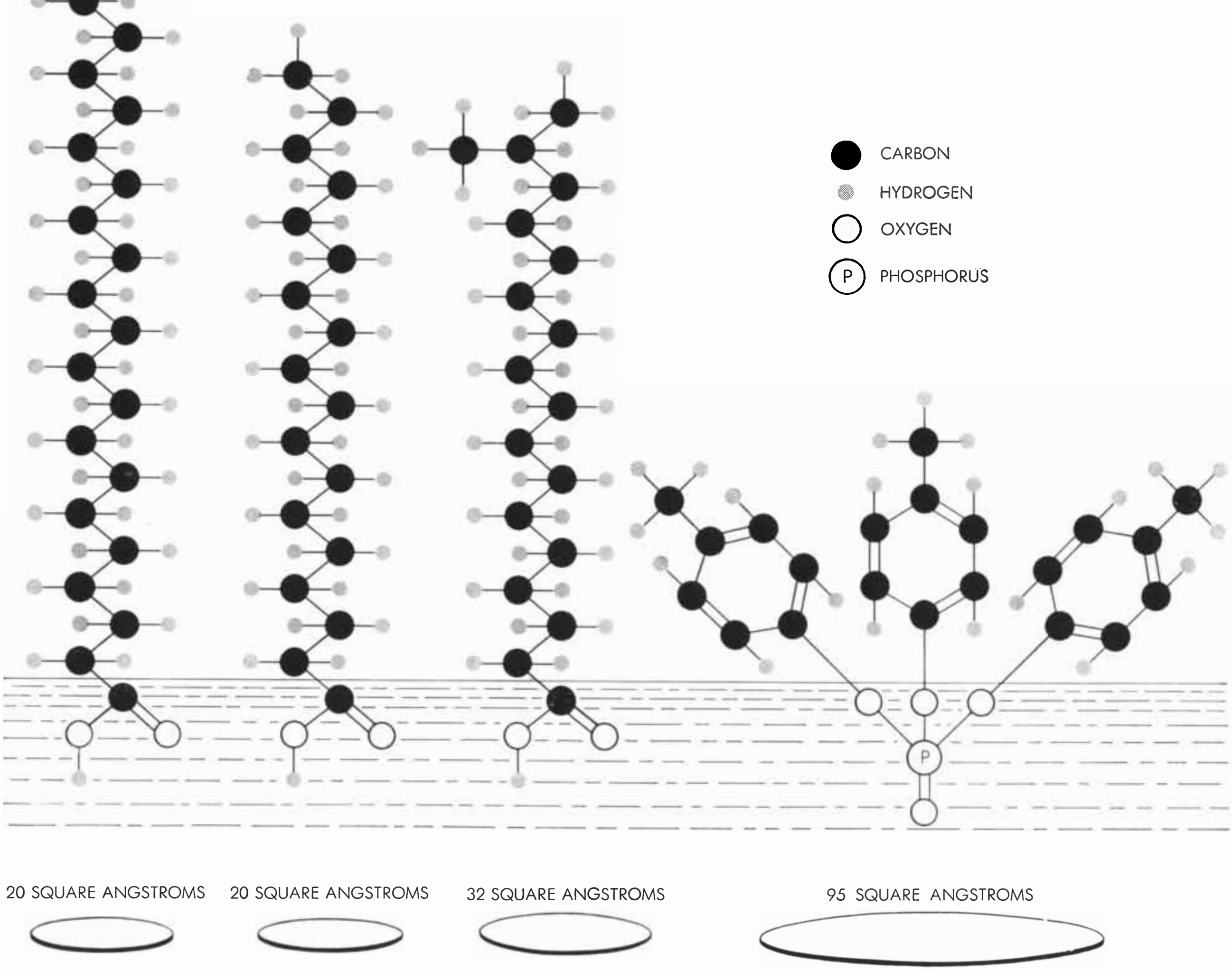




About 1930 Hans Zocher and Fritz Stiebel, using the dark-field ultramicroscope, obtained results suggesting that monolayers might not be homogeneous at low pressure or even in the region of collapse, but rather that they might form aggregates, or "islands." The method used was capable of detecting only gross impressions of the size and shape of these aggregates. Measurements of surface potential, which varies with the concentration or packing of molecules in a film, were made by a number of workers and definitely established that the films are not homogeneous. The electrodes employed in these measurements were comparatively large (about a centimeter in diameter) and so could not resolve the structure of the film in really fine detail.

In 1954 our group at the Whiting Research Laboratories of the Standard Oil Company of Indiana (now the Whiting Research Laboratories of the American Oil Company) began making electron micrographs of monolayer samples. Because thin films of organic material are transparent to the electron beam of the microscope, they are first made visible by "shadow-casting," a technique that involves coating them with a metal opaque to the electron beam. The technique also makes it possible to determine the thickness of the monolayer [*see bottom illustration on opposite page*]. Because the minute samples observed in the electron microscope are not always representative of the entire film, every effort must be made to select representative samples. Moreover, strains occurring in transfer may disturb the film. In spite of these difficulties we have





MOLECULES OF FILM-FORMING SUBSTANCES at a water-air interface are oriented with their polar groups in the water (*broken lines*) and their nonpolar hydrocarbon portions in the air. Four molecules discussed in the text are (*from left to right*) *n*-hexatriacontanoic acid, stearic acid, isostearic acid and tri-*para*-cresyl phosphate. Cross-sectional areas of molecules appear at bottom.

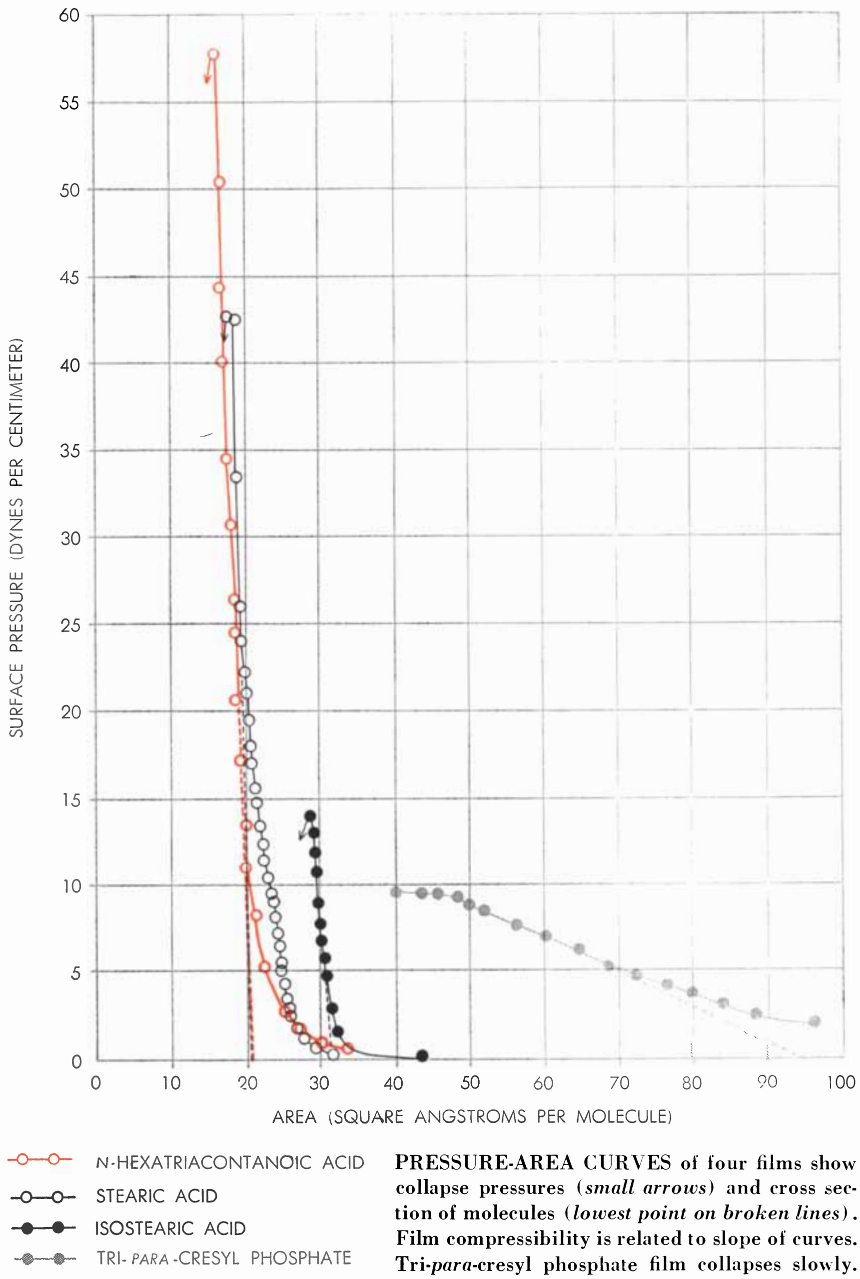
obtained sequences of pictures that undoubtedly reflect the sequence of changes as measured on the film balance.

Our electron micrographs of a monolayer formed by *n*-hexatriacontanoic acid molecules provide visual proof that monolayers are indeed inhomogeneous at low pressures. Islands of irregular size and shape appear at a surface pressure of 15 dynes per centimeter. Most of the islands are considerably less than one micron (or one ten-thousandth of a centimeter) in their largest dimension. Similar islands also appear at lower pressures. The shadow widths correspond to a film thickness of close to 50 angstroms, the length expected for a vertically oriented molecule of *n*-hexatriacontanoic acid. The micrographs thus provide direct evidence that the film is one molecule thick.

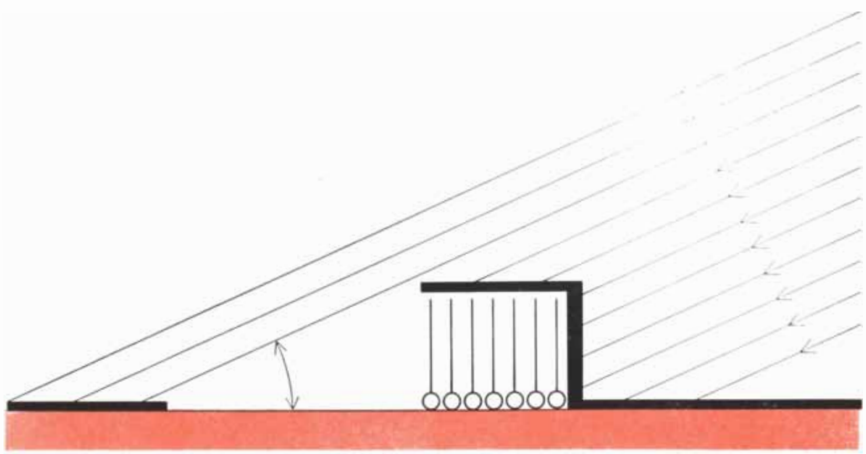
With further compression the character of the monolayer changes. At 20 dynes the monolayer enters the continuous phase, and the bare portions become holes in the film. At 25 dynes the continuous monolayer occupies a larger proportion of the available surface, and at 40 dynes large homogeneous areas of continuous monolayer appear. Uncovered areas at this pressure must result from strains or disturbances that crack the film; the matching contours of the film edges strongly suggest mechanical separation or cracking [*see illustration at middle right on page 164*].

Electron micrographs of a collapsed film suggest a mechanism for the collapse process. Collapse probably takes place in four main stages. In the weakening stage the surface pressure forces some of the vertically oriented molecules up from the water surface. The cohesion between the long hydrocarbon chains and the mutual attraction of the polar groups are great enough to cause the molecules to rise, one after the other, in closely packed folds or ridges two molecules thick. In the third stage this double-layered ridge rises and apparently breaks. In the final stage the collapsed fragment, two molecules thick, falls over upon the monolayer [*see bottom illustration on next page*].

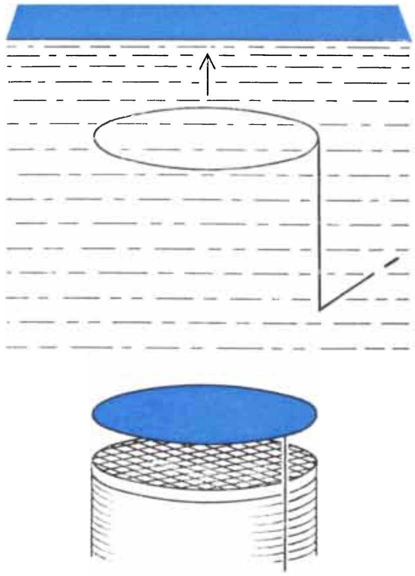
Additional evidence in support of this hypothesis is furnished by the electron micrographs. Long, narrow ridges corresponding to the second and third stages have been observed. Presumably they are the precursors of the long, flat, collapsed structures. Moreover, numerous small blisters, or bumps, found in monolayer samples at high compression may correspond to the initial stage of weakening. The linear alignment of these blisters raises the possibility that



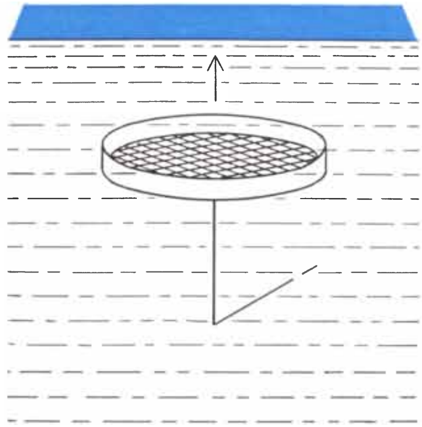
PRESSURE-AREA CURVES of four films show collapse pressures (*small arrows*) and cross section of molecules (*lowest point on broken lines*). Film compressibility is related to slope of curves. Tri-*para*-cresyl phosphate film collapses slowly.



SHADOW-CASTING makes film visible in electron microscope and provides a method for measuring the film thickness. A beam of metal atoms (*arrows*), directed at a known angle (*double arrow*), coats exposed portions of the support (*colored area*) and the film. Thickness (*vertical height*) equals "shadow" width (*unexposed portion*) times tangent of angle.



RING METHOD of film transfer is shown. Wire ring is raised (*top*) through film (*colored area*), then lowered (*bottom*) over electron microscope screen (*hatched area*).



CUP METHOD of film transfer is completed in one step. A shallow, sharp-edged cup with collodion-coated screen (*hatched area*) is raised through film (*colored area*).

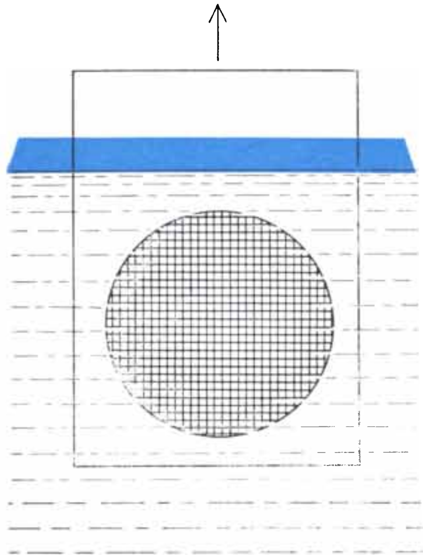
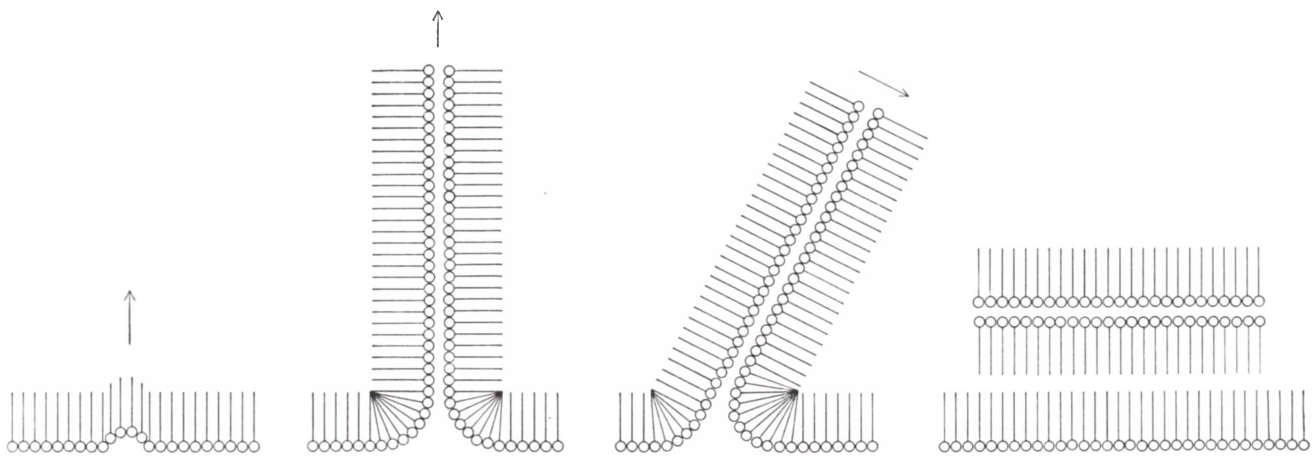


PLATE METHOD of film transfer, like the cup method, requires only one step. Film (*colored area*) adheres to screen attached to vertical glass plate when plate is raised.

they coalesce into the ridges that appear at the second stage of collapse.

The successful study of *n*-hexatriacontanoic acid led us to attempt the more difficult task of investigating the thinner stearic acid monolayer. At low pressures, in the neighborhood of five dynes per centimeter, islands 25 angstroms thick and similar in contour to those of the thicker monolayer appeared. This was not unexpected. But at 10 dynes many of the islands assumed a circular shape, resembling flattened liquid drops, with diameters ranging from 3,000 to 50,000 angstroms. These islands would seem to be the two-dimensional analogue of the spherical drop in the three-dimensional world of bulk systems. Sphere and circle are configurations of minimum energy into which one would expect the molecules to arrange themselves.

The combined film-balance and electron-microscope technique is now being extended to the study of mixed films, or monolayers with two or more components. Perhaps of principal interest is the mixture of polyvinyl acetate and stearic acid (or *n*-hexatriacontanoic acid), which like other mixed films of long polymers and fatty acids exhibits properties quite different from those of films formed by its components separately. The collapse pressure of the mixed film, for example, is markedly higher than that of the film formed by either component. More important, the film is analogous to biological films, which consist of proteins and fatty acids. By using such films and film-balance techniques, it may eventually be possible to approximate the structure of an idealized cell membrane. It is currently believed that the representative membrane consists of two protein monolayers with two monolayers of organic compounds, such as



FILM COLLAPSE probably takes place in four stages. After maximum surface pressure is reached, additional compression forces some molecules out of the film (*left*). As compression increases, a tightly packed layer, two molecules thick, rises from the surface (*second from left*). Layer bends (*third from left*) and breaks, leaving collapsed fragment resting on film (*right*).

The Air Force's eight-jet Boeing B-52G Stratofortress has a non-refueling range of over 9,000 statute miles, enabling it to span oceans and still return to U.S. bases.

BENDIX TOOL CONTROL SAVES 4 WEEKS IN PRODUCING B-52 PARTS

Numerical machine tool controls developed by Bendix literally make it possible to turn blueprints into finished parts. Result: there has been a chain reaction in production methods that's paying big dividends in time and money to manufacturers.

Taxpayers benefit, too. For example, take the global B-52 produced at Boeing Airplane Company's Wichita Division. With Bendix numerical control, the extraordinary Keller milling machine shown in the picture at the right is turning out complex finished parts, three at a time, for advanced B-52 models. Not only are these parts milled to fine tolerances, but they are completed in four weeks' less flow time. Estimated savings run 10 man hours per part—with important dollar savings to taxpayers.

How do Bendix numerical control systems make such savings possible? First, because they by-pass completely the conventional, time-consuming steps of fashioning templates and patterns. Second, because they provide fast, automatic machine tool control—accurate to within .001″—with punched tapes that feed all dimensional information and milling instructions to the machines. Third, because they help eliminate human errors and rejects that normally occur in manual machining operations.

Three-spindle Keller mill simultaneously machines three B-52 wing structural members under direction of Bendix numerical control system. Saving in flow time: 4 weeks.

Teamed with machine tools made by Kearney & Trecker, Ex-Cell-O, Pratt & Whitney, Heald, Sunstrand, Van Norman, and others, Bendix numerical controls are shrinking time and money expense for manufacturers in a wide variety of industries.

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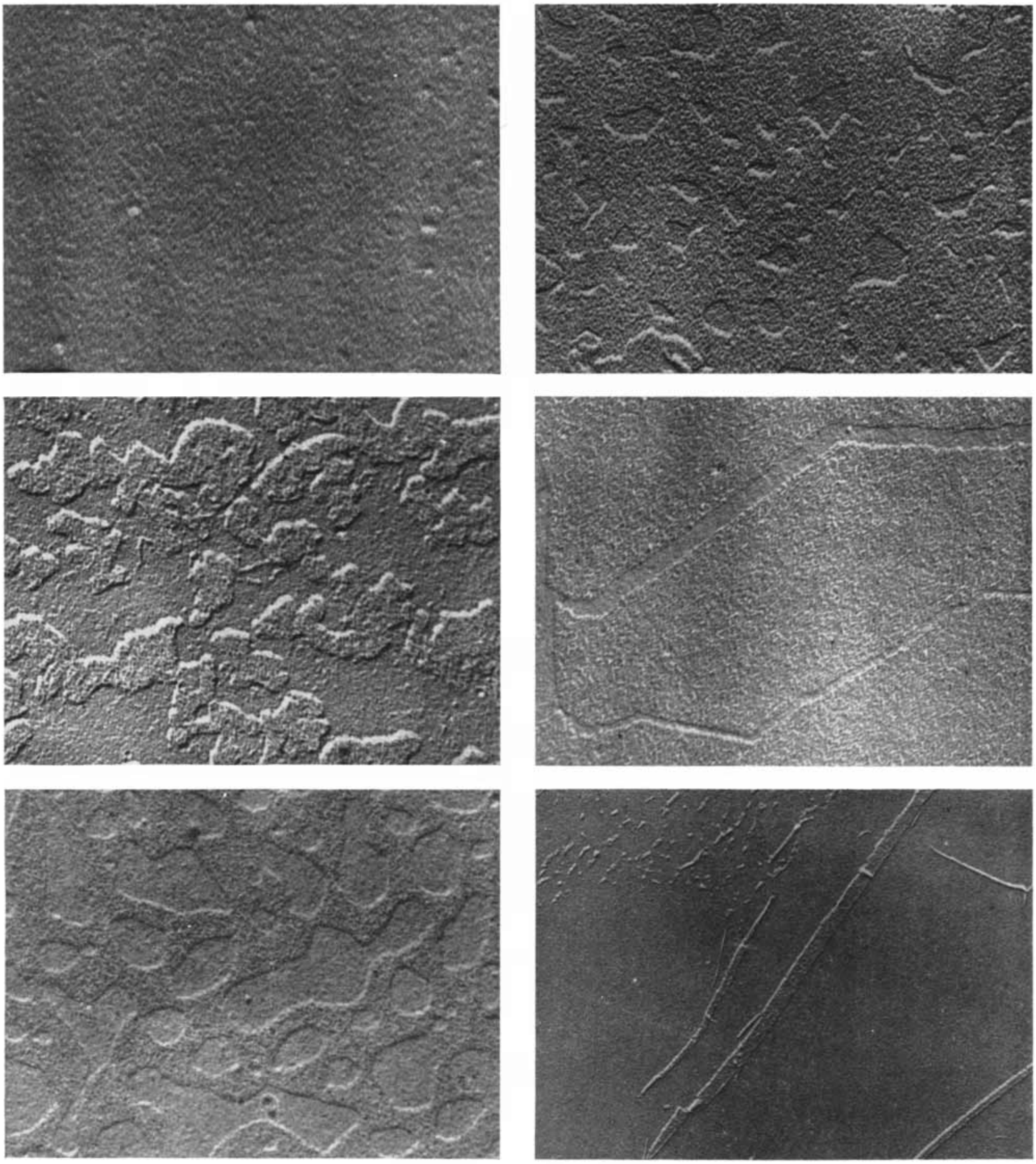
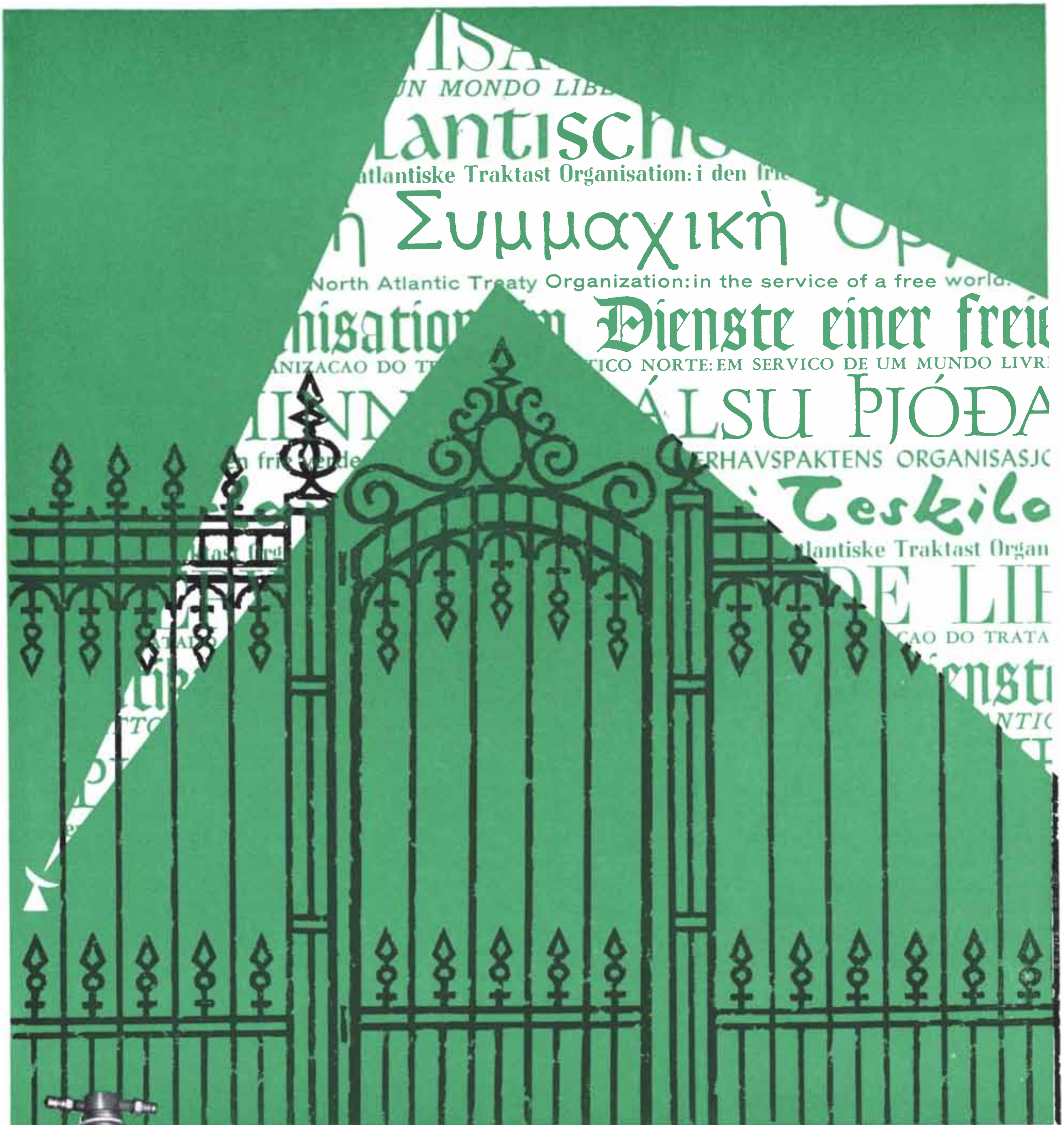
lecithin and cholesterol, sandwiched between them.

In addition, radioactive-tracer techniques are beginning to shed light on the formation as well as the structure of monolayers and mixed films adsorbed from solution onto a solid surface. At our own laboratory novel techniques have been developed for measuring directly the rate of adsorption (which in some cases determines the over-all rate of reaction in a catalytic process) of radioactively labeled compounds onto the metal-coated window of a Geiger counter. Indeed, with the application of new techniques, the field of monolayer research may become as important to an understanding of the physical and biological worlds as thin films are to processes in these worlds.



MONOMOLECULAR FILM of *n*-hexatriacontanoic acid at different stages of compression appears in five of six electron micrographs shown here. "Blank" (*top left*) shows collodion support without film. Irregular islands (*raised areas*) appear at surface pressure of 15 dynes per centimeter (*middle left*), becoming continuous at 20 dynes (*bottom left*). At 25 dynes (*top right*) film occupies more of available area. Large, homogeneous areas appear at 40 dynes (*middle right*). Narrow, flat structures appear in the collapsed film (*bottom right*), which is magnified 8,000 diameters. The magnification of the other micrographs is 40,000 diameters.



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MATHEMATICAL GAMES

How to play dominoes in two and three dimensions

by Martin Gardner

In the U. S. a standard set of dominoes consists of 28 oblong black tiles, each divided into two squares that are either blank or marked with white spots. No two tiles are alike, and together they represent the 28 possible ways in which numbers from 0 through 6 can be combined two at a time. The tiles can be regarded as line segments that are placed end to end to form linear chains; in this sense all domino games are strictly one-dimensional. When the domino concept is extended to two- and three-dimensional pieces, all sorts of colorful and little-known recreations arise. Percy Alexander MacMahon, a British authority on combinatorial analysis, devoted considerable thought to these superdominoes, and it is from his book *New Mathematical Pastimes*, published in 1921, that much of the following material is taken.

For a two-dimensional domino the equilateral triangle, square and hexagon are the most convenient shapes because in each case identical regular polygons can be fitted together to cover a plane completely. If squares are used and their edges are labeled in all possible ways with n different symbols, a set of $\frac{1}{4}n\ (n + 1)\ (n^2 - n + 2)$ squares can be formed. The illustration on page 168 shows the full set of 24 square dominoes that results when $n = 3$. If the reader constructs such a set from cardboard he will have the equipment for a first-rate puzzle. Colors are easier to work with than symbols, so it is suggested that colors be substituted for the numerals. The problem is to fit together all 24 squares into a four-by-six rectangle, with two provisos: (1) each pair of touching edges must be the same color; (2) the border of the rectangle, all the way around, must be the same color. It is a singular fact that there is only one solution pattern. Any color may be picked for the border, but in each case the pattern is the same.

In three dimensions, cubes are the only regular solids that will press together to fill a three-dimensional space completely; for this reason they are the most satisfactory shapes for 3-D dominoes. If two colors are used for the faces, no more than 10 different cubes can be painted—a number too small to be of interest. On the other hand, too many cubes (56) result if three colors are used. With six colors the number jumps to 2,226, but from this set we can pick a subset of 30 that is ideal for our purposes. It consists of cubes that bear all six colors on their six faces.

It is easy to see that 30 is the maximum number. There must be, say, a red face on each cube. Opposite this face can be any one of five different colors. The remaining four colors can be arranged in six different ways, so the total number of different cubes must be $5 \times 6 = 30$. (Two cubes are considered different if it is impossible to place them side by side in such a way that all corresponding faces match.) The illustration on page 170 shows the 30 cubes in "unfolded" form.

The 30 cubes, apparently discovered by MacMahon, have become a classic of recreational geometry. It is a chore to make a set, but the effort brings rich rewards. A set of neatly painted cubes is an endlessly fascinating family toy; it requires no batteries and is unlikely to wear out for decades. Wooden or plastic blocks, preferably with smooth sides, can be bought at most toy counters or obtained from a friend with access to a buzz saw. An alternative to painting is to paste squares of colored paper on the cubes.

For an introductory exercise, pick any one of the 30 cubes. Now find a second cube that can be placed face to face with the first one so that the touching faces match, the end faces are a second color and the other four colors are on the four sides, each side a solid color. It is always possible to do this. Since the two cubes are mirror images of each other, this means that every

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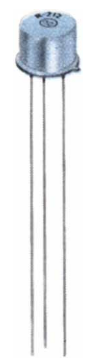
The awesome retaliatory potential of the nuclear submarine-based Polaris missile describes more vividly than words the vital importance of this weapon in America's protective arsenal.

Manufacturers of electronic elements of the Polaris' firing and guidance systems use transistors made by Tung-Sol. Here, as in so many other areas of the nation's defense and civilian electronics industries, Tung-Sol is a major source of supply for companies that require tubes, transistors and silicon rectifiers of the utmost reliability and in volume. Tung-Sol Electric Inc., Newark 4, New Jersey.



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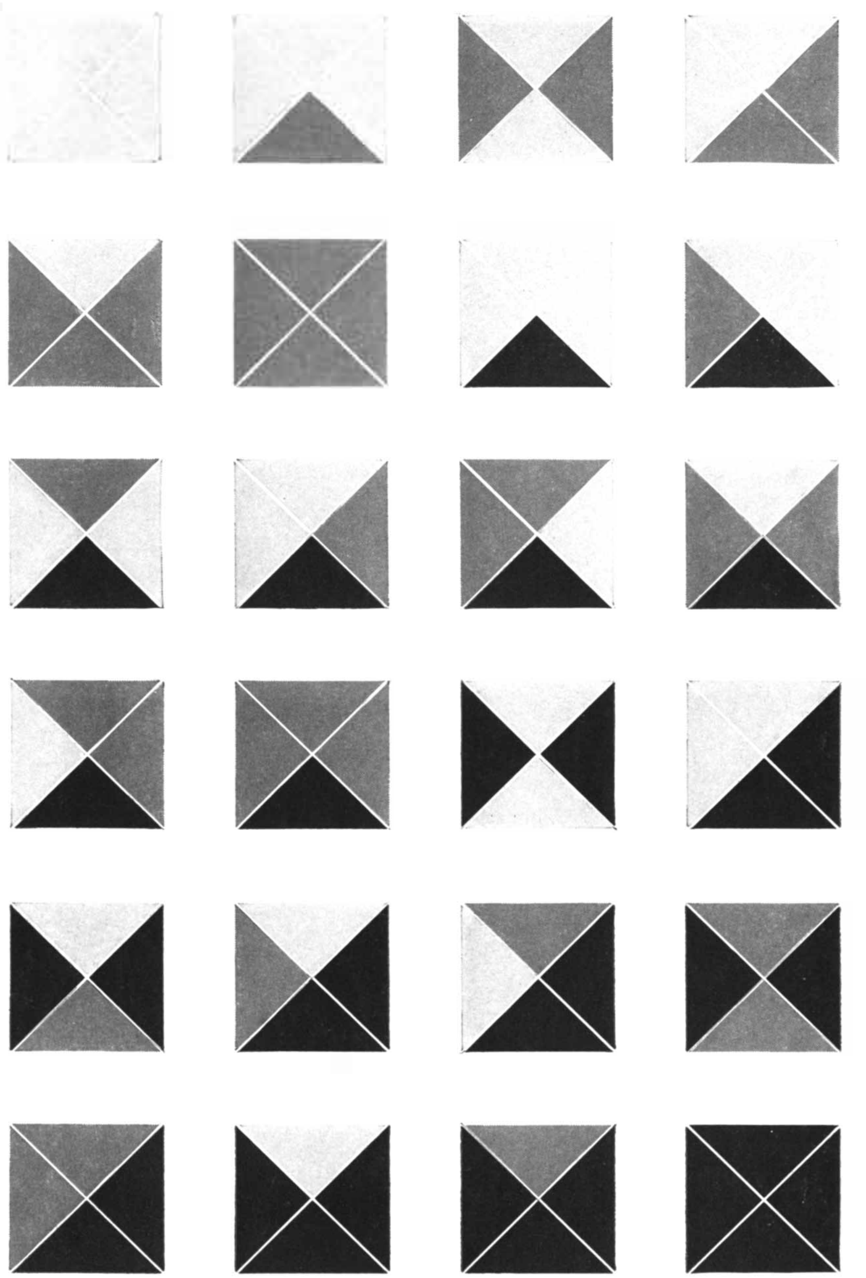


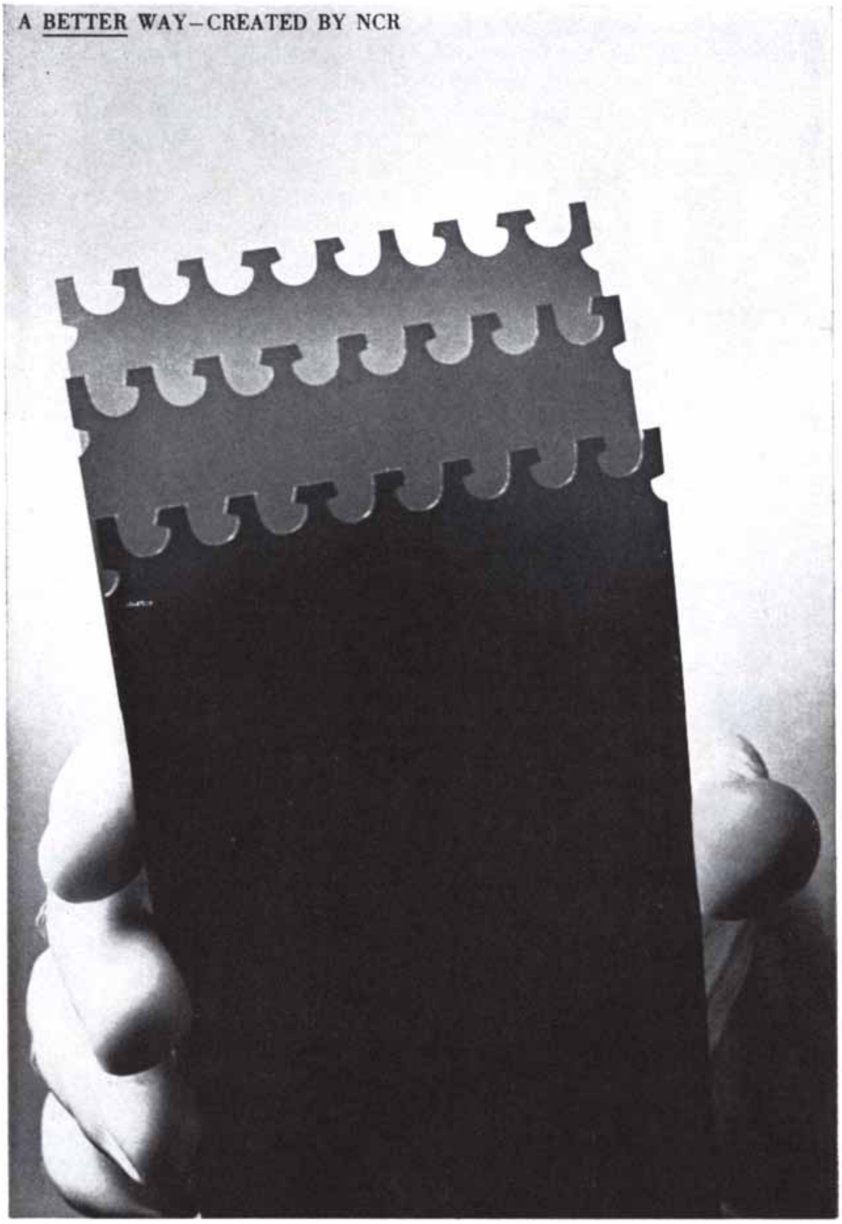
A set of square dominoes using three colors

cube, like every fundamental particle of matter, has its anticube.

(In searching for a certain type of cube, much time can be saved by lining them up in rows and turning an entire row at once by applying pressure at the ends. For example, suppose you are looking for cubes with red and blue on opposite sides. Arrange a group of cubes in a row with red on top, give the row two quarter-turns and take out all cubes that now show blue on top. Or suppose you wish to work with cubes on which blue, yellow and green touch at the same corner. Arrange a row with all blue on top, invert it and discard the greens and yellows. Turn the remaining cubes to show green on top, invert them and discard the blues and yellows. The cubes left will be of the desired type.)

It is not possible to form a straight chain of more than two cubes and have each of the four sides a solid color, but a row of six is easily made that has all six colors on each side. A pretty problem is to do this with all touching faces matching and the two end faces also matching.

Now for a more difficult puzzle. Choose any cube and place it to one side. From the remaining 29 select eight that can be formed into a two-by-two-by-two cube that is an exact model of the chosen one except twice as high. In ad-



Engineering "Card Trick": Cut Random-Access Time in Computer Memories from 3 Minutes to 1/5 Second!

Pick a card from this magnetic deck, and you have NCR's ingenious answer to the need for a fast, moderately priced exterior random-access memory. Because each of the cards above stores as much information as seven feet of magnetic tape, you can record the equivalent of 1800 feet of tape-stored information on the 256 cards that comprise the full memory.

No two cards in the memory are alike. The top of each one is die-cut according to a binary identification code. All 256 cards hang from eight trunions, each of which rotates to the right or left depending upon the signal. Only the card whose die-cut top corresponds to the alignment of all eight trunions is then free to fall. A pneumatic system pulls the card past the readout head and shoots it back to the magazine. Maximum access-time—as compared with about three minutes for the 1800-foot tape reel—less than 1/5 second!

Perhaps you would enjoy seeing some of your own bright ideas become a reality. If so, NCR may be the place for you. At the Electronics Division, original thought earns many unusual rewards, both professional and personal, for its creators.

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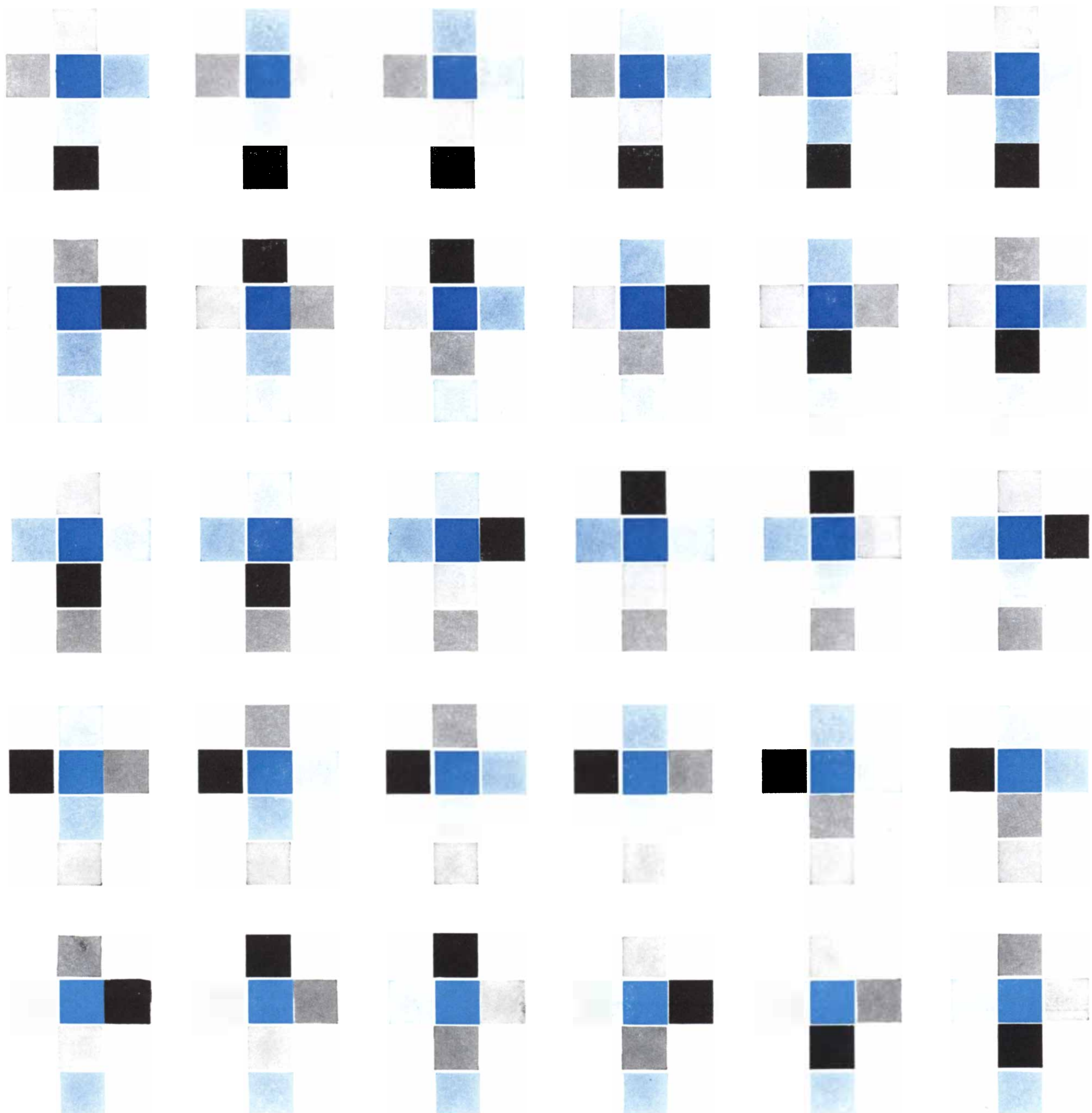
dition, each pair of touching faces must match.

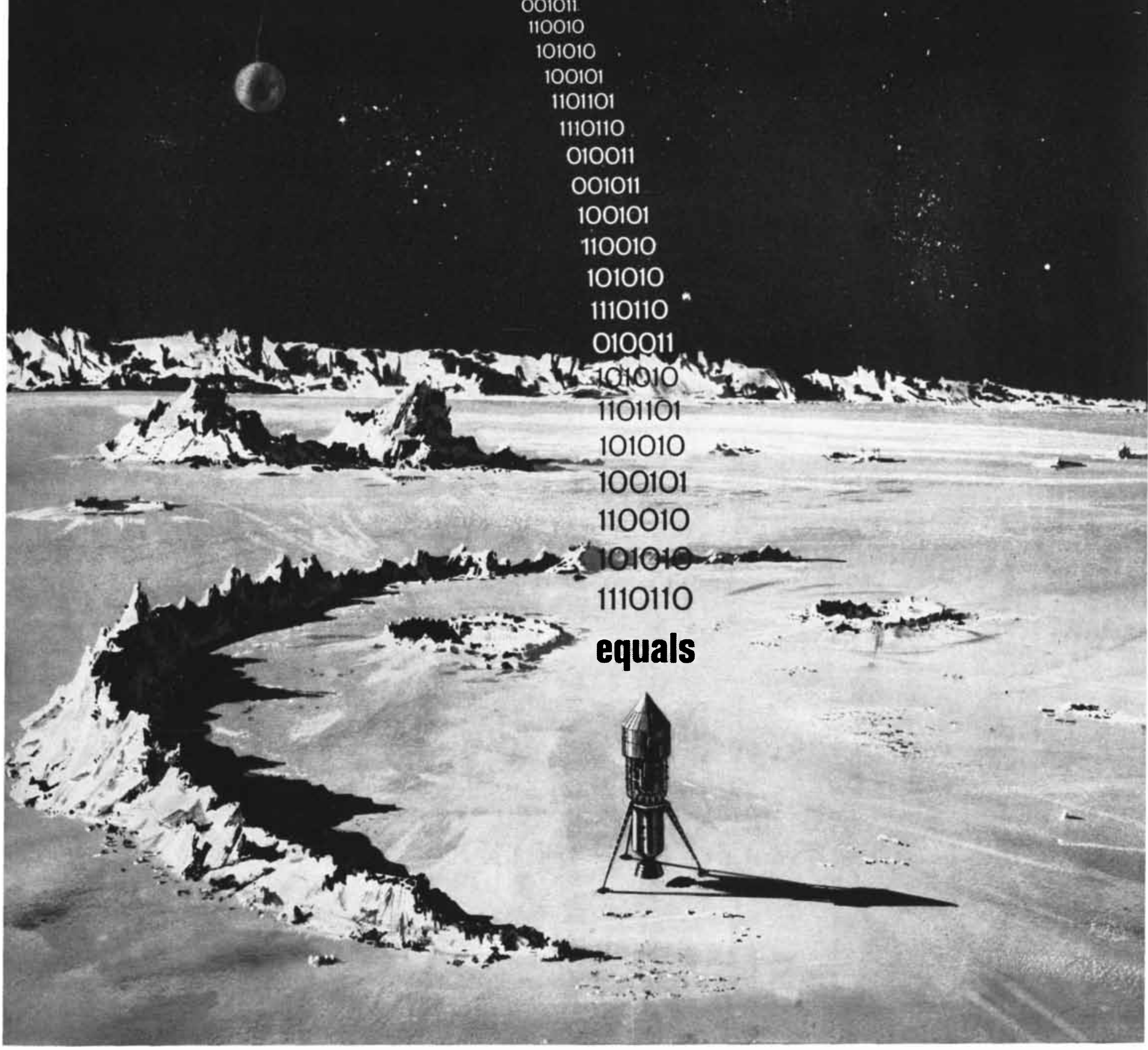
Only one set of eight cubes will do the trick, and they are not easy to find without a systematic procedure. The following is perhaps the best. Note the three pairs of opposite faces on the prototype, then eliminate from the 29 cubes all those that have a pair of opposite faces corresponding to any of the three pairs on the prototype. Sixteen cubes will remain. Turn the prototype so that one of its top corners points toward you and only the three faces meeting at that corner are visible. Among the 16 cubes you will find two that can be placed so that the same three faces are in the same position as the three on the prototype. Put these two aside. Turn the cube so that another top corner points toward you and find the two cubes that match this corner. The eight cubes selected in this way—two for each top corner of the prototype—are the cubes required. It is now a simple task to build the model.

Actually there are two essentially different ways to build the model with these eight cubes. L. Vosburgh Lyons, a Manhattan neuropsychiatrist, devised the ingenious procedure, depicted in the illustration on page 173, by which any model can be changed to its second form. The two models are related in remarkable ways. The 24 outside faces of each model are the 24 inner faces of the other, and when the two models are similarly oriented, each cube in one is diagonally opposite its location in the other.

Lyons has discovered that after a model has been built it is always possible to select a new prototype from the remaining 21 cubes, then build a two-by-two-by-two model of the new prototype with eight of the remaining 20. Few succeed in doing this unless they are tipped off to the fact that the new prototype must be a mirror image of the first one. The eight cubes needed for the model are the eight rejected



The 30 color cubes unfolded



The more advanced our scientific ventures into space become, and the more sophisticated the weapons in our defense arsenal grow, the greater need there is for special purpose computers engineered to fit system requirements exactly. Serving as the nerve and intelligence center, the computer is playing an increasingly important role in system performance and reliability.

A prime Sperry capability is computer technology—both digital and analog. In the analog field, the B-58 bombing-navigation computer is outstanding. Airborne digital applications include a countermeasures computer which sorts out the enemy's "confusion" data, decides *logically* the best means of counteracting it. Another is a subminiaturized, radiation resistant, ultra-reliable computer for missile guidance. In component technology, Sperry memory drums, most advanced in the field, include an air-bearing floated-head type with extremely long life and high storage capacity. Other advanced techniques are incorporated in studies and designs for the future . . . for computers applicable to space vehicles.

On the surface, a small digital computer for ground support equipment checks out a complete airborne reconnaissance system. This "building block" computer is unique in its universal adaptability for reprogramming.

On the Polaris submarines, a digital "brain" collates, analyzes, decodes and distributes the widest variety of navigational data ever centered in a single operation. In an anti-submarine warfare program, a high speed digital computer accepts, operates on, stores and displays instantaneous data relating to the target under consideration.

In its computer work Sperry is often joined by Remington Rand Univac and Ford Instrument Company plus component divisions specializing in semiconductor and solid state devices. General Offices: Great Neck, N. Y.

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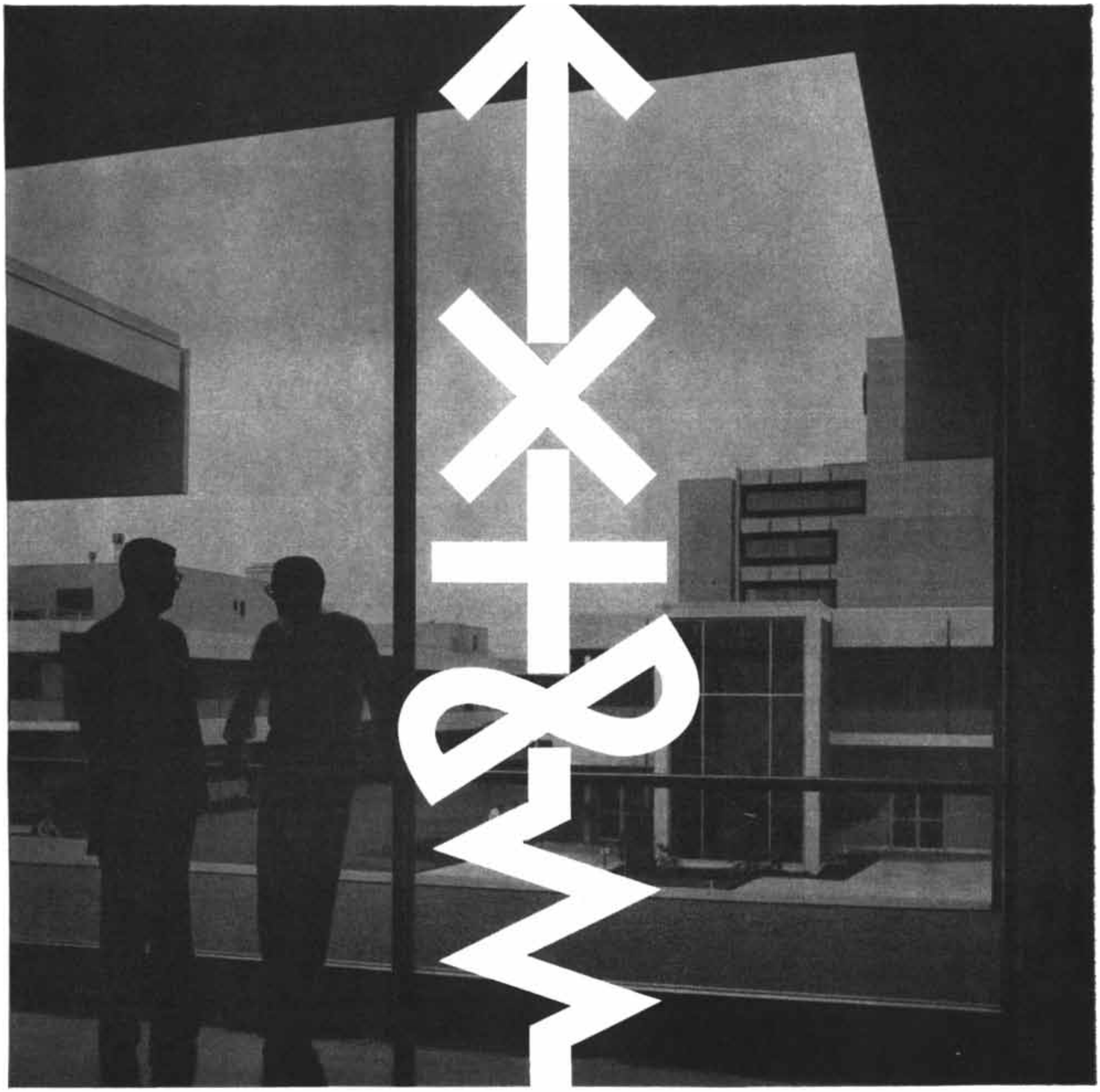


from the 16 in the last step of the procedure by which the cubes were chosen for the first prototype.

Games of the domino type can be played with any species of two- or three-dimensional domino; in fact, Parker Brothers still sells a pleasant game called Contack (first brought out by them in 1939), which is played with equilateral-triangle tiles. Of several games that have been proposed for the color cubes, a game called color tower seems the best.

Two players sit opposite each other. Each has in front of him a screen that is easily made by taking a long strip of cardboard about 10 inches wide and folding the ends to make it stand upright. The cubes are put into a container in which they cannot be seen but from which they can be taken one at a time. A paper bag will do, or a cardboard box with a hole in the top.

Each player draws seven cubes from the container and places them behind his screen, where they are hidden from his opponent. The first player opens the game by placing a cube in the middle of the table. (The privilege of opening can be decided by rolling a cube after a player has named three colors. If one of the three comes up, he plays first.) The second player then places a cube against the side of the first one, touching faces matching. Players alternate turns, each adding one cube to the structure, and in this way build a tower that rests on a square base of four cubes. A player's object is to get rid of all his cubes.

The rules are as follows:

1. Each tier of four cubes must be completed before starting the next tier.

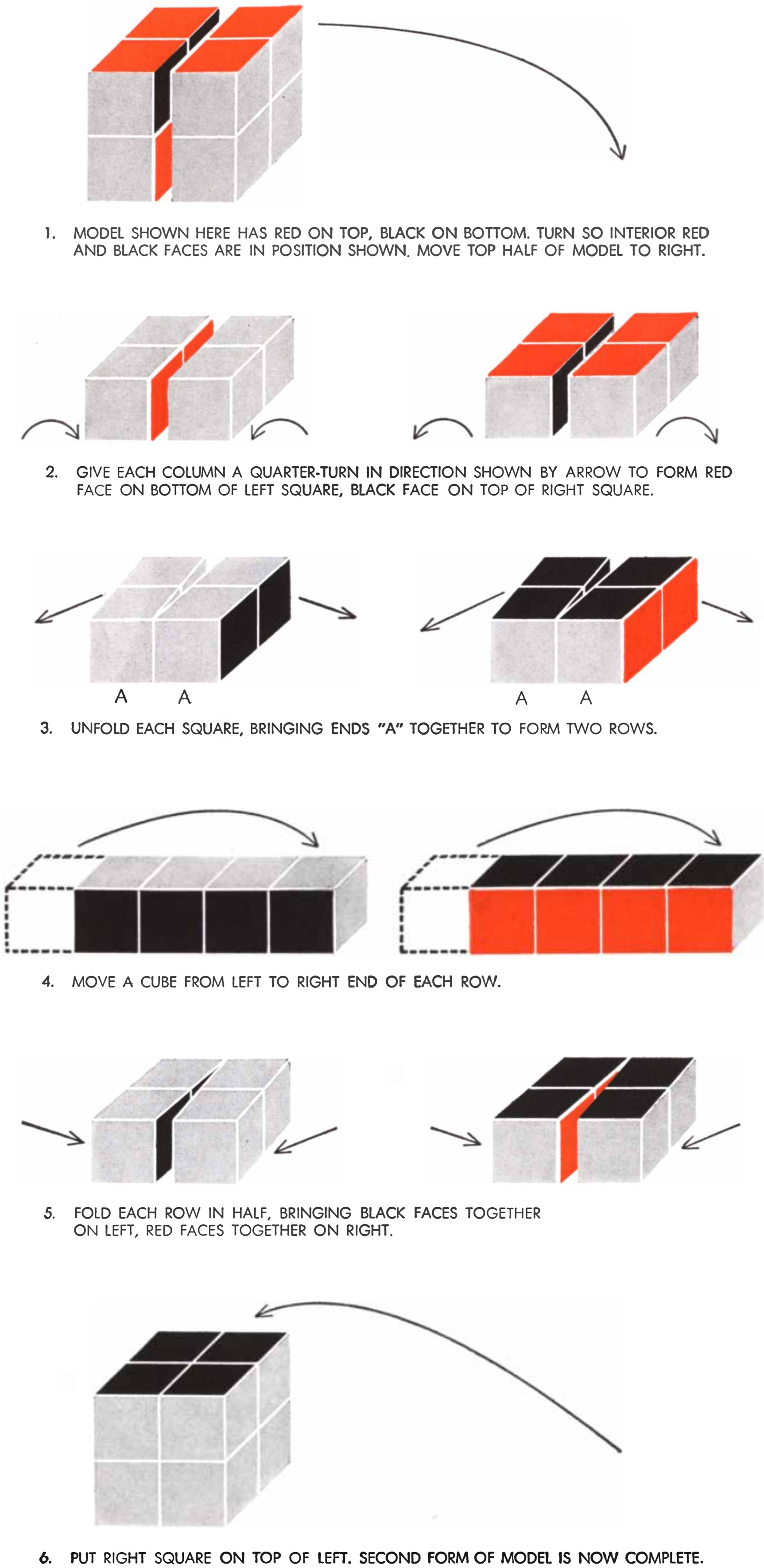
2. A cube may be placed in any open spot on a tier, provided that it meets two conditions: all touching faces must match, and it must not make impossible any remaining play on the tier. In the illustration on the next page, for example, cube *A* would be illegally played if any of its faces met at right angles with an exposed face of the same color.

3. If a player cannot play any of his cubes, he must draw one from the container. If the drawn cube is playable, he may play it if he wishes. If he cannot or does not wish to play it, he awaits his next turn.

4. If for strategic reasons a player wishes to pass up his turn he may do so at any time, but he must draw a cube from the container.

5. The game ends when one player is rid of all his cubes. He scores 10 points for winning, plus the number of cubes that remain in his opponent's hand.

6. If all cubes are drawn from the



The Lyons method of transforming a model to its second form

The game of color tower

container, turns alternate until one player is unable or unwilling to play. The other player then plays until his opponent is able or willing to continue. If both are unable or unwilling to play, the game ends and the person with the smallest hand is the winner. He scores the difference between hands.

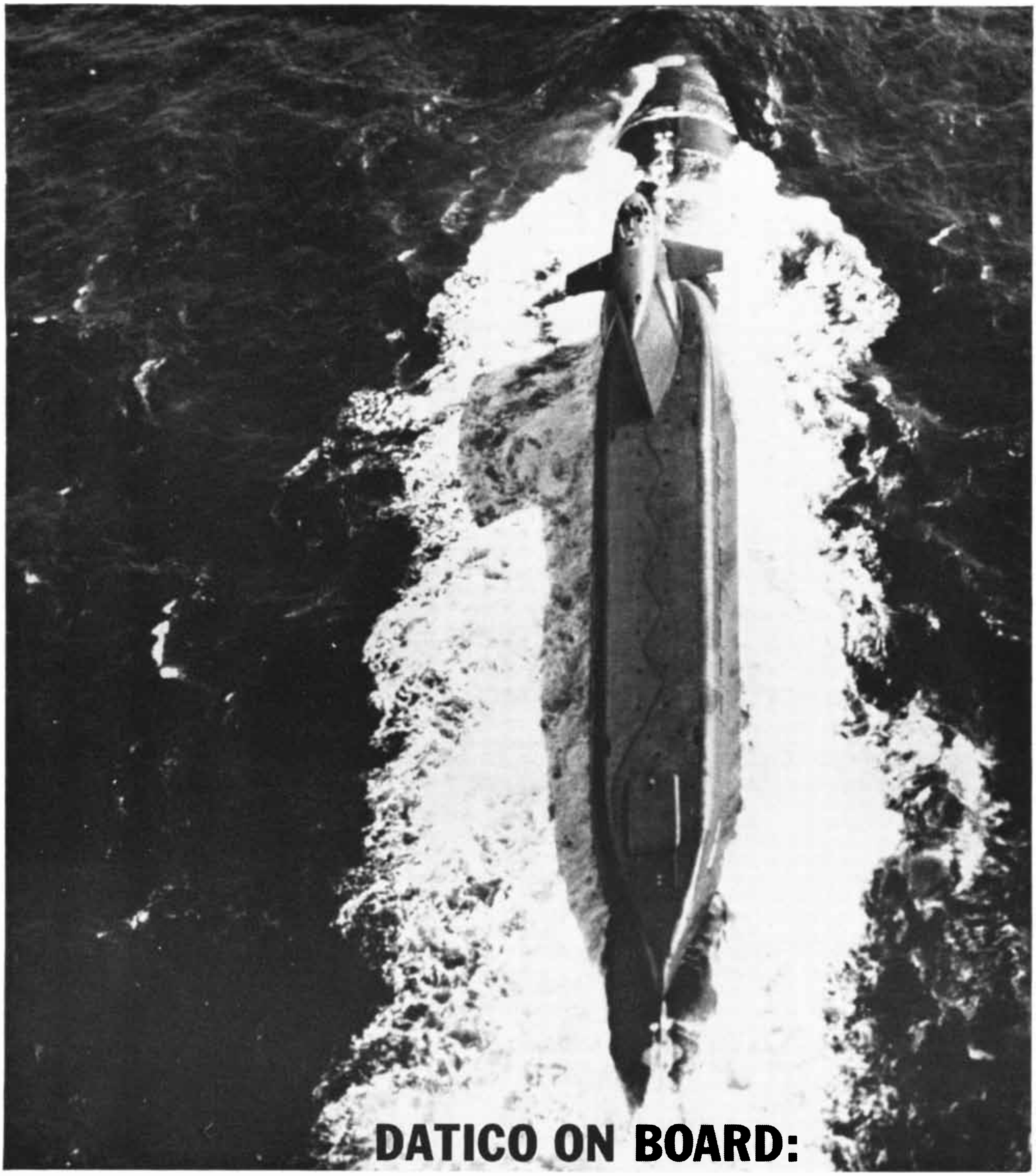
7. The goal of a set of games can be any agreed-upon number of points. If played as a gambling game, the winner collects after each game an amount equal to his score.

Various strategies occur to anyone who plays color tower for a while. Suppose your opponent has just started a new tier. You have two cubes left. It would be unwise to play diagonally opposite his cube in such a way as to make your last cube unplayable in either of the remaining three-face plays. It may be necessary to play alongside his cube to keep open the possibility of going out on your next move. The discovery of such strategies makes the learning of color tower a stimulating experience and leads to a skill in play that greatly increases one's probability of winning.

If any reader has suggestions for improving color tower I would enjoy hearing about them, as well as about any other games or unusual new puzzles with the cubes. The 30 color cubes have been around for 40 years, but they probably contain many more surprises.

The answers to the two problems in last month's department are:

1. No regular polygon with more sides



SIX MONTHS FROM CONTRACT TO COUNTDOWN

Just six months following contract award, Northrop began deliveries of Datico automatic checkout equipment for use in the Navy's Polaris Fleet Ballistic Missile program. Datico is used in factory, depot, tender, and submarine operations.

Datico is a digital automatic tape checkout system with a wide variety of applications. Its successful integration by Northrop into the Polaris and other major weapons systems demonstrates that the same basic Datico equipment can be used at all levels of maintenance and operation, utilizing the same test standards and methods and operated by personnel with the same basic training.

Northrop is at work on more advanced versions of Datico to extend its capability to an even wider range of military and industrial systems.

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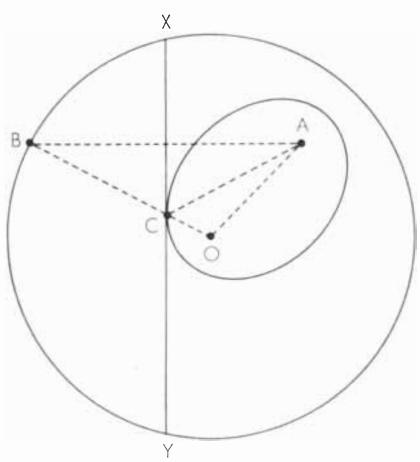
NORTHROP

than a square can be inscribed in an ellipse for this reason: the corners of all regular polygons lie on a circle. A circle cannot intersect an ellipse at more than four points. Therefore no regular polygon with more than four corners can be placed with all its corners on an ellipse. This problem was contributed by M. S. Klamkin to *Mathematics Magazine* for September-October, 1960.

2. The proof that the paper-folding method of constructing an ellipse actually does produce an ellipse is as follows. Let point A in the illustration below be any point on a paper circle that is not the circle's center (O). The paper is folded so that any point (B) on the circumference falls on A. This creases the paper along XY. Because XY is the perpendicular bisector of AB, BC must equal AC. Clearly $OC + AC = OC + CB$. $OC + CB$ is the circle's radius, which cannot vary, therefore $OC + AC$ must also be constant. Since $OC + AC$ is the sum of the distances of point C from two fixed points A and O, the locus of C (as point B moves around the circumference) must be an ellipse with A and O as the two foci.

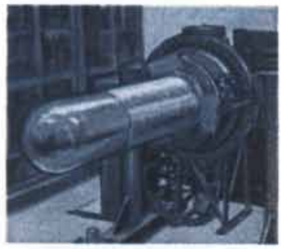
The crease XY is tangent to the ellipse at point C because it makes equal angles with the lines joining C to the foci. This is easily established by noting that angle XCA equals angle XCB, which in turn equals angle YCO. Since the creases are always tangent to the ellipse, the ellipse becomes the envelope of the infinite set of creases that can be produced by repeated folding of the paper. This proof is taken from Donovan A. Johnson's booklet *Paper Folding for the Mathematics Class*, published in 1957 by the National Council of Teachers of Mathematics.

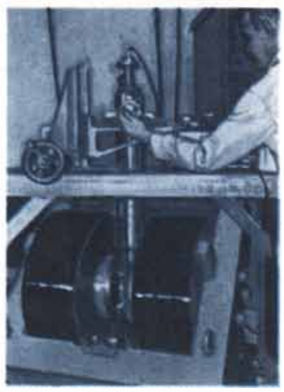


Answer to the paper-folding problem

RESEARCH SCIENTISTS







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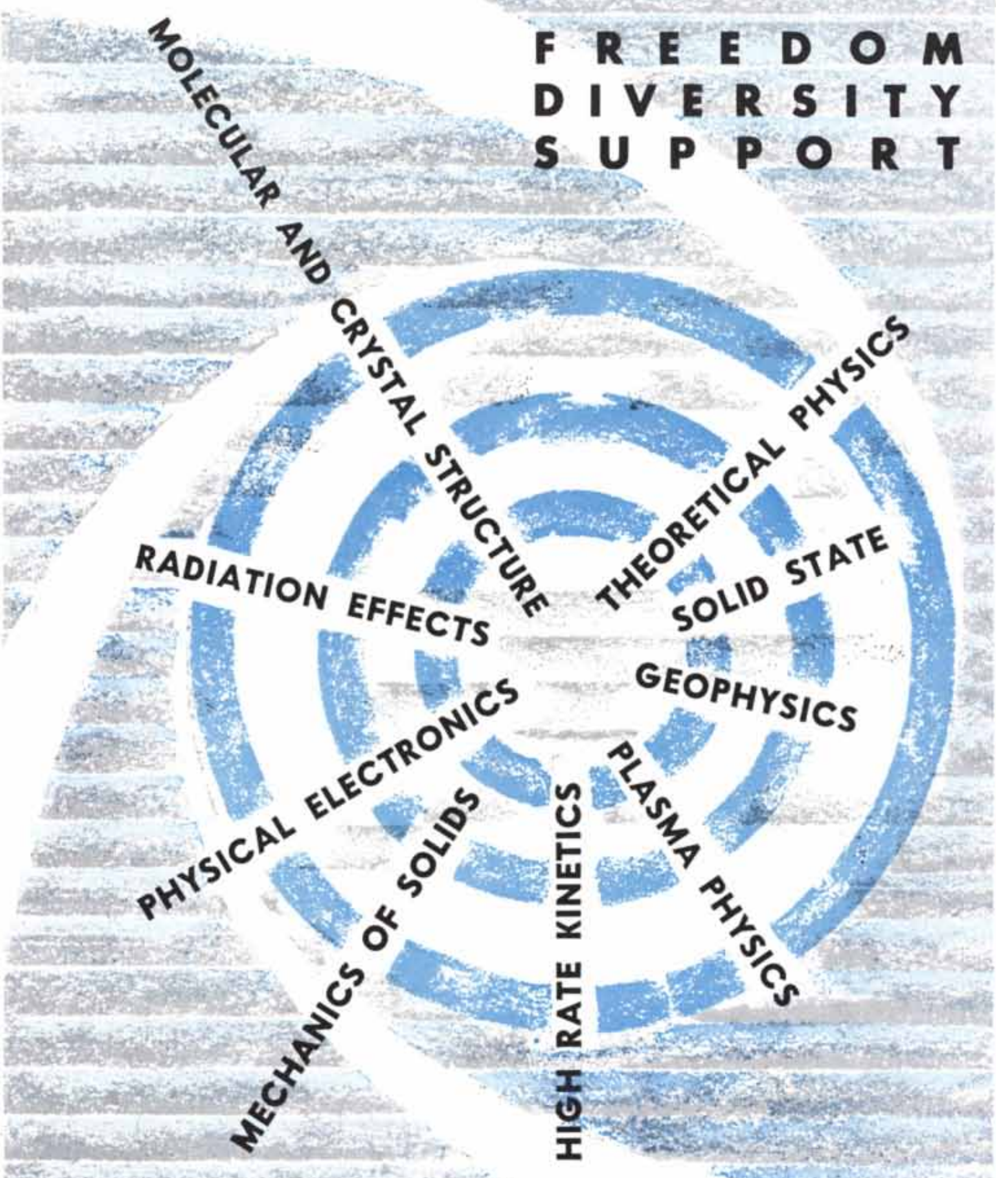

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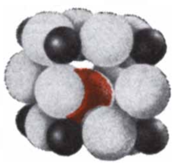
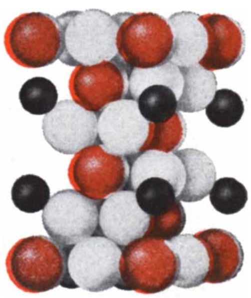
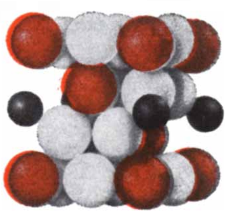


Perovskite



Five layers



Three layers

A number of new oxide compounds with the perovskite structure have been developed by one of our research groups. Investigations of related three-layered and five-layered structures are also in progress. To discover the relationships between crystal structure and physical properties, intensive studies are being carried on to determine ferroelectric, ferromagnetic and dielectric characteristics. From this basic research may come advanced materials superior to any currently available. • Our corporate-sponsored research programs into the fundamental nature of matter offer *unusual opportunity* to any scientist interested in doing *original work*. Inquiries are invited particularly from those with experience in—Solid State Physics • Plasma Physics • Particle Physics • Nuclear Engineering • Gaseous Electronics • Direct Conversion • Surface Chemistry.

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THE AMATEUR SCIENTIST

A young amateur experiments with a plant that collapses its leaves when it is touched

Conducted by C. L. Stong

Nearly everyone has heard about Venus's-flytrap, sundew, mimosa and similar plants that are capable of animal-like movements. But few residents of northern latitudes are familiar with any of the several hundred so-called "sensitive" plants because most are tropical, or at least semitropical. We now learn, however, that one grows in Brooklyn. The movements of the Brooklyn plant are not so swift or eye-catching as those of Venus's-flytrap, but they are quite as fascinating to Jack Rudloe, the high school boy who studies them. Rudloe, who now lives in Tallahassee, Fla., explains how he found the plant, how he has experimented with it and what he has learned about it.

"While taking a short cut across a vacant lot in Brooklyn four summers ago," he writes, "I happened to brush against a small green shrub with fern-like leaves. The plant had reddish-brown stems and an abundance of small yellow flowers so attractive that I stopped for a closer look. One feature was particularly interesting: the stem of each leaf bore a small, glandlike structure about the size of a pinhead, which on the younger leaves was brilliant red and strikingly beautiful when viewed through a magnifying glass. I had scarcely begun to examine the gland on one leaf when I became conscious of a change in the plant. It was moving. The leaves were folding up, slowly but nonetheless obviously [*see illustration on next page*]. What made it move?

"I spent the rest of the summer trying to find out and became a regular visitor to the lot. At night the leaves closed tightly and the leaf stems would droop at a sharp angle. Hot days or intense sunlight produced much the same effect. I could make a leaf close and droop merely by striking it several times with my finger. It was obvious that the movements were not caused by differences in growth rate. The responses were much too quick. The leaves would start to fold within seconds after being stimulated. Unless the plant was damaged in the process, it would recover from even the most violent disturbance within an hour.

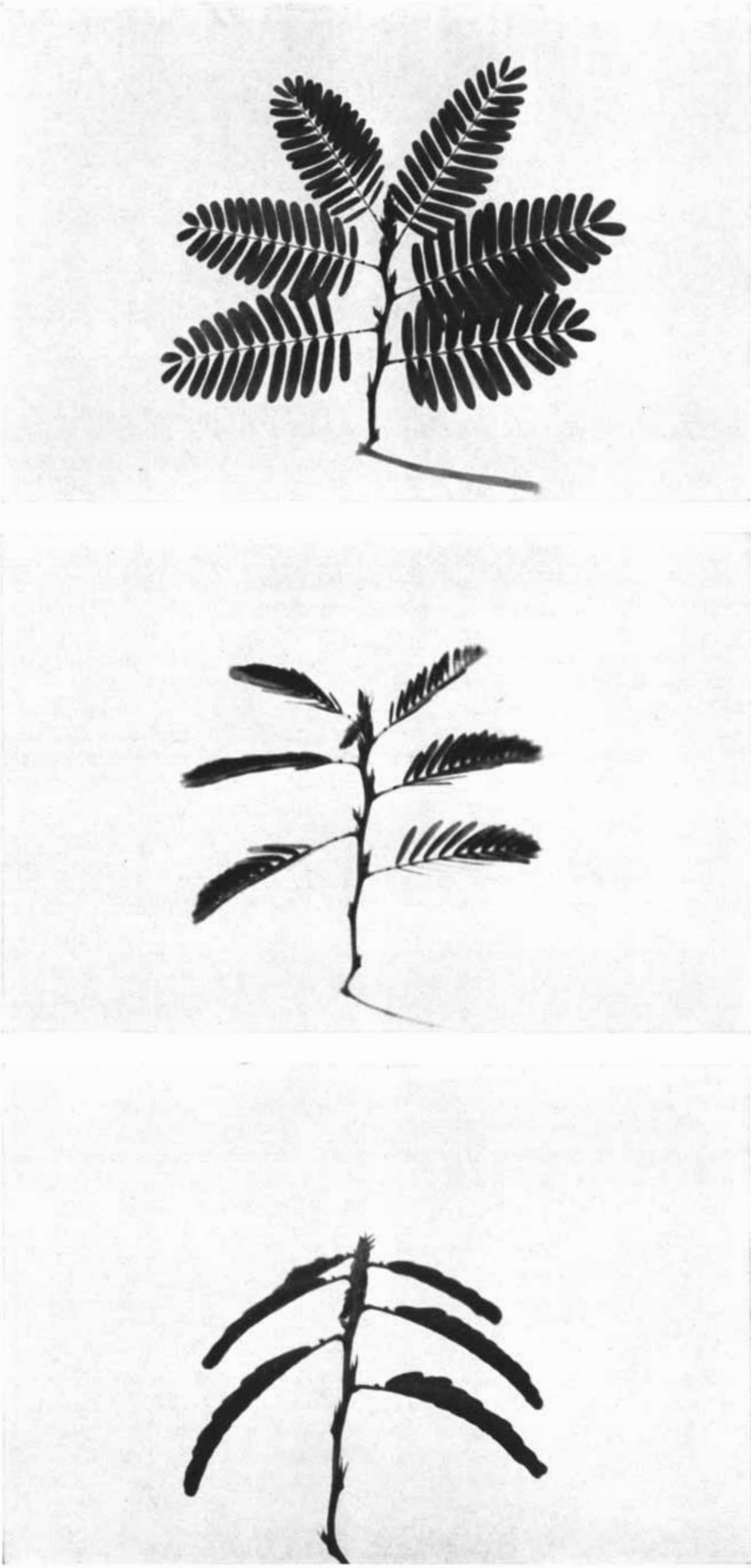
"After a few weeks I decided to transplant a few specimens to our apartment for more convenient study. All attempts failed. I discovered that even the slightest damage to the root system killed the plant. Toward the end of August the field specimens came to seed. Each plant bore an abundance of long green pods. The pods dried by October, and I collected enough seeds to fill a one-ounce bottle—a lifetime supply. I put a capsule of calcium carbonate into the bottle to absorb moisture. Then, before frost set in, I took a few specimens to the Brooklyn Botanic Garden, where they were identified as *Cassia nictitans*, the wild sensitive pea.

"The movements of *Cassia nictitans* are far more sluggish than those of the Venus's-flytrap or even of *Mimosa pudica*, the sensitive house plant that is so popular with gardeners in the southern U. S. When disturbed, the leaflets of mimosa snap shut within two seconds. Those of Cassia require from three to four minutes and will not close fully unless they are mechanically stimulated at least three times.

"During the following winter I attempted to grow some Cassia but without exception the results were disappointing. The seeds germinated well and came up promptly. Unfortunately the plants developed just as promptly. Having attained runt size in three or four weeks, they flowered, went to seed and died. I tried adjusting the soil, the room temperature and every other variable I could think of without success. Finally I simply gave up and put the seeds away.

"Subsequently we moved to Florida. One day in 1959, while unpacking a box of hobby materials, I came across the forgotten seeds. We live close to the campus of Florida State University, and during a visit to the campus shortly after finding the bottle I arranged to plant a crop in the university greenhouse, where the environment can be controlled. Once again the seeds germinated well, but the crop failed as usual. All of the young plants flowered within a month of planting. This seemed strange because I had made a careful record of summer temperature at the lot in Brooklyn and had duplicated it in the greenhouse. Finally I took the problem to George W. Keitt, Jr., a plant physiologist at the university. He suggested that the long November nights might be responsible for triggering the premature flowering [see "Light and Plant Development," by W. L. Butler and Robert J. Downs; SCIENTIFIC AMERICAN, December, 1960]. So I installed a bank of electric lights above the plants and connected it to an automatic timer set to turn on at 4 p.m. and off at 2 a.m. This solved the problem. Within two months I had a flourishing crop of normal, healthy plants. Many more have since been grown.

"While in Brooklyn I had gone through the literature in an attempt to learn about sensitive plants. Hundreds of different kinds have been described. All plants are capable of some movement, of course, particularly that resulting from unequal growth or the absorption or loss of water. Sensitive plants, on the other hand, have evolved a special motor organ, the pulvinus, that is responsible for an altogether different kind of movement. The pulvinus is an enlargement at the base of the leaflet and at the base of the leaf stem, or petiole. The center of the pulvinus contains a strand of vascular tissue surrounded by a cylinder of thin-walled cells that are separated by relatively large intercellular spaces. Some mechanism in the plant, not fully understood, controls the permeability of the cell walls. In certain states the cells become gorged with a fluid that stiffens the whole structure. In other states the fluid is secreted in the intercellular spaces and the pulvinus loses



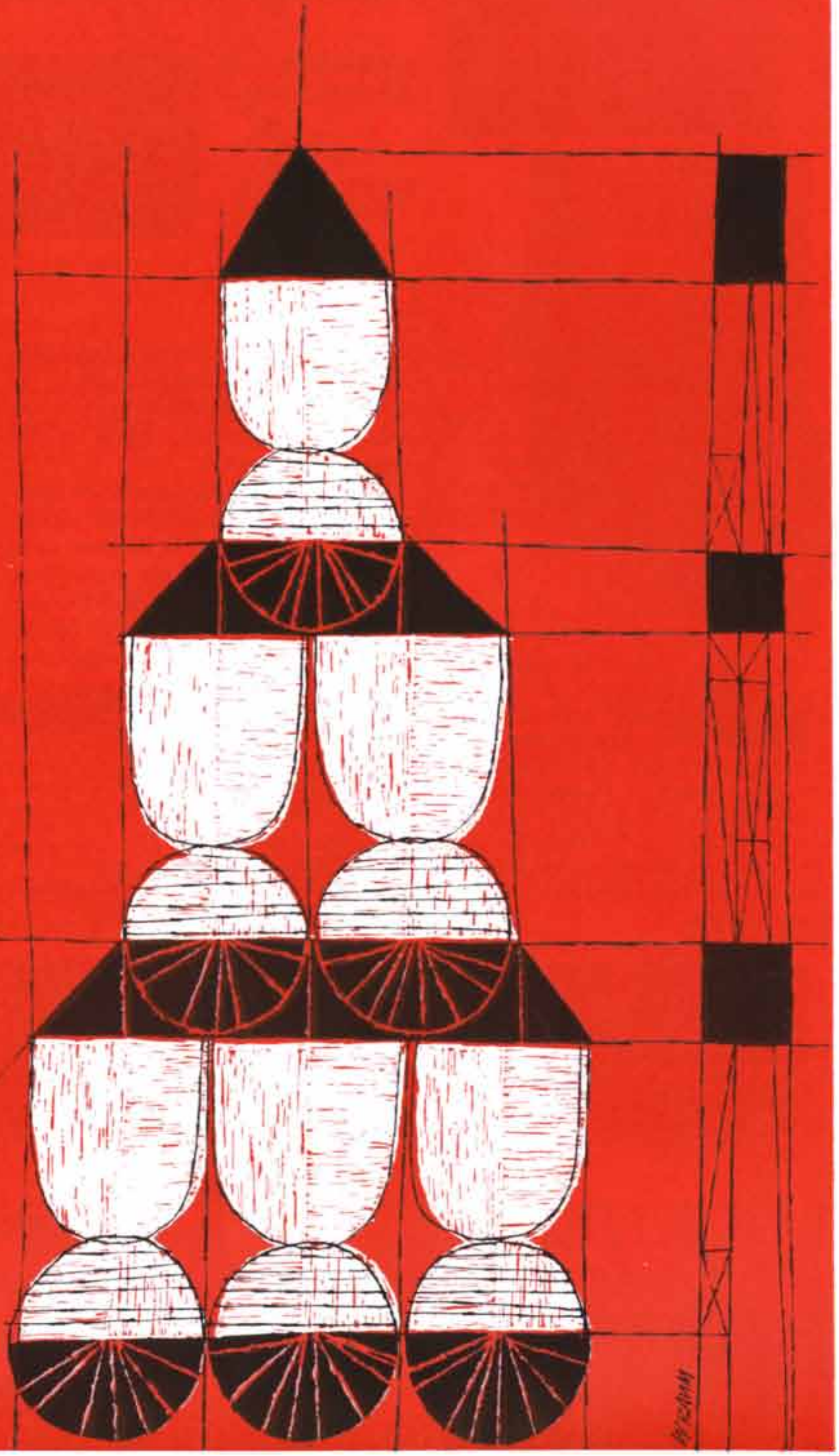
The sensitive pea (Cassia nictitans) *folds its leaves after it has been touched*

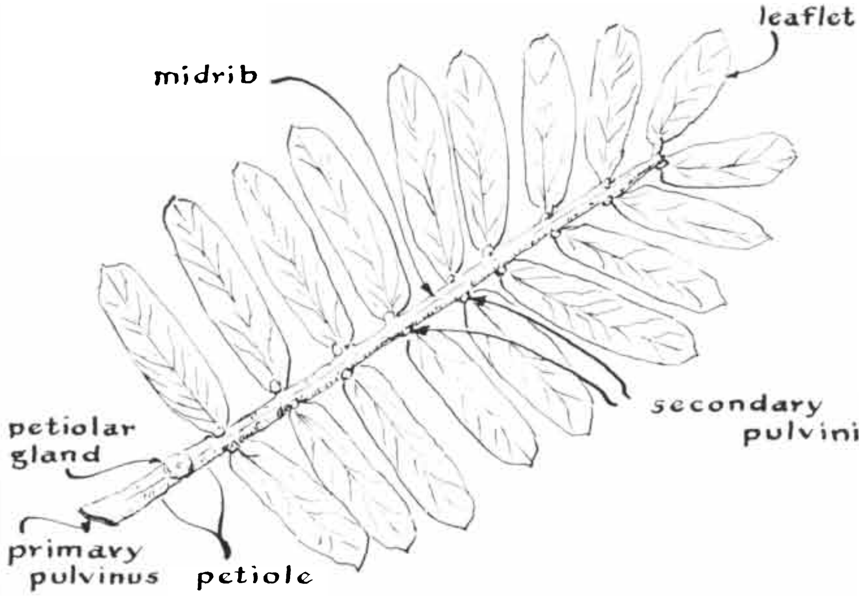
its stiffness. Such changes in permeability can occur, moreover, within selected groups of cells, such as those on one side of the pulvinus, with the consequence that one group of cells becomes flaccid while the opposing group remains turgid and the organ bends. A substantial amount of energy is thus made available for mechanical work and accounts for the movement of sensitive plants. Although the mechanism of energy conversion may differ fundamentally from that of animal muscle, the resulting action is comparable. The pulvinus can readily elevate a leaf against the force of gravity, for example.

"Unfortunately the literature makes few references to *Cassia nictitans* and barely mentions the petiolar gland. The specimens that I have observed normally grow to a height of between six and eight inches as a single stalk with leaves attached to primary pulvini on alternate sides about every half inch from the middle to the top of the stalk. Each leaf consists of a midrib that supports about a score of leaflets spaced uniformly in opposing pairs along its length. Each leaflet is coupled to the midrib through a secondary pulvinus, as illustrated in the accompanying drawing [*top of page 184*]. The petiolar gland is situated on the dorsal side of the petiole about midway between the last set of leaflets and the primary pulvinus [*see bottom illustration on page 184*].

"The gland had first caught my interest when flies buzzing around the plants in Brooklyn were attracted to it; it is a mushroom-shaped structure with a slightly depressed, elliptical top about a millimeter wide and less than a millimeter in height. During certain phases of the plant's life the gland secretes a sticky, transparent sap that collects as a drop in the depression at the top of the gland. It was this sap that attracted the flies. They fed on it. If permitted to collect undisturbed, the sap dries into a hard ball that eventually drops off. The gland then begins to secrete additional sap and the cycle repeats. When a hot dissection needle is applied to the secretion in either the liquid or solid state, the resulting smoke has the odor of burnt sugar and a black residue forms that appears to be carbon. The one chemical test that I have made so far, however, failed to indicate the presence of sugar.

"What is the function of this gland? In what way, if any, does it influence the movements of the plant? Because the reference books gave no information on this point, I decided to remove the glands from some plants to see what

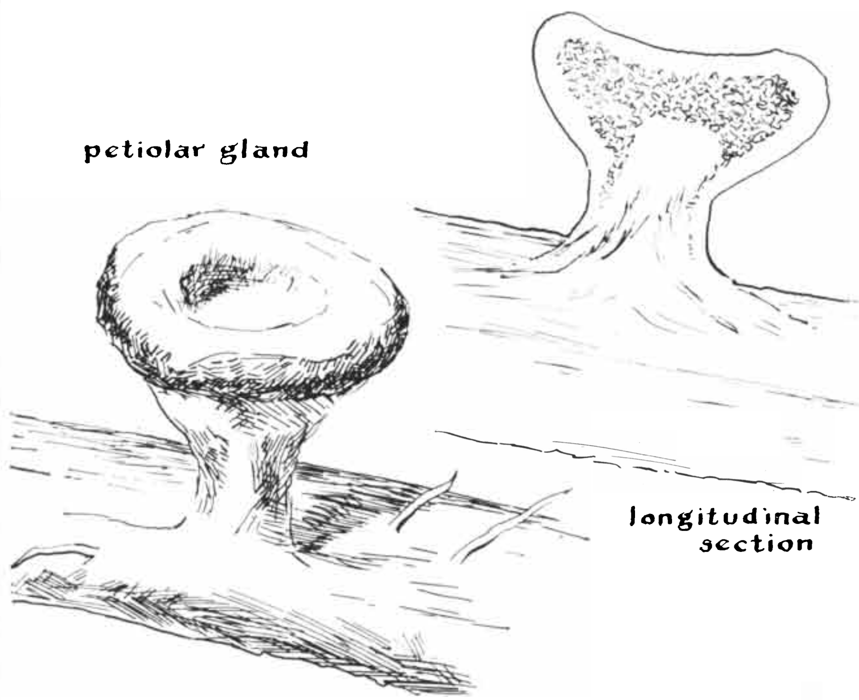




The leaf of Cassia nictitans

would happen. This would not necessarily show how the gland functions, but it might indicate whether there is any relationship between the gland and the action of the pulvini.

"First, I made a goniometer for measuring the angular closure of the leaflets. This was simply a sheet of glass about four inches wide and five inches long on which I painted a pattern of 17 radial lines, a fourfold bisection of a 180-degree angle. Each of the 16 sectors is an angle of 11.25 degrees. The sectors were numbered serially in the clockwise direction from the reference line as shown by the accompanying illustration [*page 187*]. You merely hold the goniometer between the eye and leaf, center the apex of the radial pattern on the axis of the midrib and turn the glass so the reference line is aligned with the leaflets on one side of the leaf. The opposing leaflets are then observed through one of the remaining spaces, unless the leaf is fully



Petiolar gland of Cassia nictitans

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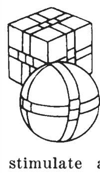

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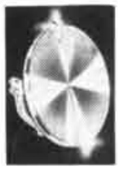

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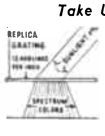

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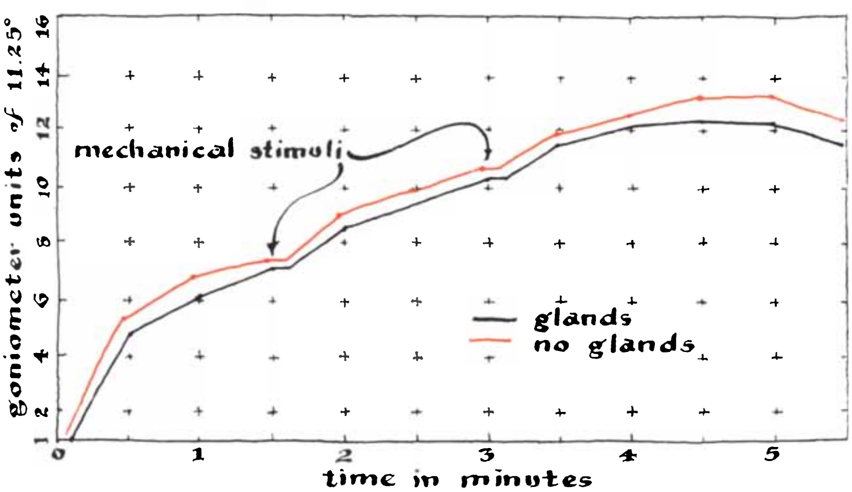
closed. To calculate the amount of closure per leaflet I multiply the number of sectors that the leaflets span by 11.25 and divide by two. To determine the rate of closure or opening I make a series of timed measurements and plot the resulting data on rectangular co-ordinate graph paper.

"In preparation for the first experiment I selected three groups of uniform, mature plants. The glands were removed from one group by placing the pointed end of a dissecting needle against the stalk of the gland and pressing the tip toward the apex of the leaf. The glands came off easily, taking along a small amount of vascular tissue from the stalk at its point of attachment to the petiole. Later I learned from experience that the risk of leaving tissue from the stalk embedded in the petiole increases with the age of the leaf. It is best to work with relatively young leaves. The removal of a gland causes only a small wound that heals in about a week.

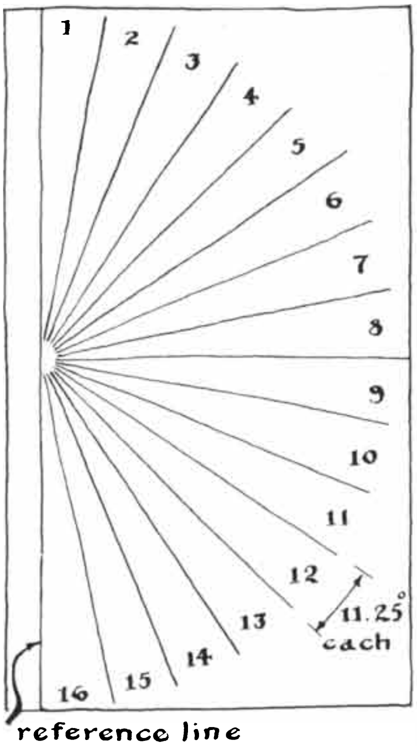
"Would the mere wounding of the petioles, apart from the removal of the glands, influence the sensitivity of the plants? In anticipation of this question the petioles of the second group were nicked in a few places between the gland and the stem. The wounds were just as severe as though the glands had been removed. But the glands were left intact. This test was discontinued after the first few experiments because the behavior of the nicked plants was identical with that of the control group. The control group was not modified. The three groups were then permitted to recover for one week.

"What effect, if any, would the presence or absence of the petiolar gland have on the response of the plant to a light blow, as when struck by the finger? To investigate the question I improvised a simple apparatus for dropping a series of weights on a selected part of the plant so that the intensity of successive impacts could be reproduced. A 10-inch length of quarter-inch aluminum tubing was supported vertically in a clamp on a ring stand, with the bottom of the tube about a foot above the bench. A slot wide enough to admit a piece of cardboard was sawed halfway through the tube near the top. When placed in the slot, the cardboard served as a support for a pellet. When the cardboard was withdrawn, the pellet would drop through the tube and strike the plant beneath. Pellets of three weights were used. One of papier-mâché weighed .32 gram; one of wax, .49 gram; one consisting of a pellet of 00 buckshot, 3.21 grams. The tube was aimed by trial and error (at first mostly error) so that the pellets struck the midrib of a selected leaf.

"No significant differences were observed between the behavior of glanded and glandless leaves. But the experiments did disclose several interesting responses. The leaflets would not close fully, for example, when stimulated by a single blow, however intense. Each initial stimulus was followed by a latent period of five to eight seconds. Movement then began and continued for 90 seconds. If not restimulated, the leaflets would then come to rest for 30 seconds and begin to reopen. Restimulation at the end of the initial 90 seconds of movement was followed by a brief latent period. A second and third stimulation would in each case be followed by 60 seconds of movement. Three stimuli produced full closure of all



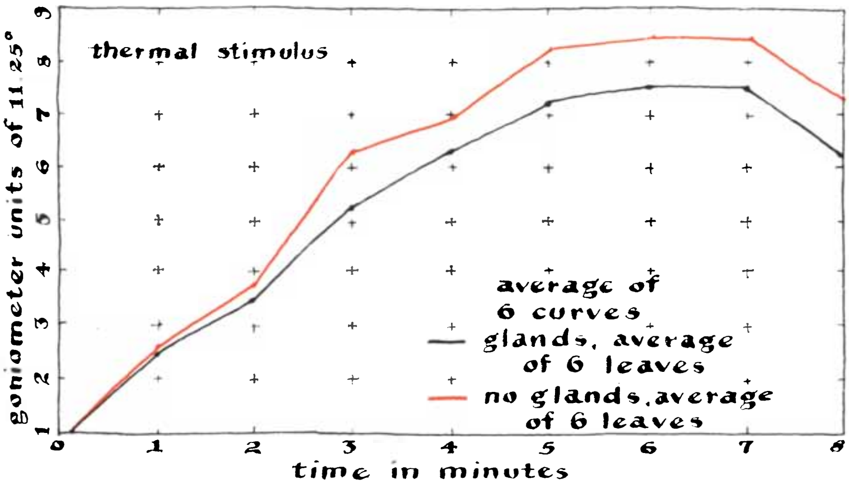
Graph showing response of plant to impact

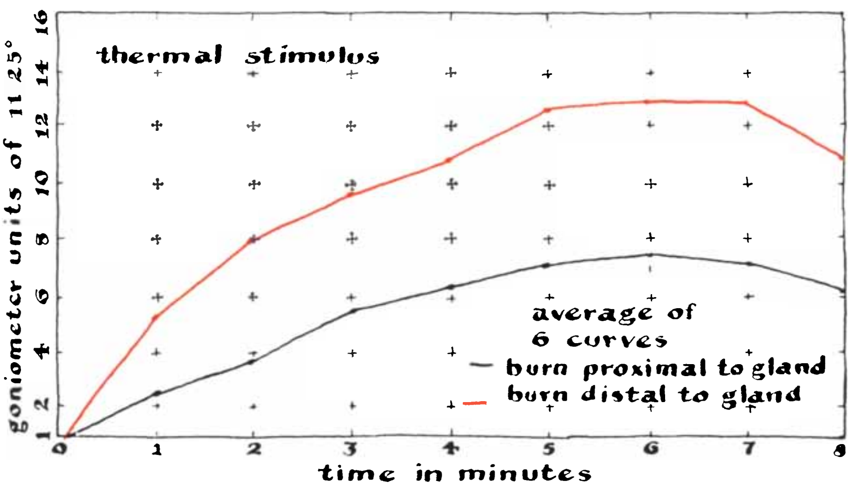


Goniometer for measuring leaf movements

leaflets and made the entire leaf droop. Maximum movement was induced by the initial impact with progressively less movement following the second and third blows. The initial rate of closure following each blow appeared to vary directly with the intensity of the impact, but not significantly [*see illustration on opposite page*].

"Would the application of heat trigger the pulvini? As the initial test I applied the tip of a hot dissecting needle to the top of the gland of the control plants and to the scar tissue of the glanded plants. No movement was apparent for eight seconds. Then the leaflets of all plants began to close, continued for six minutes, stopped for a minute and then began to open. The glandless leaves closed about five degrees per minute faster than the control plants, as illustrated by the accompanying graph [*top illustration on next page*]. The difference is not great and may not be significant. It would appear to indicate, however, that the gland is an irritable center. The stimulated gland resulted in movement at least comparable with that of the stimulated petiole. During a subsequent run of this same experiment I accidentally touched the hot needle to the petiole of a control plant in the area between the gland and the first pair of leaflets. I was about to discard the plant when I noticed that the leaflets were closing at



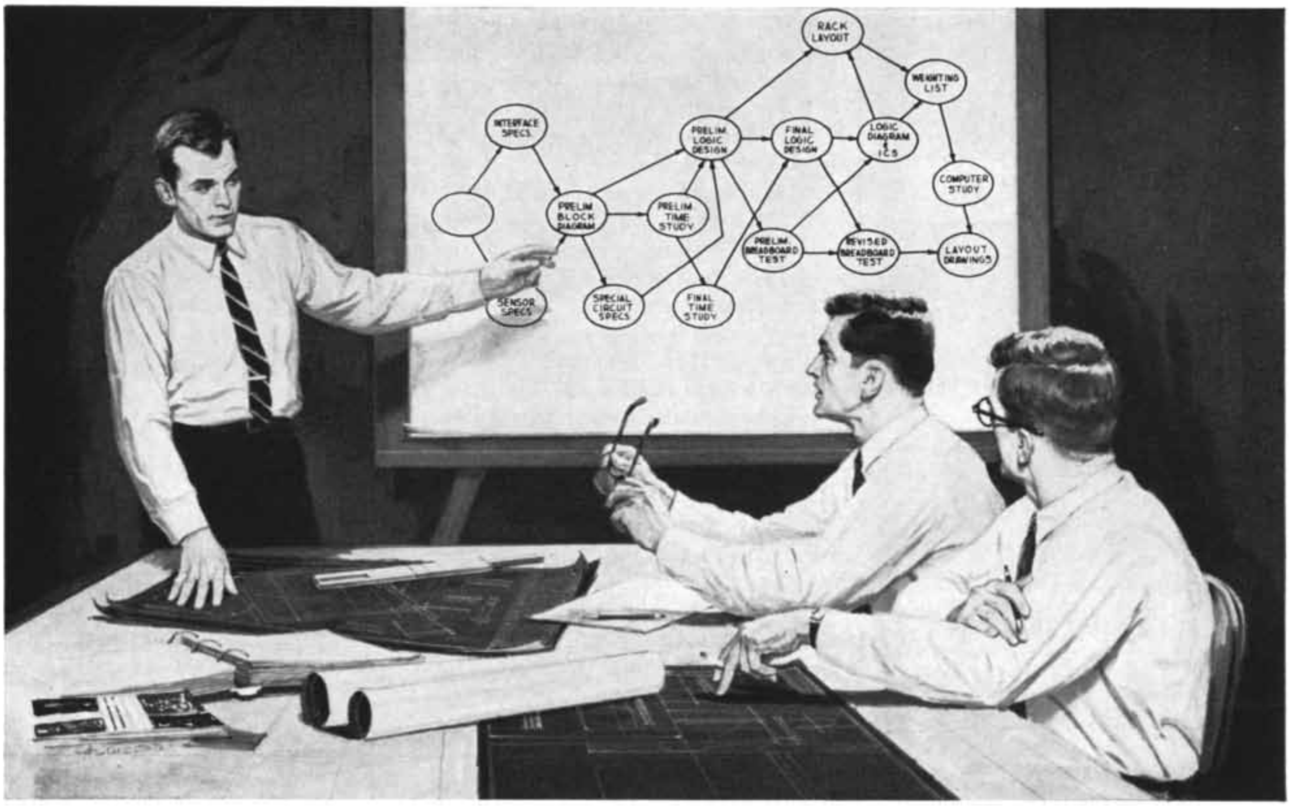


Response of plant to heat applied to gland (top) *and to petiole* (bottom)

an abnormally high rate. This suggested another experiment.

"Two groups of unaltered plants were selected. The heated tip of the needle was touched to the petioles of one group at a point about two millimeters above the gland (between the gland and the leaflets). The petioles of the second group were similarly stimulated between the gland and the stalk of the plant. The comparative reaction of the two groups was astonishing. The leaflets of the group that was stimulated between the gland and the leaflets moved through twice the angle of the second group in the same period of time [*bottom illustration on this page*]. In addition to the difference in rate of movement the plants reacted in another interesting way. The midrib darkened and the secondary pulvini, which form the junctions between the midrib and the leaflets, changed color from pale white to dark green. The heat doubtless influences the chemistry of the midrib, but the altered appearance of the pulvini may be due to differences of light refraction caused by the redistribution of the fluid in the permeable cells.

"The leaves of *Cassia nictitans* close tightly at night, with a sharp forward and upward movement. Is the gland involved? Two groups of plants were removed from the artificial light and placed near a large window with a northwest exposure. To simplify measurement all but the four most vigorous leaves were removed from each plant. The glands were also removed from one group. The plants were then permitted to recover. (Recovery was judged to be complete when the plant reacted normally to physical stimuli.) Closure of the two groups required about two hours; the rates of closure were almost identical, although the glandless group re-



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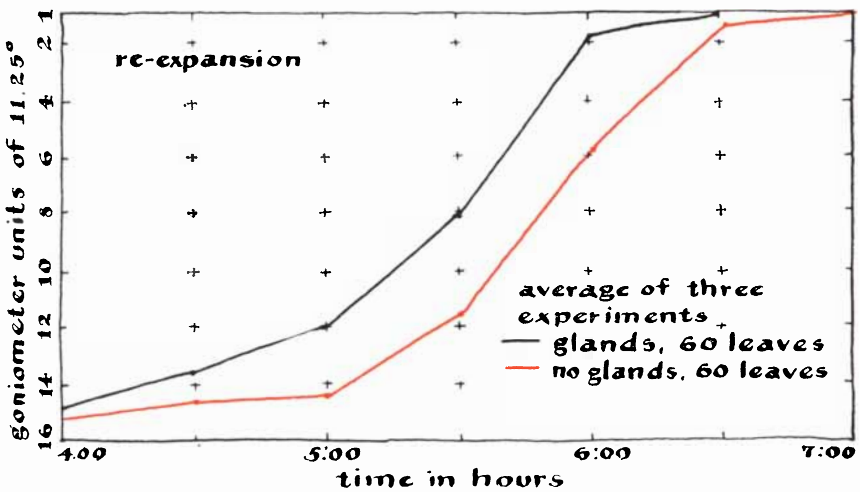
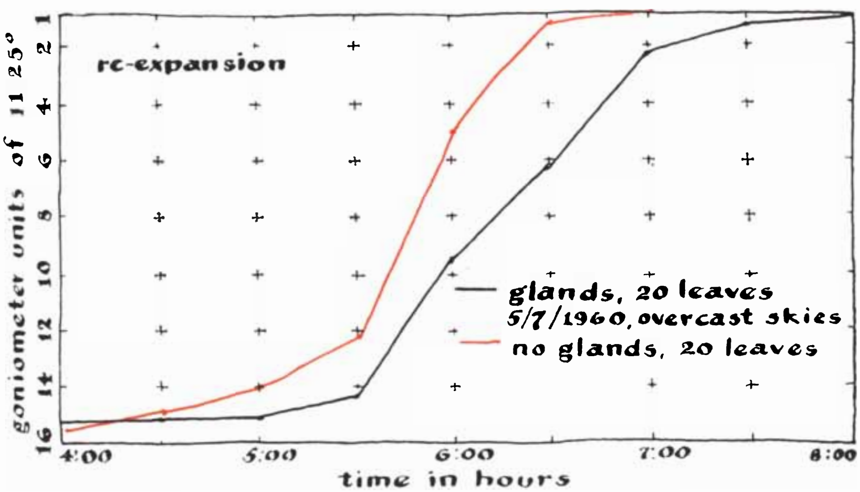
sponded at a higher initial rate. No change of color was observed in either the midribs or the pulvini.

"Subsequently I ran another series of tests with a different set of plants to check the rate of re-expansion in the morning. The plants were similarly prepared but were shifted to a window with a southeast exposure. The experiments were made in May, 1960, beginning in total darkness at about 4 a.m. The plants without glands were observed to open at a substantially lower rate than the controls, less than half as fast during the initial phase, and required 30 minutes longer than the controls to open fully [*see top illustration on this page*]. The most interesting response, however, was observed on May 7. In contrast with the previous sunny mornings, there was intense rain and the sky was heavily overcast. The plants with glands opened at a much higher rate than those without glands and were fully open an hour earlier. I can think of no reason for this reversal in behavior, and so far I have not managed to get any counsel concerning an explanation. The data plotted in the next illustration [*bottom of page*] represent the average of observations made over a period of three days in the case of the glandless plants but of only one day in the case of the controls.

"The crop was at its best during May and June. An abundance of large leaves provided an excellent opportunity to test the effects of an acid, an alkali and alcohol as stimulants. Sulfuric acid was prepared in three concentrations for the experiment by adding 12 grams, 144 grams and 588 grams of acid respectively to three vessels, each containing one liter of water. Comparable dilutions of ammonium hydroxide were prepared for the alkali solution. A single dilution of 85 per cent ethyl alcohol (by volume) was used. The stimulants were applied to the glands and petioles with a swab





Response of plant to sunrise on a clear day (top) *and a cloudy one* (bottom)

A Statement of Conviction about Overpopulation

A summary of the statement signed by distinguished citizens of 17 countries, including 34 Nobel Laureates, on what must be done to curb the population explosion —and why:

BECAUSE two-thirds of the world's people are now underfed;

BECAUSE *each day* nearly 140,000 more people are added to the world's population, and *each year* 50,000,000 more people;

BECAUSE unless a favorable balance of population and resources is achieved with a minimum of delay, there is in prospect a Dark Age of human misery, famine and unrest;

WE BELIEVE that widespread, effective and voluntary use of medically sound and individually acceptable birth control is an essential factor in any humane design to raise world living standards and achieve international peace.

THEREFORE WE SUPPORT with conviction the efforts, within individual nations, to control the birthrate.

AND WE URGE that the United Nations take the lead in establishing and implementing a policy designed to limit population growth the world over — in order that human beings everywhere may develop their highest capacities, enjoy individual freedom, health, privacy, security, and the beauty and wonder of the world.

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*Signers are from the United States unless otherwise designated.

The full statement has been presented to the United Nations. For a copy of the complete text and further information about it — including suggestions on what you can do to support the viewpoint it expresses — write or call:

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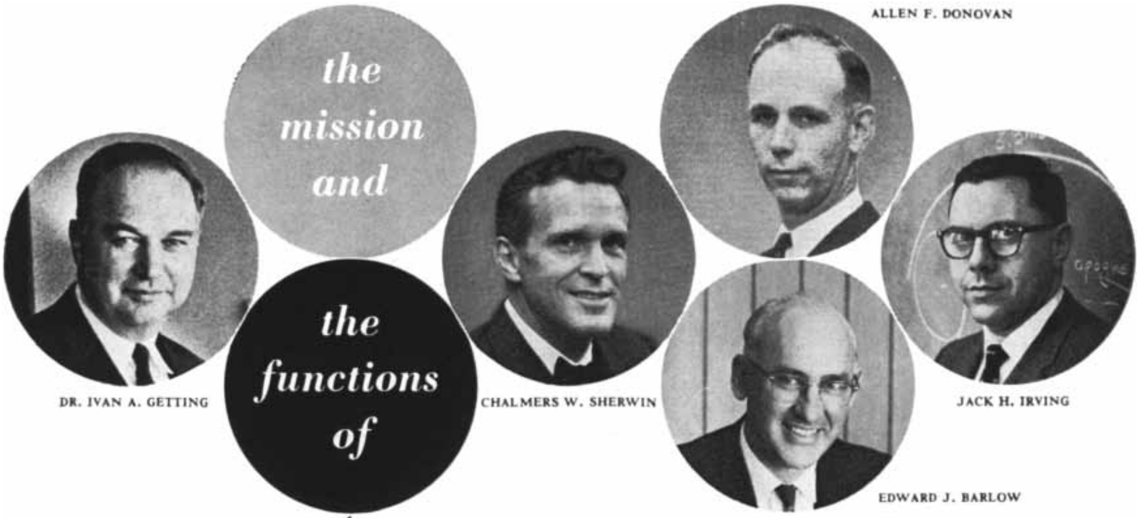
made by wrapping a few strands of cotton on the roughened tip of a dissecting needle.

"The plants, grouped and prepared as in the earlier experiments, displayed a barely detectable reaction to the weakest dilutions of acid and alkali. The intermediate concentration triggered a more obvious response: movement started in the leaflets closest to the stem of the plant and gradually progressed up the midrib to the terminal pairs. The rate of movement was perceptibly higher in the leaves with glands but in all other respects the reactions of both groups were identical.

"The highest concentration of alkali and the alcohol triggered more interesting responses. When a drop of strong ammonium hydroxide solution was applied to the glands, all leaflets closed quickly in unison, with the stimulus being transmitted first to the first pair of terminal leaflets—the pair at the apex and farthest removed from the gland. When applied to a glandless petiole, however, the alkali induced movement first in the pair of leaflets closest to the petiole and the effect progressed up the midrib to the terminal pair. When alcohol was applied to the gland, the leaflets at the apex responded first and the movement traveled progressively down the midrib to the petiole. When alcohol was applied to a glandless petiole, leaflets closest to the stem responded first and the reaction progressed quickly toward the apex. Immediately after the application of strong acid to the gland, the color of the gland changed from the normal brown (on mature leaves) to a brilliant red. The midrib simultaneously darkened and the pulvini changed color as the stimulus traveled down the midrib at the rate of one millimeter per second.

"The results of these experiments (which I am continuing) have not disclosed the purpose of the gland. They do suggest that the gland is both an irritable center and a transmission organ. Under certain conditions it can influence the movements of the plant. The reaction of the plant when alcohol is applied to the gland even suggests that the gland may be connected to the apex of the leaf by some sort of pipeline. It would be interesting to check this by one of the radioactive-isotope techniques. The experiments have also shown that the plant responds to four stimuli: impact, heat, light and certain chemicals. Finally, they have provided me with a hobby as fascinating as any I can imagine. I urge amateur botanists who are on the prowl for novel specimens to include *Cassia nictitans* in their collections."



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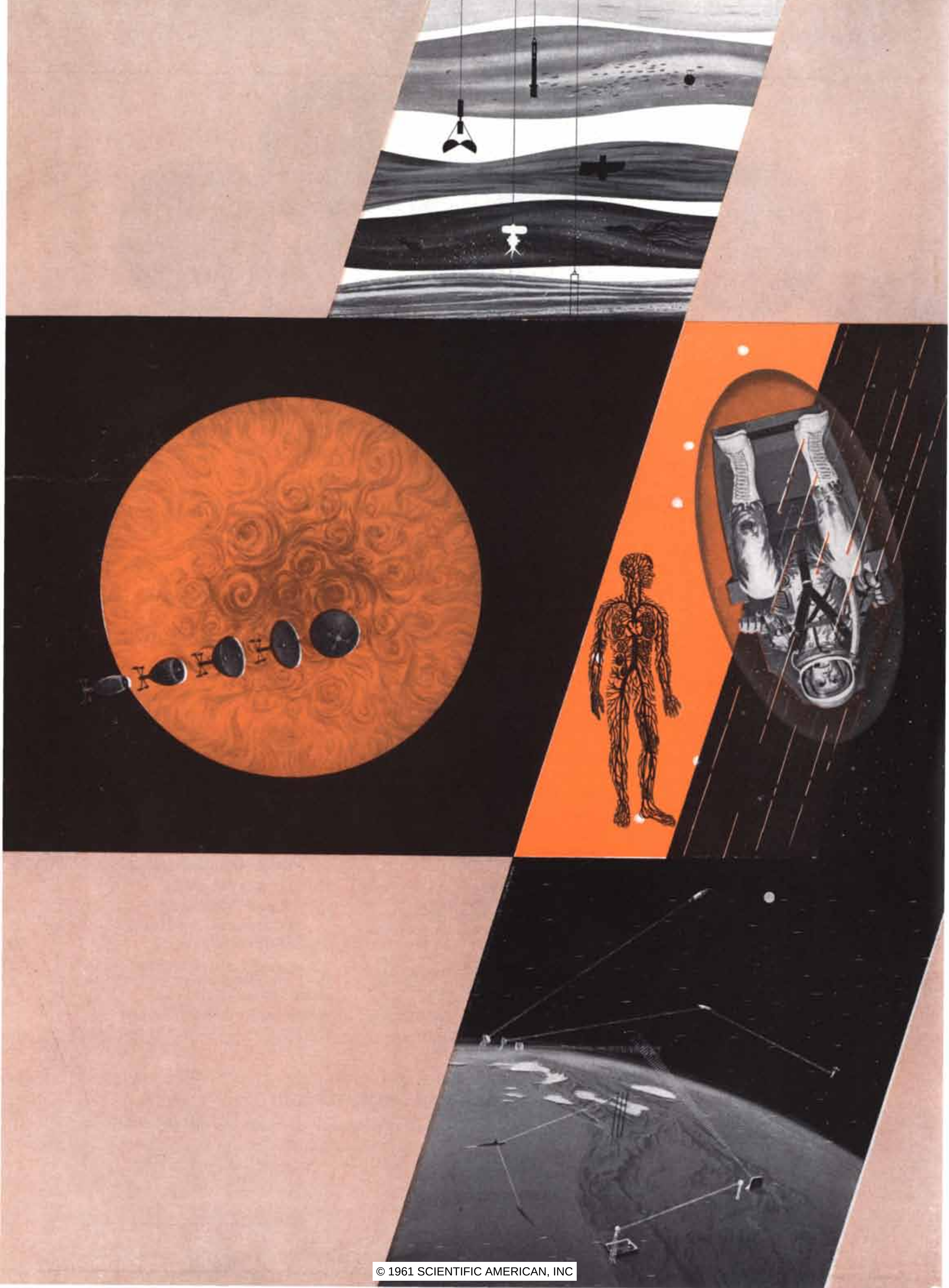

BOOKS

Two discussions of thermonuclear war

by James R. Newman

ON THERMONUCLEAR WAR, by Herman Kahn. Princeton University Press ($10).

ARMS CONTROL. Fall issue of *Dædalus*, Journal of the American Academy of Arts and Sciences ($2).

Is there really a Herman Kahn? It is hard to believe. Doubts cross one's mind almost from the first page of this deplorable book: no one could write like this; no one could think like this. Perhaps the whole thing is a staff hoax in bad taste.

The evidence as to Kahn's existence is meager. The biographical note states that he was born in Bayonne, N.J., in 1922, that he studied at the University of California at Los Angeles and the California Institute of Technology, that he has worked for 12 years for the Rand Corporation as a "military planner." An autobiographical footnote states that he was trained as a physicist and a mathematician. This explains, he says, why he finds it "both satisfying and illuminating to distinguish the three kinds of [military] deterrence by I, II, and III, [despite the fact that] many people have been distressed with the nonsuggestive nature of the ordinal numbers." I find this passionate attachment to the ordinal numbers implausible. One more personal note. In his preface Kahn says he carried the manuscript around for a year "on airplanes and railroads." This has the ring of truth. Every now and then the reader gains the impression that he is getting a collection of airport and station jottings; at times it almost seems as though the author is suffering from motion sickness.

Kahn may be the Rand Corporation's General Bourbaki, the imaginary individual used by a school of French mathematicians to test outrageous ideas. The style of the book certainly suggests teamwork. It is by turns waggish, pompous, chummy, coy, brutal, arch, rude, man-to-man, Air Force crisp, energetic, tongue-tied, pretentious, ingenuous, spastic, ironical, savage, malapropos, square-bashing and moralistic. Solecisms, pleonasms and jargon abound; the clichés and fused participles are spectacular; there are many sad examples of what Fowler calls cannibalism—words devouring their own kind. How could a single person produce such a caricature?

No less remarkable is the substance of the book. An ecstatic foreword by Klaus Knorr of Princeton University's Center of International Studies states that this is "not a book about the moral aspects of military problems." The disclaimer is much to the point; it is exactly wrong. This is a moral tract on mass murder: how to plan it, how to commit it, how to get away with it, how to justify it.

The argument of "On Thermonuclear War," so far as it attains coherence, runs like this. Kahn says he is concerned with "alternative national postures" to deter war and to survive it if it comes. It is quite possible, he believes, that we shall have another world war; in fact, several. But one war at a time. What should be done to reduce the threat? World government? Disarmament? These, he says, are utopian. Can we rely on the uncertain balance of terror to postpone the date of mankind's final war? In Kahn's view it is dangerous to hold that an all-out war is "rationally infeasible." The "survival-conscious person" has to think more boldly. We must be ready to fight as well as deter. And if we do fight "we have to 'prevail' in some meaningful sense if we cannot win."

We must therefore be equipped to erase cities, especially control centers ("Finite Deterrence"); we must have "Counterforce as Insurance," "Preattack Mobilization Base," "Limited War Capability" and "Long War (2–30 Days) Capability." Kahn defines the last concept elegantly: "Almost no matter how well one does on the first day of the war, if he has no capability on the second day—and the enemy does have some capability on that day—he is going to lose the war."

Do we need civil defense? The important thing is to fit civil defense into the large strategic program: "Counterforce" and "Credible First Strike Capability," to make sure we gain the most effective "posture" for "Preattack and Postattack Coercion." Three types of deterrence (*i.e.*, I, II and III); all kinds of weapons; readiness for all kinds of wars; a habituation to "tense situations"; "keeping our conceptual doctrinal and linguistic framework up to the moment"—these are some of the elements in the Kahn program of preparation for *Der Tag*.

Kahn summarizes his general notion of the most desirable "posture." We should have, he says, "at least, enough capability to launch a first strike in the kind of tense situation that would result from an outrageous Soviet provocation, so as to induce uncertainty in the enemy as to whether it would not be safer to attack us directly rather than provoke us. The posture should have enough of a retaliatory capacity to make this direct attack unattractive." The Higher Incoherence, otherwise known as the game-theory approach to nuclear-age strategy (which is much admired and fostered by the Rand Corporation) characterizes the argument. There is a Jewish anecdote which runs:

"Where are you going?"

"To Minsk."

"Shame on you! You say this to make me think you are going to Pinsk. But I happen to know you *are* going to Minsk."

What Bertrand Russell's paradox of the class of all classes is to the foundations of mathematics, this anecdote is to the game of international outthink. Kahn is a Minsk-to-Pinsk outthinker.

When the war is ended (2–30 days), what then? (Do we all join up again?) Some persons have said that after a thermonuclear war the world will be a graveyard and the rats will inherit the earth. Nonsense, says Kahn. This is the "layman's view," although there are many military planners, scientists, "intellectuals" and even generals who hold it. This shows they have not thought hard enough about the question. The 52 Nobel prize winners who in 1955 issued the Mainau Declaration (" '*All* nations must come to the decision to renounce force as a final resort of policy. If they are not prepared to do this they will *cease to exist*' ") are well-meaning chaps but they are guilty of "rhetoric." The facts, adduced by "homework" and "sober study," are otherwise. Kahn has "researched" the matter and is in a position to assure us that, while a thermonuclear war "is quite likely to be an *unprecedented catastrophe* for the defender" [his italics], this is "a far cry from an 'unlimited' one." The limits on the magnitude of the catastrophe "seem to be closely dependent on what kinds of preparations have been made, and on how the war is started and fought."

In Kahn's view we must distinguish between 100 million dead and 50 million dead. We must face the task in assessing "postwar states . . . of distinguishing among the possible degrees of awfulness." After all, it would be better to have "a country which survives a war with, say, 150 million people and a gross national product (GNP) of $300 billion a year, [than] a nation which emerges with only 50 million people and a GNP of $10 billion. The former would [still] be the richest and the fourth largest nation in the world [while] the latter would be a pitiful remnant. . . ."

To clear the mind "for deliberations in this field" Kahn gives us the table reproduced below. (The cryptic caption is from the book.) "Here," says Kahn, "I have tried to make the point that if we have a posture which might result in 40 million dead in a general war, and as a result of poor planning, apathy, or other causes, our posture deteriorates and a war occurs with 80 million dead, we have suffered an additional disaster, an *unnecessary* additional disaster that is almost as bad as the original disaster." Eliminating the *unnecessary* dead is, of course, "something vastly worth doing." And yet, Kahn complains, "it is very difficult to get this point across to laymen or experts with enough intensity to move them to action. The average citizen has a dour attitude toward planners who say that if we do thus and so it will not be 40 million dead—it will be 20 million dead." I suggest the "dour attitude" may be due to the fact that, unlike Kahn, we have not been mathematically trained, and big numbers are apt to be confusing.

Taking 40 million or 80 million dead as a round figure, we might ask whether the postwar "environment" would be so "hostile" that "we or our descendants would prefer being dead than [sic] alive?" Not at all, says Kahn. "Objective studies [made by Kahn and his colleagues] indicate that even though the amount of human tragedy would be greatly increased in the postwar world, the increase would not preclude normal and happy lives for the majority of survivors and their descendants." "Would the survivors live as Americans are accustomed to living—with automobiles, television, ranch houses, freezers and so on?" Kahn is optimistic. "No one can say, but I believe there is every likelihood that even if we make almost no preparations for recuperation except to buy radiation meters, write and distribute manuals, train some cadres for decontamination and the like, and make some other minimal plans, the country would recover rather rapidly . . . from the small attack."

TABLE 3

TRAGIC BUT DISTINGUISHABLE POSTWAR STATES

DEAD	ECONOMIC RECUPERATION
2,000,000	1 YEAR
5,000,000	2 YEARS
10,000,000	5 YEARS
20,000,000	10 YEARS
40,000,000	20 YEARS
80,000,000	50 YEARS
160,000,000	100 YEARS

WILL THE SURVIVORS ENVY THE DEAD?

Kahn admits it may take a little time to get back to normalcy. A number of cities may have disappeared, and the economic engine would require retuning. The economy is sometimes compared to a living organism, which may die even if 99 per cent of its cells are undamaged, but the analogy "seems to be completely wrong as far as long-term recuperation is concerned." The economy is "even more flexible than a salamander (which can grow new parts when old ones are destroyed) in that large sections of it can operate independently (with some degradation, of course). In addition, no matter how much destruction is done, if there are survivors, they will put *something* together. The creating (or recreating) of a society is an art rather than a science; even though empirical and analytic 'laws' have been worked out, we do not really know how it is done, but almost everybody (Ph.D. or savage) can do it."

Parts of the land may become uninhabitable due to fallout. But in general, according to Kahn, the fallout and contamination danger has been exaggerated. Still, if the Strategic Air Command should follow the suggestion "that some people have made" and move "into the Rocky Mountains or the Great American Desert—then some wars might easily result in the creation of large areas that one would not wish to live in, even by industrial standards. It is very unlikely that areas such as the Rocky Mountains would ever be decontaminated. Some people might be willing to visit and perhaps hunt or fish for a few weeks (the game would be edible) but, unless they had a very good reason to stay, it would be unwise to live there and even more unwise to raise a family there."

Kahn favors us with a lengthy analysis of genetic damage. It is not so easily repaired as a ranch house; on the other hand, the damage is likely to be "spread out," and on the installment plan we

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could afford it. We might have to pay for a war through "20 or 30 or 40 generations. But even this is a long way from annihilation. It might well turn out, for example, that U. S. decision makers would be willing, among other things, to accept the high risk of an additional 1 per cent of our children being born deformed *if that meant not giving up Europe to Soviet Russia*." Kahn is of the opinion that if genetic damage is "borne by our descendants and not by our own generation," we must not take it too much to heart. ("While I believe that this statement is a defendable one, it is not one I would care to defend in the give and take of a public debate") Embryonic deaths are "of limited significance.... These are conceptions which would have been successful if it had not been for radiation that damaged the germ cell and thus made the potential conception result in a failure. There will probably be five million of these in the first generation, and one hundred million in future generations. I do not think of this last number as too important, except for the small fraction that involves detectable miscarriages or stillbirths. On the whole, the human race is so fecund that a small reduction in fecundity should not be a serious matter even to individuals."

Leaving aside the question of genetic deaths, which lie within a price range Kahn feels we should be prepared to pay, how many of the living—to wit, us—should we be prepared to throw into the pot? Kahn says that 180 million "is too high a price to pay for punishing the Soviets for their aggression." But there remains the "hard and unpleasant question": If not 180 million, then how many? Maybe even 100 million is too high. "Almost nobody," Kahn observes, "wants to go down in history as the first man to kill 100,000,000 people." "I have discussed this question," he says, "with many Americans, and after about fifteen minutes of discussion their estimates of an acceptable price generally fall between 10 and 60 million, clustering toward the upper number.... The way one seems to arrive at the upper limit of 60 million is rather interesting. He takes one-third of a country's population, in other words somewhat less than half" It is gratifying to learn that "no American that I have spoken to who was at all serious about the matter believed that any U S. action, limited or unlimited, would be justified...if more than half of our population would be killed in retaliation."

One small brush stroke may be permitted to fill out this portrait of the mind of Herman Kahn. We are asked to imagine ourselves in the "postwar situation." We will have been exposed to "extremes of anxiety, unfamiliar environment, strange foods, minimum toilet facilities, inadequate shelters, and the like. Under these conditions some high percentage of the population is going to become nauseated, and nausea is very catching. If one man vomits, everybody vomits. It would not be surprising if almost everybody vomits. Almost everyone is likely to think he has received too much radiation. Morale may be so affected that many survivors may refuse to participate in constructive activities, but would content themselves with sitting down and waiting to die—some may even become violent and destructive. However, the situation would be quite different if radiation meters were distributed. Assume now that a man gets sick from a cause other than radiation. Not believing this, his morale begins to drop. You look at his meter and say, 'You have received only ten roentgens, why are you vomiting? Pull yourself together and get to work.'"

Herman Kahn, we are told, is "one of the very few who have managed to avoid the 'mental block' so characteristic of writers on nuclear warfare." The mental block consists, if I am not mistaken, of a scruple for life. This evil and tenebrous book, with its loose-lipped pieties and its hayfoot-strawfoot logic, is permeated with a bloodthirsty irrationality such as I have not seen in my years of reading. We are now in a position to comprehend the noble Houyhnhnm's horror at Gulliver's account of the condition of man:

"He said, whoever understood the Nature of *Yahoos* might easily believe it possible for so vile an Animal, to be capable of every action I had named, if their Strength and Cunning equalled their Malice.... That, although he hated the *Yahoos* of this Country, yet he no more blamed them for their odious Qualities, than he did a Gnnayh (A Bird of Prey) for its Cruelty, or a sharp Stone for cutting his Hoof. But, when a Creature pretending to Reason, could be capable of such Enormities, he dreaded lest the Corruption of that Faculty might be worse than Brutality itself."

After the unsavory experience of the Kahn book I had looked forward to the arms-control issue of *Dædalus*. This is a quarterly journal published by the American Academy of Arts and Sciences. The Academy is an organization of 1,800 members, one of whose major activities is to elect new members annually. Its net being widely flung, I had assumed I would encounter the opinions of educators, scientists and other serious-minded men who had thought fruitfully about some of the steps which have to be taken if human life is to continue on this planet. I am bound to say that I was deeply disappointed. In addition to giving the floor to Herman Kahn—a 37-page dose on "Doomsday Machines," "Doomsday-in-a-Hurry Machine" and other obscene lunacies—the issue contains a medley of pieces scored more or less in the Kahn key, and an assortment of legal, political and economic oddments which offer neither light nor warmth nor shelter to the anxious reader. A few bright interludes are to be found in this dismal repertory (Erich Fromm and Kenneth E. Boulding are among those who have some penetrating things to say), but if this issue of *Dædalus* is a fair sample of the high thoughts of American academicians on the "potentially feasible routes as well as the obstacles to arms control," then American arts and sciences are in a bad way, and unless a new crop of sensible politicians comes to the rescue we can kiss ourselves and posterity good-by. It is not only the fact that *Dædalus* gave Kahn houseroom that shocked me but also that so many of the contributors accept his inhumanity as the basis for their own speculations.

The contents of the issue are divided into six main groups: "Background," "Major Issues and Problems," "The Implementation of Arms Control," "The Formation of United States Arms Control Policy," "Related Techniques and Issues," "Beyond the Cold War." I shall sample, which is quite enough.

Donald G. Brennan, a mathematician and "communication theorist," discussing the "setting and goals of arms control," tells us that "there is an increasing recognition of the fact that the simple form of the 'balance of terror' theory to implement Type A deterrence is inadequate, and that the balance, as was aptly noted by Wohlstetter, is 'delicate'"; that there are "pro" and "con" hazards to arms control: "it may improve some component of our security, either in the short or the long term, and it may degrade some other—again, either in the short or the long term"; that "smaller" nuclear weapons having a yield as low as that of 55 tons of TNT can be developed and "probably would be advantageous for the United States, *provided that they did not lead to the use of much larger weapons*" (a point which may have escaped you); that it is important for us "to educate the Soviets in mutually desirable strategies [a Marquis of Queens-

berry touch] and armament policies. For this purpose we would first have to educate ourselves in some detail as to what these were—which hardly prevails at the present time." "We have men today," says Brennan, "as capable as those who drafted our own Constitution; it is not necessary to wait for the once-in-a-century appearance of an Abraham Lincoln." I must assume from all this that Brennan is better in the theory than in the practice of communication.

Edward Teller coaxes us to accept the concept of limited war. "Limited warfare can very well stay limited." (After all, half a loaf is better than none.) "All-out war will never be in our interest, and we should never start it." If the Russians should start, "they will probably pick a time when our guard is down. While a limited nuclear war is in progress, we shall be much better prepared than in times of peace. The time of a limited nuclear conflict, therefore, would be the worst time for the Russians to launch an all-out attack." If I understand this sequence, it implies that the U. S. would be well advised to get into a limited war as quickly as possible and keep it going indefinitely.

From Henry A. Kissinger comes a "reappraisal" of limited war. With that waffling judiciousness so characteristic of his writings, he weighs the question of whether the limited war we must be ready to fight should be "conventional or nuclear" (taking it for granted, of course, that we are also prepared to wage a "general nuclear war"). His answer is yes and no and both and neither. A substantial build-up of conventional forces and a greater reliance on a conventional strategy are "essential," he says; on the other hand, "it is equally vital not to press the conclusions too far. . . . Conventional forces should not be considered a substitute for a capability of waging a limited nuclear war, but a complement to it. It would be suicidal to rely entirely on conventional arms against an opponent equipped with nuclear weapons. . . . A conventional war can be kept within limits only if nuclear war seems more unattractive. . . . The aggressor must understand that we are in a position to match any increment of force, nuclear or conventional, that he may add"—an interesting form of potlatch.

In a thoughtful essay on the domestic implications of arms control, Kenneth Boulding disposes effectively of the myth that U. S. prosperity depends on arms expenditures. If we had money to spend sensibly, we might in time become sensible enough to know how to spend it. The economic problem is really trivial: reduce armaments and family life will go on, as will business, industry, schools, milk deliveries. The nation would thrive even if the Pentagon were turned into a garage. The Pentagonians, to be sure, might not thrive until they learned another trade. A specter, says Boulding, is haunting the chancelleries and the general staffs, "more frightening perhaps than that which Karl Marx invoked in 1848; it is the specter of Peace—that drab girl with the olive-branch corsage whom no red-blooded American (or Russian) could conceivably warm up to. She haunts us because we cannot go back to Napoleon, or to Lee, or even to MacArthur: the military are caught in an implacable dynamic of technical change which makes them increasingly less capable of defending the countries which support them, except at an increasingly intolerable cost. The grotesque irony of national defense in the nuclear age is that, after having had the inestimable privilege of losing half (or is it three-quarters, or all?) our population, we are supposed to set up again the whole system which gave rise to this holocaust."

Jerome B. Wiesner, in his analysis of arms-limitation systems, makes some obvious but very useful points. In this tortuous business it is the obvious which is usually scanted. He points out that until recently neither the U. S. nor Russia was sincerely attempting to reach an agreement on arms limitation; moreover, that the U. S. delegations to the disarmament discussions, the nuclear-test-ban conferences and the surprise-attack conferences "had very inadequate technical preparation." Defy the foul fiend, yes, but how? The objective should be to find security systems which are less dangerous than the arms bolero rather than to achieve a system capable of providing absolute security, "an obviously unattainable goal." Wiesner makes it clear that an unconscionable amount of time has been spent on the essentially trivial issue of detecting underground tests. "Ironically," he says, "an inspection system for monitoring a truly comprehensive disarmament agreement would probably have no need at all for a system to detect underground nuclear tests." The pother about nuclear-stockpile control does not impress him. Admittedly it is impossible to determine exactly the size of the stockpiles. But the range of uncertainty is not so great as we have been led to believe, and it is likely that "an intensive study of the physical means of estimating past nuclear production could greatly reduce this uncertainty." Wiesner makes an excellent point about establishing a stable deterrence system using only a relatively small number of ballistic missiles. Assume the deterrent force consists of a number of Minuteman missiles installed in underground concrete emplacements. Such emplacements can be made pretty secure against very heavy shock waves, so that if guided missiles are used to deliver nuclear weapons in attacking hardened targets, the accuracy of the missiles would be very important. "If a nuclear weapon had to make impact within one-half mile of a target to destroy it, a missile having a median accuracy of half a mile would have a 0.5 probability of doing so, two missiles would have a 0.75 probability of doing so, three missiles a 0.875 probability and four missiles would have approximately a 0.94 probability of destroying the target. When the number of targets to be attacked is large and the number of survivors that can be tolerated is small, the certainty with which each individual target must be destroyed becomes extreme, and the number of attacking missiles required can become quite large. . . . To demonstrate how difficult it is to destroy a hardened missile force, an example will be given. If it is agreed that each side is to have 200 missiles in its deterrent force and if the missiles were protected for 300 pound/sq. inch overpressure, 1,000 missiles having a median accuracy of one mile would be required to have a 0.9 probability of reducing the attacked force to 10 missiles. It obviously would not require a very intensive inspection effort to detect an attempted build-up of this magnitude."

Two more pieces are worth mentioning. Saville R. Davis, managing editor of *The Christian Science Monitor*, has a tidily lethal piece called "Recent Policy Making in the United States Government." It will not be celebrated by admirers of John Foster Dulles, Admiral Arthur Radford, Lewis Strauss and Edward Teller. Radford's and Strauss's torpedoing of Harold Stassen's efforts to negotiate a disarmament agreement makes a distressing tableau; so does the pressure that Strauss, with the help of Teller and the late Ernest O. Lawrence, brought to bear on the President on behalf of continued nuclear testing in order to perfect "clean" weapons. "Evidence is available to the writer [says Davis] which clearly indicates that the President and Mr. Dulles were unwitting prisoners, in their lonely isolation at the top of the government pyramid, of the special selection of knowledge and attitudes which came to them through official channels and especially through Mr. Strauss. They had no alternative against which to measure the partisan quality of this advice or its scientific inadequacies."

Suppose every person had the means of killing himself and his family, knowing that this would result in the death of two Russian families. This is the exemplar of contemporary lunacy, and in discussing it psychiatrists should have a principal role. The profession is ably represented in this symposium by Erich Fromm. He puts the case for unilateral disarmament. Among the concrete steps which could be taken unilaterally so as to induce the other side to reciprocate are the sharing of scientific information, the stopping of atomic tests, troop reductions, evacuation of certain military bases, the discontinuation of German rearmament. Risks are involved in these steps, to be sure, but they are not crippling risks, they do not invite a major assault and they are risks any sane man would prefer to the risks of the arms race.

Fromm emphasizes the need for breaking through the "thought barrier," the "frozen stereotypes" which prevent us from seeking peace by any means other than threat and counterthreat. We do nothing more than circle the forest. It is absurd to imagine that a policy based on deterrence can indefinitely keep the peace, but even if it did, what kind of peace would it be? Under the constant threat of destruction, most human beings begin to come apart. They grow callous, hostile, increasingly indifferent to the values we cherish. Freedom is lost, the individual becomes nothing. "Things are in the saddle, and ride mankind," Emerson said a century ago. In the computer and missile age they ride us harder.

Fromm examines some of the popular psychological arguments advanced against disarmament, for example "The Russians cannot be trusted." If this is meant in the moral sense, it is true: political leaders of any nationality are rarely trustworthy. They may be good to their mothers, kind to their children and honorable in dealing with the grocer, but public and private faces are not the same. The state, which is an idol, can and does commit immoral acts, which the community applauds—acts which the community would deprecate or punish if committed by individuals.

Yet the phrase "Trust the Russians" has a meaning that is relevant to politics. We must have faith in their being sane men whose conduct is therefore to some extent predictable. We must not assume that they will destroy themselves for the pleasure of destroying us. A rational policy of disarmament must have its ultimate roots in two simple convictions: that we want to live, that the Russians want to live. This conviction is no less applicable to those who make the decisions than to those who are compelled to obey them. This issue of sanity, as Fromm points out, leads to another consideration which affects us as much as it does the Russians. "In the current discussion on armament control, many arguments are based on the question of what is *possible,* rather than what is *probable.* The difference between these two modes of thinking is precisely the difference between *paranoid* and *sane* thinking." It is *possible* my wife and children are planning to poison me; it is possible a meteorite will hit me on the head when I leave the house this afternoon; it is possible the manuscript of this review will disintegrate by molecular action before my secretary types it; but I do not live by these possibilities. One lives by what is likely or one is mad. A certain faith in life, in oneself and in others is necessary in order to operate. In the twilight of our probationership here on earth—to use Locke's phrase—we learn to depend on probabilities. Arms control is hopeless if we insist on covering every possibility.

"At midwinter in the year 1085 William the Conqueror wore his crown at Gloucester and there he had deep speech with his wise men." Thence, as Frederic Maitland tells us, missions went throughout England bringing back a *descriptio* of the new realm. These are preserved in the famous *Domesday Book.* We have need of a *descriptio* of man's realm; of what he has made of the world and of himself in 20,000 years; of the treasures he has stored, of the ideas he has borne and nurtured. We have need, appropriately, of a new *Domesday Book* to enable us to reckon whether we wish to preserve what we have and what we are or whether we are preparing to risk all in the war of every man against every man. For this we need deep speech with our wise men, a few of whom, but too few, have thus far been called into council. That there is some wisdom in the pages of this issue of *Dædalus,* some sane counsel, is good; that they can scarcely be heard over the strident clamor is tragic.

Short Reviews

THE SCIENCES WERE NEVER AT WAR, by Sir Gavin de Beer. Thomas Nelson and Sons Ltd. (30 shillings). The line which comprises the title of this book comes from a letter Edward Jenner wrote to the National Institutes of France about 1803, when he asked its help in securing the release of certain

British captives in France. Jenner's name was a talisman by itself; on another occasion a similar request of his was presented to Napoleon, who was about to brush it aside when the Empress Josephine drew his attention to the signature it bore. Napoleon is said to have exclaimed: "Ah, Jenner. On ne peut rien refuser à cet homme." But one did not have to be a Jenner to gain a hearing from emperors and prime ministers, let alone one's fellow scientists, in countries with which one's own country was at war. Lesser scientists could, a century ago, ask for favors pertaining to the delivery or safeguarding of botanical specimens, to travel through hostile territory, to the exchange of books and periodicals, to the transmission of scientific information. Benjamin Franklin, our envoy in Paris during the Revolution, granted an exceptional passport to Captain James Cook, guaranteeing his ships against molestation by American men-of-war; Humphry Davy was welcome in France while it was at war with England; Sir Joseph Banks could, in the midst of a war, carry on extensive correspondence with Frenchmen about all kinds of scientific matters and successfully intercede on behalf of friends and colleagues in his own country as well as the enemy's. Times have changed. De Beer has collected in this volume letters written in a happier period: the wartime correspondence of Sir Hans Sloane, René de Réaumur and Franklin in the 18th century; the exchanges of scientific information during the French Revolution; the letters between scientists of countries at war during Napoleon's period. The letters are well annotated, but there is not enough over-all commentary by De Beer himself, who is as engaging as he is learned.

CRITICAL PROBLEMS IN THE HISTORY OF SCIENCE, edited by Marshall Clagett. The University of Wisconsin Press ($5). Proceedings of the Institute for the History of Science at the University of Wisconsin in September, 1957. Leading specialists took part in this gathering, among them A. R. Hall, Robert Merton, Ernest Nagel, I. E. Drabkin, Dorothy Stimson, E. J. Dijksterhuis, Giorgio de Santillana, Cyril Smith and Thomas S. Kuhn. A few of the papers make interesting additions to knowledge of the history of scientific ideas.

ARCHITECTURAL FOLLIES IN AMERICA, by Clay Lancaster. Charles E. Tuttle Company ($10). Pictures and text describing some of the zanier products of hammer, nail and saw, mostly in the

18th and 19th centuries. Among the prizes are Browne's Folly, a Charles Addams house built in Essex County, Mass., in the 1730's, the adventures of which included removal to a new site and being cut into three sections to become three separate buildings; Robert Morris' pale blue marble palace in Philadelphia; the Wedding-Cake House in Kennebunk, Maine; Mrs. Trollope's ill-fated Moorish-style bazaar in Cincinnati; Phineas Barnum's villa Iranistan, with its polychromed bulbous domes, minarets, spires and tracery verandas built within eyeshot of the New York and New Haven railroad at Bridgeport, Conn. (on an adjacent six-acre lot he maintained an elephant with a harness and provided its Ceylonese trainer with a timetable so that the elephant would be plowing whenever the trains came along); houses built in "steamboat Gothic" style; completely circular and cylindrical barrel houses; polygonal houses (octagonal, such as Thomas Jefferson's retreat near Lynchburg, Va., and Fowler's Folly near Fishkill, N.Y.; and duodecagonal, such as David G. Galbraith's remarkable 1897 creation near Fort Worth, Texas); Palmer Castle in Chicago, with its woodwork of ebony and gold; the Winchester Mystery House of San Jose, Calif. (Winchester Arms fortune), which kept a crew of 16 carpenters constantly employed, had 160 rooms, a couple of thousand doors, gold and silver chandeliers, 13 bathrooms, 40 staircases, trap doors, secret passageways (it flourished as late as 1922, when Mrs. Winchester died); the great Corn Palaces of Mitchell, S.D.; the superb Elephant Hotel of Coney Island, built in the shape of a pachyderm, with steps going up the legs, guest rooms scattered throughout its anatomy and a huge banquet hall situated in the creature's behind; the leaning tower of Niles, Ill., a half-size replica of the leaning tower of Pisa; and sundry bottle houses, streetcar houses, airplane bungalows and what not. Many illustrations, some in color.

ARMY EXPLORATION IN THE AMERICAN WEST: 1803–1863, by William H. Goetzman. Yale University Press ($6.50). A detailed, scholarly account of the U. S. Army Corps of Topographical Engineers during the opening of the American West. The book makes it clear that, while many of these engineers remain comparatively unknown, their skill, energy and achievement exceeded that of some of the most glamorized figures of the early West. Illustrations, bibliography and a first-class collection of War Department maps (folded into a pocket at the end of the volume).

VISTAS IN ASTRONOMY, VOL. III, edited by Arthur Beer. Pergamon Press, Inc. ($18). This volume continues a superb international survey of astronomy, the first two volumes of which were reviewed in these pages two years ago. Among the topics considered are the dynamics of stars in the neighborhood of the sun (R. V. D. R. Woolley), the rediscovery of Neptune (R. A. Lyttleton), the clock paradox (W. Cochran and V. Fock), the design of large telescopes (G. M. Sisson), the electronic computer as an astronomical instrument (Marshal A. Wrubel), the visual Milky Way (Sergei Gaposchkin), evolution of the stars (Olin J. Eggen), the galactic magnetic field (L. Mestel), color photometry (Gerald E. Kron and A. N. Argue). Illustrations.

GHOST SHIP OF THE POLE, by Wilbur Cross. William Sloane Associates, Inc. ($5). The story of the dirigible *Italia,* of its ill-conceived and ill-fated voyage of arctic exploration in 1928, of Umberto Nobile (who built the ship and led the expedition), of the tragicomic international search to find the survivors when the rickety craft broke in two (a search in which Roald Amundsen lost his life) and of all the misfortunes that befell Nobile after the event. Cross comes now as a paladin to rescue Nobile's reputation, to free his name of the clouds that have shadowed it for 30 years. The story itself is a good one, and Cross tells it well, but the elaborate effort to rehabilitate Nobile is unimpressive and out of proportion either to his virtues or his sufferings. He was a somewhat pathetic Italian general who designed and built not-too-dependable dirigibles, had grandiose ambitions, was unfitted by talent or temperament to lead an expedition and should have stayed at home. His troubles came more from his bungling attempts to defend himself against charges of cowardice than from anything he can properly be charged with.

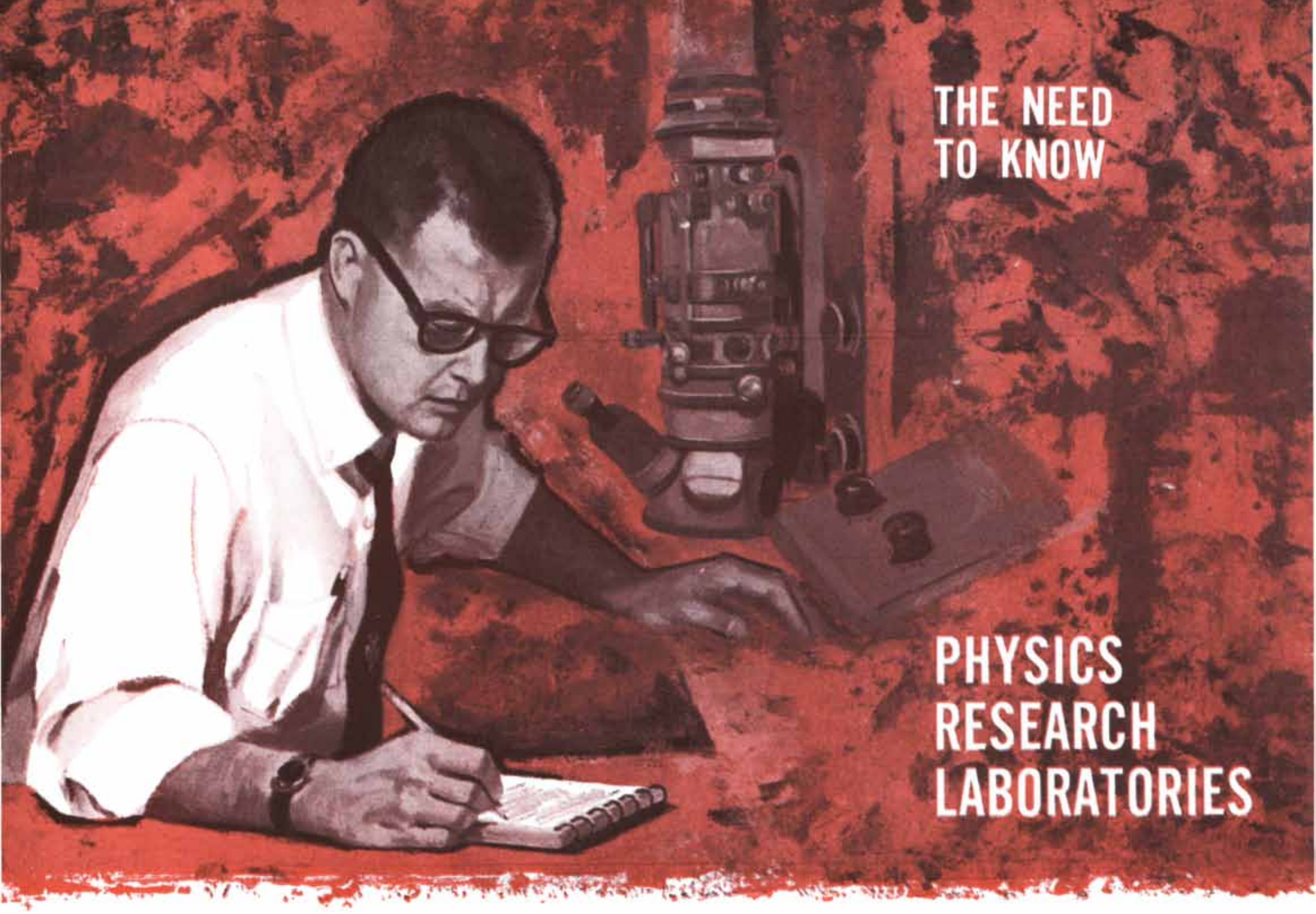
DEVELOPMENT OF RELIGION AND THOUGHT IN ANCIENT EGYPT, by James Henry Breasted. Harper & Brothers ($1.95). The argument of Breasted's classic volume, comprising the Morse Lectures delivered at Union Theological Seminary in New York 47 years ago, has in the intervening time been much modified by the discovery of many new texts, by advances in the interpretation of old texts, by substantial increases of knowledge in archeology and allied subjects. Nevertheless, the book is still a monument (as John A. Wilson says in his introduction to this paperback reissue), still worth reading, for "in its cadences and in its stresses, it is our story."

Indian Miniatures, text by W. G. Archer, color plates in collaboration with Madanjeet Singh. New York Graphic Society ($25). The 100 Indian miniatures (50 in color) reproduced in this volume, with a supporting text, ranging in date from the 11th to the 19th century, are not only charming, delicate and good to look at but in their variety provide "an essential clue to the Indian mind," a remarkable mirror for certain of the ways of life, the style, the manners and the imagination of a segment of human society.

Europe from the Air, edited by Emil Egli and Hans Richard Müller. Wilfred Funk, Inc. ($15). This volume consists of nearly 200 aerial photographs of European scenery: mountains and cities, rivers and forests, cathedrals, industrial areas, roads, railways, docks, airports, and the landscapes of the Continent and Britain. Many of the pictures are exceptionally fine, and the collection as a whole contributes, as the text points out, to one's understanding of the relation between physical environment and cultural development.

Animal Growth and Development, by Maurice Sussman; The Cell, by Carl P. Swanson. Prentice-Hall, Inc. ($2.95 each). The first two volumes of a new series on the foundations of biology. The rationale of the program, which is to include 11 volumes, is that no single textbook of biology can provide either the coverage or the flexibility of a series such as this, consisting of short, up-to-date monographs prepared by research specialists and designed to meet the needs of both students and teachers. The books are pitched at the college level, run to about 100 pages each and are illustrated.

Moon Maps, by H. P. Wilkins. The Macmillan Co. ($6). A set of moon maps, with an accompanying gazetteer, designed for use at the telescope. The maps are on a scale of 55.4 miles to the inch, thus being, according to the author, the largest and most detailed yet produced, and are bound together with the text on separate rings so that any map and page of text can be placed flat next to each other and read at the same time. The book also includes a chart of the



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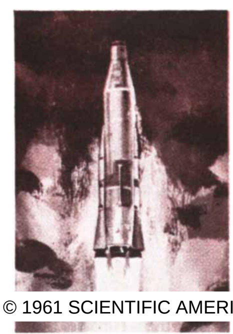

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other side of the moon based upon the photographs made by *Lunik III.*

THE WAR: A CONCISE HISTORY, 1939–1945, by Louis L. Snyder. Julian Messner, Inc. ($7.95). A fast-reading, exciting, well-documented history of the last big war from the rape of Poland to the Nuremberg Trials. Snyder combines the competence of the trained and disciplined historian with the verve, and capacity for re-creating immediacy, of a first-class war correspondent. His ability to select and condense, his feeling for the whole scene, his insight into motives and aims, his balanced judgment about events that too often contemporary opinion has conveniently warped and distorted to suit contemporary prejudices—all together make this an admirable book.

Notes

CONTEMPORARY THEORIES AND SYSTEMS IN PSYCHOLOGY, by Benjamin B. Wolman. Harper & Brothers ($7.50). A comprehensive, clearly written survey of general psychological theory today. The author treats various psychological theories that started with orientation toward natural sciences: psychoanalysis and related systems, Gestalt and field psychologies, psychology and its relation to scientific method.

PIERRE TEILHARD DE CHARDIN: HIS LIFE AND SPIRIT, by Nicolas Corte. The Macmillan Company ($3.25). A brief biography of the well-known Jesuit paleontologist.

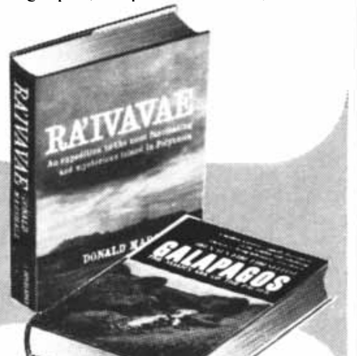
THEORY OF DETONATION, by Ia. B. Zeldovich and A. B. Kompaneets. Academic Press, Inc. ($10). A systematic presentation of detonation theory, one of the important areas of application of gas dynamics, based on researches at the Chemical Physics Institute of the Academy of Sciences of the U.S.S.R.

ENCYCLOPAEDIA OF OCCULTISM, by Lewis Spence. University Books, Inc. ($15). From Ab (Semitic magical month) to Zulu Witch Finders, an unaltered reprint of a reference work on supernatural hocus-pocus, first published in London in 1920.

FLUID MECHANICS, by L. D. Landau and E. M. Lifshitz. Addison-Wesley Publishing Company, Inc. ($14.50). A translation of Vol. VI of two Soviet physicists' *Course of Theoretical Physics*, dealing with the theory of motion of liquids and gases.

INDEX OF ADVERTISERS

MARCH, 1961



BIBLIOGRAPHY

Readers interested in further reading on subjects covered by articles in this issue may find the lists below helpful.

ELECTRICAL PROPULSION IN SPACE

ARC PLASMA THRUSTOR STUDIES. R. J. Page, R. D. Buhler, W. A. Stoner and P. S. Masser in *American Rocket Society Paper No. 1508–60;* 1960.

ELECTRICAL THRUST DEVICES FOR PROPULSION. Paul S. Masser, Russell J. Page and Willis Stoner in Report No. P-FR099–1032. Plasmadyne Corporation, September 15, 1959.

GENERALIZED PROPULSION SYSTEM ANALYSIS AND MISSION REQUIREMENTS. Paul S. Masser, Russell J. Page and Willis Stoner in *A Preliminary Evaluation of Advanced Space Propulsion Systems,* Vol. 1. Plasmadyne Corporation, March 25, 1959.

PLASMA ACCELERATION. Edited by S. W. Kash. Stanford University Press, 1960.

ELECTROSTATIC PROPULSION. Edited by D. B. Langmuir, E. Stuhlinger and J. N. Sellen in *Progress in Astronautics and Rocketry,* Vol. V. Academic Press, 1961.

NEW PENICILLINS

THE CHEMICAL CONVERSION OF PENICILLIN-G INTO A BIOLOGICALLY ACTIVE SYNTHETIC PENICILLIN SERIES. John C. Sheehan and James P. Ferris in *Journal of the American Chemical Society,* Vol. 81, No. 11, page 2912; June 5, 1959.

THE CHEMISTRY OF PENICILLIN. Edited by Hans T. Clarke, John R. Johnson and Sir Robert Robinson. Princeton University Press, 1949.

FORMATION OF 6-AMINOPENICILLANIC ACID FROM PENICILLIN BY ENZYMATIC HYDROLYSIS. G. N. Rolinson, F. R. Batchelor, D. Butterworth, J. Cameron-Wood, M. Cole, G. C. Eustace, Marian V. Hart, M. Richards and E. B. Chain in *Nature,* Vol. 187, No. 4733, pages 236–237; July 16, 1960.

A NEW PENICILLIN (BRL 1241) ACTIVE AGAINST PENICILLIN-RESISTANT STAPHYLOCOCCI. R. KNOX in *British Medical Journal,* Vol. 2, No. 5200, page 690; September 3, 1960.

SYNTHESIS OF PENICILLIN: 6-AMINOPENICILLANIC ACID IN PENICILLIN FERMENTATIONS. F. R. Batchelor, F. P. Doyle, J. H. C. Nayler and G. N. Rolinson in *Nature,* Vol. 183, No. 4656, pages 257–258; January 24, 1959.

PRE-CAMBRIAN ANIMALS

THE GEOLOGY AND LATE PRECAMBRIAN FAUNA OF THE EDIACARA FOSSIL RESERVE. M. F. Glaessner and B. Daily in *Records of the South Australian Museum,* Vol. XIII, No. 3, pages 369–401; July 2, 1959.

THE OLDEST FOSSIL FAUNAS OF SOUTH AUSTRALIA. M. F. Glaessner in *Sonderdruck aus der Geologischen Rundschau,* Vol. 47, No. 2, pages 522–531; 1958.

SEARCH FOR THE PAST. J. R. Beerbower. Prentice-Hall, Inc., 1960.

TIME, LIFE AND MAN: THE FOSSIL RECORD. R. A. Stirton. John Wiley & Sons, Inc., 1959.

GRAVITY

SIR ISAAC NEWTON'S MATHEMATICAL PRINCIPLES OF NATURAL PHILOSOPHY AND HIS SYSTEM OF THE WORLD. Edited by Florian Cajori. University of California Press, 1947.

DIALOGUES CONCERNING TWO NEW SYSTEMS. Galileo Galilei. Dover Publications, Inc., 1953.

MEANING OF RELATIVITY. Albert Einstein. Princeton University Press, 1956.

HOW THEMISTOCLES PLANNED THE BATTLE OF SALAMIS

A DECREE OF THEMISTOKLES FROM TROIZEN. M. H. Jameson in *Hesperia,* Vol. XXIX, pages 198–223; 1960.

THE HISTORIES. Herodotus. The Penguin Classics, Penguin Books, 1959.

THE PERSIAN EMPIRE AND THE WEST. J. A. R. Munro. The Macmillan Company, 1926.

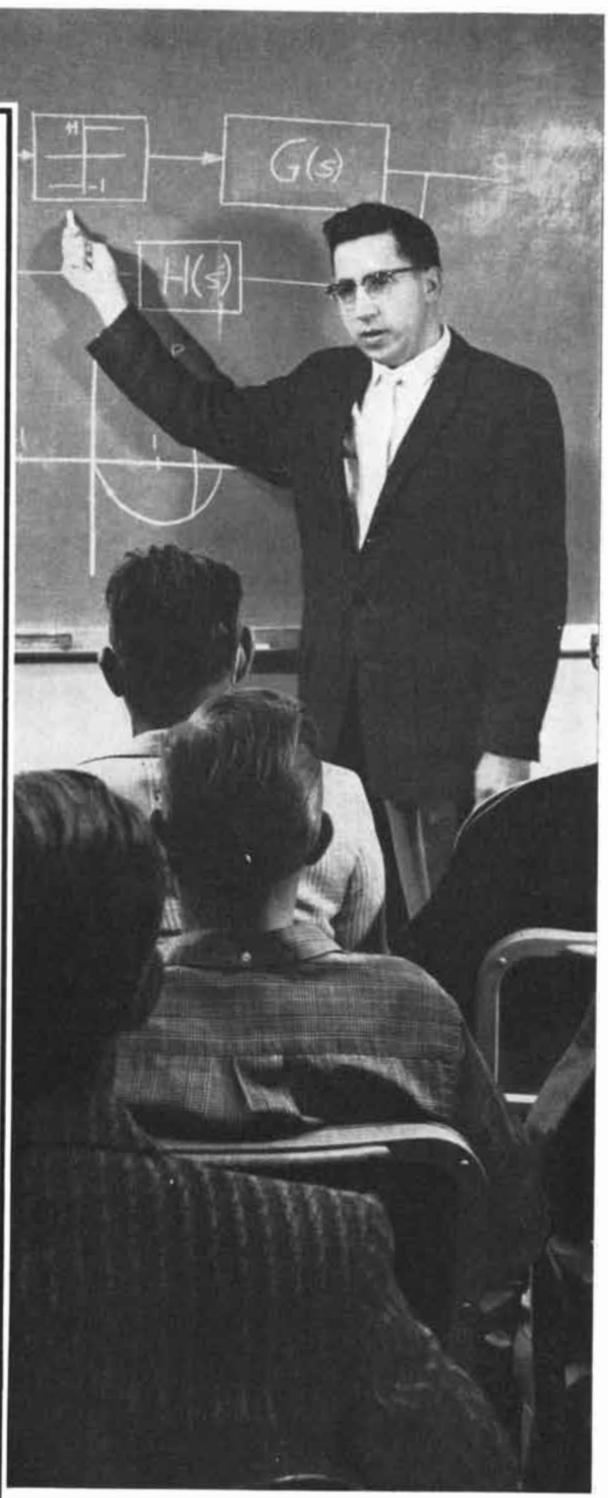
THEMISTOCLES. Plutarch in *Lives of the Noble Grecians and Romans,* pages 133–155. Modern Library, 1932.

LEE WAVES IN THE ATMOSPHERE

SOME ASPECTS OF THE FLOW OF STRATIFIED FLUIDS. I: A THEORETICAL INVESTIGATION. Robert R. Long in *Tellus,* Vol. 5, No. 1, pages 42–57; February, 1953.

THEORY OF MOUNTAIN WAVES OF LARGE AMPLITUDE. R. S. Scorer and H. Klieforth in *Quarterly Journal of the Royal Meteorological Society,* Vol. 85, No. 364, pages 131–143; April, 1959.

THEORY OF WAVES IN THE LEE OF MOUNTAINS. R. S. Scorer in *Quarterly Jour-*



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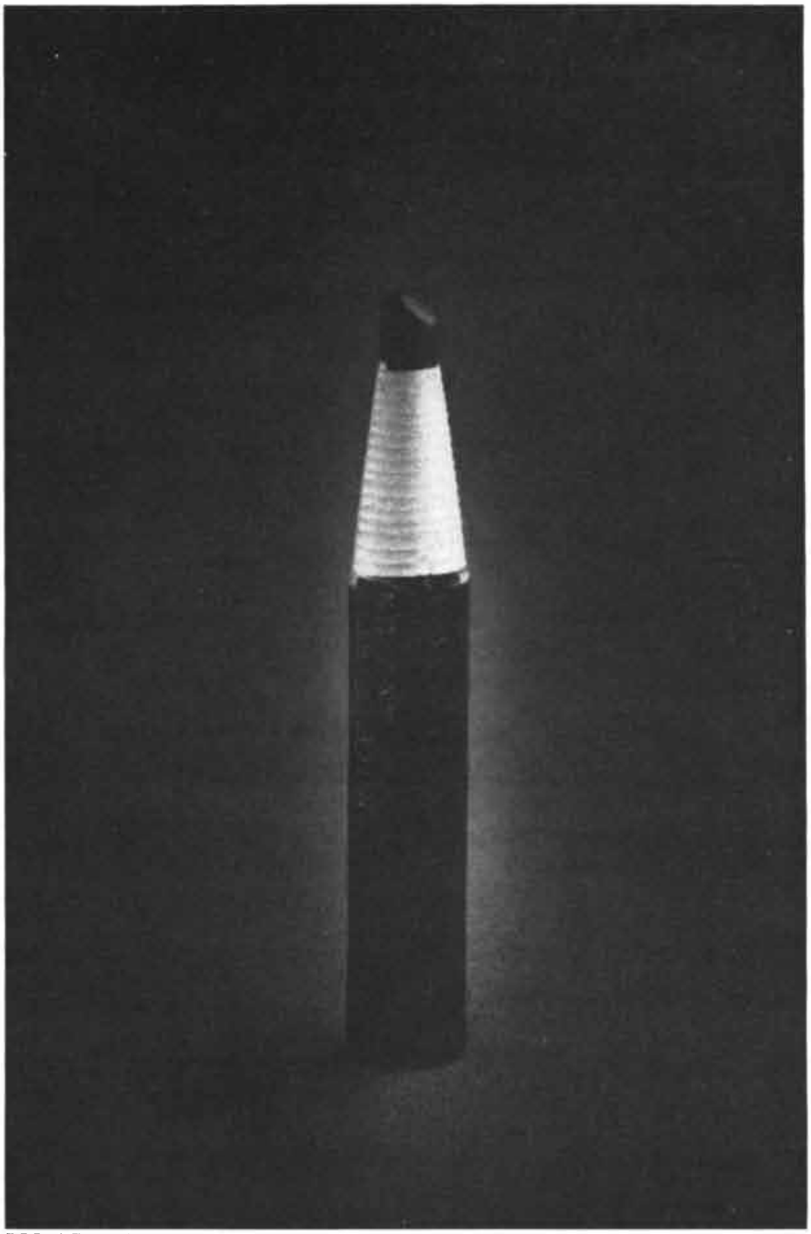

nal of the Royal Meteorological Society, Vol. 75, No. 323, pages 41–56; January, 1949.

SHADOWS AND DEPTH PERCEPTION

Experimental Psychology. Robert Sessions Woodworth and Harold Schlosberg. Chapter 16. Henry Holt and Co., 1954.

Light and Shade and Their Applications. Matthew Luckiesh. D. Van Nostrand Co., 1916.

MONOMOLECULAR FILMS

Electron Micrographs of Monolayers of Stearic Acid. Herman E. Ries, Jr., and Wayne A. Kimball in *Nature*, Vol. 181, page 901; March 29, 1958.

Monolayer Structure as Revealed by Electron Microscopy. Herman E. Ries, Jr., and Wayne A. Kimball in *Journal of Physical Chemistry*, Vol. 59, No. 1, pages 94–95; January, 1955.

Monomolecular Films of Mixtures. Herman E. Ries, Jr., and Hurley D. Cook in *Journal of Colloid Science*, Vol. 9, No. 6, pages 535–546; December, 1954.

The Physical Chemistry of Surface Films. William D. Harkins. Reinhold Publishing Corporation, 1952.

The Physics and Chemistry of Surfaces. Neil Kensington Adam. Oxford University Press, 1942.

Structure of Fatty-Acid Monolayers and a Mechanism for Collapse. Herman E. Ries, Jr., and Wayne A. Kimball in *Proceedings of the Second International Congress of Surface Activity*. Butterworths Scientific Publications, 1957.

MATHEMATICAL GAMES

Colored Polyhedra: A Permutation Problem. Clarence R. Perisho in *Mathematics Teacher*, Vol. 53, No. 4, pages 253–255; April, 1960.

New Mathematical Pastimes. Percy Alexander MacMahon. Cambridge University Press, 1921.

THE AMATEUR SCIENTIST

Heliotropism of Cassia Nictitans. George F. Atkinson in *Bulletin of Torrey Botanical Club*, Vol. 21, page 81; February 20, 1894.

Native Flora and Ferns of the United States in Their Botanical, Horticultural and Popular Aspects. Thomas Meehan. U. S. Series II, 1880.

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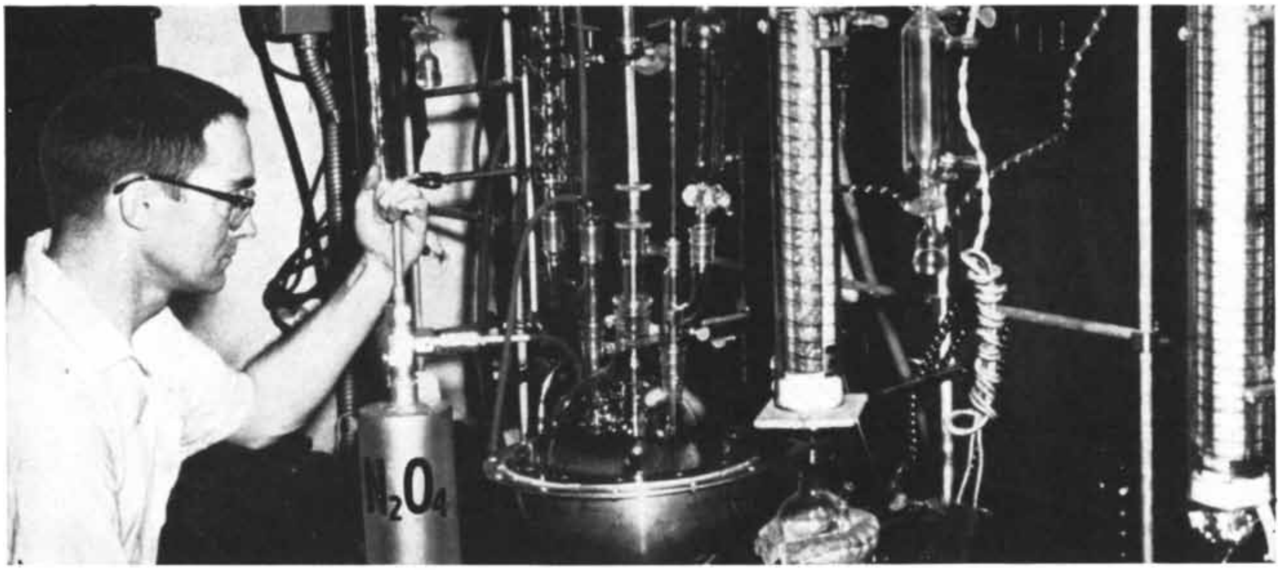

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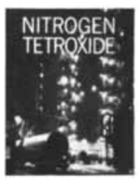

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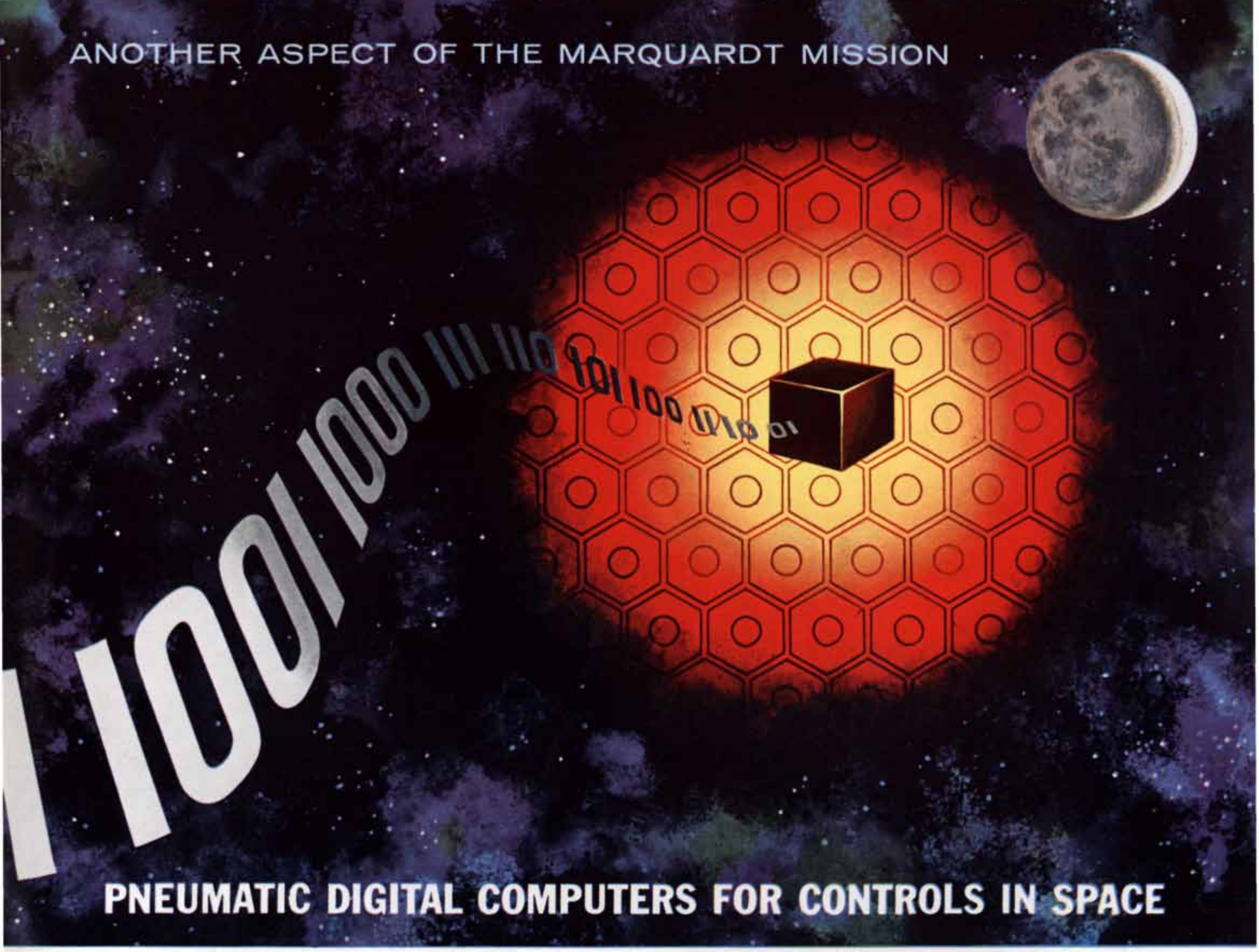

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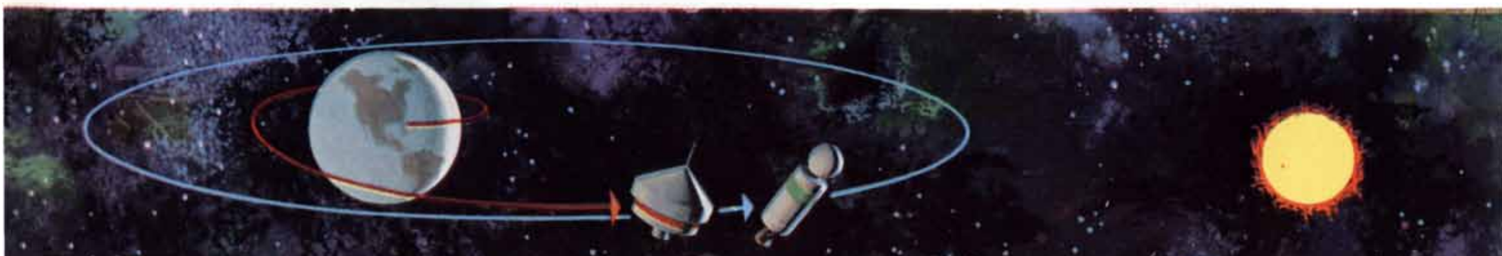
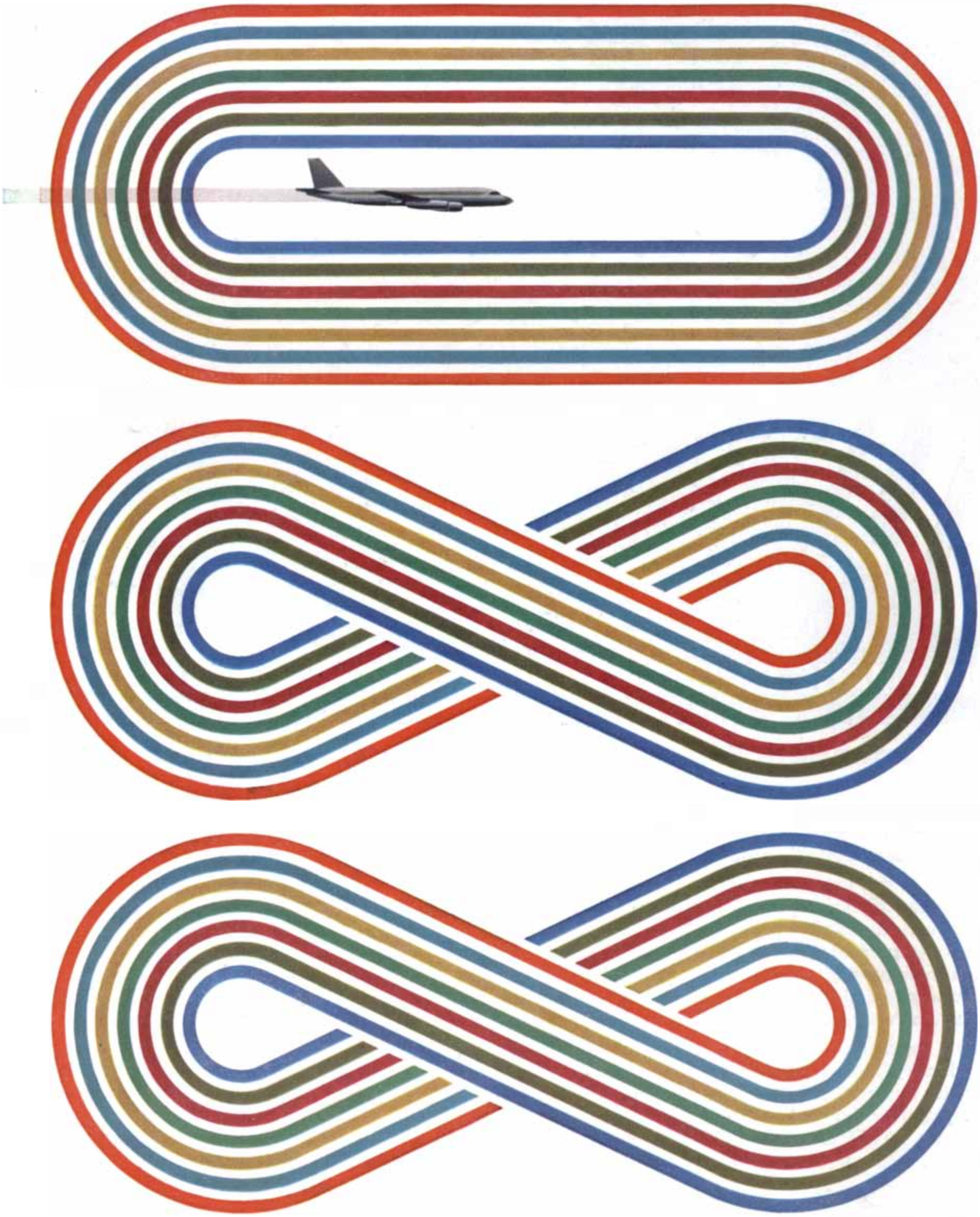


The Convair 880 is the world's newest and fastest commercial jetliner. Years ahead in concept and design, the 880 sets new standards for speed and comfort. Now in service with Delta, Northeast, and TWA airlines.



GENERAL DYNAMICS