SCIENTIFIC AMERICAN

EXPERIMENT IN FLOWERING

FIFTY CENTS

April 1958

Nips Crime at the Roots

For years, the insect "underworld" raided the nation's cornfields. But no longer without penalty! There's a new "policeman" on that beat . . .

That policeman is a powerful insecticide, *aldrin.* Standing watch *under* our most valuable crop, aldrin keeps the delicate feeder roots free from harm. Used before or at time of planting, aldrin destroys rootworms, wireworms, seed corn maggots, white grubs, and other cornfield soil pests when they eat, inhale, or merely *touch* it.

The result? *Welcome harvest news:* More plants survive, corn stalks withstand windstorms better with deep, natural roots. But wind or no wind, good roots mean better yields. And the stalks stand straight for efficient mechanical picking.

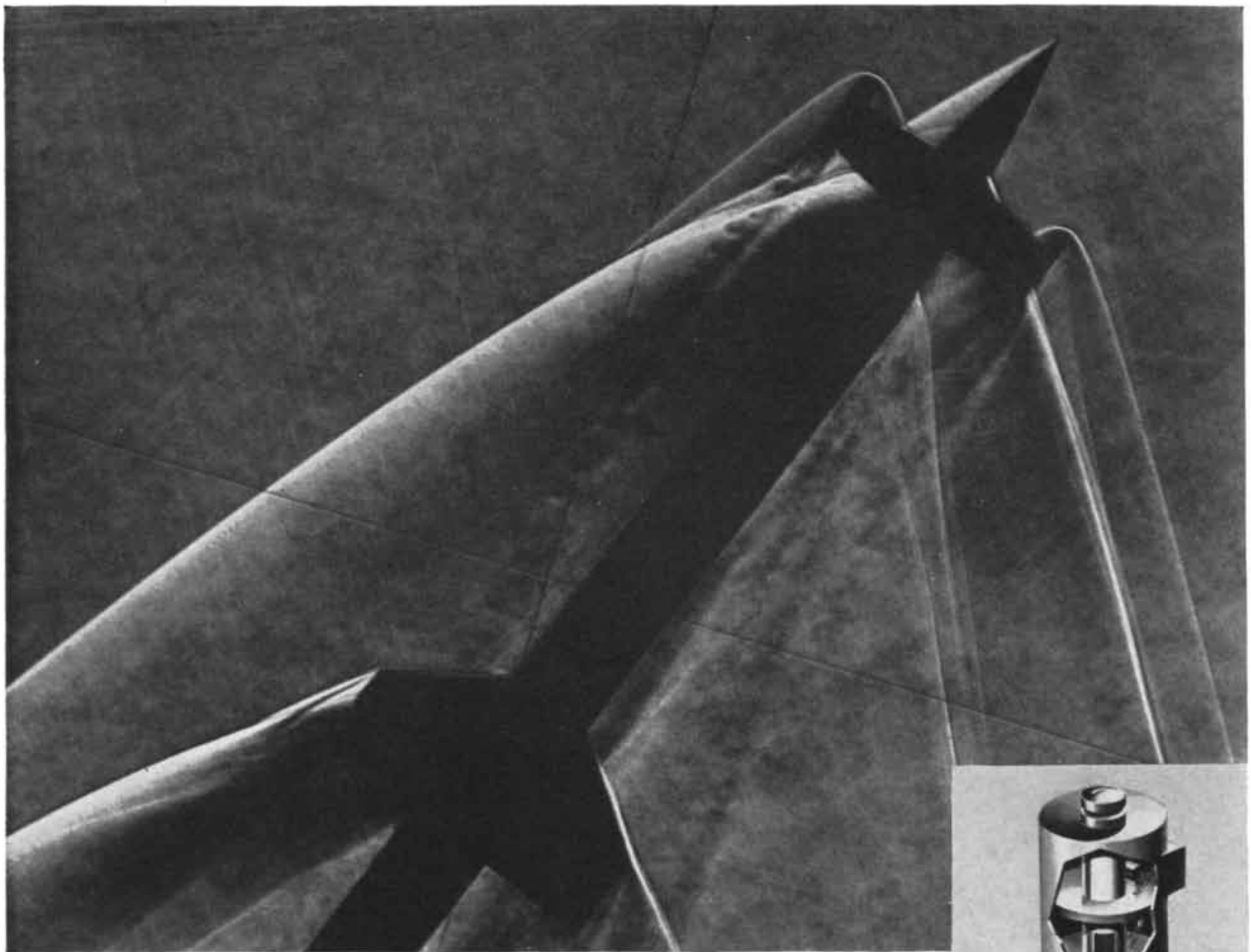
Protecting vital crops against the costly ravages of root-destroying soil insects is another of the many ways Shell Chemical serves the farmer.

Shell Chemical Corporation

Chemical Partner of Industry and Agriculture

NEW YORK

SHELL



In the wind tunnel of the Naval Supersonic Laboratory at M.I.T., a missile model is subjected to speeds of several Mach numbers. B-L-H SR-4 bonded wire strain gages report longitudinal and latitudinal stresses, drag, lift, etc., with high accuracy.

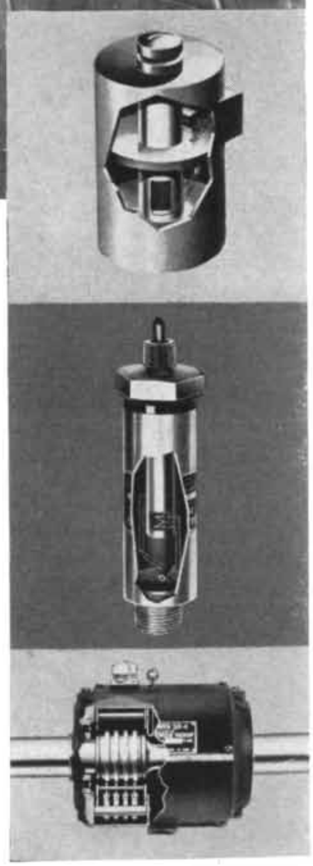
B-L-H ELECTRONIC TRANSDUCERS measure forces with new ease and accuracy

With the arrival of the Space Age have come increasingly severe demands on measuring instrumentation for precision and versatility. Accurate center of gravity computations, for example, are now more than important—they are vital.

B-L-H SR-4® transducers are highly responsive, durable and adaptable. Stock units offer long-term accuracy of ±1/10% and repeatability of ±1/20%. They will measure any forces involving tension or compression, torque, etc. With appropriate instrumentation, they can also determine center of gravity, weigh loads at rest or in motion, control batch and continuous processes, and record all data required. The type and number of applications are virtually unlimited.

The heart of every B-L-H transducer is its SR-4 bonded wire strain gages. They are bonded to a metal element in the transducer and approximately 10 milliamperes is fed through them. They receive the same strains as the transducer when a force is applied. Their electrical resistance changes in linear relationship with strain. The voltage output can be calibrated directly in terms of load—or fed into any common types of instrumentation, such as dial indicators, graphic recorders, digital printers, computers, etc.

For more information on SR-4 electronic transducers—load cells, pressure cells, or torque meters—ask to have a B-L-H man call on you—or write on your company letterhead for a copy of "Modern Force Measurement." Address Dept. 5-D.



(top to bottom) Load cell, pressure cell, and torque meter transducers.

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division

Waltham, Mass.

SR-4® strain gages • Transducers • Testing machines

Established 1845 **SCIENTIFIC AMERICAN** April, 1958 Volume 198 Number 4

ARTICLES

DEPARTMENTS

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THE COVER

The painting on the cover depicts three cocklebur plants used in an experiment on the mechanism of flowering (*see page 108*). The black paper over parts of two of the plants produces the effect of night.

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

Page	Source
28-29	U.S. Navy (*top*); Jacques Piccard (*bottom*)
30-31	Jacques Piccard
32-33	Bunji Tagawa
34-35	James Egleson
36	Radiation Laboratory, University of California
37	James Egleson
38-39	Mount Wilson and Palomar Observatories
40	Eric Mose
41	Rockefeller Institute for Medical Research
42-43	Strong Memorial Hospital
44	Eric Mose (*top*), Rockefeller Institute for Medical Research (*bottom*)
45-46	Eric Mose
56	Bernarda Bryson
58	Alex Semenoick
59-60	William Vandivert
62	Alex Semenoick
68	Superintendency of Antiquities, Province of Naples
70-71	Bunji Tagawa
72-78	Superintendency of Antiquities, Province of Naples
83	U. S. Air Force
84-90	John Langley Howard
97	Roman Vishniac
98	Muriel Williams
100-106	René Martin
108-110	Bunji Tagawa
112	Frank B. Salisbury
114-117	Bunji Tagawa
127	Walter J. Semerau
128-130	Roger Hayward
136-138	Walker Van Riper

New Team . . .

TITANIUM AND ZIRCONIUM

for your corrosion problem areas

Chart shows corrosion resistances of zirconium and titanium to typical chemicals.

TYPICAL CORROSION RESISTANCES OF ZIRCONIUM AND TITANIUM

CORROSIVE MEDIA	METAL RESISTANCE	
	ZIRCONIUM	TITANIUM
Sulfuric Acid	excellent to good below 80%	good below 5%
Nitric Acid	excellent	excellent
Hydrochloric Acid	excellent	good below 10%
Phosphoric Acid	excellent to fair below 85%	poor
Chromic Acid	excellent	excellent to good
Aqua Regia	poor	excellent
Wet Chlorine Gas	poor	excellent
Chlorine Water	excellent	excellent
Sodium Hydroxide	good below 90%	good below 50%
Ferric Chloride	poor	excellent
Calcium Chloride	excellent	excellent
Cupric Chloride	poor	excellent
Sodium Chloride	excellent	excellent
Ammonium Chloride	excellent	excellent
Aluminum Chloride	excellent	excellent to fair

Steam jet made of zirconium, which has given trouble-free performance after a year in hydrochloric acid service. For comparison, a throat piece from a steam jet (below) is shown after only a week of similar service.

By specifying titanium or zirconium for processing equipment, you can now overcome most of the corrosive media which attack other metals.

Even with such hard-to-handle chemicals as chlorides and oxidizing acids, equipment can have extremely long service life when made from these corrosion-resistant materials. Problems of product contamination in chemical and food processing can also be virtually eliminated.

Mallory-Sharon is in position to offer you *both* titanium and zirconium mill products for equipment fabrication—plus engineering assistance and unbiased recommendations on the most suitable material.

Titanium is now available from stock in a complete range of mill products, may be readily fabricated, and more than pays its extra cost where ordinary metals fail. Zirconium facilities are being rapidly increased, and mill shapes are now in production.

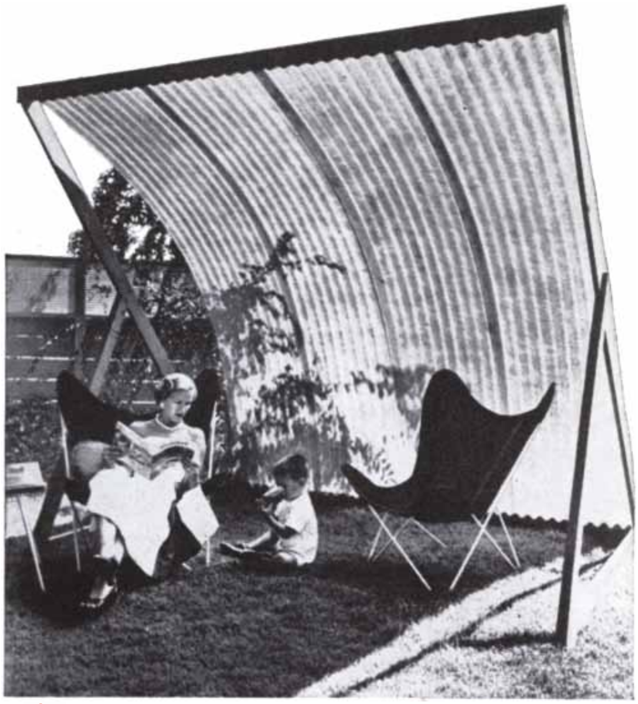
For information on the corrosion-resistant properties of titanium or zirconium write Mallory-Sharon Metals Corporation, Niles, Ohio.

MALLORY-SHARON

METALS CORPORATION • NILES, OHIO

Integrated producer of Titanium • Zirconium • Special Metals

Life on the Chemical Newsfront



CLEARER, WHITER POLYESTERS for reinforced plastics, which are rapidly finding broader use in structural and decorative applications, can now be made with AERO* *phthalic anhydride* in its new whiter flake form. Cyanamid's phthalic anhydride offers high purity and water-whiteness for transparent or translucent polyesters. It provides exceptional clarity as an ideal base for tinted or white materials.

(Industrial Chemicals Division)

*Trademark

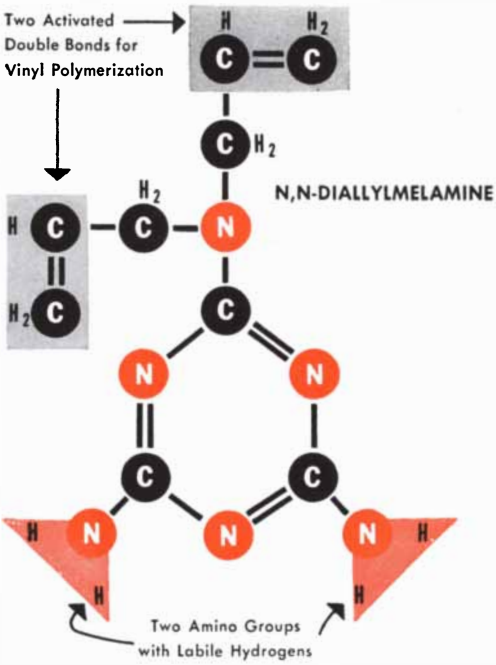
INTERPRETING THE CHEMIST'S WORK and its importance in our daily lives is no easy task. Cyanamid has found its on-the-spot Department Store Clinics highly effective in giving retail sales people—and through them, the consumer—a clearer understanding of the work of chemists in the improvement of textiles through modern finishes. CYANA® *textile finishes,* for example, make it possible to "tailor" fabrics for virtually any styling or use through such qualities as hand, water repellence, durability of nap and wrinkle resistance. Translating these chemical achievements into manufacture of fabrics and their proper use by consumers is an important part of Cyanamid's program.

(Organic Chemicals Division)

THESE PUPPETS "STOLE THE SHOW" during Paper Week at a novel introduction of Cyanamid's new HE (high efficiency) *Wet-Strength Process*.† Through this diverting device, advances in paper technology made possible by this new process were projected to 2000 A.D. Not only does the new HE Process use an average of 40% *less* wet-strength resin to produce papers fully equivalent in wet strength, it also provides a means of producing papers with properties never before obtainable. Details of this resin-saving process and its licensing can be secured through Cyanamid representatives.

(Industrial Chemicals Division)

†Patent applied for by American Cyanamid Company



THE COMBINED CAPABILITIES of vinyl polymerization, copolymerization and condensation in *N,N-diallylmelamine* lead to an unusually wide range of possible products with resin or polymer characteristics. The presence of two vinyl groupings in the same molecule offers the additional advantage of cross-linked products. Curable resins are formed when N,N-diallylmelamine is reacted with certain vinyl monomers. When reacted with acrylonitrile, a cross-linked product receptive to acid dyes is obtained. N,N-diallylmelamine-formaldehyde resins, prepared in alkaline solutions, are compatible with polyvinyl acetal or hydrolyzed polyvinyl acetate plasticizers. We will welcome your inquiry for samples and technical data.

(Market Development Department)

FINAL "COUNT-DOWN" on equipment before going on stream is made at Cyanamid's new plant for production of *aniline* at Willow Island, W. Va. This new fluid-bed catalytic reactor, first of its kind, adds 24 million pounds per year capacity to meet any foreseeable demand from the expanding industries concerned with aniline-based products. With existing capacity at Bound Brook, N. J., this additional production will assure dependable aniline service.

(Organic Chemicals Division)

LETTERS

Sirs:

I should like to point out that it is not entirely correct to say, as Richard F. Post does ["Fusion Power;" SCIENTIFIC AMERICAN, December, 1957], that the electromagnetic "pinch effect" was produced experimentally only a decade ago. Dr. Post is presumably referring only to the effect in a *gas discharge*. But the existence of the effect was experimentally shown over 50 years ago by Carl Hering (an electrical engineer at the University of Pennsylvania) by passing "a relatively large current through a nonelectrolytic liquid conductor contained in a trough." Hering described his observations to Edwin F. Northrup, who was then secretary to a well-known electrical instrument company in Philadelphia. Northrup immediately proceeded to do a number of elegant experiments using mercury, showing not only the magnitude of the effect but also its inherent instability. He also calculated the "pinch" pressure for a cylindrical conductor carrying an axial current, and verified it experimentally. Northrup published his results in *The Physical Review*, Vol. XXIV, pages 474-497, 1907. He concludes the paper with the seemingly prophetic words, "Further thought along an engineering line may bring about developments of a unique and useful character," though of course he could not have anticipated the direction these developments have taken in recent years. We also learn the origin of the name given to this effect: to quote again from the paper, "As the action of the forces on the conductor is to squeeze or pinch it, he [Hering] jocosely called it the 'pinch phenomenon.' "

It should be mentioned that, while the "pinch effect" has become famous fairly recently because of its use in fusion research, it has long been known as a significant factor in problems in electrical engineering involving heavy currents, such as electric arc furnaces, circuit breakers, etc. In fact, a textbook published as long ago as 1929 gives an elementary account of the theory (*Electromagnetic Problems in Electrical Engineering*, by B. Hague; Oxford University Press, 1929).

B. S. CHANDRASEKHAR

Westinghouse Research Laboratories
Pittsburgh, Pa.

Sirs:

The stimulating article by Elijah Adams on the barbiturates [SCIENTIFIC AMERICAN, January] covered many of the effects of these drugs at moderate or high dose levels. Very interesting effects at lower dose levels have, however, recently been reported by several workers (*cf.* P. B. Dews, the New York Academy of Sciences, 1956).

Sodium pentobarbital can produce an *increase* in the rate of occurrence of a simple learned response. With a dose of 1.0 milligram per kilogram in the pigeon the frequency of occurrence of behavior increases.

The experiment is the following (*cf.* "How to Teach Animals," by B. F. Skinner; SCIENTIFIC AMERICAN, December, 1951). A hungry pigeon is trained to peck on a key by presenting it with grain whenever it responds. The grain reinforcements are then presented only intermittently, after a given number of responses or for the first peck after a given interval of time elapses. Then, under the drug, the pigeon may respond two or three times as frequently when food is presented according to the interval-time procedure, but does not show much of a change when the number of responses is reinforced. At higher doses the rate of responding decreases in both procedures, although a smaller dose can produce the decrease in the interval procedure. These results can be obtained from the same pigeon during the same experimental session by training it to respond in the interval procedure in the

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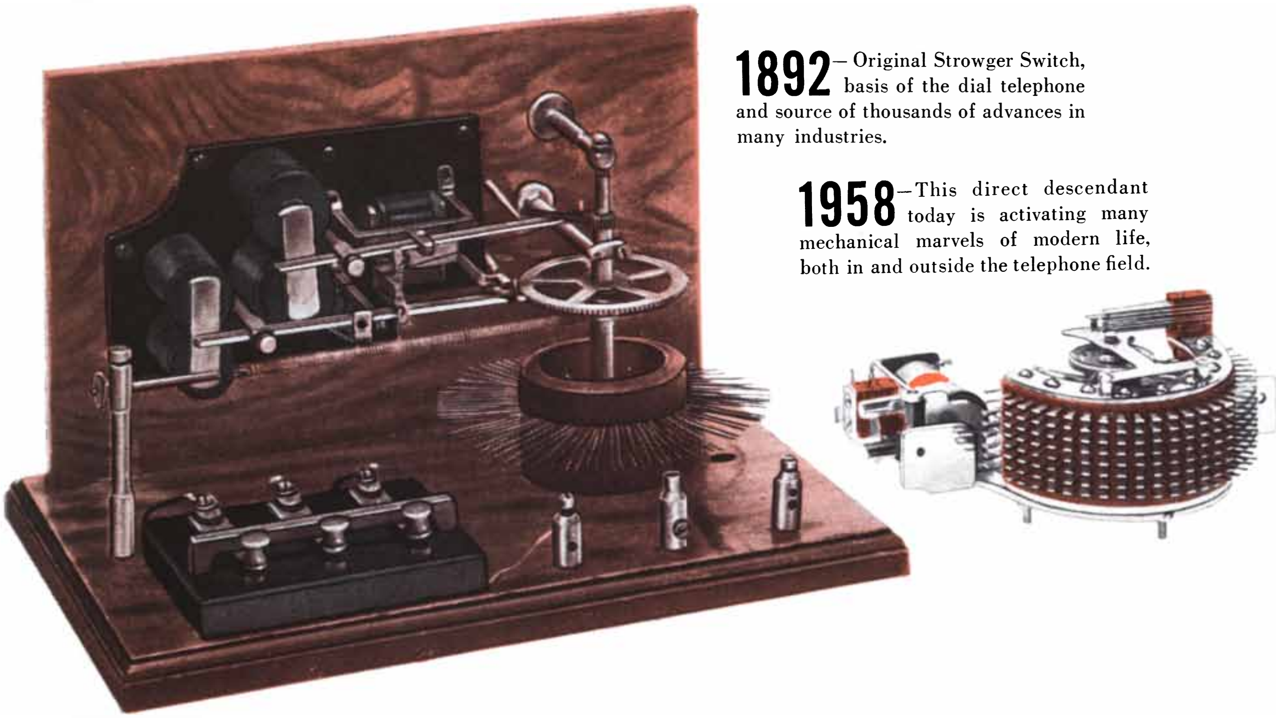


1892—Original Strowger Switch, basis of the dial telephone and source of thousands of advances in many industries.

1958—This direct descendant today is activating many mechanical marvels of modern life, both in and outside the telephone field.

Where did automation begin?

It is hard to believe—but automation began with the crude contraption pictured on the left.

This is the original Strowger Switch, made by Automatic Electric in 1892 for use in the first dial telephone systems. But the principles which this device pioneered are the root of all automation today.

Automation might be defined as machines run by other machines through automatic controls.

And it is safe to say that the majority of mechanisms operated remotely today use types of relays and switches which Automatic Electric originated.

This includes everything from the machines in industrial plants, electronic computers ("mechanical brains") or guided missiles, to stock-exchange quotation boards and variable-pitch airplane propellers.

In the telephone field, Automatic Electric research and development have made two of the greatest recent contributions to the advancement of telephone communications.

One is dialing of long-distance calls without the need for calling the operator. The other is the automatic recording of billing data on toll calls.

All this grows out of an ambition to do things better than they have been done before—plus the resources and talents needed to make the dreams of yesterday the realities of today.

With new and expanded research facilities and production facilities, we are ready now to be of greater service than ever before.

• • •

Career opportunities available at Automatic Electric and General Telephone Laboratories for promising young people with experience in: Logical Circuit and System Design and Packaging, Magnetic and other Memory Devices, High-Frequency Pulse Techniques, Semiconductor Research, Electrical and Electromechanical Engineering. Write Engineering Personnel Department.

AUTOMATIC ELECTRIC ®

Northlake, Illinois

Subsidiary of **GENERAL TELEPHONE**

presence of one stimulus, and in the ratio procedure in the presence of another stimulus. The drug can then be given, and the stimuli are alternated to obtain records of behavior in the same organism under the same drug condition.

These techniques show not only surprising effects of barbiturates at very low doses, but also the dependence of the effect upon the conditions under which the organism is behaving.

LEWIS R. GOLLUB

Psychological Laboratories
Harvard University
Cambridge, Mass.

Sirs:

I read with intense interest the article in your February issue entitled "The Metabolism of Ruminants."

I should like to call your attention to a slight discrepancy when you said that the King Ranch in Texas has developed a new breed (of cattle) based on a Brahman-Hereford cross.

Sir, I believe that the cross you have in mind is a Brahman-Shorthorn cross; three eighths Brahman, five eighths Shorthorn. It is truly a beautiful and magnificent animal.

JAMES A. WELCH

University of Texas
Austin, Tex.

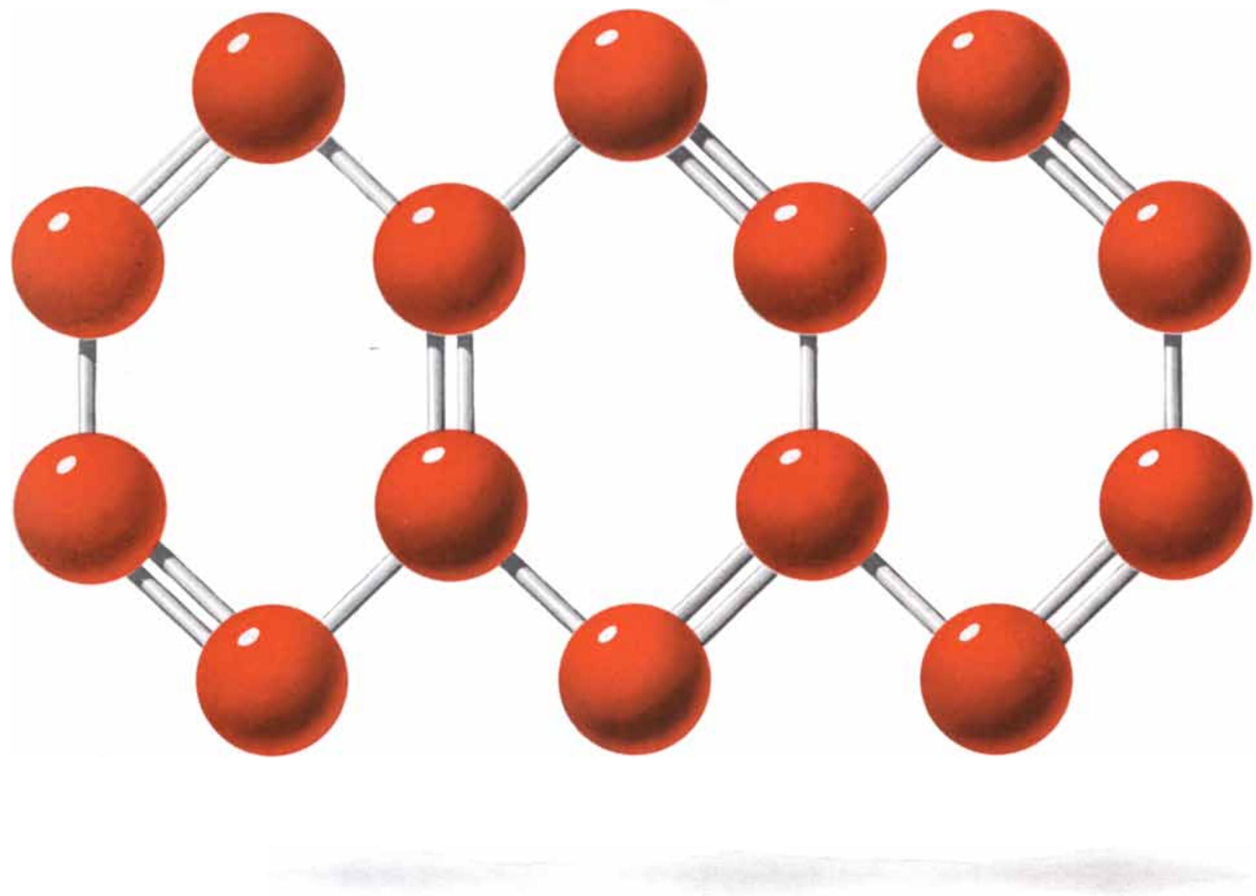
Sirs:

The proposed electric power plant driven by volcanic steam in New Zealand ["Science and the Citizen"; SCIENTIFIC AMERICAN, December, 1957] will neither be the world's first nor the world's largest.

Volcanic steam has been used to produce electric power in Italy at Larderello, Tuscany, since July, 1904. The installed capacity was increased gradually until about 1935, and then much faster to about 200,000 kilovolt-amperes at the beginning of World War II. Practically all the power plants were destroyed during the war. A new modern plant, completed in 1951, has now increased the total capacity to 330,000 Kv-a. . . .

PIER A. ABETTI

Power Transformer Department
General Electric Company
Pittsfield, Mass.



Anthracene: an aromatic treasure-trove

Long familiar in laboratories and textbooks, anthracene is now available commercially as Barrett begins quantity production. Anthracene's unusual properties and attractive price promise a wealth of future applications.

Anthracene is well known as a coal-tar constituent. A reactive chemical, it bears a close relationship in molecular structure to other commercial chemicals, including anthraquinone dyes. It has already found application as an intermediate in the manufacture of these important dyes.

Anthracene undergoes both the Diels-Alder and Friedel-Crafts reactions. It can be reduced, nitrated, sulfonated and reacted with halogens. Its photochemical reactions include dimerization, photo-oxidation and solvent reaction. Products of anthracene reactions are being investigated as intermediates for synthesizing resins, tanning agents, plasticizers, dyes, pharmaceuticals, adhesives, paper chemicals and oil additives.

The photosensitive properties of anthracene are interesting. It absorbs ultraviolet light and has been used to lend light stability to gasoline. Exposed to certain types of radiation, it emits flashes of light which are put to practical use in scintillation counters.

With anthracene as a starting point, you may derive a wide selection of functional groups leading to commercially valuable products. We would be glad to send you a sample of commercial Barrett Anthracene (90-95% purity) so that you may investigate this promising aromatic in your own area of interest. Requests should be submitted on your company letterhead.

Barrett®

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Allied Chemical

Powdered Aluminum:
Rock Buster

Oxygen-hungry Reynolds Aluminum Powders used in cutting torches for scrap, slag and concrete

Aluminum is an oxygen-grabber. Which means, of course, that you can put finely powdered or granular aluminum together with oxygen and generate a lot of heat.

One of the ways industrial chemists have used this phenomenon is in "guns" or torches for cutting and scarfing. They've used Reynolds Aluminum Atomized Powder to cut up furnace "spills" and heavy scrap, and to make small slabs and billets from big ingots.

In addition to slicing up metals of all kinds, these powder guns go through concrete, slag, fire brick, and sand and metal crusts like a hot knife through butter. In fact, recently a "powder lance" using a mixture of Reynolds Aluminum Atomized Powder, iron powders and oxygen zipped through a 12 inch-thick concrete slab in one minute flat.

In these rock-slicing guns, air or gas provides the pressure and oxidizing atmosphere for the combustion of the stream of powdered aluminum. Nozzles of various types focus the heat of the burning aluminum with needle-threading accuracy.

VERSATILE REYNOLDS POWDERS

The most popular ammunition for these guns is Reynolds Atomized Aluminum Powders—No. 40, 120, and 200. And these are but three in a well-rounded line of aluminum powders and pastes which includes: leafing and non-leafing pastes, and leafing and non-leafing flake powders for coatings, finishes and plastics; and atomized, granular and flake powders for pyrotechnics, explosives and powder metallurgy.

In addition to the cutting work described above, the Reynolds Atomized Powders (No. 40, 120 and 200) are used widely by industry:

- **as powerful reducing agents in chemical reactions, e.g. winning metal from its oxides**
- **in heavy explosives, ammunition and pyrotechnics**
- **in powder metallurgy**
- **as an extender in catalytically polymerized epoxy resins**
- **in cold solder**
- **as strengtheners and heat conductors in plastic molds**

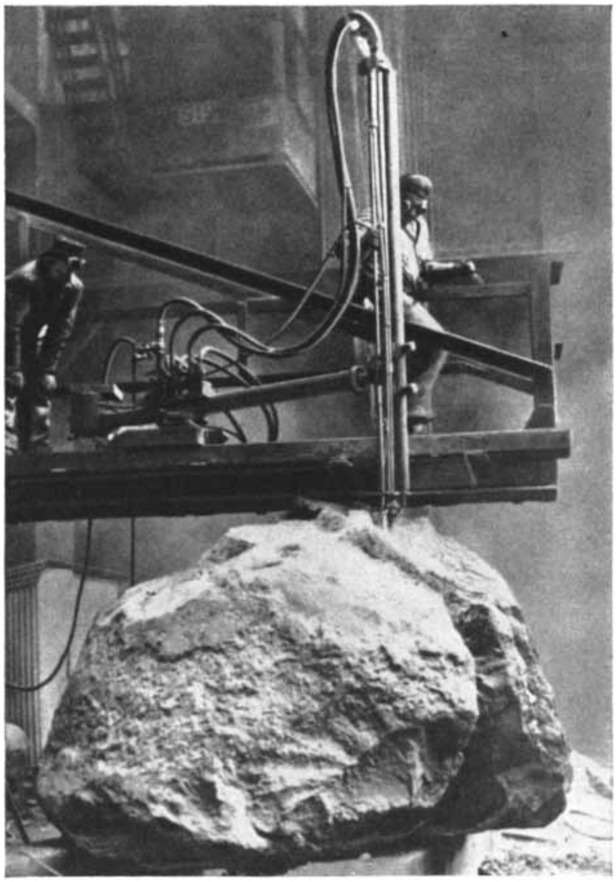


Photo Courtesy Linde Co., Division of Union Carbide Corp.

POWDER PROPERTIES

The following table lists some of the physical characteristics of Reynolds Atomized Aluminum Powders, all of which are made from high purity metal.

Typical Properties of Reynolds Atomized Aluminum Powders

GRADE	RETENTION ON NO. 325 (44 MICRON) SCREEN percent average	APPARENT DENSITY grams per cc	PARTICLE SIZE Microns
1-701	65	1.20 ± 0.15	32 ± 5
40	40	1.20 ± 0.10	30 ± 5
120	20	1.00 ± 0.10	20 ± 5
200	10	1.00 ± 0.10	15 ± 5
1-511	5	1.00 ± 0.10	13 ± 3

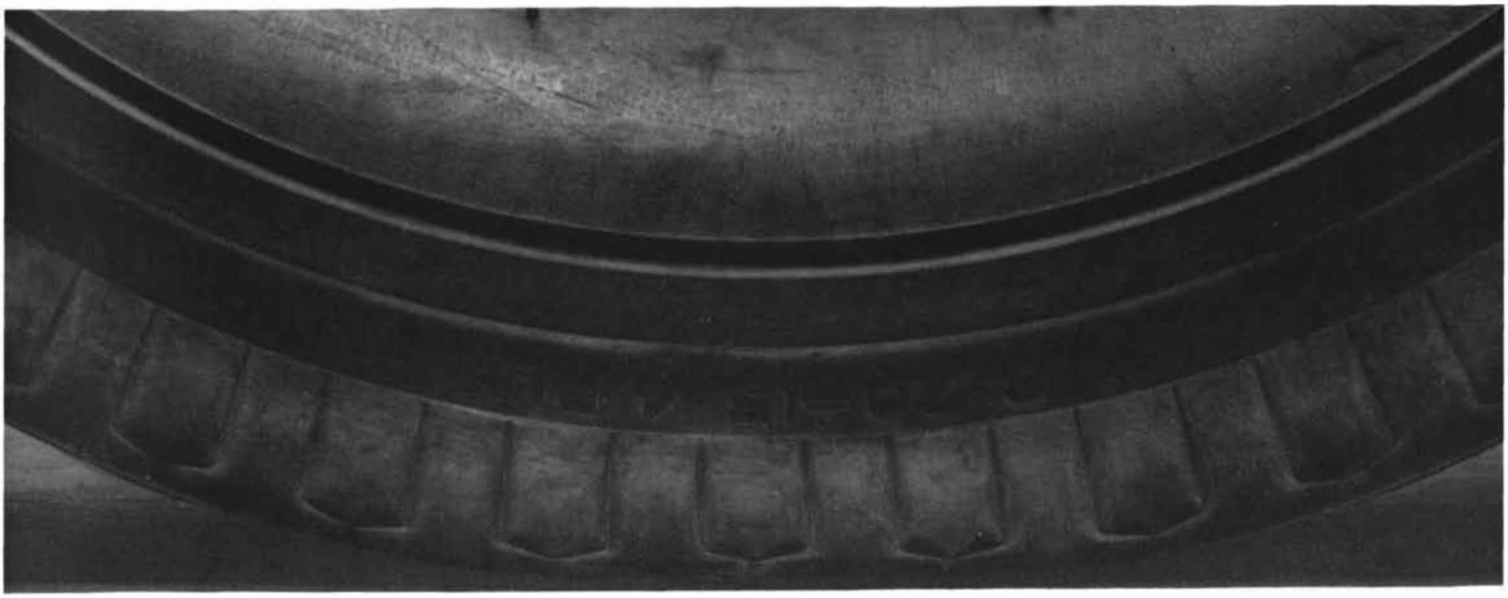
In addition to these powders, Reynolds can supply aluminum in granular, flake, powder and paste forms, in a wide range of controlled particle sizes and apparent densities. Specific data is available on request.

If you have some ideas on possible uses for aluminum powders or pastes, and would like to know more, Reynolds chemists and engineers will be glad to work with you on research and development. Write *Reynolds Metals Company, P.O. Box 1800-PS, Louisville 1, Kentucky.*

The Finest Products Made with Aluminum are made with REYNOLDS ALUMINUM

Watch Reynolds All-Family Television Program "DISNEYLAND", ABC-TV.

Ozone meets its match



Severe sidewall cracks can force motorists in Southern California to discard even the best premium-grade tires before the tread is worn out. Such a tire is shown in the unretouched photograph at top. It has already suffered deep cracks even though it has only 30% tread wear.

The cause of this destructive and unsightly cracking is ozone—a form of oxygen that is especially harmful to ordinary rubber. While ozone is present everywhere, the local atmospheric conditions in Southern California permit it to accumulate in abnormal concentrations. In these amounts, ozone quickly and quietly destroys ordinary rubber products.

However, a leading tire manufacturer has now solved this problem by making sidewalls with *neoprene*—the Du Pont synthetic rubber with proved resistance to ozone cracking. As shown in the unretouched photograph at the bottom, this new tire is still free of sidewall cracks after approximately the same length of service as the cracked tire.

This is one more example of how Du Pont synthetic rubbers can improve the rubber products you make or buy. This Du Pont family now includes neoprene with its balanced combination of properties; HYPALON* for unusual chemical resistance; ADIPRENE* synthetic rubber for outstanding abrasion resistance; and VITON*, a fluoroelastomer which will soon be available for high temperature uses up to 500° F. For more information, write to E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Department, Room SA-4, Wilmington 98, Delaware.

*Registered Du Pont Trademarks

DU PONT

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NEOPRENE

Better Things for Better Living

. . . through Chemistry

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

APRIL, 1908: "Dr. Alfred Russel Wallace, F.R.S., has replied to Prof. Percival Lowell's *Mars and Its Canals* in a small volume entitled *Is Mars Habitable?* Dr. Wallace takes the view that if the surface of the planet is so wonderfully smooth and level as Prof. Lowell states it to be, then the great network of straight canals could possibly have been constructed by intelligent beings for irrigation purposes. But he points out emphatically here that, if it were so smooth, then such a system would be quite unnecessary, as the water would naturally irrigate as much of the surface as it could reach. If it be admitted for a moment that the polar caps are frozen water, he joins with the late Miss Clerke in the view that the excessively scanty supply of water, coupled with the loss through evaporation, could not possibly supply the innumerable canals."

"An event of extreme interest, not only to astronomers but to the world at large, will soon take place. This is the return of the periodic comet made famous by the genius of Halley. The last return of Halley's comet was in 1835. Pontécoulant computed that its next perihelion would occur on May 24, 1910. Astronomers will not wait till that time, however, for their first view of the comet. Prof. O. C. Wendell has published in *Popular Astronomy* an ephemeris based on the elements of Pontécoulant. From this it appears that at the present time the comet is less distant from the sun than Saturn. Its position, on the northern edge of the constellation Orion, is favorable for observation, but it is doubtful if even the great telescopes of today can reach it as yet."

"Sir Oliver Lodge, F.R.S., principal of Birmingham University, had an overcrowded audience when lecturing on 'The Ether of Space' at the Royal Institution. Was the ether material?, Sir Oliver asked. That was largely a question of words. It belonged to the material world; though it was not matter in the ordinary sense, it might be the substratum of which matter was made. An electron might be regarded as a knot in the ether; a knot in a string was composed of string, but the string was not composed of knots. There was an essential distinction: matter moved; the ether was strained, exerted stress and recoiled. All potential energy was in the ether, which could vibrate and rotate but was absolutely stationary, so to speak. All we could do was to alter its configuration; everything else was stationary."

"The London publication *Who's Who* makes one concession to the curiosity of human nature in which its example has not yet been followed by its American counterpart. It records not only the professional pursuits and achievements but also the 'recreations' of the men who find a place in its list. Of the chemists, Sir William Ramsay refreshes himself with languages and cycling; Prof. Frederick Soddy, with travel and climbing; Dr. Ludwig Mond, in the collection of works of art, chiefly of the early Italian school. The mathematicians and physicists appear on the whole a sober and serious band. Many of them record no recreation at all. Sir Oliver Lodge is among this number, but he gives himself away in another section of his biography. For how can we accept your repudiation of the lighter side of life, Sir Oliver, when you admit that you are a member of two golf clubs? Prof. J. J. Thomson is fond of tennis and golf. Prof. Karl Pearson devotes his leisure to antiquarian studies in genealogy and folk custom. The Hon. C. A. Parsons uses the word 'various,' but notes particularly his practice in rowing—not, presumably, with the aid of the turbine."

SCIENTIFIC AMERICAN

APRIL, 1858: "Messrs. W. R. Dunlap & Co. of Cincinnati, Ohio, order 15 copies of the SCIENTIFIC AMERICAN, which they intend for the use of their apprentices. They inform us that it is their intention in future to pursue this course. This company is engaged in the manufacture of steam engines and boilers, also flouring mills, complete in every department. We venture to express the opinion that they will find the investment which they have made one of the very best, and that their apprentices will

be rendered more useful to them accordingly."

"The galvanic gas igniter of Saml. Gardiner, Jr., has been applied to the great chandelier of the Senate Chamber in Washington, and with decided success. By the simple turning of the circuit key, fifteen hundred gas jets were ignited in an instant!"

"There is a project on foot at St. Petersburg, Russia, for establishing a strictly overland telegraphic company with North America. The plan has been presented to the government by a Belgian engineer, and consists in carrying a telegraphic line through Siberia, and in establishing a submarine communication between Capes East and Prince of Wales, then joining the lines to those of the U. S. through the territories of Russia and England."

"Some idea of the immense magnitude of the monster steamer *Leviathan* (formerly *Great Eastern*) may be formed from the fact that the mere cost of completing her for sea, putting on board stores, &c., and fitting her for the trip she is expected to make to Portland, Me., the coming summer, will come to the enormous amount of $600,000. No less than 10 anchors are required to hold her at her present moorings, each with lengths of cable from 40 to 160 fathoms."

"So far as the particular attention of European nations to the progress of the American people in arts, sciences and manufactures is concerned, we must certainly place Austria among the first. The Austrian railways are the only ones in Europe where the American form of railroad carriage is exclusively employed. Our general system of construction and arrangement of the parts of locomotives is extensively adopted in that country. The first river steamboat for the Old World on American principles was constructed for the Danube, and since that time two immense boats of 50 feet beam have been built for that river on the American model, and with engines furnished from New York. Morse's electric telegraph has from the very start monopolized the Austrian telegraph wires. This increased general introduction of the works of American genius and skill into Austria of late years is in a great measure attributable to the persevering efforts of Chas. F. Loosey, who, before assuming the office of Austrian Consul in New York, was actively engaged in his profession of civil engineering in Vienna."

TRIMETHYLOLPROPANE . . . a fast 10,000,000 lbs. to feed growing industry

The properties of this free-flowing polyol are of prime importance to the fast-growing polyurethane foams industry. Trimethylolpropane's ability to improve both rigid and flexible foams, coupled with its easier processing, offer extremely valuable manufacturing advantages. And in the large alkyd resins industry serving the $1.6 billion paint market, this chemical intermediate is also finding important application.

But, until Celanese developed a method for high-volume, low-cost production, the usefulness of trimethylolpropane was severely limited. Today, a major Celanese production facility at Bishop, Texas, is geared to turn out in excess of 10 million pounds, providing industry with a high quality product at a practical price.

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ON THESE TWO PAGES YOU WILL READ HOW SHE HAS SOLVED ONE OF THE GREATEST PROBLEMS IN THE DEVELOPMENT OF GUIDED MISSILES TODAY

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You'll find these women everywhere in our Army, Navy and Air Force. You'll find them as the wives of scientists, or married to engineers for some of the largest industrial concerns in the nation.

They know more about the problems of raising a family virtually alone than they do about the business of producing the missiles themselves.

This advertisement is a tribute to the courage of such women, and to the very real contribution they are making to the development of a guided missile arsenal for this nation's defense.

Where AC fits in this picture

AC has been a leader in the development of an inertial guidance system for use in many types of guided missiles. This system, which we call the AChiever, is now in ballistic missiles and air-breathing missiles developed for use by our armed forces. It has made headlines and proved itself in flight in such missiles as the Air Force's Thor and Matador . . . and in the Navy's Regulus II.

The AChiever has far broader application than most systems developed for a similar purpose. It can, for example, guide a missile far beyond the confines of earth. It could put a satellite into orbit . . . or take a rocket to the moon . . . and it is not subject to interference by any known natural or man-made force. And, AChiever is in volume production.

These remarkable accomplishments have been made possible in large part by the faith and understanding of the wives of the men at AC and their counterparts in the armed forces, in science and industry.

—If you are such a woman, and your husband has engineering or scientific training which could make a contribution to this program, and is not a member of the armed forces, ask him to write—or write yourself—to the personnel section of AC in Milwaukee.

AC SPARK PLUG ✇ THE ELECTRONICS DIVISION OF GENERAL MOTORS

THE AUTHORS

ROBERT S. DIETZ, RUSSELL V. LEWIS and ANDREAS B. RECHNITZER ("The Bathyscaph") are practitioners of three of the scientific disciplines that come together in the study of the deep ocean. Dietz is a geologist. He works at the London branch of the Office of Naval Research, and was responsible for U. S. backing of the Piccard bathyscaph. He took his B.S. and graduate degrees at the University of Illinois, was an Air Force pilot in World War II, and later helped apply sonic devices to deep-sea studies for the Navy (see his article "The Pacific Floor"; SCIENTIFIC AMERICAN, April, 1952). In 1953 he went to Japan to study the mysterious transmission of sound to the California coast from the underwater volcano Myojin. Lewis is an electronics engineer who helped develop the sonobuoy, a submarine-detection device. He traveled widely giving instructions in its use, and was one of the survivors of the sinking of the U.S.S. *Block Island* by German submarines in 1944. Lewis has worked on sonar since 1945. He has tested sonar gear on many naval craft, including the atomic submarine *Nautilus*. Rechnitzer, the third author, is a biologist. He studied conservation at Michigan State University, then went to the Scripps Institution of Oceanography to work on applying serology and chromatography to classifying fishes. In 1956 he received a Ph.D. in zoology from the University of California at Los Angeles.

GEOFFREY BURBIDGE and FRED HOYLE ("Anti-Matter") have worked together on various problems in astrophysics. Burbidge graduated from the University of Bristol and acquired a Ph.D. in meson physics from the University of London in 1951. While studying physics, he married an astronomer, which converted him to astrophysics. Burbidge has been an Agassiz Fellow at Harvard College Observatory, a researcher at the Cavendish Laboratory of the University of Cambridge, and a Carnegie Fellow at the Mount Wilson and Palomar Observatories; he now teaches at the Yerkes Observatory of the University of Chicago. Hoyle is also an astrophysicist, but his background is more mathematical than physical. By the age of six he knew the multiplication table up to 12 times 12. Failing eyesight caused him to give up cricket when he was 13, but did not prevent him from staying up all night with a three-inch telescope his parents had bought for him. Hoyle's county (Yorkshire) gave him a scholarship to the University of Cambridge, where he soon won a prize fellowship to St. John's College. Now a senior fellow there, Hoyle is widely known for his books *The Nature of the Universe* and *Frontiers of Astronomy*.

ARPAD CSAPO ("Progesterone") is associate professor at the Rockefeller Institute for Medical Research. Born in Hungary, he received his M. D. from the Medical University of Szeged in 1943. He sought a career in medical research, but because of wartime dislocations found himself in charge of the delivery room in Szeged's University Hospital. On duty every other day for 24 hours, he conducted several thousand deliveries. Even more frustrating to Csapo than the stringencies of wartime obstetrical practice was the dearth of basic knowledge of reproduction. As soon as the war ended he began to study reproductive physiology. In 1948 he was invited to join the Svedberg Laboratory in Uppsala, Sweden. The next year he came to the U. S., where for seven years he worked at the Carnegie Institution in Baltimore and at the Johns Hopkins Hospital.

WALTER C. MICHELS ("The Teaching of Elementary Physics") says: "My interest in physics teaching is a natural result of my job. I have been at Bryn Mawr College since 1932, and have been chairman of the Department of Physics since 1936. Bryn Mawr is peculiar in that it has only 650 undergraduate students and yet conducts a full program of graduate work with 200 graduate students, both men and women. We have to give an introductory course in physics that serves at once the future physicist, the major in some other science and the student of liberal arts." One result of Michels's unconventional course was the textbook *Elements of Modern Physics*. Michels is president of the American Association of Physics Teachers. During the last six years he has become increasingly involved in the movement to improve science teaching. He is a graduate of the Rensselaer Polytechnic Institute and the California Institute of Technology.

AMEDEO MAIURI ("Pompeii") has been superintendent of antiquities in the Naples region for 34 years. He is perhaps best known in the U. S. for his

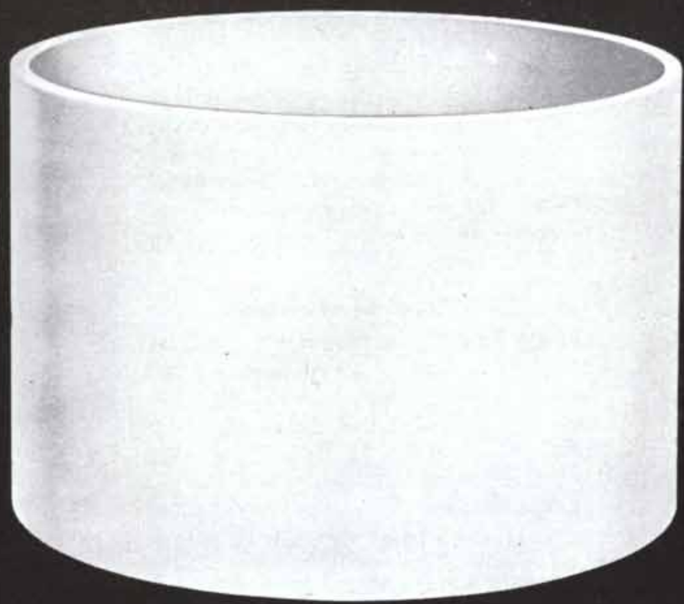
beautifully illustrated book *Roman Painting*. Maiuri was born 72 years ago near the border of the Neapolitan Campania. As a boy he was passionately devoted to the classics, especially Virgil. His admission to the Archaeological School of Rome turned him from a sedentary philologist into an active field archaeologist. Maiuri completed his training at Athens and on Crete. Then he was called to head an archaeological mission to the island of Rhodes, where he restored the medieval castle of the Knights Hospitalers and turned it into one of the principal museums of the eastern Mediterranean. His more recent work includes the discovery of the Cave of the Sibyl at Cumae and the excavation of the Roman spa at Baia and of the villas of the Roman emperors on the island of Capri.

LAMONT C. COLE ("The Ecosphere") is professor of zoology at Cornell University. Despite a boyhood passion for snakes, he graduated from the University of Chicago as a physicist. His return to the animal kingdom resulted from a trip down the Colorado River with A. M. Woodbury of the University of Utah, who inspired him to study ecology. Cole's chief interest is now in natural populations. He has taught at Cornell since 1948. Before that he occupied the late Alfred Kinsey's post in entomology at Indiana University, which he had taken over when Kinsey "turned to the study of bigger and better things."

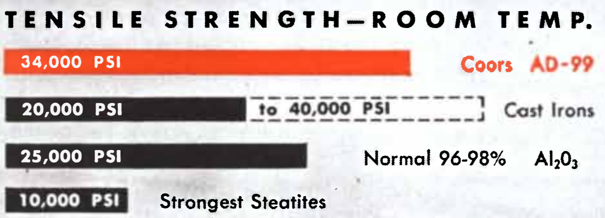
HANS KALMUS ("The Chemical Senses") has been studying the sensory abilities of dogs and bees at the Galton Laboratory of the University of London, where he has taught since his flight from Czechoslovakia in 1939. A native of Prague, he studied zoology and medicine at the German University there and taught comparative physiology. He has worked at Indiana and McGill universities, and is the author of a popular book entitled *Genetics*. This is his third article for SCIENTIFIC AMERICAN; the first two were "Inherited Sense Defects" (May, 1952) and "More on the Language of the Bees" (July, 1953).

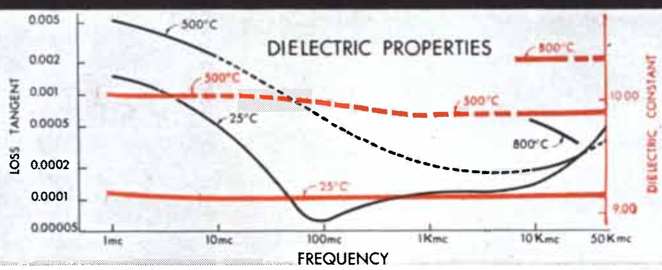
FRANK B. SALISBURY ("The Flowering Process") studied the chemistry of flowering under James Bonner at the California Institute of Technology, where he received his Ph.D. three years ago. Now he teaches plant physiology at Colorado State University. His article "Plant Growth Substances" appeared in SCIENTIFIC AMERICAN for April, 1957.

Coors NEW AD-99 ALUMINA CERAMIC



AD-99 Ceramic Tube Envelope 10" dia. x 8½"





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75% OF TENSILE STRENGTH AT 2000° F

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FOR **Y**OUR **I**NFORMATION

WHERE DO URETHANES STAND TODAY?

A few years ago, these versatile plastics were heralded as "the next great synthetic." How have they made out? In brief—some good, some not so good, some phenomenally successful. Here we will try to give you the low-down and a quick sum-up.

First, the *dark* side of the picture: Progress is still "developmental" as far as adhesives, rubber and coatings are concerned ("developmental" being a nice word to imply that not half as much has been done in these fields as we'd like to see). Adhesives, while good, are still too expensive. Rubber—for tires, for example—is hampered by bonding and other problems. (O-rings and gaskets work fine, however.) While initial results with wire coatings and paints are favorable, there's still a lot of work to be done in those areas.

New types of urethanes

On the bright side, new combinations of isocyanates with such materials as polyethers, polyesters, dimer acids and other polyols are pushing urethanes ahead in many fields. (Our NATIONAL ANILINE DIVISION has developed some highly workable prepolymers for polyether- and polyester-type urethanes.) Excellent results are being obtained with *flexible* foams, taking advantage of their "comfort characteristics" and low compression set. This accounts for the continually increasing use of urethane foam in automobile crash pads and seats, furniture upholstery and slabbing for the better-grade mattress market. A particularly bright spot in flexible urethane applications is interlining, where the new material is described (too modestly, we would say) as "the newest textile." Perhaps a million square yards of urethane foam went into outer garments during 1957.

Egg bouncing from 12-foot drop demonstrates superior cushioning properties of flexible urethane foam.

Rigid foams, with their unique combination of properties, are moving ahead particularly fast. To wit: Refrigeration panels for trucks and railroad cars, for home refrigerators and industrial freezers; flotation chambers for boats; void-filling applications as in airplane tail fins and nuclear submarines; various as-yet-unannounced uses in the missile and satellite programs. These applications make use of one or more of the many properties of rigid urethanes: excellent thermal insulation, structural strength, and their ability to be foamed-in-place, to bond without adhesives, and be formulated in a wide weight range.

Buoy for dock has rigid urethane foam core, polyester-glass fiber surface—resists shock, marine growth.

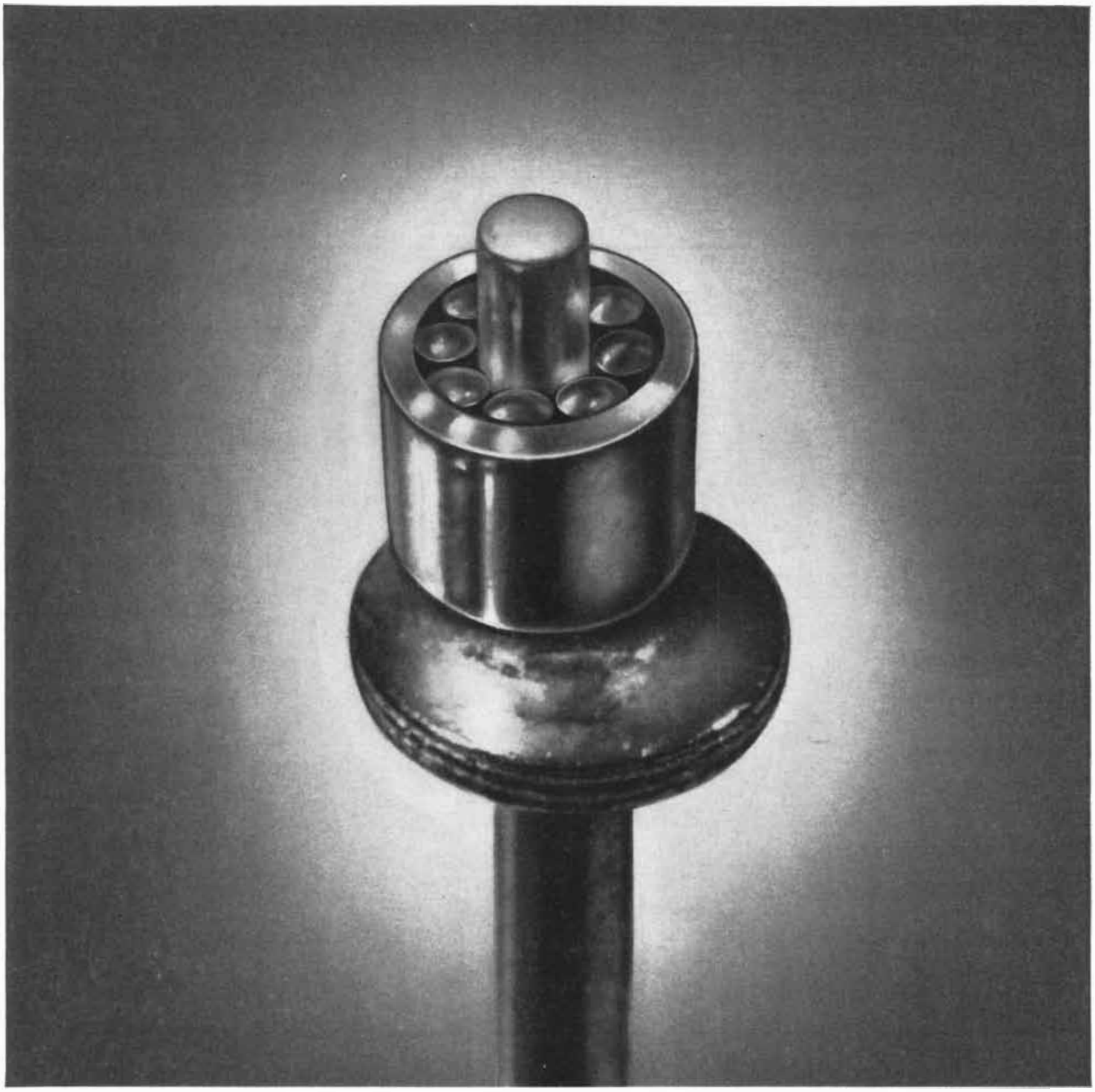
Looking ahead

Would a look into the future be inapropos at this point? Not with versatile urethanes—especially in rigid foam form. For instance: panels for insulated freight cars; sidings for house trailers; perhaps even walls for prefabricated homes. There are dozens of household uses still untried, by the way: bath mats of flexible foam to cushion falls, for instance. Contributions to the rocket program? There's a real challenge for urethanes here—one which many alert manufacturers will doubtless meet.

WHY NOT GET MORE FACTS about urethanes and the NACCONATES that make them possible? Two new technical bulletins have just been printed: One on polyether flexible foam formulations, another on rigid foams. Write for them (or for other information) on your company letterhead, telling us about your proposed use. Address: Allied Chemical, Dept. 48, 61 Broadway, New York 6, N. Y.*

*Allied does not make urethane foams, but our National Aniline Division supplies isocyanates under the trademark NACCONATE. Our Barrett Division makes PLASKON polyesters.

Allied Chemical



A TORRINGTON BEARING NO BIGGER THAN A PINHEAD!

This miniature anti-friction cam follower bearing was photographed on the head of a pin and magnified thirty-two times! Shown actual size on the right, it is, we believe, the smallest roller bearing made.

Its outside diameter is only .0620 in.; stud diameter is .0220 in. Rollers are .0110 in. in diameter and .0390 in. long. Radial load capacity is four pounds. It is one of a proposed series of miniature needle roller bearings being developed by Torrington.

These developments in miniaturization are part of Torrington's continuing research and development program designed to produce ever higher levels of bearing design and performance.

THE TORRINGTON COMPANY

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RESEARCH FOR PROGRESS IN BEARING DESIGN AND PERFORMANCE

Established 1845 SCIENTIFIC AMERICAN April, 1958 Volume 198 Number 4

The Bathyscaph

In this remarkable vessel men can visit the ocean bottom at depths of more than 15,000 feet. Explorations with it are now yielding significant geophysical and biological information

by Robert S. Dietz, Russell V. Lewis and Andreas B. Rechnitzer

It is an interesting fact that man has seen more of the surface of the moon than he has of the earth. Most of the earth's surface—the three quarters covered by the oceans—is unknown territory. We have explored some of the underwater shelves of the continents in submarines, dredged up samples of mud from scattered sites on the deep sea bottom and photographed a few spots on the sea floor with cameras dropped on cables. But these can hardly be called even glimpses of the subocean planet; we have never actually set eyes on a deep-sea landscape.

Auguste Piccard's invention of the vessel called the bathyscaph has now opened the road toward manned exploration of that unknown world. His vehicle is capable of taking us down to bottoms as deep as 20,000 feet, where the pressure runs to 600 atmospheres and passengers have to be insulated as they would in a space ship. In a sense the bathyscaph corresponds to a rocket to the moon. But whereas a rocket capable of carrying a man to the moon has yet to be designed, the bathyscaph has already met all its tests with flying colors and has made more than 100 voyages for science.

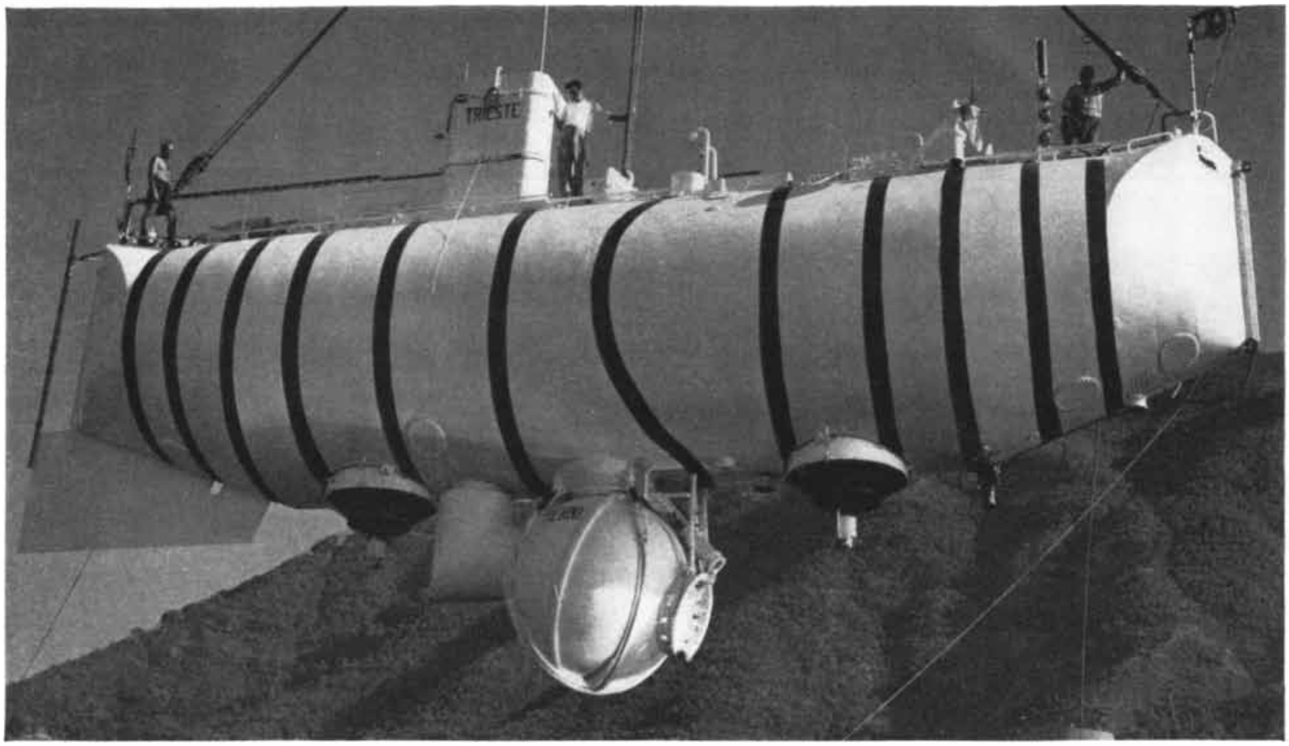
During the past year a group of U. S. and European scientists made more than a score of deep dives in the Mediterranean in the bathyscaph *Trieste*, owned by Auguste Piccard and his son Jacques. The series of dives was financed by the U. S. Office of Naval Research, which is interested in developing the bathyscaph as a research tool. With Jacques Piccard as pilot, the scientists made a systematic study of the ship's performance and saw enough of the undersea world to become highly enthusiastic about the bathyscaph's possibilities.

The bathyscaph should not be confused with a submarine or with William Beebe's famous bathysphere. Submarines are limited to dives of a few hundred feet. Beebe's craft went down to about 3,000 feet, but it was merely a steel ball hanging on a wire rope and could not be dropped all the way to the bottom because of the risk of fouling the rope, its only means of ascent. The bathyscaph is a radically new invention—an untethered ship operating under its own power, able to withstand enormous pressures, absolutely watertight, equipped with electrical controls and scientific instruments, and capable of diving to deep sea bottoms and rising again by its own devices. Its range is so deep that the craft could probably go to the bottom of every area of the oceans except the very deep trenches.

Like most good inventions, the bathyscaph is beautifully simple in concept. It is built essentially like a blimp [*see photograph on next page*]. Its cabin (gondola) is a sphere of steel more than three and a half inches thick; the ball weighs 11 tons and has a diameter of six and one-half feet—large enough to carry two men. As in a blimp, the cabin hangs from a big "bag" (some 50 feet long) which provides the buoyancy—but in this case the buoyant filling is not a gas but gasoline, 30 per cent lighter than water. The float carries 28,000 gallons of gasoline, divided in 10 compartments. It does not need to be pressurized (its steel skin is only one third of an inch thick), because water flows into it through holes on the underside so that the internal pressure increases to equalize the external as the craft goes down.

The ship carries 10 tons of iron pellets as ballast to help control its descent and ascent. It starts to submerge by taking water into two air tanks at the ends of the float. As the craft descends, the increasing pressure of the water compresses the gasoline (which of course floats on top of the water entering the compartments). The compression of the gasoline reduces the buoyancy, so that ballast has to be jettisoned to slow the descent—a ton of iron pellets for every 3,000 feet of descent. At the bottom of its dive the ship is held down by its remaining iron ballast; to rise to the surface again it merely drops ballast. As a safety measure, to make sure that release of the ballast cannot become jammed, an electrically operated magnetic device is used to hold the pellets; if the electric power should fail, the pellets would fall out automatically.

The *Trieste* has electric batteries and two propellers which can drive the ship horizontally. Thus it can move along the sea floor. But its power supply is so lim-

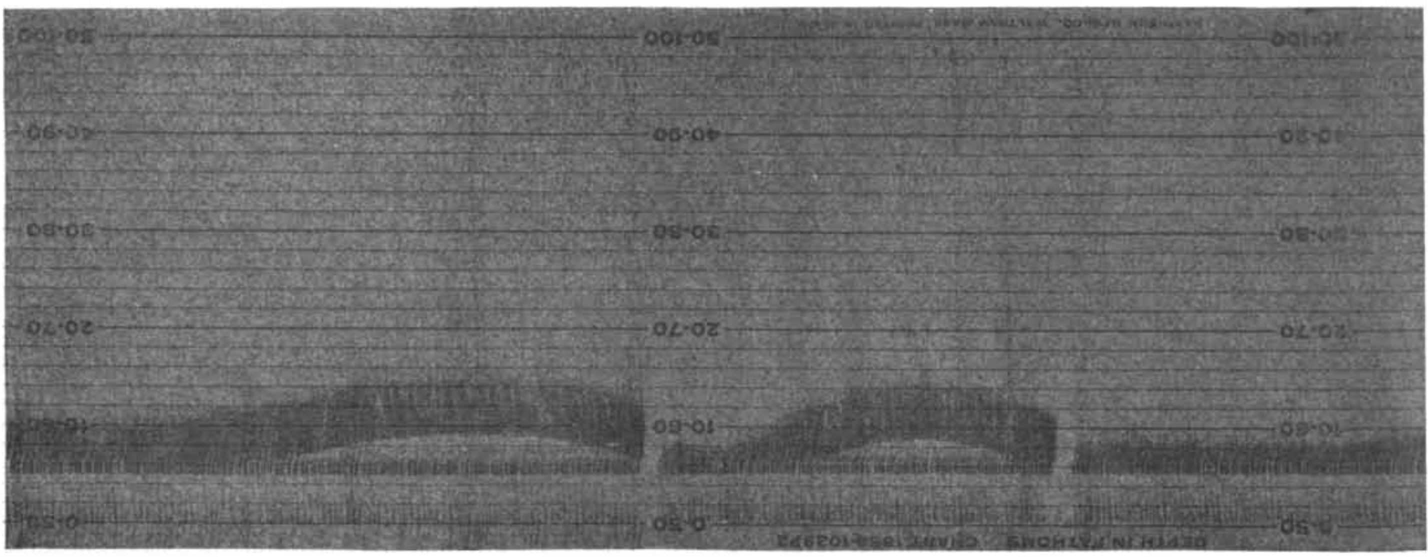


BATHYSCAPH "TRIESTE" resembles a blimp. Its oblong buoyancy chamber corresponds to a blimp's gas-bag, but is filled with gasoline rather than helium. Its spherical observation cabin corresponds to a blimp's gondola. Black lines mark compartments.

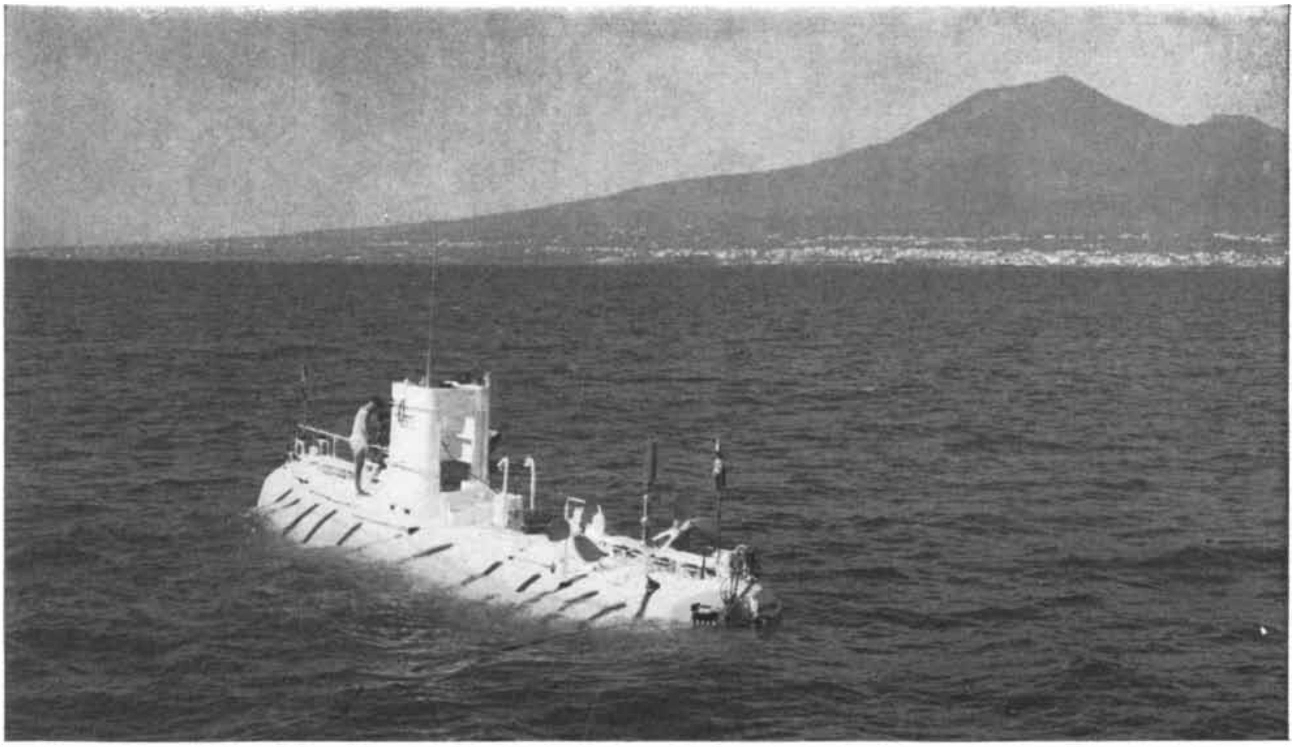
ited that the ship's practicable horizontal range is not much more than 100 feet.

The cabin carries an oxygen supply for 48 hours. It has two small cone-shaped windows which give a wide-angle view of the surrounding sea. Among the items of scientific equipment are mercury-vapor floodlamps, a camera with an electronic flash, an echo-sounder with a range of 600 feet, and a telephone, which receives and transmits directed sound waves through the water. The telephone not only allows the crew of the bathyscaph to talk with observers in a surface ship above but also gives a measure of distances (*e.g.*, from the submarine to the surface or to the bottom), based on timing the round-trip travel of the sound waves.

The designers had to solve many tricky technical problems to make the bathyscaph work—problems in handling high-pressure electrical equipment, in providing accident-proof buoyancy con-



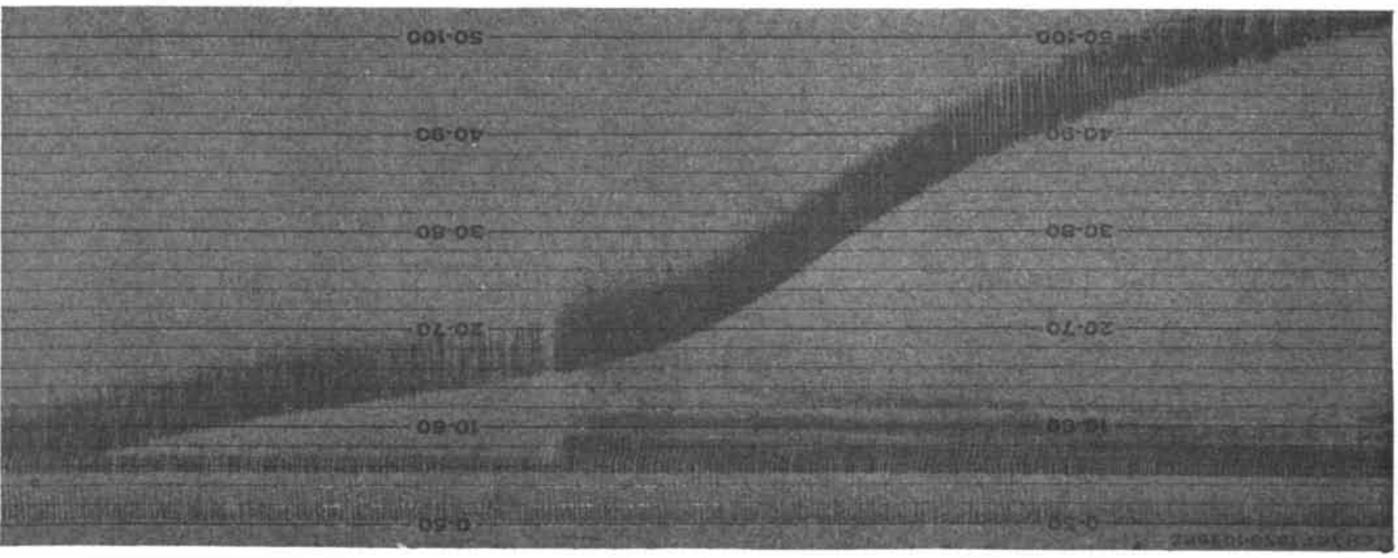
"TRIESTE" LANDING on the ocean bottom 3,000 feet down is graphically depicted in this echo-sounder trace. Reproduced here upside down, the trace in its normal position would show bottom coming "up" to meet the bathyscaph. From right to left the trace



"TRIESTE" IS TOWED to its diving location. Its own power supply, which will propel it only for about 100 feet, is saved for maneuvering on the ocean bottom. In the background is Mount Vesuvius. All the 1957 dives took place near the Bay of Naples.

trols, in leakproofing the cabin against tremendous water pressures, and so on. An indication of their success in these technical details is the fact that the cabin has never leaked a drop of water. The difficult problem of insulating electrical apparatus mounted on the float against sea water was solved by the simple and ingenious stratagem of immersing it in nonconducting liquids with which water does not mix.

Our series of dives was made in the Tyrrhenian Sea off Naples, near the base where the *Trieste* has been kept since it was built in 1953. The sea here goes down to depths of 10,000 feet and more, and it is an excellent spot for tests. Each dive took a few hours; sometimes two were made in one day. The craft, carrying Jacques Piccard and another observer, would descend very slowly, spend a short time on the bottom and then rapidly come to the surface, taking



shows the vessel descending fairly rapidly, slowing and touching down on the bottom. The gaps at left show that the sounder was shut off while the vessel was on the bottom; the humps following the gaps show the vessel ascending briefly and descending again.

careful observations of the water, its animal life and the performance of the ship throughout the journey.

As the bathyscaph sinks below the surface, it becomes uncannily steady, in sharp contrast to the rocking of a ship on the surface waves. So far as human senses can detect, there is no yawing, pitching or rolling whatever once the craft descends below the waves. The compass shows that it does swing slowly and irregularly, but the movement is very slight.

About 75 to 100 feet down, at the boundary between the warm surface water and the cold, denser water below, the descent of the bathyscaph would often come to a halt. To break through the thermocline into the lower layer it was necessary to reduce buoyancy by valving off some gasoline or to carry an extra heavy load of iron ballast.

As the bathyscaph moves down into the darker depths of the sea, something like snow begins to stream past the windows—only moving upward instead of falling! It consists of tiny particles of debris and microscopic animals in the water, made visible in our floodlights by the so-called Tyndall light-scattering ef-

SHALLOW-WATER DEBRIS, including fragments of eelgrass and a broken bottle (*top*), litters the steep slopes around Capri 500 feet down.

MARINE WORMS (*long filaments at left*) were often seen in shallower dives. This photograph was made west of Capri at about 900 feet.

CLUSTERS OF HOLES, varying in pattern, were further evidence of deep-sea life. This photograph was made south of Capri at 3,000 feet.

SIX-FOOT CONGER EEL casts its shadow in the bottom 3,000 feet down. The box at top center contained cheese but failed to attract fish.

fect, just as a beam of sunlight shows the dust particles in a darkened room. This "sea snow" becomes most intense near the zone of complete darkness (at about 1,500 to 2,000 feet), probably in part because the optical conditions in that region become more favorable for seeing particles. Lower down, living organisms are doubtless less abundant.

Oceanographers have long thought that some sunlight may penetrate as deep as 3,000 feet into the sea, because the film in cameras lowered to that depth sometimes comes up fogged. The dives of the *Trieste* produced a different explanation. Beginning at about 1,300 feet the observers saw flashes of phosphorescence from luminous animals which were numerous enough to fog photographic film.

The Mediterranean is a comparatively barren sea, so we did not expect to see many animals in its depths. But we were pleasantly surprised. On or near the sea bottom we found a number of fishes, among them a species of deep-sea cod, the tripod fish, a grenadier or rattail fish, a six-foot eel and a fish called *Cyclothone,* a deep-sea relative of the herring. This fish seemed to be attracted to the

A FEW MINUTES LATER one worm has disappeared into its hole. The light cloud at the upper right may be ink ejected by a squid.

HOLES IN BOTTOM, presumably made by animals, were observed in nearly all dives, as in this photograph made at 2,700 feet near Sorrento.

GIANT RIPPLE-MARKS, some 15 feet from crest to crest, were found 9,000 feet down south of Ponza. How they were formed is not known.

DEEP-SEA FISH (*right*) feeds amid clots of loose mud which cover the bottom 10,000 feet down. Bright spot is reflection from cabin window.

light of our floodlamps; another fish was so startled that it darted into the sea floor in complete panic. But most of the bottom fishes living in complete darkness paid little or no attention to our lights. On the other hand, the light did attract a small crustacean—a white, swimming isopod—and hundreds would collect in our light beam. Curiously, these isopods seemed to be alarmed by the feel of iron; when they happened to land on a pile of our jettisoned iron pellets they would hastily take off again.

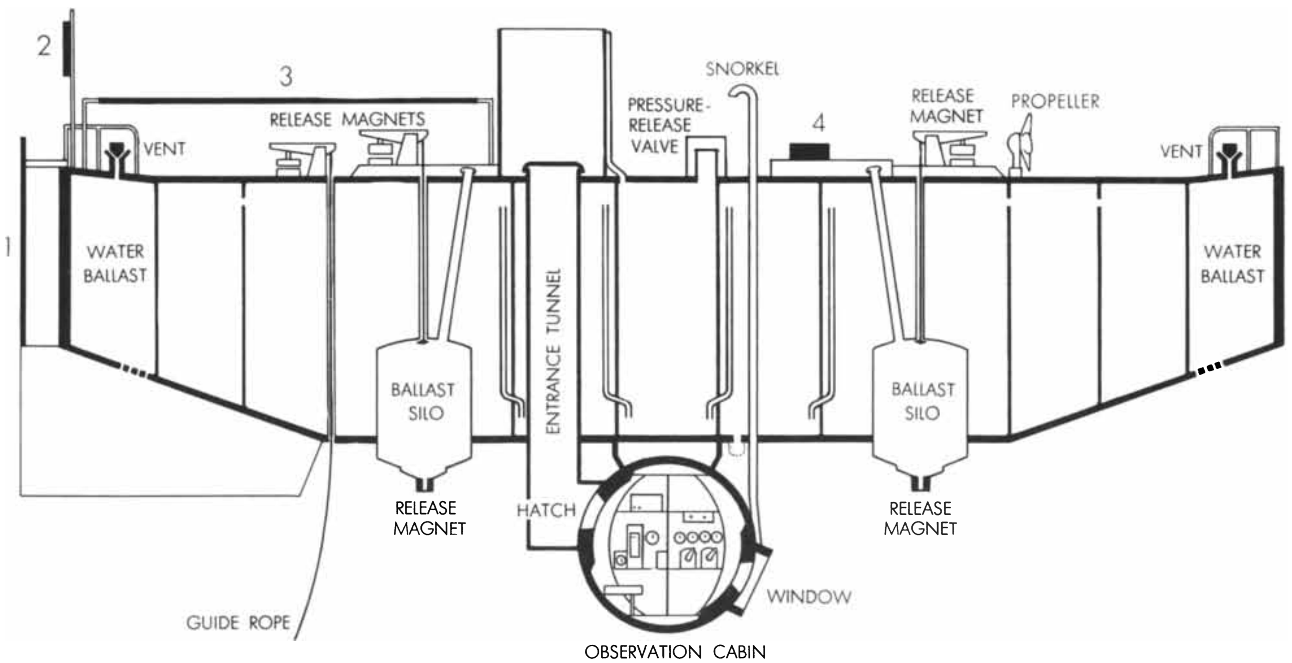
Apparently the isopods are one of the main sources of food for the bottom fishes. Worms and other burrowing animals in the bottom also supply food. The bottom is perforated with many holes, some of them up to an inch or more in diameter, which indicate the existence of these animals. We noticed that some of the fishes worked along the bottom looking for food, often grubbing head down in the mud: the rattail fish would raise its tail like a banner. It seemed that the fishes must rely primarily on the senses of smell and touch to find their prey. Oddly, most of the fishes ignored the cheese and meat that the bathyscaph carried outside its hull as bait to attract them.

Lacking power to move very far along the bottom, the *Trieste* was not able to explore the topography of the sea floor. In most dives the bathyscaph landed on a flat bottom consisting of extremely fluid mud: a few pounds of iron pellets dropped from the craft would stir up a great cloud of mud shaped like a doughnut. After seeing these clouds of mud it is easy to believe that "turbidity currents" and avalanches of loose clay can indeed account for the erosion of great canyons and the deposit of plains of silt in the sea, according to the prevailing present theory [see "The Origin of Submarine Canyons," by Bruce C. Heezen; SCIENTIFIC AMERICAN, August, 1956].

In one dive the observers found the bottom mud firmer and rippled, with ridges three feet high and troughs 15 feet wide. Plainly these must have been formed by oscillating movement of the water. In general the dives in the Tyrrhenian Sea confirmed the recent finding of oceanographers that deep-sea water is by no means as still as used to be thought. Even in the Mediterranean, which has no tides to speak of, we sometimes found sluggish currents along the sea bottom. South of Capri these currents generally flowed westward. We could mark the flow of water by the motion of floating particles over the bottom. At higher levels, without a fixed background for reference, it was not possible for the observers in the bathyscaph to see or feel any water movements. But during two dives the compass showed that the craft suddenly swung through an arc of more than 90 degrees, once at a depth of 4,000 feet and the other time at 7,000 feet. A possible explanation is that the ship was crossing the boundary of a current in the water.

Acoustic scientists in our group made a number of studies of the transmission of sound in deep water. Carrying hydrophones and elaborate electronic gear, the bathyscaph proved to be an excellent underwater sound laboratory. It was a far quieter listening post than a surface ship, and it was able to explore deep sound-transmission channels which had never been plumbed before. Investigators of underwater sound have known for some time that there are layers in the water, set apart by special conditions of temperature, salinity and pressure, which trap sound into a channel and transmit it for considerable distances—sometimes hundreds or even thousands of miles. Some of these channels are transitory, some more or less permanent. Using directional arrays of hydrophones, observers in the *Trieste* searched for such channels and discovered an unexpectedly deep one at 4,700 feet south of the island of Ponza in the Tyrrhenian Sea.

Our underwater telephone also picked up undersea sounds, some of which apparently were noises of fishes and other sea animals: the loud whistling of porpoises, clicking sounds like those made by garibaldi fish and the crackling-brushfire sound of snapping shrimp. On occasion the telephone picked up the screw



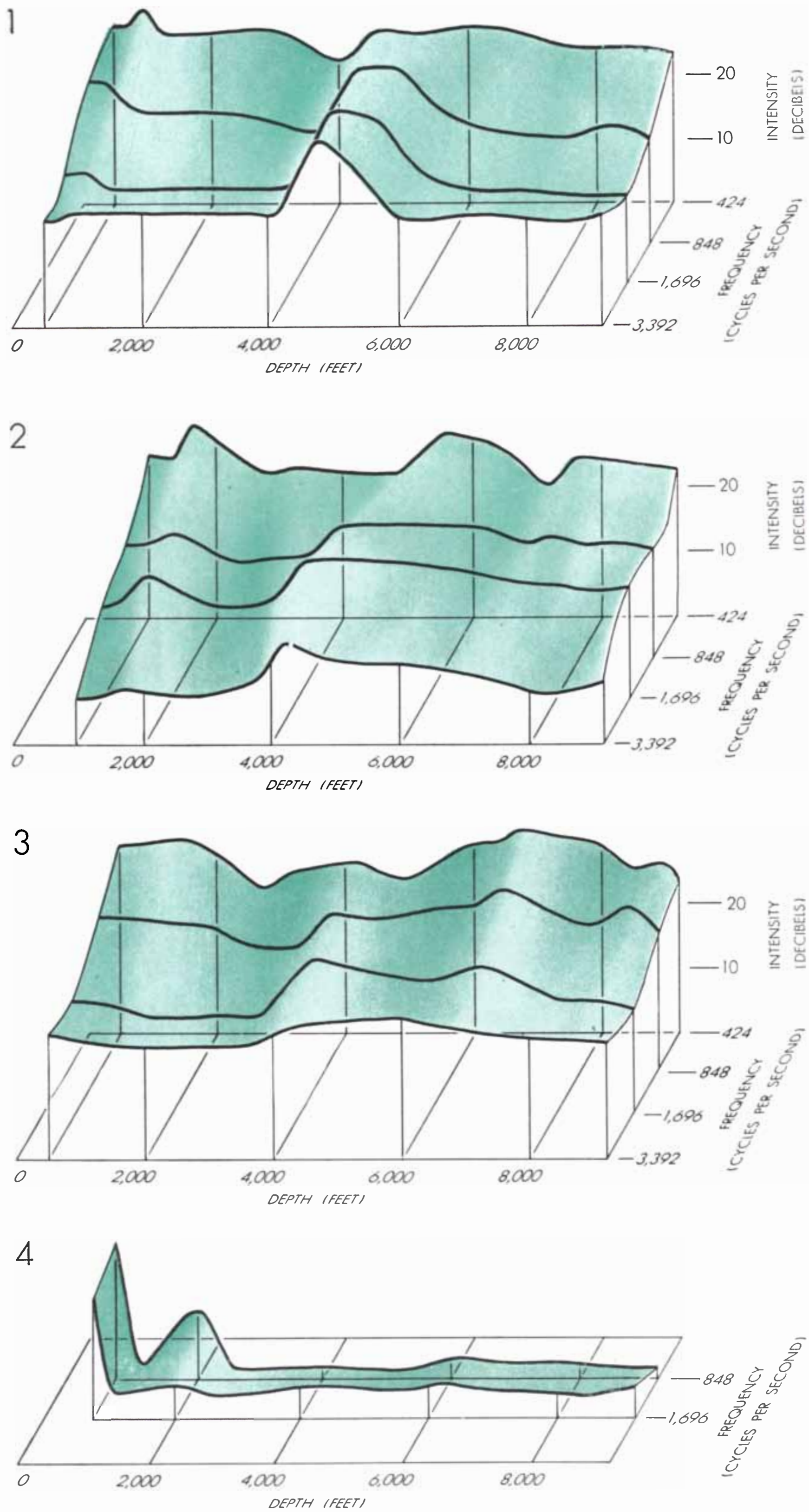
STRUCTURE OF "TRIESTE" is shown in schematic cross section. For safety the ballast, silos and guide rope are held in place by electromagnets; if current fails during a dive they drop automatically and the vessel returns to the surface. Numbers show hydrophones which pick up sound arriving in a horizontal plane (1), in a vertical plane (3), from above (4) and from all directions (2).

beats of passing surface ships when the bathyscaph was submerged at depths of several thousand feet.

The bathyscaph represents a major breakthrough in every respect. It has overcome the bugaboo of the great pressure in the ocean deeps and shown that man can journey there quite safely and comfortably. The floors of the oceans—their mountains, valleys, plains and curious life—now become accessible to man's direct exploration. Already we can see more of the sea floor in a single dive than all the photographs made with cameras on cables have shown us up to this time. Not only can we see the terrain but we can take instruments down to study at first hand the propagation of sound and other heretofore inaccessible phenomena in the deeps. Moreover, in future we shall be able to take samples of material and life from the ocean floors systematically and intelligently; instead of groping blindly we will know what the samples represent and what sort of environment they come from. We may well discover new mineral resources and types of geological processes of which we have not been aware; we should certainly discover many new animals, including ancient forms now supposedly extinct, possibly even trilobites.

As for the bathyscaph itself, the present versions—the *Trieste* and the French bathyscaph known as the FNRS-3—must be considered mere prototypes in a class with the Wrights' first airplane or the Model-T Ford. Already there are ideas for radical improvements: to give better control of buoyancy the light metal lithium might be used as the buoyant material instead of gasoline, or perhaps the need for a float might be eliminated altogether by finding a lightweight substitute for the heavy steel hull of the cabin—possibly aluminum alloys or plastics with some rigid stiffener.

Already the French Navy is building a bigger and stronger bathyscaph which will carry three men and be capable of going down to more than 35,000 feet—as deep as the deepest ocean trenches. Its float will be twice as large as the present ones, and its cabin will be enclosed in a steel hull six inches thick. Because of the great pressure it is designed to withstand, its windows will be tiny peepholes not much larger than an eye, but a special optical system will be installed to give a wide view. The craft will be able to dive and rise on an inclined path instead of only vertically, and it will have enough power to roam widely along the ocean bottom.



UNDERWATER SOUND INTENSITY (above an arbitrary zero) is shown at various depths in graphs from hydrophones oriented in different directions. Peaks around 1,000 and 4,700 feet in sound arriving horizontally (1) are not duplicated in sound arriving vertically (3); they indicate underwater "sound channels." Similar channels studied elsewhere can transmit sound thousands of miles. The peak around 2,000 feet in sound arriving vertically (3) and from above (4) is probably from the screw-beats of ships. Omni-directional hydrophone (2) shows both the sound-channel and the screw-beat peaks.

Anti-Matter

The discovery of the anti-proton and the anti-neutron raises the following question: Do anti-atoms made of these and other anti-particles exist in the universe?

by Geoffrey Burbidge and Fred Hoyle

Ever since the discovery of the positron—the opposite number of the electron—physicists have speculated about the possible existence of anti-matter. If an anti-electron could exist, why not an anti-proton and an anti-neutron? Within the last three years the Bevatron, the great accelerator at the University of California, has indeed produced anti-protons and anti-neutrons [see "The Antiproton," by Emilio Segrè and Clyde E. Wiegand; SCIENTIFIC AMERICAN, June, 1956]. Since electrons, protons and neutrons are the basic building stones of atoms, we have strong grounds for asking: If anti-particles, why not anti-atoms—that is to say, anti-matter which is the symmetrical opposite of the matter we know?

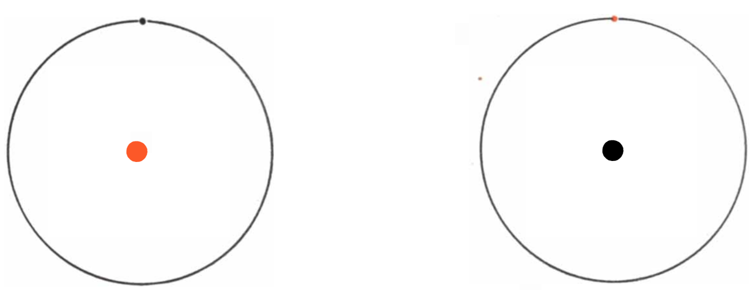
There can be no anti-matter on the earth, because particles and anti-particles annihilate each other the instant they meet. If there is anti-matter in space, we cannot recognize it with our telescopes, for anti-matter should look exactly like ordinary matter. But the problem of looking for evidence of anti-matter in the universe is not entirely hopeless. We shall consider here some possible indirect evidence on the subject. Such inquiries are not altogether academic, for, although the question of the existence of anti-matter has no practical importance to us on the earth, it does raise fundamentally important questions in modern physics and cosmology.

Our starting point is the known fact, established by laboratory experiments, that when a particle and an anti-particle collide they destroy each other, converting the entire mass of both particles into energy. The energy released by such an annihilation amounts to two times mc^2, in accordance with Einstein's famous equation for the conversion of mass into energy. The mutual annihilation of a proton and an anti-proton meeting at low velocity, for example, releases about 1.8 billion electron volts of energy. This energy emerges first in the form of mesons, but the mesons speedily decay and the ultimate carriers of the energy are gamma rays, neutrinos and very high-speed electrons and positrons [*see diagram on next page*].

If we could find evidence of such annihilations going on somewhere in the universe, we might have a proof of the existence of anti-matter. Let us examine our own galaxy, the Milky Way, and start with the gas in its interstellar space. Assume that this thinly dispersed gas, made up mainly of hydrogen at an average density of only one atom per cubic centimeter, contains some anti-protons. Would the annihilating collisions between these anti-protons and protons produce any observable effects on the interstellar gas?

About 90 per cent of the energy generated in an annihilation is carried by gamma rays and neutrinos. Almost all of this energy would escape from our galaxy into outer space, for the chances of gamma rays or neutrinos being intercepted and absorbed by the atoms in the thin gas are exceedingly small. The situation is otherwise, however, for the electrons and positrons that carry the remaining 10 per cent of the energy from annihilations. These charged particles would be trapped inside our galaxy by its magnetic field: there is considerable evidence that our galaxy does possess a weak magnetic field.

Now the high-energy electrons and positrons would gradually give up their energy to the gas as a whole—mainly by exciting and ionizing the atoms and by electron-positron annihilations. This injection of energy would have the effect of heating the gas and generating turbulent motions. We know that there are other processes which heat and stir up the interstellar gas in our galaxy. But suppose we assume, for the sake of putting an outside limit on the total possible amount of anti-matter in our galaxy, that all the energy of the gas is generated by annihilation of anti-matter. We know from various observations what the total energy of the gas in the galaxy is—it amounts to about one 100-billionth of an erg per cubic centimeter. On this basis we can calculate that the ratio of anti-matter to ordinary matter in our



ANTI-HYDROGEN ATOM (*right*) would have an anti-proton (*black circle*) and positron (*colored dot*). Hydrogen atom (*left*) has a proton (*colored circle*) and electron (*black dot*).

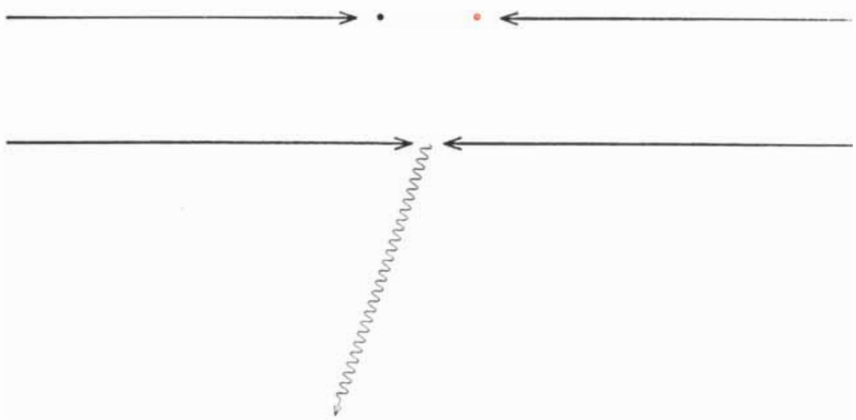
interstellar gas cannot possibly be more than one part in 10 million, spread thinly through the galaxy. From this small proportion we must deduce, incidentally, that even if anti-matter can somehow segregate itself from ordinary matter to form stars, it is extremely unlikely that there are any stars of anti-matter in our galaxy.

The establishment of a maximum figure for the amount of anti-matter does not prove that it is present, but it enables us to go on to an interesting speculation. This has to do with the recently discovered radio waves in space, stemming from so-called radio "stars" and from our galaxy as a whole. We know that electrons and positrons accelerated by a magnetic field emit a type of radiation called synchrotron radiation. This radiation can take the form of radio waves. The question then arises: Is annihilation of anti-matter responsible for some of the mysterious radio broadcasts we are receiving from space?

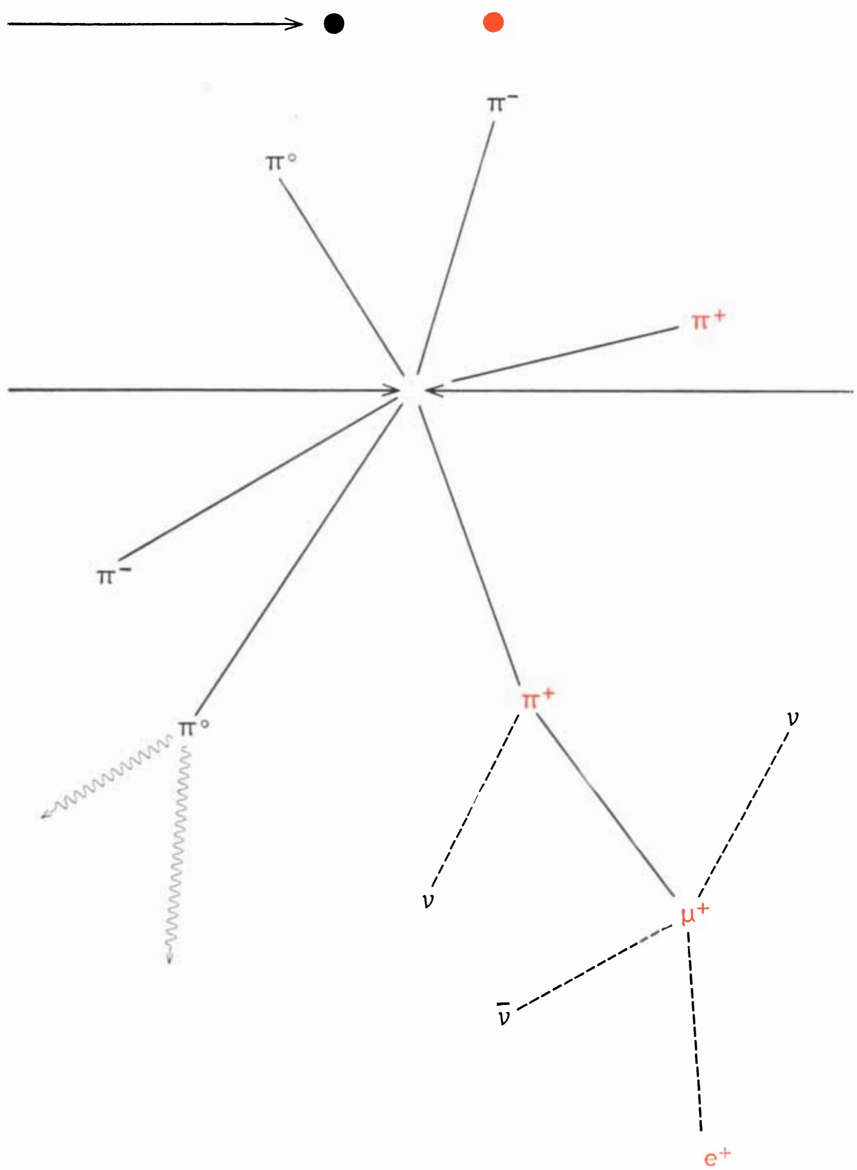
A particularly good subject for examining this question is the famous Crab Nebula, one of the strongest radio emitters in our galaxy. There is persuasive evidence that the radio emission and most of the light from this remnant of a supernova are synchrotron radiation [see "The Crab Nebula," by Jan H. Oort; SCIENTIFIC AMERICAN, March, 1957]. The Nebula appears to have a comparatively strong magnetic field and particles traveling at extremely high speeds. It is therefore conceivable that the radio emission of the Crab Nebula arises from electrons and positrons which have been created by annihilation of anti-matter. Calculating how much radio energy would be generated if one part in 10 million of the interstellar gas were anti-matter, we arrive at a figure which is close to the actual radio output of the Nebula (about 10^{33} ergs per second). The synchrotron radiation at visible wavelengths may arise from acceleration of some of the electrons and positrons to very high speeds by fast-moving gas clouds in the Nebula.

This is still no proof of the existence of anti-matter, because the original explosion of the supernova might account for its high-energy electrons and positrons. All that can be said is that the items of evidence we have considered are consistent with the possible presence of some anti-matter in our galaxy.

We come now to the wider scene. Are there, outside our own galactic system, galaxies entirely composed of anti-



ELECTRON-POSITRON annihilation occurs when particle and anti-particle collide. If the annihilation occurs in the field of an atom, the mass of the particles may be converted into only one photon (*wavy line*). If it occurs in free space, two photons will be emitted.

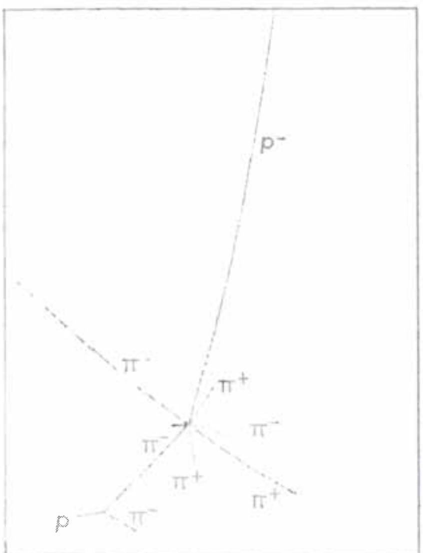


PROTON–ANTI-PROTON annihilation converts the particles to pi mesons (π), which decay as indicated at bottom. In this purely schematic diagram the Greek letter ν represents a neutrino; the same letter with a line over it, an anti-neutrino; the letter μ, a mu meson.

ANNIHILATION OF AN ANTI-PROTON made by the Bevatron at the University of California is recorded by these tracks in a liquid-propane bubble chamber. The event is outlined in the drawing at right. The anti-proton is annihilated by an encounter with a proton in a carbon nucleus. The short track to the left of the "star" of pi mesons is a fragment of the nucleus. At lower left a proton matter? If there are, we might possibly detect their existence if we saw an ordinary galaxy and an anti-galaxy in collision: this should be a really violent event. Here again we have one or two interesting cases for study.

Some astronomers believe that the extraordinary object called Cygnus A is a pair of galaxies in collision [see "Colliding Galaxies," by Rudolph Minkowski; SCIENTIFIC AMERICAN, September, 1956]. We are getting exceptionally strong radio signals from this object, even though it is very far away—at least 270 million light-years. The two colliding galaxies might be systems of matter and anti-matter, but suppose we make the less radical assumption that both consist predominantly of ordinary matter and each contains one part in 10 million of anti-matter. Assuming further that the magnetic fields of the two galaxies have combined to accelerate electrons and positrons, we can calculate that the annihilation of anti-matter in the colliding galaxies would generate a total of about 10^{44} ergs per second of radio energy. According to the measurements of radio astronomers, Cygnus A is actually emitting radio energy at precisely this rate!

The case of the galaxy known as Messier 87, another strong radio emitter, is even more interesting—indeed, it was M 87 that first aroused the speculation that a galaxy might contain anti-matter. M 87 looks like an unusually bright but normally shaped galaxy; there is no evidence that it represents a pair of galaxies in collision. However, it is emitting very



(P) recoils from a collision with a pi meson. The experiment was performed by groups under W. M. Powell and Emilio Segrè.

powerful synchrotron radiation at radio wavelengths and has a bright jet or streak emitting such radiation at wavelengths of visible light [*see photograph at bottom of page 39*]. Astrophysicists have been at a loss to account for its extremely strong radiation, and it is tempting to suppose that the energy is coming from the galaxy's capture of a gob of anti-matter from an anti-galaxy.

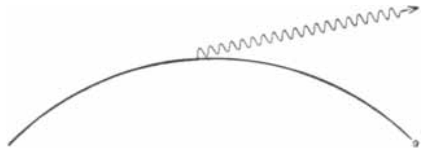
Yet notwithstanding the evidence tending to uphold the idea of the existence of anti-matter on the cosmic scale, most physicists, including the authors of this article, do not look too favorably on the hypothesis. Let us consider some of the difficulties.

In all present theories of the history of the universe—evolutionary or steady-state—symmetry arguments demand that if anti-matter exists both matter and anti-matter must be created in equal amounts. The evolutionary theory would require that the original nucleus from which the universe expanded must have contained both kinds of matter in equal parts; the steady-state hypothesis of the continuous creation of matter would imply that matter comes into being as pairs of particles and anti-particles. In either case, atoms and anti-atoms must somehow be separated selectively if they are to condense into stars and galaxies—otherwise they would destroy each other. It appears that the only way they could be so separated is by a gravitational force of repulsion between atoms and anti-atoms—in short, by anti-gravity, as opposed to the gravitational attraction that operates between atom and atom of ordinary matter.

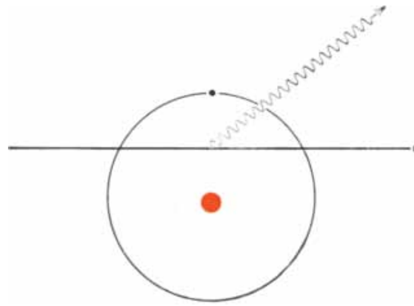
It is upon this rock that the anti-matter ideas have foundered. For the idea of anti-gravity cannot be accepted without destroying basic principles of the general theory of relativity. The successes of the relativity theory are so great that most scientists are not prepared at the present time to consider with equanimity the very considerable upheaval that would come about if it had to be abandoned or drastically modified.

Experiments designed to look for the existence of anti-gravity are possible in principle and may be worth doing. One obvious test would be to generate a beam of anti-protons in an accelerator and project it over a path parallel to the earth to see whether it would rise or fall; if the beam rose, it would indicate that anti-gravity was operating.

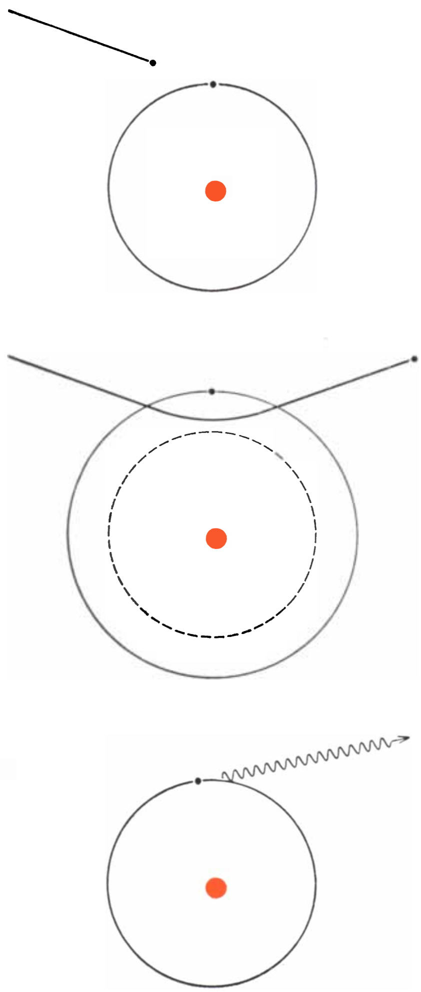
Maurice Goldhaber of the Brookhaven National Laboratory has speculated on the possible existence of two separate



RADIATION from electron in curved path transfers energy to the surrounding gas.



ENERGY TRANSFER also takes place by means of radiation emitted when an electron passes through the field of an atom.

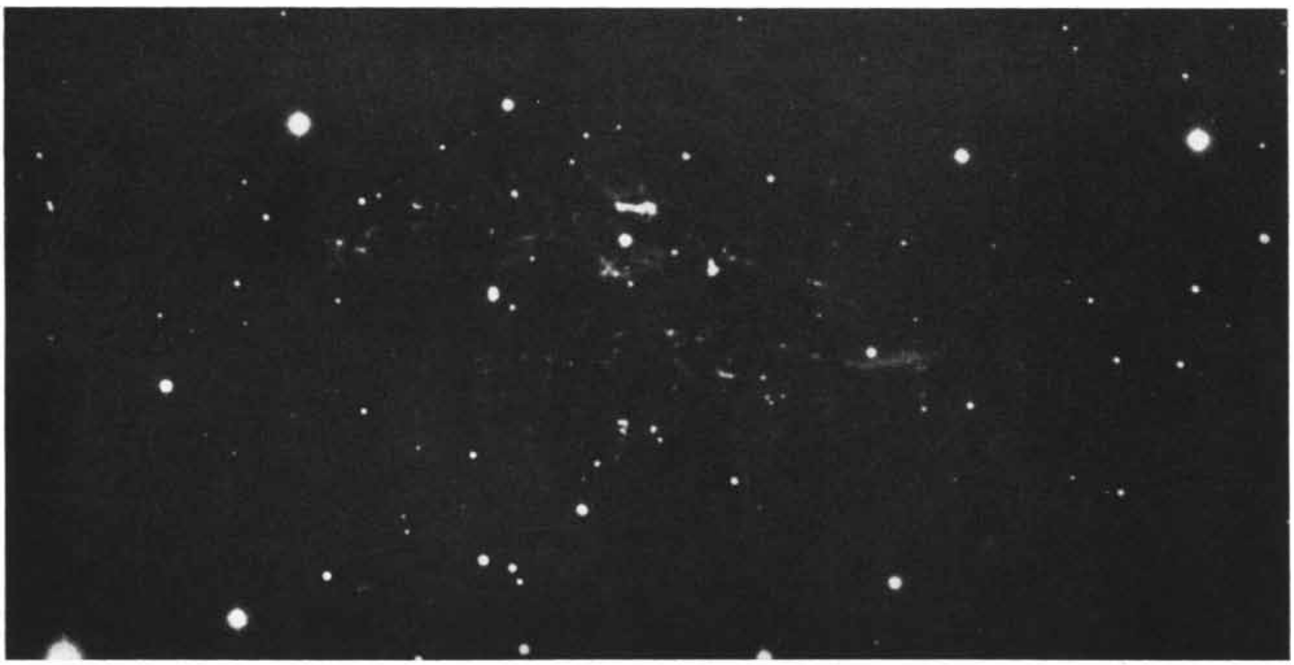


EXCITATION of atomic electron to higher energy level is a third way to take energy from free electrons. When the excited electron drops back to orbit, it radiates energy.

worlds—one composed of matter and the other of anti-matter. Inspired by the primeval atom of Abbé Georges Lemaître, he suggests that the universe originated from a single "particle" called the "universon." This divided immediately into a pair of "particles"—the "cosmon" and the "anti-cosmon." They flew apart with great kinetic energy (by some unspecified process) and eventually decayed, one giving rise to the cosmos we know, the other to an anti-cosmos beyond reach of our observation. Goldhaber goes on to speculate on whether some anti-matter from the anti-cosmos may have been injected into our cosmos; possibly this would be the source of the radio energy being emitted by some of our galaxies and gas clouds.

Some cosmologists have become more receptive to the idea of two separate universes since the recent overthrow of the parity principle—that is, the discovery that certain particles of our universe are unsymmetrical, in the sense that they have a particular "handedness." It be-

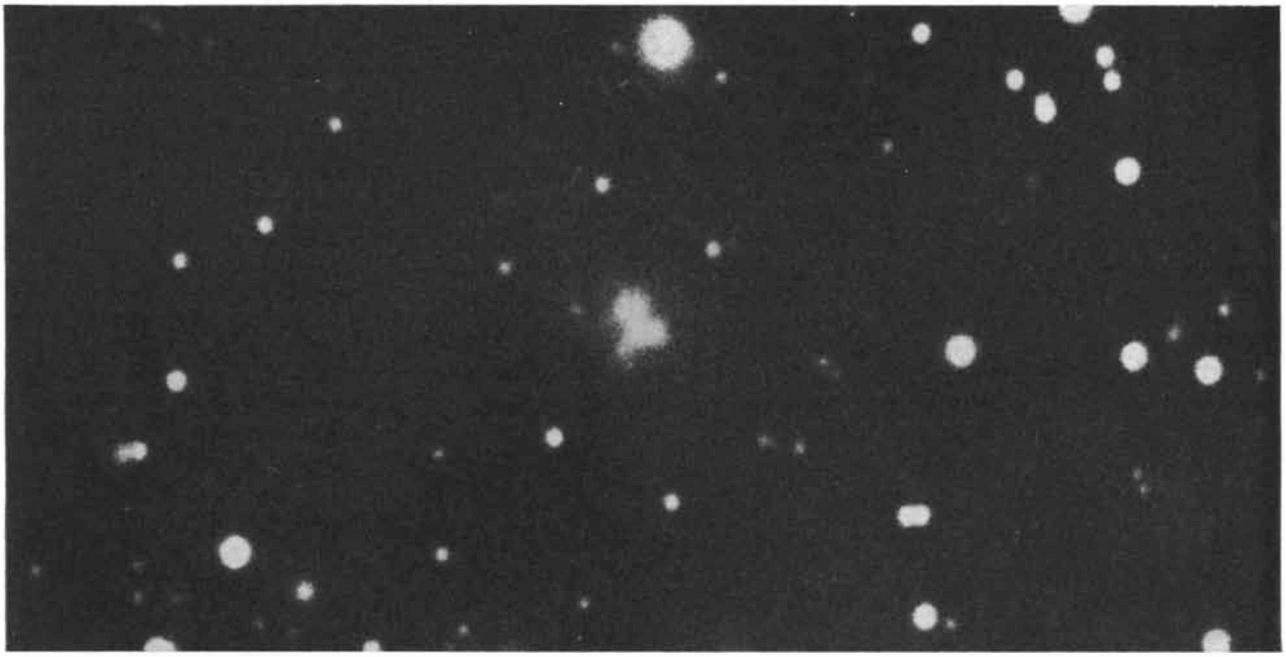
CRAB NEBULA is the remnant of a supernova which occurred in 1054. Its light comes from highly accelerated charged particles, which may have been created by the annihilation of anti-matter. This photograph is from the 100-inch telescope on Mount Wilson.



CASSIOPEIA A, the strongest isolated source of radio waves in the sky, is seen as a series of faint luminous wisps in this photograph from the 200-inch telescope on Palomar Mountain. It is probably also the remnant of a supernova and may contain anti-matter.

comes reasonable to ask whether symmetry may be preserved after all by the existence in some other part of the universe of an equal amount of anti-matter with the opposite "handedness."

We may sum up as follows. Anti-matter may exist in our galaxy, but it cannot exceed about one part in 10,000,000 of ordinary matter if it is there. It is most unlikely that any of the stars in our galaxy can be made of anti-matter. Outside our galaxy, other galaxies in remote parts of the universe may consist entirely of anti-matter. The nearest approach to direct proof of the existence of such bodies is the presence of strong radio sources whose energy is difficult to explain by any known process but might be explained by the annihilation of anti-matter. On the other hand, if anti-matter does exist in the universe, we do not understand at present how the bulk of it became separated from matter. To explain this would apparently require a revolution in our thinking on cosmological problems.



CYGNUS A, a strong emitter of radio waves, may be a pair of colliding galaxies which appear as the blob in the center of this 200-inch-telescope photograph. Its observed radio energy can be calculated if the galaxies are assumed to contain some anti-matter.

MESSIER 87 is apparently a single galaxy, but the radiation of light and radio waves by the bright jet at right is unusually strong. This radiation may be caused by the annihilation of anti-matter in the jet. The photograph was made with the 200-inch telescope.

PROGESTERONE

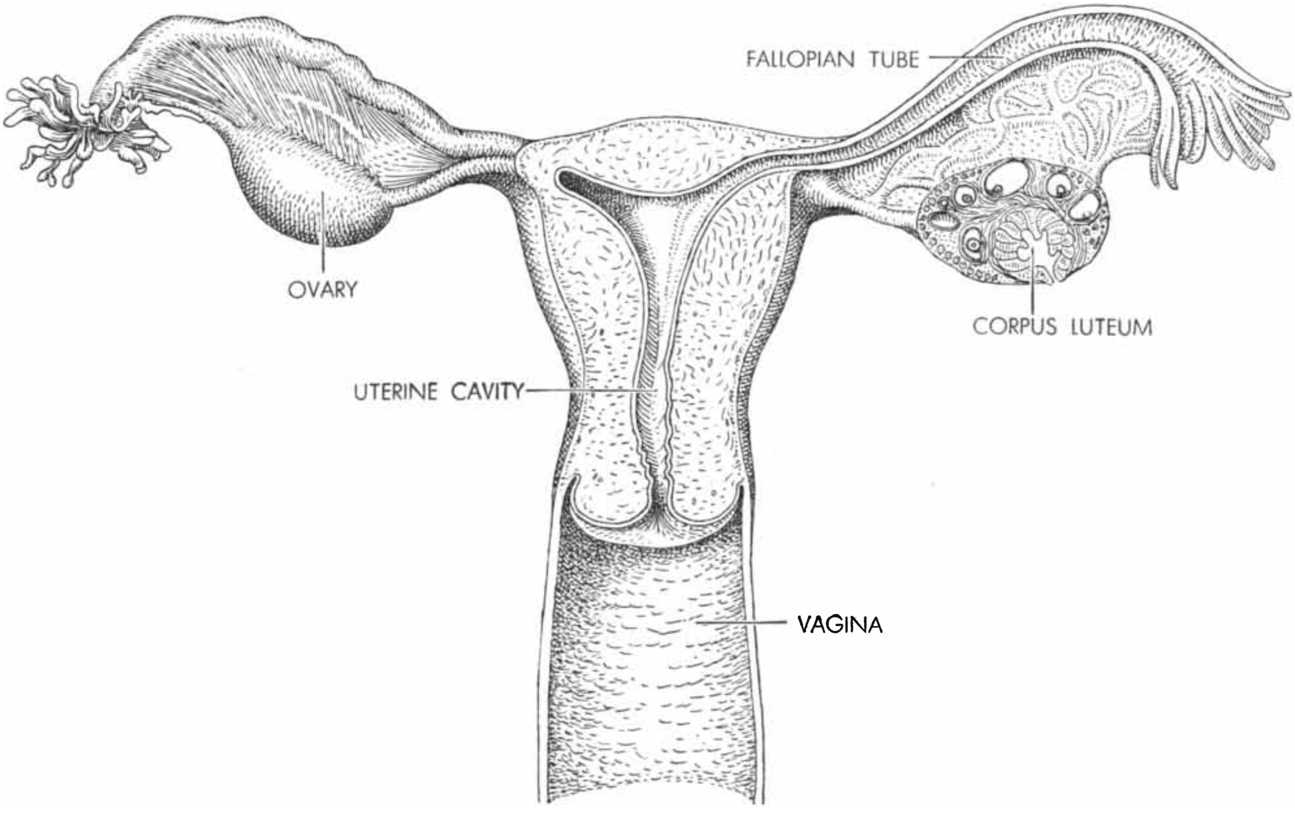
This hormone both causes the uterus to prepare itself for pregnancy and guards the embryo against premature birth by inhibiting the contraction of uterine muscle

by Arpad Csapo

In 1900 a great professor of embryology at the University of Breslau, Gustav Born, called to his deathbed one of his bright former students, Ludwig Fraenkel. He presented the young man with a strange intellectual bequest: namely, an injunction to explore a mysterious yellow body in the ovaries called the "corpus luteum." It was Born's notion that secretions by this organ would be found to play a vital part in the protection of the embryo in the womb.

Thirty years later Born's legacy bore brilliant fruit in the discovery of the hormone progesterone. The finding of this hormone raised hopes of reducing the great toll of life taken by miscarriages. The hope has not yet been fully realized, but it now seems on the way to fulfillment. What is more important, Born's deathbed intuition put biologists on a track which has carried them a long way toward solving some of the mysteries of development and birth.

In Born's day scientists had only a sketchy knowledge of the mechanisms of a mammal's gestation. They knew that the story began in the ovaries, where the eggs reposed in small sacs called follicles; that once each month, in a mature human female, a follicle ripened, burst and discharged its ripe egg; that the egg then traveled down a tube toward the uterus, and if it chanced to meet a spermatozoon on the way, might be fertilized; that once fertilized, it would



ORGANS OF REPRODUCTION in the female are depicted in partial cross section. The section through the ovary at right reveals a few unripe follicles and the corpus luteum, which develops from a follicle after ovulation and secretes the hormone progesterone.

implant itself in the lining of the uterus and there begin its development as an embryo. But they were not aware that all these events were controlled by a system of hormonal secretions—chemical messengers.

Born provided the lead by calling attention to the corpus luteum. It is a bright yellow body which develops from the ruptured follicle within 24 hours after the follicle has discharged its egg. Born suspected that this body served as an endocrine gland—that is, an organ of secretion. Young Fraenkel, obedient to his professor's deathbed request, undertook to investigate the corpus luteum's function. With a hot needle he destroyed the corpora lutea of a female rabbit shortly after her eggs had been fertilized. The eggs promptly died. Quite evidently the corpus luteum was necessary in some way for the normal progress of pregnancy. Meanwhile two workers in France, Paul Bouin and Albert Paul Ancel, discovered evidence of one of its functions. They found that after the formation of the corpus luteum, which takes place in each cycle of the female's periodic ovulation, the lining of the uterus developed folds and secreted a fluid. They called this event "progestational proliferation," meaning that the change in the uterus was a preparation for gestation.

Not much more than this was known when in 1928 George W. Corner (today the dean of U. S. endocrinology) began his famous experiments which were to lead to the discovery of the all-important hormone. Corner, then at the University of Rochester, first confirmed the crucial role of the corpus luteum in preparing the uterus for implantation and assuring survival of the fertilized egg, and then he set out to identify the active substance secreted by the organ. After many chemical manipulations, Corner and a student, Willard M. Allen, extracted from the corpora lutea a substance which, in Corner's characteristically humorous terms, looked "like a poor grade of automobile grease." Whatever it looked like, their crude extract proved to be capable of performing the functions of the corpora lutea when supplied to an animal in which those organs had been destroyed. The substance naturally was named progesterone. In his well-known book, *The Hormones in Human Reproduction*, Corner conveys some of the excitement of the discovery: "Can I forget the time I went racing up the steps of the laboratory in Rochester, carrying a glass syringe that contained the world's entire supply of crude progesterone, stumbled and fell and lost it all? Or the day Willard Allen showed me his first glittering crystals of the hormone, chemically pure at last?"

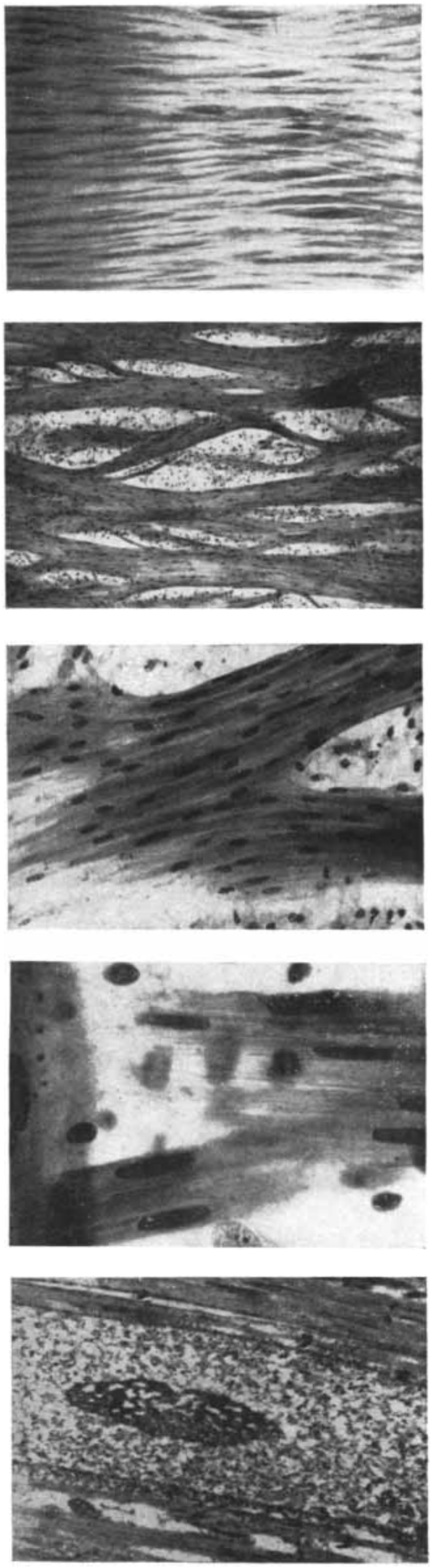
Corner, Allen and their associates learned that progesterone not only prepared the uterus but acted as the guardian of the embryo throughout pregnancy. If the corpora lutea were removed, the embryo would wither away or abort or be delivered prematurely; on the other hand, heavy doses of progesterone could prolong pregnancy beyond its normal duration.

It is heartening to recall the simplicity and beauty of these classic experiments. By simple pursuit of the facts, often seen with the naked eye, without theories, models or schematizations, the investigators arrived at clear and straightforward descriptions of fundamental processes. They carried out their experiments with much common sense, modesty and a feeling for the mystery of life. And as a product of their work they were able to turn over to physicians a crystallized substance which promised to control the all-too-frequent mishaps of pregnancy.

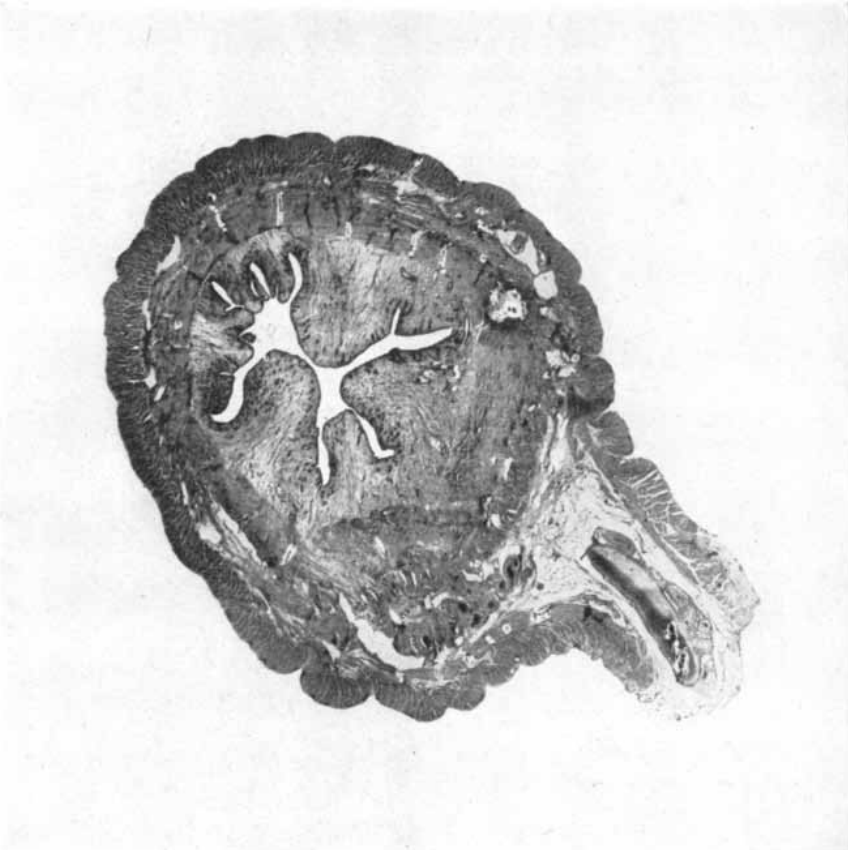
The statistics alone are appalling. In the U. S. several hundred thousand lives are lost every year before or at birth. George W. Anderson, the Johns Hopkins Hospital obstetrician, has estimated that 10 per cent of all pregnancies in this country end in spontaneous abortions and 7 per cent in premature delivery. He attributes at least one third of the abortions and more than half of the premature births to a misfunctioning of the muscles of the uterus which causes them to expel the embryo or fetus before its time. To this toll must be added the many deaths of babies (and mothers) caused by poor functioning of the uterine muscles during delivery at the normal time.

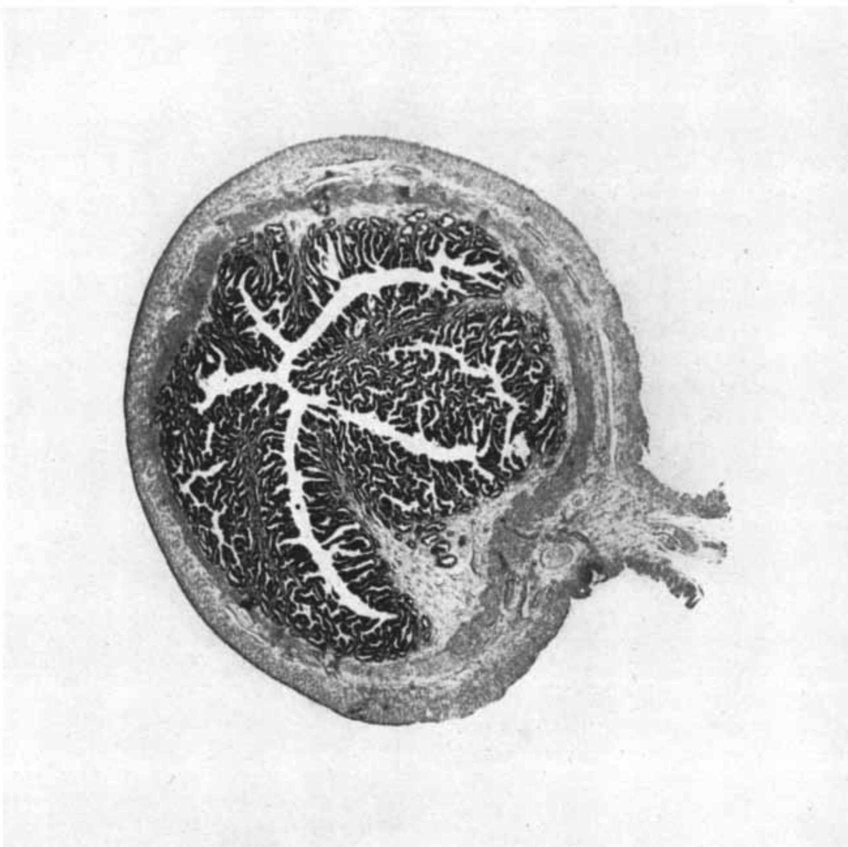
Progesterone seemed to offer an answer to this sad story. As the key substance in maintaining pregnancy, it promised to become a powerful tool to prevent miscarriage and premature birth. Physicians enthusiastically began to treat habitual aborters with injections of progesterone. But the hopes were quickly disappointed, for the treatment rarely helped. As one who saw patients suffer miscarriages one after the other in spite of progesterone therapy, I can testify personally to the disappointment that came with the failure of progesterone's promise.

What was wrong? Why was progesterone effective in maintaining preg-



UTERINE MUSCLE observed at low magnification (*top*) appears very fibrous. Higher magnifications (*next three pictures*) show that the fibers consist of fibrils containing elongated muscle cells with oval nuclei (*dark spots*). An electron micrograph of a single cell (*bottom*) shows still smaller fibrils and mitochondria (*small dark spots*); the nucleus is at the center. The muscle is that of a pregnant rabbit about to give birth.





CROSS SECTIONS OF RABBIT UTERI show the differences in the uterine lining under the influence of estrogen (*top*) and of progesterone (*bottom*). These photographs were provided by George W. Corner of the Rockefeller Institute for Medical Research.

nancy in rabbits but not in human beings? Many biologists concluded that reproduction in rabbits and in human beings followed different rules; that the process differed so much in the two species that what applied to one simply did not apply to the other. But a researcher must demur against this common and convenient explanation of discrepancies between laboratory and clinical findings. It can be a dangerous obstacle to investigation in the medical sciences. If we had to rely primarily on study of human beings to elucidate physiological functions and disease, we would not only be greatly handicapped in investigation but could never arrive at anything but diffuse and uncertain conclusions, because of the complexity of human biology and psychology. Moreover, we might well become lost in superficial complexities and fail to discover basic processes and principles.

No doubt rabbits and human beings are different. But are there not fundamental common denominators in the conduction of nerve impulses, in the contraction of muscles and in body chemistry which apply to all mammals? Indeed there are, and we are vastly indebted to experiments on animals for information on such basic processes.

The fact that we had come to a dead end in the road with progesterone only indicated that we needed to make a fresh start at a more basic level—perhaps the chemical level. The key to the problem evidently lay in the muscles of the uterus and the regulation of their functioning by progesterone.

The turning point in my own approach came one day in 1945 as I listened to a lecture by my former teacher, the celebrated biochemist Albert Szent-Györgyi, at the University of Budapest. It was the lecture in which Szent-Györgyi announced his discovery of the two muscle proteins, myosin and actin, and put forward his revolutionary theory that the contraction of muscles could be explained in terms of an interaction between actomyosin and the energy-supplying substance adenosine triphosphate (ATP). He had actually made an artificially prepared thread of actomyosin contract like muscle by adding ATP to the preparation. Thus Szent-Györgyi had reduced one of the oldest mysteries of biology to a chemical process which could be analyzed. His new approach was so exciting that before the lecture was over I had decided to attack the problem of progesterone and the uterine muscle by his methods.

Szent-Györgyi gladly gave me a bench in his laboratory. Together we concentrated on the uterine muscle—the executioner of the death sentence upon embryos doomed to spontaneous abortion. Obviously the death sentence itself came from a higher source—a jury composed of the pituitary gland, the thyroid, the ovaries, the placenta and perhaps the adrenals. But we hoped to find in the muscle cells the code which would tell us the specific terms of the verdict and how it was executed. We found that actomyosin and ATP, reacting in the presence of ions, were responsible for the contraction of the muscles of the uterus, just as they were in the skeletal muscles Szent-Györgyi had previously investigated, though in the uterine muscle the reaction proceeded at a much slower pace. We also found that at this elementary level there was no detectable difference in the behavior of actomyosin extracted from the uterus of a woman, a cow, a rabbit or a rat.

We then tried to test the effects of progesterone and other hormones on the contraction of the actomyosin threads, but found with disappointment that the hormones had no influence on our artificial preparations. However, analyzing strips of uterine muscle tissue at various stages of the sexual cycle in pregnancy and nonpregnancy, we discovered indications that hormones regulated the amount of actomyosin manufactured by the tissue: that is, some hormone or hormones stimulated the muscle to increase its working capacity, so that it became powerful enough to deliver the offspring.

The next step in the investigation now shifted to Baltimore, where I went to join Corner and his associate S. R. M. Reynolds at the Carnegie Institution's endocrinological laboratory. We set out to identify the hormone responsible for control over the working capacity of the uterine muscle. We removed the ovaries of mature rabbits by careful surgery and then tested the effects of various suspected hormones one by one. It turned out that the muscle's synthesis of actomyosin, and also of ATP, was controlled by the ovarian hormone estrogen. Progesterone, strangely enough, had no effect on this synthesis.

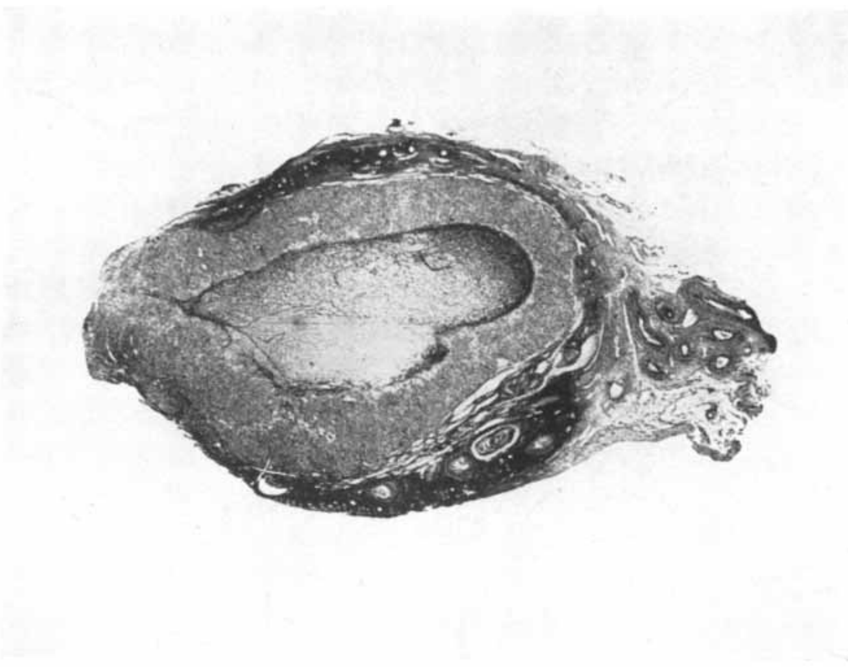
To find some order in this complex picture, let us review what had been learned so far about the roles of estrogen and progesterone. Estrogen is the star of the first act in the female's reproductive development. It brings the young female to sexual maturity, causes the eggs to ripen and controls the periodic cycle of ovulation. After a follicle in the ovary has ripened and released its egg, the follicle is transformed into a corpus luteum and begins to secrete progesterone. This hormone induces the lining of the uterus to prepare itself for implantation of the egg. After a fertilized egg has found lodging in the uterine lining and has begun to develop as an embryo, the placenta forms around the embryo. Among its other functions, the placenta secretes estrogen and progesterone and maintains this secretion through the rest of pregnancy. Estrogen causes the muscles of the uterus to build up their power of contraction. On the other hand, progesterone acts, in some unknown manner, to inhibit contraction of the muscles and thus to prevent premature expulsion of the embryo from the uterus. Reynolds had shown experimentally, in fact, that progesterone blocked uterine contractions.

In short, as long as progesterone is dominant in the uterus, the powerful uterine muscles cannot contract to deliver the embryo. The problem is: How and under what circumstances does progesterone exert its blocking effect? We had found that the elementary contractile unit of muscle—actomyosin—is not affected by progesterone. The hormone must therefore act upon the muscle at a higher level of organization. To investigate its action we had to look into the response of intact, living muscle.

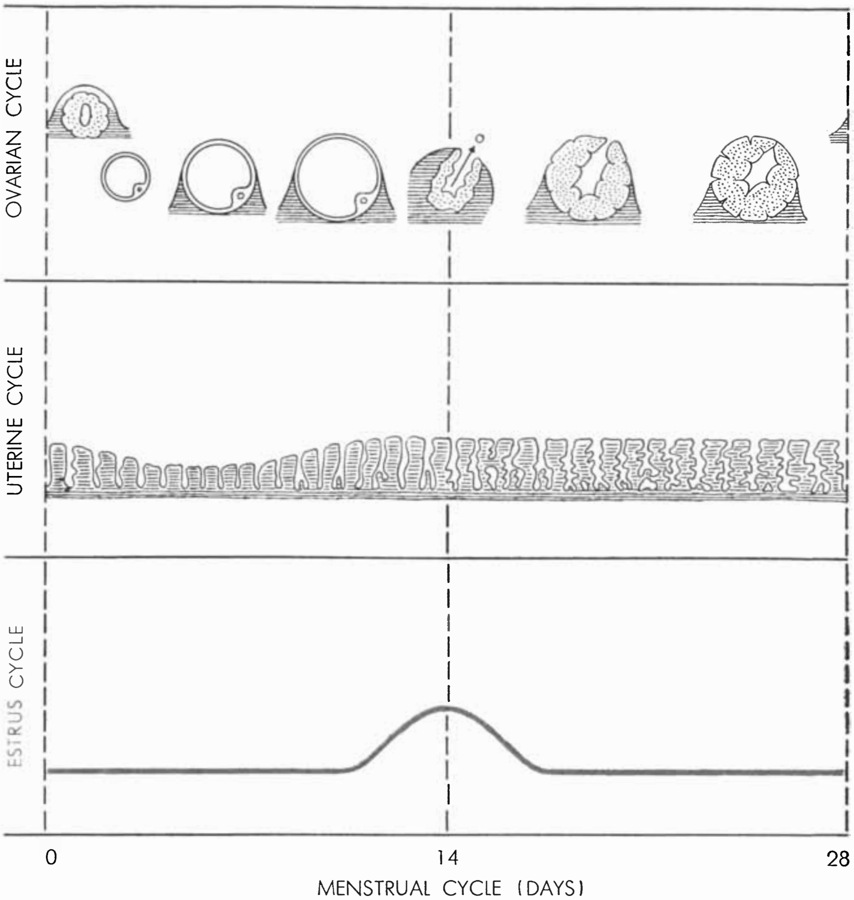
To do so we used methods of electrical stimulation based on principles described by Alan L. Hodgkin of the University of Cambridge. Our experiments showed that progesterone inhibited contraction of the muscles of the uterus by reducing their excitability and blocking conduction of a stimulus. When the uterus was dominated by progesterone, no excitation wave spread from the point of stimulation, no matter how strongly we stimulated it.

The general mechanism of control over the muscles of the uterus now became clear. Estrogen primes the gun, so to speak, and progesterone blocks it from firing. Throughout normal pregnancy the muscles are ready to explode on 24 hours' notice, but they cannot fire until the gun is cocked: that is to say, until the progesterone block is withdrawn. This finding explains why the age-old search for a drug to induce abortion has consistently failed. The uterus cannot respond effectively to stimulants while it is under the control of progesterone.

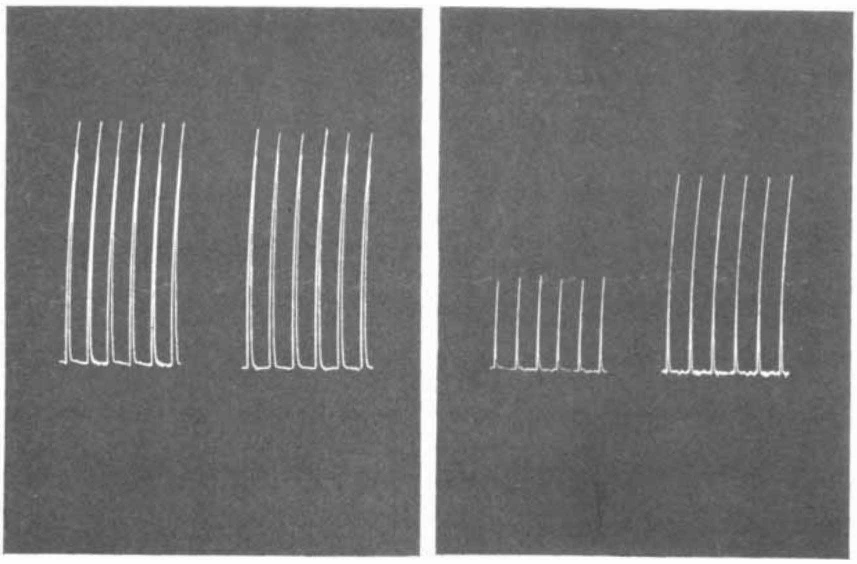
We have been pursuing investigations into the mechanics of the uterine muscle, and in this we have been greatly helped by the classic studies of the British biophysicist A. V. Hill on frog muscle. From the standpoint of behavior the jumping muscle of the frog would seem to be as different as can be from the muscles of a mammal's uterus. The jumping muscle works so rapidly that



CORPUS LUTEUM of a monkey is magnified eight times in another photograph supplied by Corner. The corpus luteum of the monkey is very similar in appearance to that of man.



MENSTRUAL CYCLE repeats in about 28 days except during pregnancy. In the estrogen-dominated phase (*first 14 days*) the corpus luteum (*top left*) degenerates and an ovarian follicle (*circular*) ripens. The uterine lining regresses during the first few days and a new lining is then regenerated. After the ovum is released (*14th day*) the ripe follicle develops into a corpus luteum and secretes progesterone, which dominates the second phase of the cycle. Should the ovum become fertilized, as it can during the height of the estrus period (*graph at bottom*), the progesterone phase is prolonged until the end of pregnancy.



TRACINGS of uterine muscle segments under estrogen domination (*left*) show that the muscle contracts fully whether half of it is stimulated (*first tracing*) or all of it (*second*). Under progesterone domination (*right*) stimulating half the muscle segment (*third tracing*) produces only half as much tension as if the whole segment is stimulated (*fourth tracing*).

the frog can catch a fly on the wing, whereas the uterine muscle functions slowly and deliberately. If the muscles were exchanged, the frog would never catch a fly and a fetus could not survive the rapid contractions of the uterus. Yet we have found that in some basic respects the two muscles function in exactly the same way. Economical Nature uses a single mechanism to catch at least two flies!

But our particular concern is the control of the uterine muscle. How does progesterone carry out its blocking action? Various items of evidence, including its effect on the excitability of the muscle, suggest that it controls the ionic make-up of the muscle cells—that is, their content of ions. Indeed, Beni Horvath of the National Institutes of Health has found that when progesterone is dominant, there is a reduction in the gradient of concentration of the potassium and sodium ions across the membrane of the muscle cell. We also found an indication that under progesterone domination the cells hold their calcium ions more strongly. Just what these ionic changes in the cell mean, and how progesterone produces them, are still unexplained. Perhaps the ultimate explanation of muscle action and control will take us to the level of excited electrons and quantum mechanics, as Szent-Györgyi has suggested. Biologists may have to end up as physicists. But one thing is clear: tracking down the action of progesterone to the molecular level will revolutionize endocrinology.

However, it will just add another dimension to the science. If we are to understand how muscles and their hormone regulators work, we must study the phenomenon in all its aspects, from the molecular level up to the magnificent organization of cells that performs the coordinated functions of the muscles. This calls for biophysical, biochemical, histological and physiological investigations. We are now engaged in such a broad program of study of the uterus at the Rockefeller Institute for Medical Research.

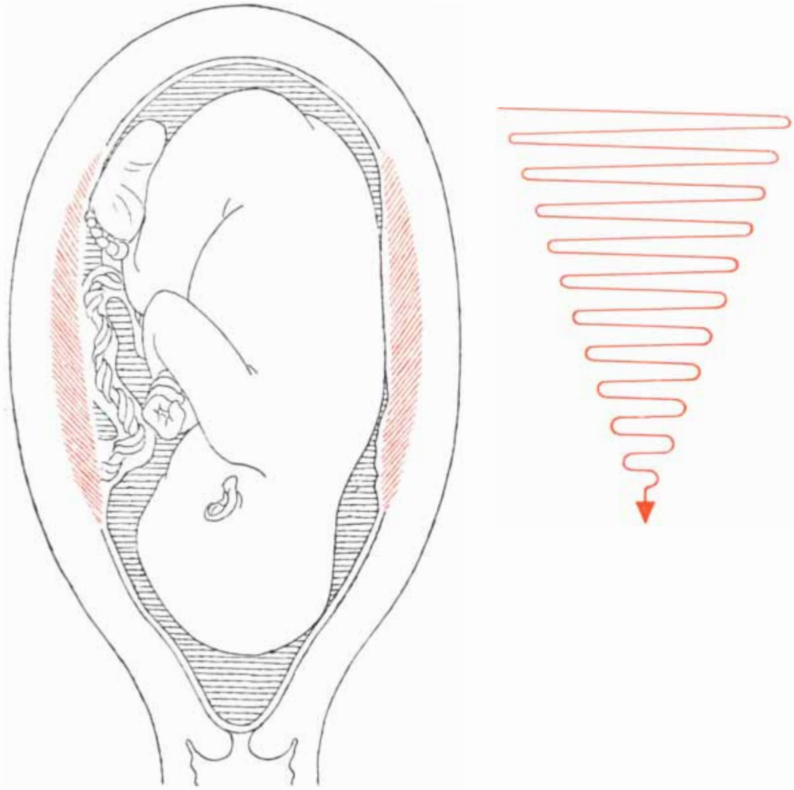
Meanwhile the things learned so far have already yielded some practical results. We know, for example, that progesterone takes about 16 hours to exert its effects, so that it cannot help if it is administered after abortion or premature labor has already started. What is more important, it has become plain that one of the reasons for the failure of this treatment in the past was that the doses used were far too small. The standard dose was 20 milligrams of progesterone a day. Our experiments suggested that the dose should be raised to 100 to 200 milligrams a day. This treatment, skillfully administered by Dr. Eleanor Delfs of the Johns Hopkins Hospital to a woman who had had six miscarriages, gifted her with two healthy, full-term babies. That these successes were entirely due to the massive progesterone dosage was proved by the fact that the patient had a miscarriage between the two babies, when no progesterone treatment was employed, and another miscarriage after the second successful pregnancy, because of a delay in starting the treatment.

The tragedy of miscarriage cannot be measured solely in terms of the number of babies lost. Loss of the baby has a profound psychological effect on the women who are habitual aborters, and premature birth brings its further tragedies of babies born with such afflictions as cerebral palsy, epilepsy or blindness (retrolental fibroplasia).

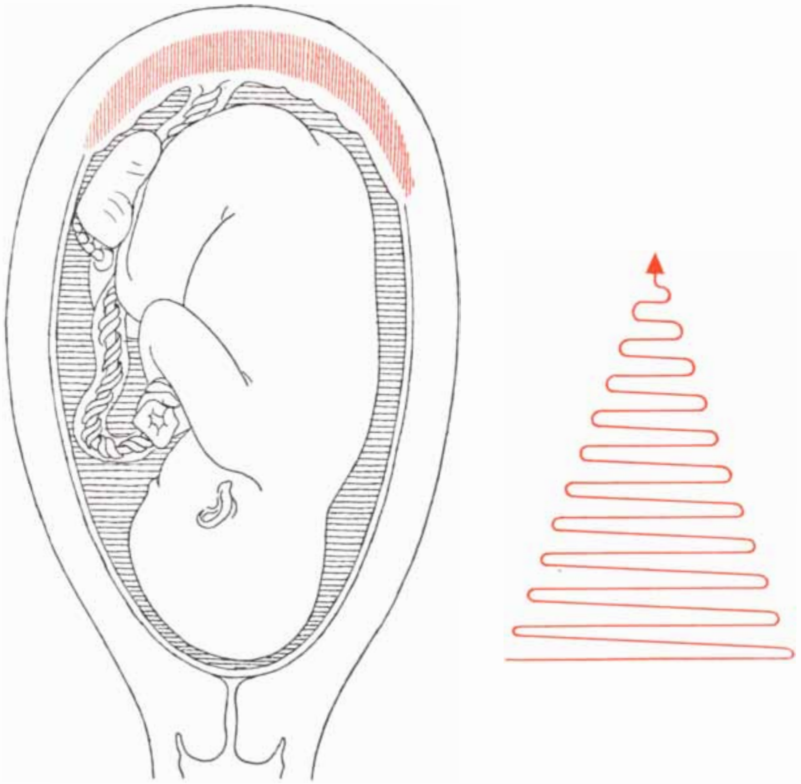
Progesterone, promising as it is, can by no means be considered a potential cure-all for miscarriage. Often abortion or premature delivery is due to defects of the fetus or of the placenta's functioning. Only in cases where there is a deficiency of progesterone can dosage with the hormone be of any help. One of the objects of our research is to find a method of detecting such a deficiency.

Recently we learned something about progesterone which sheds new light on the process of delivery itself. The discovery was suggested by a certain rare anomaly of pregnancy sometimes observed by doctors (another instance showing that science is a two-way street and laboratory researchers can often get valuable ideas from the observations of practitioners). The anomaly that provoked our interest was the fact that on rare occasions, in a uterus bearing twins, there is a wall between them, dividing the uterus into two chambers. In these cases the fetus in one chamber may be born prematurely, while the twin in the other chamber may not be delivered until as much as two months later.

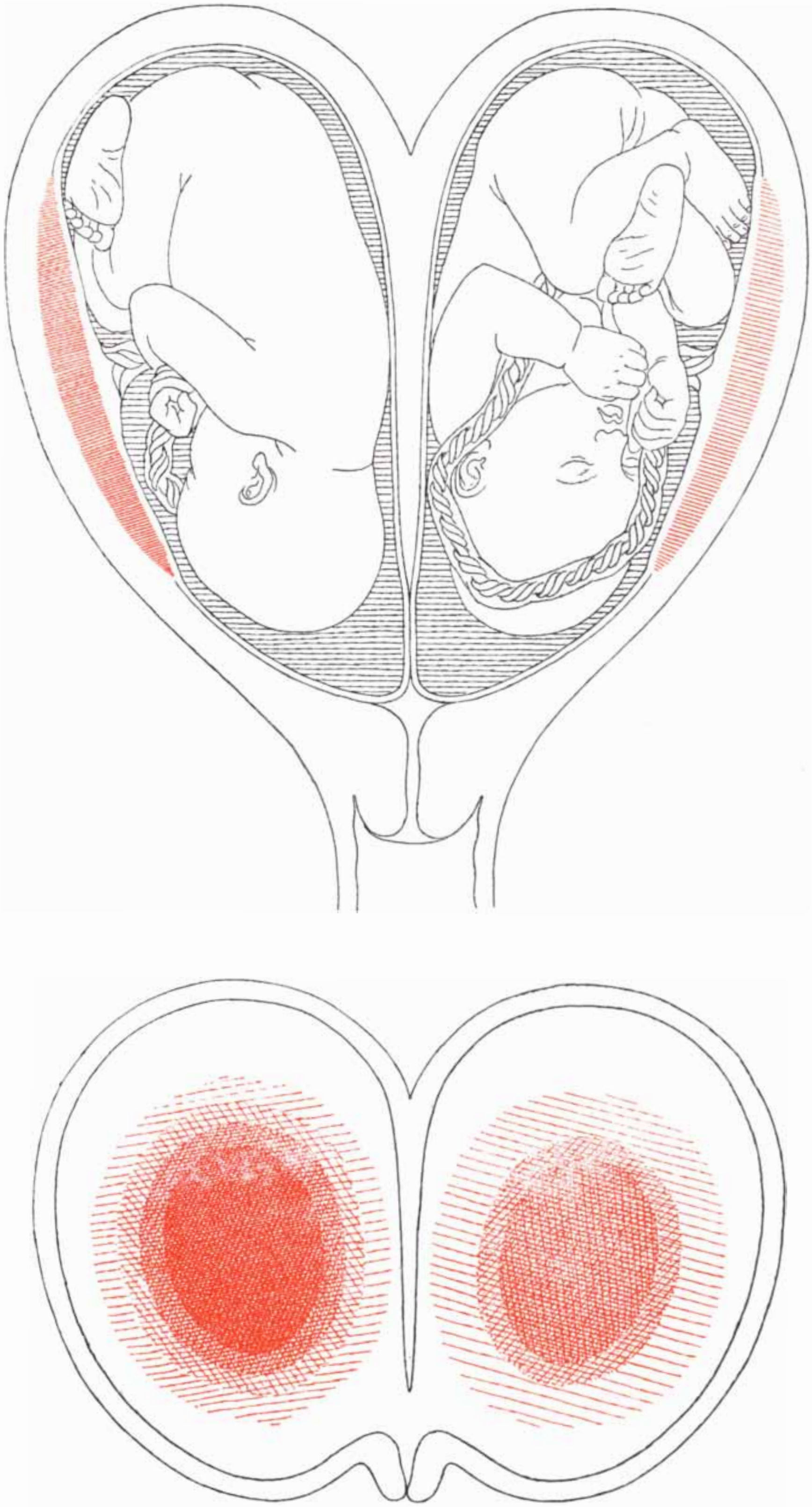
Corner called attention to this curious freak of nature one day at the height of our enthusiastic researches on progesterone. How was it that, in one and the same uterus, the progesterone block acted to hold off the delivery of one twin but not the other? True, the two fetuses had separate placentas, and the placenta is known to be the main source of pro-



NORMALLY LOCATED PLACENTA (*colored area*) **releases progesterone well down in the uterus. At the time of birth the decline in supply of the hormone and the recovery from the progesterone block starts at the top of the uterus and moves downward, resulting in waves of contraction (*colored arrow*) which push the fetus downward toward the opening.**



HIGH-PLACED PLACENTA (*colored area*) **concentrates the progesterone near the upper end of the uterus. At the time of birth the muscles in the lower portion, most distant from the placenta, are the first to recover from the progesterone block. The contractions (*colored arrow*) which result push in the wrong direction, exhausting muscles without progress.**



TWINS in a two-horned uterus can be born at different times if one placenta (*pale color*) stops producing progesterone before the other (*dark color*). The shading in the lower diagram represents the concentration of progesterone in the two parts of the uterus. In the left side the level is too high for birth contractions to take place, but the level in the right side is inadequate to block muscle contractions. Thus the baby at right is born first. Progesterone cannot pass through the wall from the left chamber to the right to prevent birth.

gesterone in the late stages of pregnancy. But if the placenta distributed its progesterone via the bloodstream, as other hormone-manufacturing glands usually do, a failure of one placenta should not matter, for the blood would distribute progesterone from the producing placenta throughout the uterus. Could it be that the placenta actually does not release its hormone into the blood? If so, it must deliver progesterone to the muscles of the uterus by diffusion through the tissues. This would explain why little or no progesterone from the placenta in one chamber reached the tissues in the other.

We performed experiments on rabbits in the late stages of pregnancy to find out whether the concentration of progesterone, as shown by the strength of its blocking effect, does in fact decline with distance from the placenta. The experiments proved that it does. This opened a new perspective on the delivery process and why it sometimes goes wrong.

We suppose that labor starts when production of progesterone by the placenta begins to decline. Because the hormone is distributed by diffusion, the areas of the uterus most distant from the placenta are the first to be relieved of progesterone's blocking effect and therefore are the first to start contracting. This means that the pattern of the uterus's contraction may depend to a large extent on where the fetus happens to be planted in its wall. If it is high in the uterus, the lower end of the uterus will start contracting first, and the contraction waves will move upward—that is, in the wrong direction. The fetus will be pushed away from rather than toward the birth canal.

Obstetricians are well acquainted with the phenomenon of labor pains without progress. In such cases they sometimes give drugs to stimulate the uterine muscles. If our theory is correct, the stimulants may only exhaust the muscles and actually frustrate the delivery process. Expulsion of the fetus cannot begin until the upper end of the uterus is freed from the progesterone block and initiates downward contractions. So it seems that the old-fashioned precept of obstetrics—to "wait and wait patiently"—may be the wisest after all. Further laboratory and clinical research should tell us whether this hypothesis of the contraction patterns is correct.

Much remains to be done before the research on progesterone can provide obstetricians with a means of confident reassurance for their fearful and distressed patients. But we already have reason to be grateful for Born's legacy.

Kodak reports on:

Mr. Brethen and Lecture Assistant Sandmeyer . . . color films for sophisticates . . . slush-molding and the insidious sun

Craftsmanship

After this one, Mike Brethen's pay checks will have to follow him around in his retirement. He joined us right out of the Army in 1919 and wound up no less a craftsman than the old fellow who gets $65 for a pair of shoes. Rather than on a last or lathe, Mike's craftsmanship has been expressed over a big stoneware crock of acid with ice floating in it as sodium nitrite diazotizes an aromatic amine, after which he adds the resultant diazonium salt to the cuprous salt of whatever halide is required and gets an oily layer containing his aromatic halide. A Swiss chemistry lecture assistant named Sandmeyer proposed this eight years before Mr. Brethen's birth. Since many full-grown adult organic chemists despair of professional advancement from doing Professor Sandmeyer's reactions over and over again, a clear field was left Mr. Brethen to specialize in doing it very well.

On his last day at work he sat down and figured out he had run exactly 50 different versions of the Sandmeyer, counting the displacement of diazonium by iodine, which needs no copper.

Take *m-Dibromobenzene*. What could be simpler? Yet the other day we had a request for it from a man who is so eminent that organic chemists everywhere know his surname only as the designation for a certain green textbook 4½ inches thick. He couldn't find *m-Dibromobenzene* on the market, and he apparently thought it wise to let an expert make it, so the job fell to Mike Brethen. Now, therefore, it becomes Eastman 7276.

Mike's pupils and our other craftsmen are hard at work keeping some 3600 stock bottles of Eastman Organic Chemicals filled. The job is never ending. We hope the orders are too. Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

L is for long, *S* is for short

We have a refinement in the kind of color film that can be printed to gorgeous big *Type C* color prints for dry mounting or to any number of even more brilliant color transparencies, large or small. The reference is to *Kodak Ektacolor Film*. Now it comes in *Type L* for long exposures and *Type S* for short exposures.

If you were naive you would ask, "Why should I pick long exposures if I can have short exposures?" But *you* don't ask that.

You know that while high film sensitivity is the aim, nevertheless the departure from a strict reciprocity between the effects of illumination and exposure time is different between the three emulsion layers of a color film, leading, hitherto, to color imbalance unless the exposure time is kept within narrow prescribed limits. You therefore experience a feeling of release when we tell you that the barriers on both sides have fallen: *Type L* is balanced for exposure times from 1/5 second to 60 seconds, such as encountered in photomicrography and photomacrography; *Type S* is good down to the briefest flash of a gas discharge lamp.

In case you have a friend who fails to grasp your explanation of the preceding paragraph and who has questions about this Type C–Type L–Type S *business, tell him to write to Eastman Kodak Company, Professional Goods Division, Rochester 4, N. Y.*

What's a polyethylene, Pop?

The pentasyllable "polyethylene" is now tossed around by fifth-graders. The public knows that polyethylene is polyethylene. To impart some complexity to the subject, we give you two new polyethylenes.

• This is *Epolene C polyethylene* at 300°F, exhibiting 8000 cps viscosity. Addition of 25% paraffin, with which it is completely compatible, drops the viscosity at this temperature to only 1300 cps. Being polyethylene, it has strength, flexibility at low temperature, resistance to water and water vapor, inertness to chemical activity. The low viscosity permits secure bonding to paper with conventional roll-coating equipment modified to operate at slightly higher temperature instead of a complicated extrusion-lamination process. You can also make shells out of *Epolene C* by pouring it into a cooled mold and pouring out the excess that hasn't cooled enough to solidify. Toy manufacturers call this slush-molding. Toy manufacturers are a smart lot.

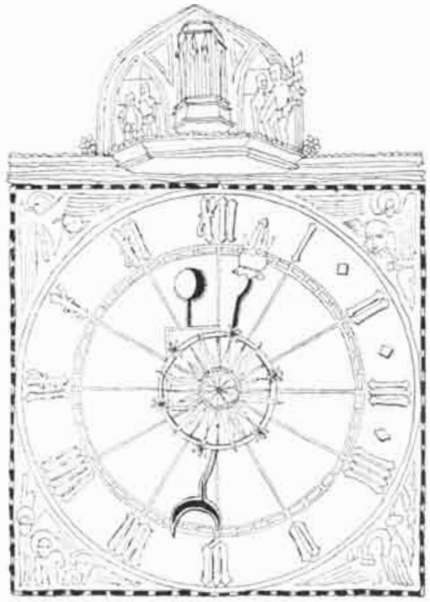
• The other new one is *Tenite Polyethylene* fortified against the unfortunate tendency of ultraviolet radiation to take the edge off some of its virtues. We have found an effective inhibitor and a way of incorporating it. Now, to the advantage of polyethylene in agricultural and horticultural applications, its life in the sun can be at least doubled for sheeting and quadrupled for molded objects. The outdoor formulation even comes in a good choice of colors.

All reasonable questions about polyethylene, either Epolene C *or inhibited* Tenite Polyethylene, *will be answered by Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).*

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
TRADE MARK

SCIENCE AND



More Engineers

Enrollment in engineering courses and schools in the U. S. rose to an all-time high in the fall of 1957. The U. S. Office of Education reports that the total was 257,777 students—6 per cent more than in the previous record year of 1947. Of these 4,180 were working toward doctoral degrees—a 23 per cent increase over the year before.

The number of engineering degrees awarded last year also was at a record level, with electrical engineering leading in popularity.

Kalinga Prize

Bertrand Russell, British mathematician and philosopher, has been awarded the Kalinga prize for popularization of science for 1957. The prize, worth 1,000 pounds, is given by UNESCO with funds from the Kalinga Foundation of the Indian State of Orissa.

Among Russell's popular scientific books are *The ABC of Atoms, The ABC of Relativity, The Scientific Outlook* and *A History of Western Philosophy.* In 1950 he won the Nobel prize for literature.

Education and Congress

Two rival bills for Federal aid to education have been introduced in Congress. An Administration bill, sponsored by Senator H. Alexander Smith of New Jersey and Representative Carroll D. Kearns of Pennsylvania, calls for spending about $1 billion over a four-year period. A Democratic bill, sponsored by Senator Lister Hill and Representative Carl Elliott, both of Alabama, provides for expenditures of about twice this sum over a six-year period; some of its provisions would continue indefinitely.

Details of the bills were reported in a recent issue of *Science.* The Administration bill would provide from $7.5 million in the first year to $30 million in the fourth year for scholarships, emphasizing the fields of science and mathematics. This would allow some 10,000 scholarships a year, averaging $750 with a maximum of $1,000. Grants would be based on need. The Hill-Elliott bill, on the other hand, would appropriate $40 million a year for six years, providing 40,000 scholarships of $1,000 a year. These would go to new college entrants on the basis of scholastic merit. In addition 20,000 scholarships would be granted in the coming year to undergraduates who need funds to complete college. The bill also would provide $40 million a year for loans of up to $1,000 a year to approved students. Repayment would begin one year after the borrower ended full-time studies; to encourage graduates to go into teaching, the bill would forgive one fifth of the loan for each year spent in teaching. Along with science and mathematics, modern foreign languages are given special encouragement in the Hill-Elliott bill.

At the graduate level the Administration bill would give colleges and universities $500 a year for each fellowship granted or would pay one half of the cost of expanding the graduate program, up to a total of $125,000 a year for a single institution. The Hill-Elliott bill would give money directly to graduate students, setting up 1,000 Federal fellowships the first year and 1,500 a year for the next five years. Each fellowship would provide a basic $2,000 for the first year and $2,400 for the third year, plus an allowance for dependents and up to $1,000 a year for tuition.

By way of aid to teachers the Administration bill proposes to allot $150 million a year to the states on a matching basis for hiring science and mathematics teachers, increasing teachers' salaries, or buying laboratory and other special teaching equipment. It would supply an additional $15 million to improve teaching methods and courses of study and to train teachers.

The Hill-Elliott bill would allow the states $40 million a year for elementary and high-school teaching facilities on a matching basis, would grant $40 million to higher schools, would give $100 million a year to teachers directly for summer courses and extension studies in all subjects, but with special preference for science, mathematics and modern languages, and would give states $10 million a year for improving instruction and $55 million to the U. S. Commissioner of Education for research into audio-visual teaching methods.

Both bills would provide funds to states for educational and vocational guidance to students.

The Hill-Elliott bill would authorize the National Science Foundation to set up and carry out a system of services, such as abstracting and translating, for more effective dissemination of scientific information.

Scientific Information

Floundering in the welter of scientific publication, scientists in the U. S. have recently undertaken steps to improve communication.

Fourteen groups engaged in digesting the world literature have formed a National Federation of Science Abstracting and Indexing Services. At another conference sponsored by Western Reserve University 125 scientists decided to ask the National Academy of Sciences to make a "crash study" of the possibility of creating a national center for coordinating scientific and technical information.

The American Institute of Biological Sciences, now translating four U.S.S.R. biological journals and some standard Soviet reference works in the life sciences with a subsidy from the National Science Foundation, estimates that $1 million more per year would be needed to keep U. S. biologists up to date on important Soviet publications in biology. Urging that for the long run U. S. scientists must learn to read Russian, the Institute recommends that Russian be made a language requirement for the Ph.D. and that university courses in scientific Russian be set up with public subsidies.

Consultants Bureau, Inc., a commercial translation firm, has obtained exclusive English-translation rights to 20 major Soviet scientific journals, for which it will pay royalties to the Soviet Government. It is said to be the first such agreement ever made; the Soviet Union is not a party to the International Copyright Convention. One objective of the agreement is to speed up the delivery of the journals in the U. S.

Horse-and-Buggy Meteorology

Mark Twain's complaint that "everybody talks about the weather, but nobody does anything about it" was echoed last month by a special Committee on Meteorology of the National Academy of Sciences. The Committee found meteorological research in the U. S. seriously neglected. It recommended that support of meteorological research in universities be doubled, that a $50-million National Institute of Atmospheric Research be set up within the next five years and that activities to stimulate interest in meteorology and to recruit scientists into the field be increased "tenfold or more," with the help of Federal funds.

Almost all the basic research in meteorology now is carried out under contract with the Defense Department. The Committee said that because the study of the atmosphere is an inherently large-scale, long-term problem, it cannot be carried out adequately under the present system of year-to-year military contracts with separate institutions. Only a national institute can fill the need, the Committee believes. It suggests that the institute be operated by an association of universities under contract to the National Science Foundation, with an operating budget of $50 million a year. Among other facilities the institute should have a large computer, a meteorological flight squadron, a radar laboratory and a rocket and satellite branch.

The Advisory Committee on Weather Control set up by Congress in 1953 delivered its final report last month and told much the same story. It said that present understanding of the weather is too scanty to justify any specific recommendation about weather control except to do more research. It called attention to "the extreme shortage of competent scientists and engineers" in meteorology and to "the deficiency of basic knowledge in the general area of atmospheric physics."

The Committee's conclusion on the effects of cloud-seeding was that this measure may increase rainfall by 10 to 15 per cent during winter in mountainous areas of the Western U. S. (where natural updrafts are available to transport the silver iodide crystals), but in other areas the effect, if any, has been too small to be detected by statistical analysis.

National Observatory

Aden B. Meinel has been appointed director of the National Astronomical Observatory soon to be set up in Arizona. The 36-year-old astronomer was formerly associate director of the Yerkes and McDonald Observatories.

The new observatory will be operated by an association of universities under contract to the National Science Foundation. The universities are: California, Chicago, Harvard, Indiana, Michigan, Ohio State, Wisconsin and Yale.

Not So Rare Air

Sputnik I showed that the atmosphere at a height of 250 miles is about 40 times denser than had been thought, according to a report in *Science* by I. Harris and R. Jastrow of the Naval Research Laboratory, who took part in radio observations of the satellite's orbit.

During a 12-day period soon after its launching last October, the period of its trip around the earth shortened at the rate of about 2.7 seconds each day. From this the NRL workers calculated the drag of the atmosphere and then estimated that at 120 miles (the approximate low point of Sputnik's orbit) the density of the air amounts to about 5×10^{-14} of a gram per cubic centimeter; at 250 miles (the high point) its density is one tenth of that. Extrapolating these figures, Harris and Jastrow estimate that a 22-pound, 20-inch sphere traveling between 250 and 600 miles would have a lifetime of about four years.

Brisk Breeze

An air-speed of 32,400 miles per hour has been achieved in a new wind tunnel, according to a recent U. S. Air Force announcement. The air reached this velocity for about one tenth of a second. The new tunnel is said to be the first to exceed 25,000 miles per hour, the escape velocity from the earth.

Known as Hotshot II, the tunnel is located at the Arnold Research and Development Center in Tullahoma, Tenn. It is used to investigate various problems, including re-entry into the earth's atmosphere.

Ductile Ceramics

Brittleness is supposed to be an inalienable property of ceramic materials, but Earl R. Parker of the University of California has discovered a paradox—a ductile ceramic. He found that single crystals of magnesium oxide can be stretched without breaking, even at room temperature. Parker was led to this discovery by metallurgical theory, which predicts that a crystal of cubic shape with ions in its structure should be ductile. Magnesium oxide fills this bill and turned out to be indeed malleable.

Only freshly separated single crystals exhibit the property. After a few minutes some unknown change makes them brittle. Parker suspects it may have something to do with impurities, and he is now preparing to study highly purified samples.

A permanently ductile ceramic would find many applications in the fabrication of heat-resistant parts. Magnesium oxide has a very high melting point—about 5,000 degrees Fahrenheit.

Chemistry of the Gene

Two biologists at the California Institute of Technology have discovered a proof of the theory that DNA (deoxyribonucleic acid), the basic hereditary material, is a two-part molecule, each half of which can be passed on intact from parent to offspring. Their finding supports the ideas of J. D. Watson and F. H. C. Crick, who picture DNA as a double chain and hold that each half acts as a template for synthesizing its matching half, thus accounting for the reproduction of genes [see "Nucleic Acids," by F. H. C. Crick; SCIENTIFIC AMERICAN, September, 1957].

Matthew Meselson and Franklin Stahl at Cal Tech grew bacteria on a medium labeled with the heavy isotope of nitrogen (N-15) until practically all the nitrogen in the bacteria's DNA was heavy nitrogen. Then they looked for the labeled material in offspring of the bacteria grown in a normal medium (ordinary nitrogen). Each cell in the first generation contained DNA which was half labeled and half unlabeled; in cells of later generations that received labeled DNA, the labeled half was intact.

According to the theory of Watson and Crick, the DNA molecule is made of two complementary chains locked together and wound in a double helix. In the reproductive process they presuma-

SILICONE NEWS

Electronics Go Miniature

Silicones Provide the Means

SMALLER, STRONGER MIDGETS WITH SILICONES—*Smaller, always smaller. Save weight, save space. These are standard in electronic specifications. As a result today's miniatures for home, industry and defense often pack as much power as their bigger predecessors. But when heavy work loads are concentrated in small units, heat problems frequently arise. Here's how Dow Corning Silicones help subdue the heat and make possible the highest efficiency for these electronic midgets.*

RUBBER SKULL-CAP — SAC's Snarks have silicones on the brain. Delicate electronic "thinking" centers in these missiles are embedded in RTV Silastic*, the Dow Corning silicone rubber that vulcanizes at room temperature.

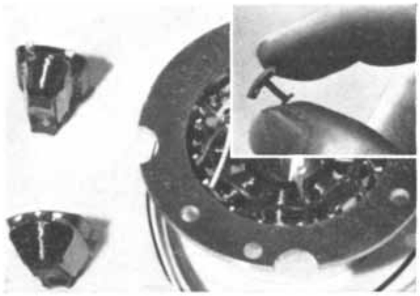
Northrop Aircraft, producer of the Snark, finds that RTV Silastic fills a multitude of needs. First, it's easy and fast to apply . . . they squeeze it from a gun as you would a caulking compound. It sets up to a rubbery solid within 24 hours. Then come the operational advantages: RTV Silastic cushions the circuits against vibration or rough handling, protects against moisture, improves electrical properties, and is easily repaired with more RTV when it's necessary to open a unit for repairs.

No other material could supply these features and withstand heat in the bargain. That's why, for the Snark's intricate electronic brains, skull sessions start under RTV Silastic.

*T.M. REG. U.S. PAT. OFF.

"MIGHTY MITE" — To provide power in certain electronic control systems, Minneapolis-Honeywell has evolved a tiny new Servo motor. No larger than a golfball, and weighing a mere two ounces, this little unit nonetheless develops a stall torque of 0.75 ounce inches and will withstand operating temperatures of 500 F and higher.

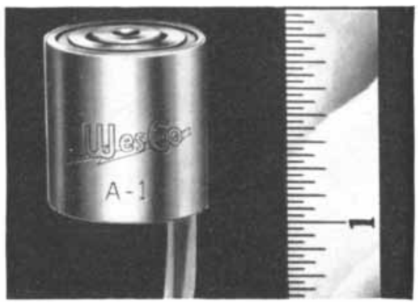
Secret of the Servo's efficiency? Silicones. Dow Corning insulating resins and molding compounds are used extensively. They make sure of the mighty mite's ability to stand up under heavy duty. Designed to drive various of Honeywell's control system assem-



blies, such as calibrators, synchros, and similar components, the Servo is a fine example of how space and weight can be saved with silicones.

IT TAKES PULL — Solenoids are magnetic coils that "suck in" a metal plunger to activate a circuit, and they're rated on their pull. Naturally, you'd expect this pulling power to diminish with size. But with silicone insulation you actually get *more* pull in a smaller package.

By using Dow Corning silicone insulating components and Sylkyd* enameled magnet wire, the West Coast Electrical Manufacturing Corporation, of Los Angeles, produces miniature solenoids of surprising strength. The WESCO A-1, for example, weighs only 2½ ounces, yet



can pull 3½ pounds. An intermittent duty unit, the A-1 saves space and weight for manufacturers of industrial computers or airborne electronics systems. Another big plus: Silicones increase the solenoid's rated service life five times!

***FOR MORE INFORMATION* on any of these silicone products or applications, write Dept. 984.**

first in silicones

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CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST GOBAIN, PARIS

bly separate and each acts as a template to build a new complementary chain.

Sorting Fats

A recent improvement in the powerful analytical method of gas chromatography may lead to better understanding of arteriosclerosis and the metabolism of fats. S. R. Lipsky of Yale University has developed a technique for separating closely similar fats and fatty acids in samples weighing as little as one thousandth of a gram.

Until now the study of the fatty material in blood and in sclerotic arteries has centered chiefly on cholesterol, which is easily measured. However, many investigators suspect that other fats and fatty acids play an equal or more prominent role. But these substances are so much alike that it has been very difficult to separate them in the small quantities with which the biochemist must work.

Gas chromatography was invented a few years ago by the British chemists A. J. P. Martin and A. T. James. The mixture to be analyzed is placed at one end of a heated tube filled with a sandlike material that has been soaked in certain liquids. In this heated tube the sample of mixed material vaporizes, and the vapors of its assorted substances are pushed forward by a stream of inert gas. As they move down the tube, the vapors are absorbed by the liquid and then released at a rate which depends on their molecular weights and boiling points. The lightest vapors reach the far end of the tube first. The chief trick in separating the fatty acids, some of which differ in molecular weight by only one unit, was to find a liquid that would release them at sufficiently different rates. After a long series of trials Lipsky found two compounds of diethylene glycol which have the necessary sensitivity.

Good Grafting

The individualism of animal tissue has long been a frustration to surgeons and a puzzle to biochemists. Skin or other tissue transplanted from one animal to another cannot live in its new environment but shrivels up and dies in a week or two. Now research is beginning to uncover the reasons for this specificity and find ways of getting around it. Progress in the field was summarized last month at a conference sponsored by the New York Academy of Sciences.

Helene W. Toolan of the Sloan-Kettering Institute reported successful transplants of skin from rabbit embryos to adult rabbits. If the skin came from embryos in the first third of the gestation period, before connective tissue had begun to form, the grafts succeeded in about half the trials. Reuven K. Snyderman, also of Sloan-Kettering, tried grafting skin from early human embryos on adults. Of eight transplants, four were successful; two have lasted for nearly a year. Snyderman thinks the four failures may have been caused by infections.

Successful transplants were made even with tissues stored by freezing. This suggests the possibility of accumulating a "bank" of embryonic tissue for use in the surgical treatment of burns.

Dr. Toolan conjectures that ordinarily connective tissue may be the "antigen" that calls forth an antibody or immune reaction from the host on which the tissue is grafted; the success of the embryonic grafts seems to be due to their lack of connective tissue.

Anti-Tranquilizers

A new class of pills is being developed to do for the depressed what tranquilizers do for the overstimulated. These anti-tranquilizers, or "psychic energizers," are milder than Dexedrine and require a week or so to take effect.

The first to appear was Marsilid (iproniazid), originally developed by Hoffman-La Roche, Inc., as an anti-tuberculosis drug. Because of side effects, including stimulation of the central nervous system, it did not make the grade as a treatment for TB, but doctors noticed that it had a favorable action on some depressed patients. In trials at the Rockland State Hospital in New York it helped some chronically depressed patients who had not responded to any other treatment. As a psychic energizer the dosage of Marsilid needed is not large enough to produce undesirable side effects. The drug reportedly works by inhibiting the enzyme that destroys brain regulators such as serotonin, epinephrine and norepinephrine.

Other drug houses have produced energizers. Some have a mild action and are designed to pep up people who are oversedated or just slightly depressed. Among other things, energizers are being tested as treatments for senility, mental strain from overwork, and anxieties that call for a tranquilizer plus an energizer that will prevent the patient from letting down too much.

According to *Chemical and Engineering News*, tranquilizer sales reached \$150 million last year, and energizers are expected to climb to \$50 million in the coming year.

How ounces of rubber can harness herds of horses

Keeping the herds of horses harnessed in today's aircraft engines "on the go" often depends upon a few ounces of rubber. In the form of "O"-rings, frequently no bigger than a pencil eraser, this rubber serves as a packing on actuating cylinders, selector valves and other vital parts where positive sealing is essential.

It used to be that "O"-ring failures were all too frequent. Ordinary rubber could not withstand the various hydraulic fluids, the –40°F. to 160°F. temperatures, the flexing, the stretching, the elongation. But the picture changed when Goodyear introduced CHEMIGUM—first of the truly oil-resistant rubbers.

The unique composition of CHEMIGUM soon made possible "O"-rings with an absolute minimum of swell or shrinkage, excellent resistance to heat and cold, very low compression set and maximum squeeze combined with minimum friction. And its easy processing permitted meeting tolerances in the very low thousandths of an inch.

Perhaps the fate of your product also can be assured a success by CHEMIGUM. For full details plus the finest in technical service, just write to

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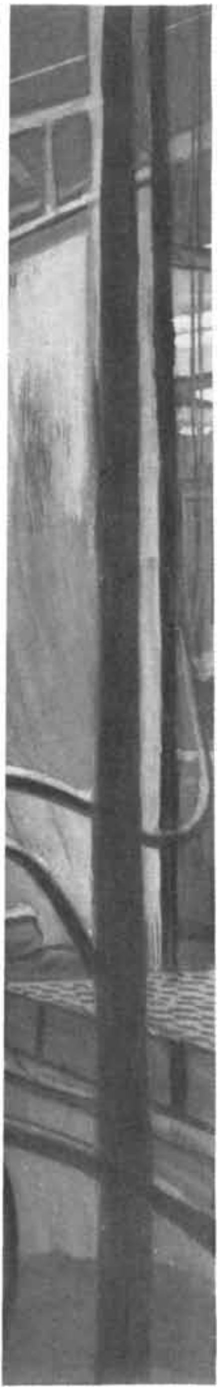
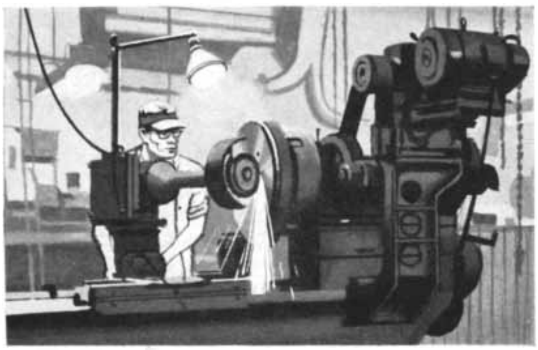


One of the ways Socony Mobil helped The Goodyear Tire and Rubber Company save over twice the cost of lubricants purchased in 1957

Nearly 100 pumps actuate the hydraulic presses and other equipment used to produce wheel rims at Goodyear's Metal Products Division. Under a Mobil program of Correct Lubrication some of these pumps have been in continuous service twice their expected life. Others with a normal plant service life of five years are still operating after *11 years*. This plant has never had a pump failure due to lubrication since the Mobil program began.

The fact that a pump failure, besides halting production, can cost up to $400 for labor and $3300 for other repairs underscores this record.

Here is another example of Correct Lubrication in Action. This cost-cutting Mobil Program gives you the benefit of complete engineering service throughout your plant . . . plus the benefits of Mobil's laboratory facilities . . . and 92 years of lubrication experience. It is turning maintenance costs into profits for The Goodyear Tire and Rubber Company. Why not for you?



$21,400 saved. Under the Mobil Program, Goodyear, to achieve maximum economy, purchases only the highest quality oils. Mobil engineers constantly check oil condition . . . advise when to reclaim. This assures minimum replacement with new oil.

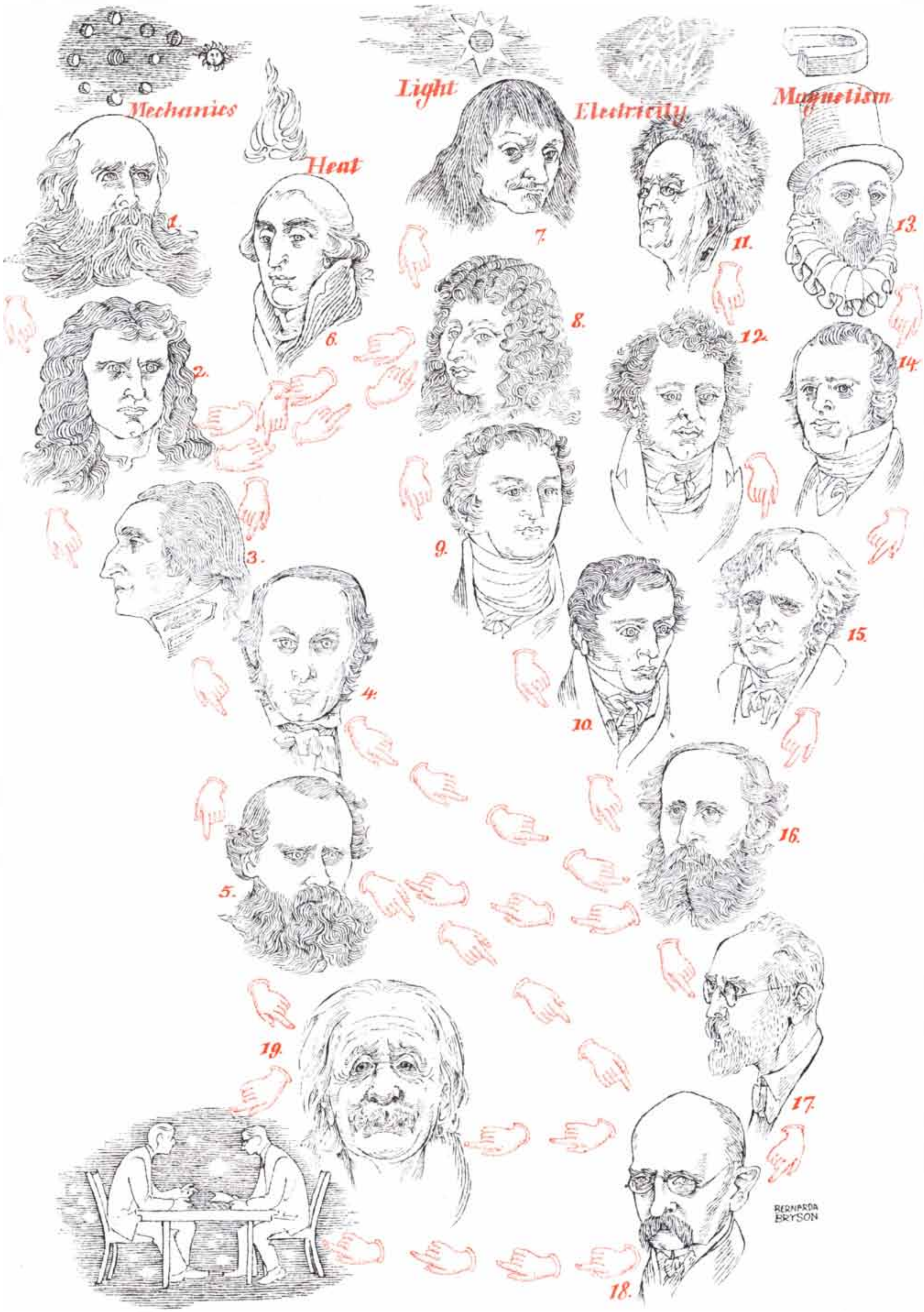
$825 a year saved. Mobil engineers helped set up maintenance pattern for Goodyear's many stock handling trucks . . . made motor oil recommendation. Result—motor overhaul period extended from every three months to every four years.

$6,000 a year saved. High temperatures in paint drying ovens caused stoppage of conveyor system . . . cost $500 a month in labor and materials. Mobil recommendation of special grease eliminated breakdowns.

Total 1957 savings—2.7 times purchase price of oils and greases. Through close cooperation between company personnel and Mobil engineers, maintenance costs are held to a minimum...oils deliver maximum life.

Correct Lubrication

Another reason You're Miles Ahead with Mobil!



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BERNARDA BRYSON

The Teaching of Elementary Physics

To give more students a better understanding of the nature of physical science, a new approach to high-school physics is evolving. Its main feature: emphasis on basic principles

by Walter C. Michels

In the public discussion that has followed the Russians' launching of their satellites, the word "physics" has probably occurred almost as often as "satellite," "rocket" or "missile." Many speakers and writers have implied that the technological progress of the U.S.S.R. can be attributed entirely to the fact that even high-school graduates there have had some 12 years of study in mathematics and six in physics. It seems to follow that all the U. S. needs to do to regain undisputed scientific and technological leadership in the world is to introduce more physics courses and mathematical instruction into its schools. Like all panaceas, this cure for our ills has the attraction of simplicity. It has the further attraction of potent medicine, because physics and mathematics are considered "hard" subjects and we still retain some of the atavistic belief that unpleasant medicines are especially effective—particularly when our children, rather than we, take them.

UNITY OF PHYSICS is reflected in the drawing on the opposite page, which shows how the branches of physics have converged to form the subject that must be taught today. The pioneers whose portraits appear here are: Galileo Galilei (1), Isaac Newton (2), Count Rumford (3), James Prescott Joule (4), Lord Kelvin (5), Joseph Black (6), René Descartes (7), Christian Huygens (8), Thomas Young (9), Augustin Jean Fresnel (10), Benjamin Franklin (11), André Marie Ampère (12), William Gilbert (13), Hans Christian Oersted (14), Michael Faraday (15), James Clerk Maxwell (16), Hendrik A. Lorentz (17), Max Planck (18) and Albert Einstein (19).

But before we rush into a program designed only to persuade more students to take more physics, it may pay us to examine physics instruction in the context of American education as a whole, to ask what we want it to accomplish and to estimate whether improvement in quantity or in quality is the more important.

At present, between one fifth and one fourth of the students graduating from high schools in the U. S. have taken a course in physics. This is almost the same as the proportion of high-school graduates who go on to college. The agreement is more than coincidental—most of the leading colleges either require or strongly encourage some preparation in physics. The engineering schools, which are the first choices of about one quarter of all the boys in the college preparatory group, almost invariably require physics for admission. Thus a large percentage of the students who take physics in high school are a "captive audience," in the sense that they are required to pass the course to get into college.

Much of the argument for bringing more students into secondary-school physics courses seems to be based on the idea that this will ultimately produce more scientists and engineers. It is difficult to predict the extent to which this recruiting effort, even coupled with offers of college scholarships, will succeed. Motivational factors and temporary fluctuations in the demand for professional workers may well be more powerful influences than educational offerings in shaping the careers of young men and women. Some increase in the number of available engineers and scientists will undoubtedly result from present pressures and from Federal support of education; yet we may be disappointed in the results if we set this increase as our only, or even our primary, goal.

Many scientists and some of our best educators believe that there is a more important reason to increase emphasis on physics in the schools. They believe that our educational system is failing to give most of our population an adequate understanding of the nature of physical science and of its role in the economic, political and cultural life of the 20th century. George Stewart, in his book *Man—An Autobiography*, points out that mankind's way of life has changed more since 1700 than it had from prehistoric times to that date. Our economy of abundance, our increased leisure with its cultural benefits, our rapid communication systems with their effect on international relations, our increasing ability to employ nature for our own ends—all of these are direct consequences of the ideas and the methods introduced by Galileo, Newton and the physical scientists who have stood on the shoulders of these giants. An understanding of science is as important to the businessman, to the lawyer, to the statesman or to any other citizen as an understanding of language or literature or of political and military history. Physics is the most basic of the natural sciences. For this reason, the study of physics is essential to the education of all of the population. The future rests not so much on the number of engineers and scientists produced each year as it does on the intellectual and cultural climate in which they work, and this, in turn, will be determined by our success or failure in making physical science a significant part of general education.

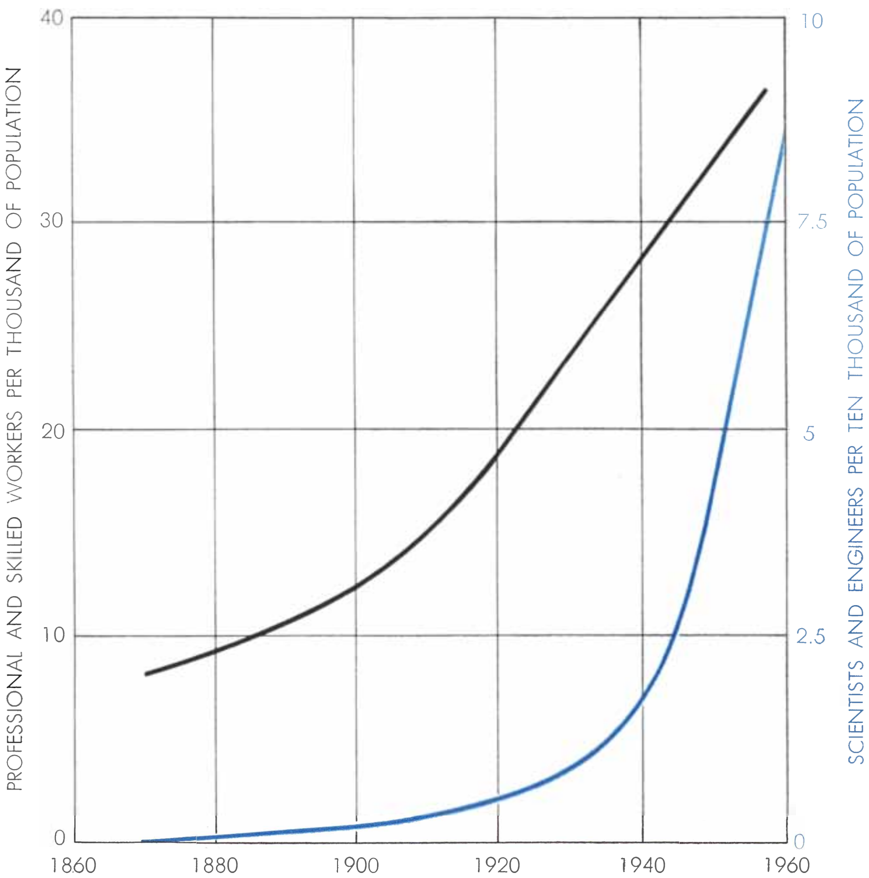
Today's Physics Courses

Physics, like any other subject, can contribute whatever the student is willing and able to take—anything from true understanding down to mastery of a few facts to be regurgitated on an examination. The quality of the course itself will depend on the textbook, on the laboratory aids available and, most of all, on the ability of the teacher. A truly able teacher possesses both a knowledge that goes well beyond the level at which he is teaching and an understanding of the people he is teaching. From the first of these he draws illustrative materials and constantly changing methods of presentation, and so makes his subject interesting and exciting enough to fire the imagination of his students. The second quality allows him to tailor his approach to the mental abilities of the students and to choose the phrase or the illustration that will make his meaning clear or will untangle a difficult passage in the textbook. It is because both of these abilities are needed that we are faced with so serious a shortage of science teachers. We cannot solve the problem by bringing into the classroom scientists with an advanced knowledge of their subject but with no feeling for teaching, or by assigning physics to good teachers who know little physics.

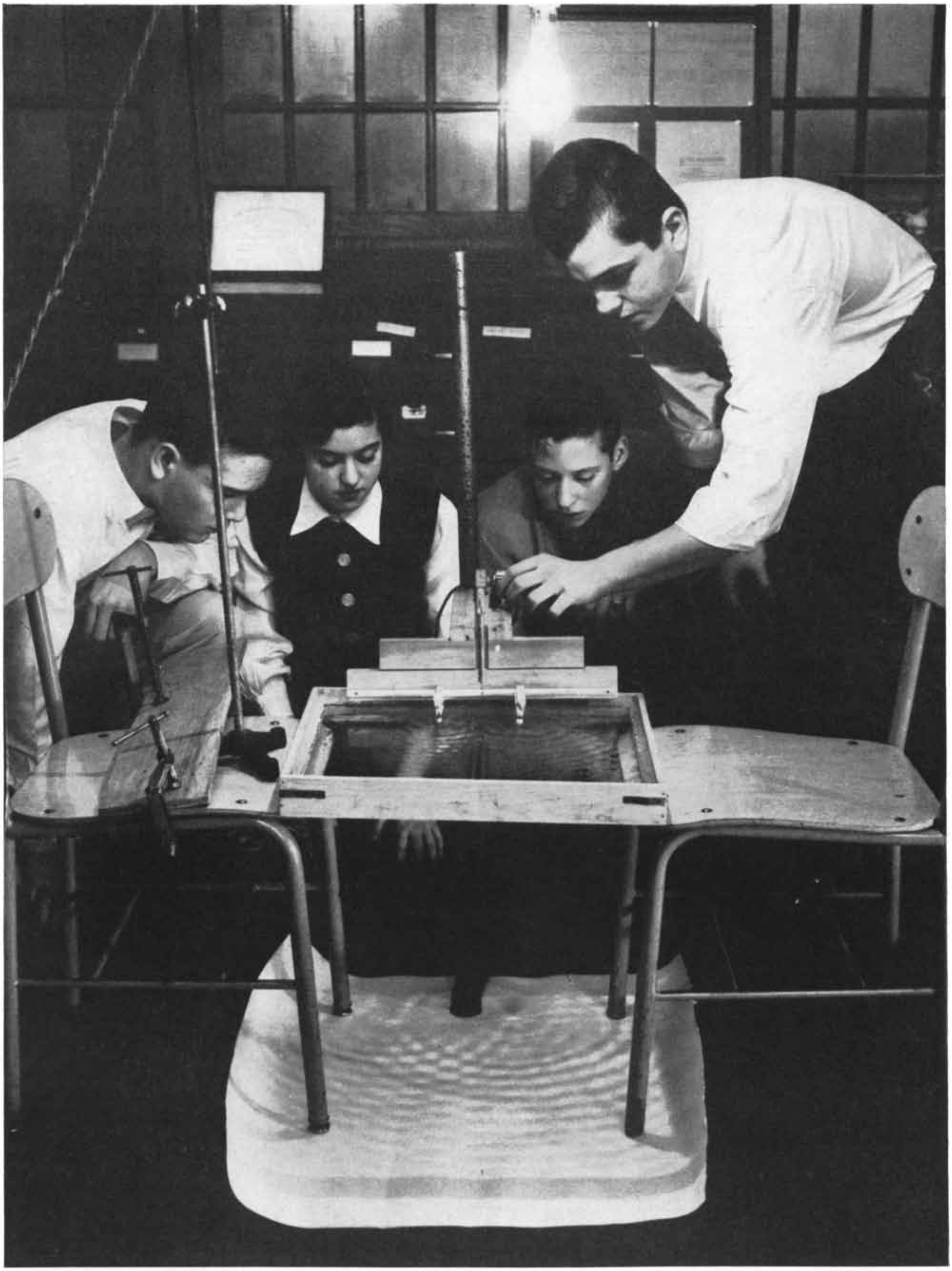
In the best of our schools—those that attract good teachers and give them the equipment and time required for a good job—the physics courses contribute to the student's education many things that he cannot obtain from other studies. Here he learns the basic principles that underlie events from the throwing of a baseball to the launching of a satellite; he learns to observe phenomena with care, to extract from them the parts that are most important and to use his observations to test a theory. Because the phenomena dealt with are simple and subject to measurement, he obtains practice in the analysis of their causes—practice which will stand him in good stead when he later faces the problem of analyzing more complicated happenings without allowing his prejudices to influence his interpretation of them. His interest in and understanding of algebra and geometry are likely to be advanced as he sees that these subjects supply valuable tools for the description both of nature and of the products of modern technology. He learns to read carefully, with the idea that every word in a well-written piece of exposition is there for a purpose; at the same time, he learns to communicate ideas in a clear, succinct and unambiguous manner, using graphic methods and mathematical descriptions as well as words. Whether the student is destined to become an engineer, a businessman, a lawyer or a housewife, he or she can be expected to retain these advantages of the physics course long after the detailed facts and the techniques of physics are forgotten.

Few physics courses accomplish all of these things, and many fall far short of the goals that we have set. One reason for their shortcomings is that tradition, economic pressure and mistaken ideas about the nature of science have given us textbooks which sometimes hinder rather than help the teacher. The content of the courses is heavily influenced by the fact that a large proportion of the students taking them are preparing for engineering. These students are interested in the technical applications of physics. The authors of textbooks and the teachers are tempted to catch their interest by loading the course with technology. Some of the textbooks abound in pictures and diagrams of Diesel shovels, locomotives, gasoline engines and automobile transmissions. No one can object to the use of practical machines to illustrate the principles of physics, but we must protest when the text is so overloaded with these illustrations that the principles themselves have to be treated in a summary fashion, if not omitted entirely. Further, many modern machines are too complex to be described adequately or discussed correctly on the basis of the physical knowledge available to the students. Under these circumstances, too many physics courses demand only rote memorization of isolated facts and of formulas into which numbers can be substituted to achieve answers which often mean little to the student who has obtained them.

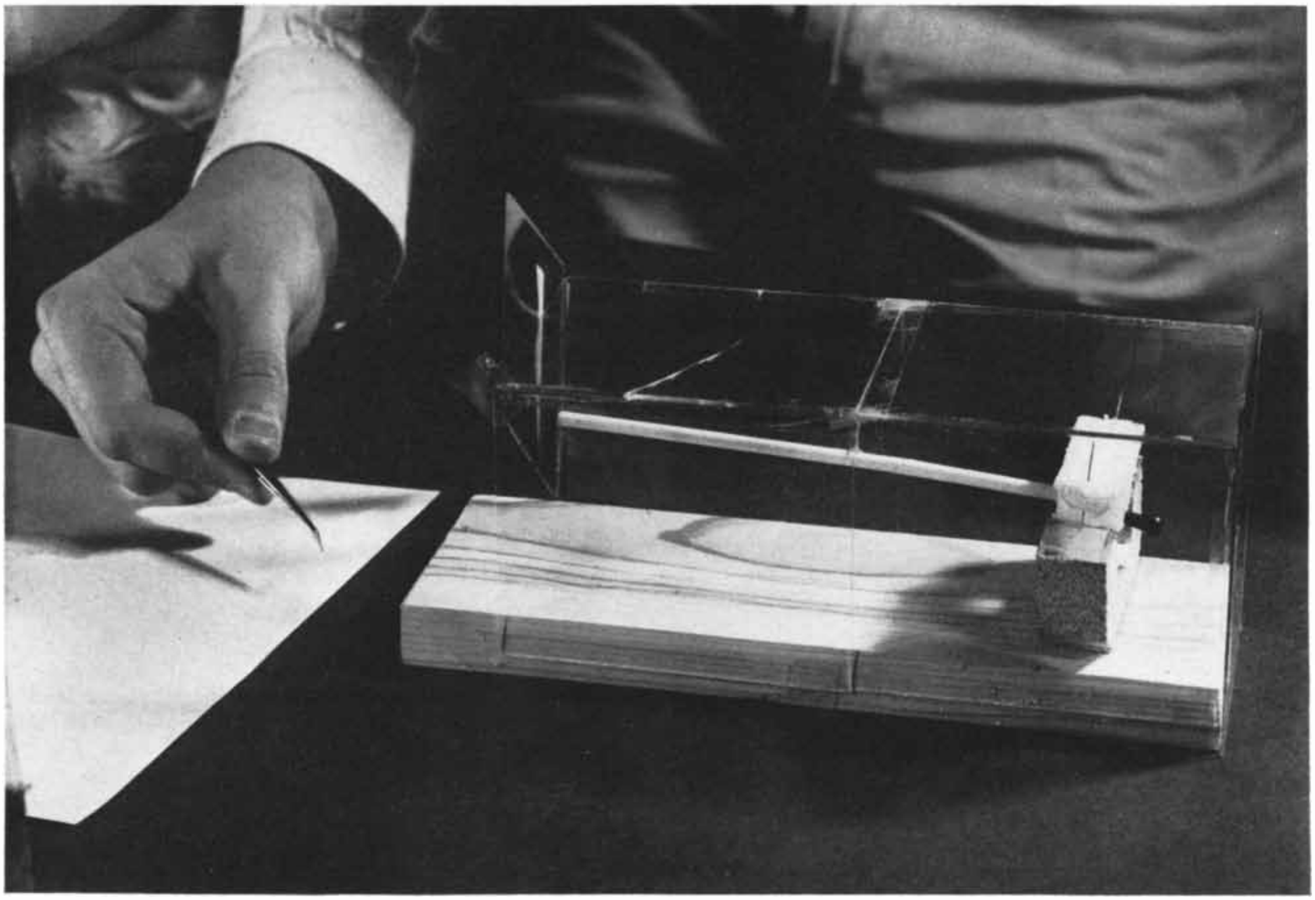
A second fault of many textbooks is the breakdown of physics into topics or "units"—a misuse of the basically sound pedagogical idea that students should



PROGRESS OF CIVILIZATION requires an increasing proportion of technically trained individuals in the population. The graph shows the historical rate of growth of this group.



RIPPLE TANK, in which a pair of vibrating plungers generate sets of circular waves, is used to study wave phenomena in the laboratory. The apparatus pictured here and on the following three pages was developed by the Physical Science Study Committee. Much of the material is built by the students themselves. The photographs were made at the Bronx High School of Science in New York. This is one of the schools where the Committee's new program is being tested. The instructor of the course is Alexander Joseph.



MICROBALANCE is made of a drinking straw, wood screw and other simple materials. The arm balances on a pair of needles resting on a glass slide. At top left a student places a standard weight in the straw to calibrate the balance. At top right she marks the arm's position. One millimeter on the scale represents 45 micrograms. At bottom a student prepares to weigh a bee's wing.

not be confused with too many facts or concepts at any one time. The difficulty is that the texts rob the units of meaning. Sound, heat, light, electricity, magnetism, mechanics and atomic physics are discussed separately as if they had little or no connection with one another. This method of presentation belies the very nature of the subject, for the chief thing that distinguishes the physical sciences from other intellectual activities is the existence of a central theory, based on a very few simple laws and principles, which applies to all phenomena. All of the particular subjects listed above can be closely related on the basis of fundamental principles such as the conservation of energy, of matter and of momentum.

Principles *v.* Applications

As an example of the failure of the piecemeal approach let us take one of the bulwarks of physics courses—Ohm's law. In the first half of the 19th century Georg Simon Ohm of Germany showed that the voltage required to produce a steady current in any part of a given electric circuit was proportional to the current. That is to say, if the current maintained in a wire is to be doubled, the battery must supply twice as strong an "electrical push." Ohm thus arrived at the concept of electrical resistance and at the idea that the resistance of a conductor depended only on the material and dimensions of the wire, not on the amount of current flowing in it. We now know that Ohm's law holds only for special classes of electrical conductors (*e.g.*, metals). In fact, it is the failure of Ohm's law to apply to the flow of electricity in vacuum tubes and in the materials known as semiconductors that has made all of modern electronics possible. Yet the typical introductory physics course leaves a student with the firm conviction that Ohm's law is one of the most basic principles of physics, or at least that he will not pass his final examination if he cannot substitute numbers in the formula: $E = IR$. If he remembers that E is a voltage, I is a current and R is a resistance, he will be able to arrive at the correct answers to conventional examination questions. But if he tries to apply Ohm's formula to any circuits other than the simple ones in which he has been drilled, he will probably go far astray, for he has learned only the letter of the law, not its meaning.

Only a few years before Ohm's law was discovered, the great principle of the conservation of energy (the first law of thermodynamics) had been established. James Prescott Joule of England went on to show that heat, such as that present in a kettle of hot water, and mechanical energy, such as that carried by a rolling stone, were one and the same thing. Further, he found that electrical energy too was connected with these forms of energy. He arrived at the conclusion that a current in a wire produced heat at a rate which was proportional to the square of the current. In the same symbols that we have used to state Ohm's law, we can write Joule's law as $H = I^2R$, where H stands for the rate at which heat is produced.

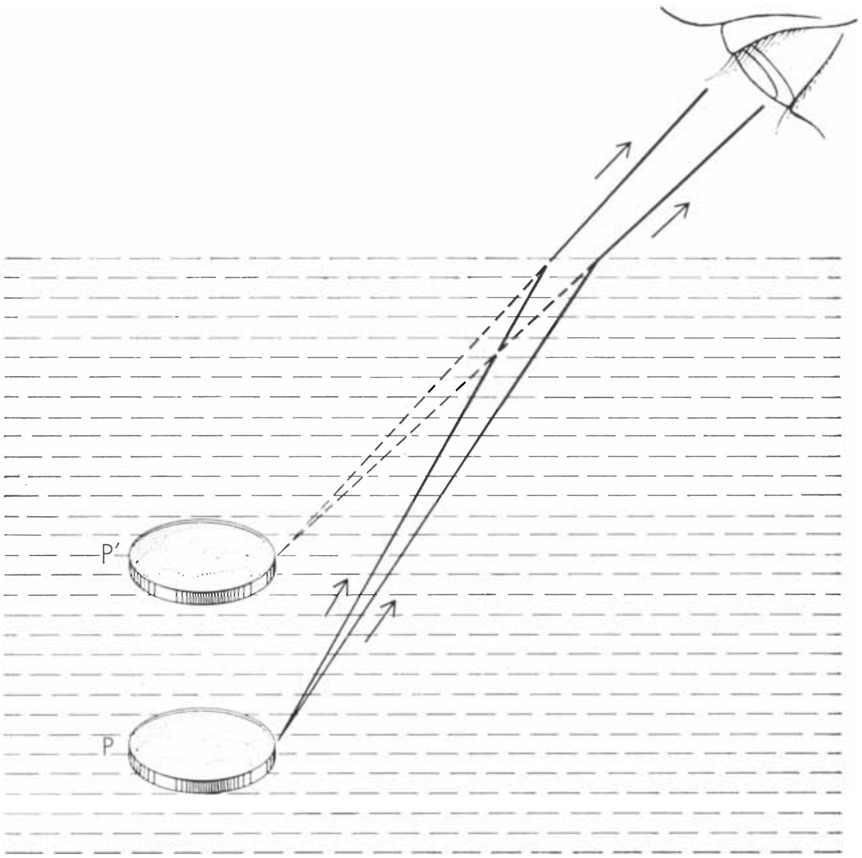
Joule's law is mentioned in many introductory texts but is seldom given as much prominence as Ohm's law. Moreover, it is almost always presented as an entirely independent principle, connected with Ohm's law only through the fact that both involve current and resistance. Actually Joule's law and Ohm's law both express exactly the same thing. Either can be derived from the other or from the principle of the conservation of energy. The electromotive "force" involved in Ohm's law is the energy necessary to move a unit of electrical charge from one end of a conductor to the other. Combining this concept with the fact that the current is merely the rate at which electrical charge is carried through the conductor, we can state Ohm's law as follows: "The energy required to move a unit of electrical charge along the length of any conductor is proportional to the rate at which charge is being moved." For conductors that obey Ohm's law, Joule's law also must hold, because the rate at which energy must be supplied is just the energy per unit charge times the rate at which charge is moved, that is, it is equal to IR times I, or I^2R. According to the principle of conservation of energy, the energy required to move the current against the resistance of the conductor must either be converted to heat or be stored up in some form. When the current in a conductor is steady, there is generally no way that energy can be stored, so the heat given off must be equal to I^2R, in accordance with Joule's law.

It is perfectly true that a discussion of the relation between Ohm's law and Joule's law requires close attention on the part of the student. When he has grasped the reasoning, however, he will have recognized why Ohm's law holds only for steady currents. He will also be able to apply that law to circuits he has never seen before. Most important of all, he will realize that the conservation of energy is a fundamental principle which applies alike to mechanics, to heat and to electricity.

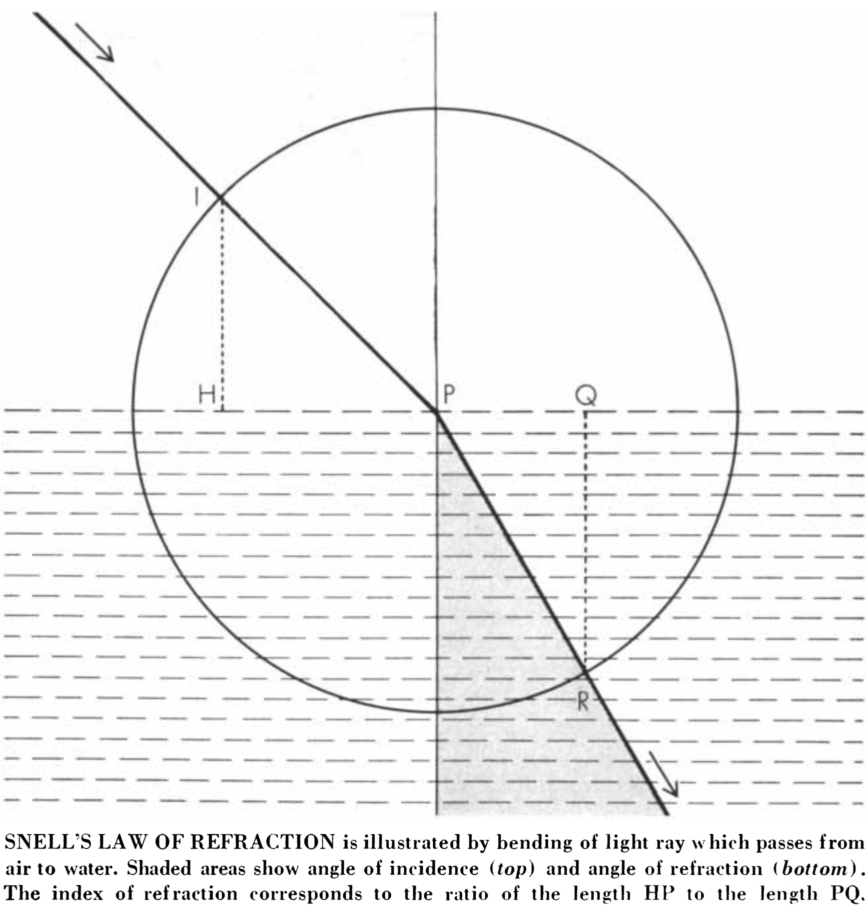
To illustrate further the difference between teaching the principles of physics and merely discussing its application, as courses commonly do, let us take an example in optics. The problem is to explain a virtual image—for instance, the image of an object that you see when you look at it through a magnifying glass. The distinction between a virtual image and a real image (such as is formed by a camera lens) is that the rays of light do not actually pass through the virtual image; rather, the image is a displaced projection formed by extension of straight lines from the eye through the points in the lens where the light from the object itself is bent by refraction [*see upper drawing on next page*]. Now many high-school texts deal with this subject mainly in terms of a "lens equation" which provides a formula for determining the distances of the object and the image and the focal length of the lens. The equation says that the reciprocal of the object's distance from the lens plus the reciprocal of the image's distance is equal to the reciprocal of the focal length, thus: $1/u + 1/v = 1/f$. The student must learn this formula and also a set of rules which say that the distance of the object behind the lens is reckoned as *positive*, but that the distance of the image, if it is behind the lens, is expressed by a *negative* number. He may be given a problem asking what the distance of the image from the lens will be when he looks at an object through a magnifying lens with a focal length of one inch if the lens is held three fourths of an inch from the object. If he remembers the formula and the rules correctly, with a little algebra he can arrive at the answer that v is equal to minus 3—the image is three inches behind the lens. By applying another formula he can learn that the image is four times larger than the object being examined.

The formulas are approximately correct for simple lenses, and they are indeed useful for designers of optical instruments. But they are unlikely to have much meaning for a student or to convey anything about the process by which the image is formed. It is very doubtful that his learning to use the formulas contributes appreciably either to his intellectual development or to his understanding of light or of lenses.

Suppose now that the same subject is taught in a course that emphasizes physical principles rather than their applica-



APPARENT DISPLACEMENT of a coin submerged in water can be understood by tracing paths of light rays from coin to eye. Because of refraction at the surface they appear to be coming from point of broken lines, and this is where coin appears to be.



SNELL'S LAW OF REFRACTION is illustrated by bending of light ray which passes from air to water. Shaded areas show angle of incidence (*top*) and angle of refraction (*bottom*). The index of refraction corresponds to the ratio of the length HP to the length PQ.

tions. The student may first be asked how we know where an object is. After learning that from each point on the surface of an object rays of light diverge in a cone to the eye (a fact discovered by Franciscus Maurolycus of Messina in the 16th century but seldom emphasized in physics texts), and after studying the law of refraction discovered by Willebrord Snell in 1621, the student may apply that law to a simple problem such as why a coin lying on the bottom of a glass seems to rise when the glass is filled with water. By a simple drawing of the refraction of the light where it passes from the water to the air he can project the displacement of the virtual image, as the illustration at the left shows. Having done this, he can extend the same process to any lens and locate an image by a scale drawing.

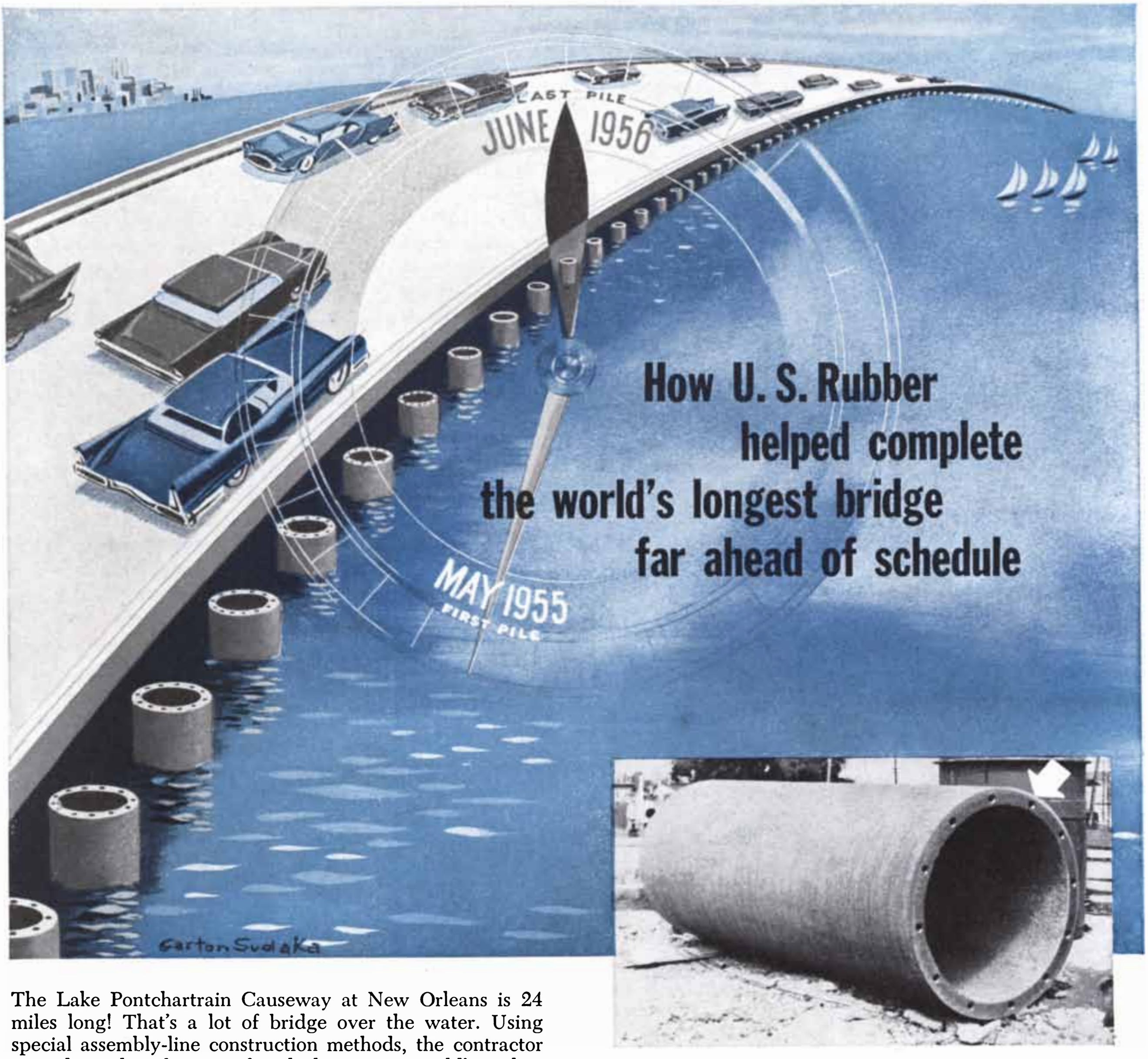
This procedure will probably take longer than memorizing and applying the lens equation, but it should give a student an insight into the behavior of light as it passes through a lens, reinforce his knowledge of the law of refraction and equip him with a method that is applicable to all lenses, not just to the thin spherical lenses to which the simple lens equation applies.

New Approaches

These examples are sufficient to illustrate how greatly physics teaching could benefit from a new approach. Even a good teacher is somewhat at the mercy of the current textbooks and of tradition. A poorly prepared one who has been pressed into physics from some other subject has few weapons with which to fight the trend. He cannot be expected, without more time than is allowed by a busy teaching schedule and an overabundance of record-keeping, to learn enough about physics to challenge the text or to present the subject in an enjoyable and exciting way. If physics in the schools is to be improved to the point that the times demand, we must either find a way of attracting more good teachers or we must see that the poorly prepared teacher is given help.

To draw a wider group of students in the secondary schools into physics we must reduce the number of engineering applications taught in the course and devote the time thus gained to the ideas, methods and history of physics. In the past, attempts have been made to interest more students by giving "descriptive" courses, which present physical phenomena but avoid theory and the use of any mathematics beyond arithmetic or a very little algebra. Some of

ENGINEERED RUBBER PRODUCTS



54″ o.d. section of finished pile showing precise round channels formed by U. S. Rubber Tubing. There are 12 of these cores in every section. Each core has a diameter of 1.375 inches.

The Lake Pontchartrain Causeway at New Orleans is 24 miles long! That's a lot of bridge over the water. Using special assembly-line construction methods, the contractor turned out the job in one-fourth the time it would've taken had ordinary construction methods been followed.

U.S. Rubber's special #4830 Rubber Tubing was one of the big reasons why this gigantic project was completed so quickly. With this tubing, it was possible to prefabricate, in sections, the almost 8 miles of cylindrical concrete piling that supports the bridge. Here's how they did it:

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these courses, particularly when taught with a sense of showmanship, have certainly been popular. No doubt a descriptive course is better than no course at all. But can it give a student the understanding of physical nature and of science that the times require? The distinguishing characteristic of physics is that it involves a central theory, of very broad validity, in terms of which observed phenomena are interpreted and understood. To omit large parts of that theory in order to avoid mathematical difficulties is to deny the able student the intellectual stimulation that is one of the prime rewards of education.

Perhaps good descriptive courses should be developed for the benefit of the lower half of our expanding high-school population, but it is my opinion that we cannot afford such courses for the able students who promise to become the intellectual, political and cultural leaders of the future. For this group there seem to be two possible answers. The first, and best, is to restore solid mathematics courses to the required curriculum for all students in college preparatory courses. The time when we can afford to suppose that intelligent students cannot or will not take a minimum of three years of mathematics in high school is past. The second solution is to include in the physics course whatever mathematics is required for the work, over and above the minimum requirements for graduation from the high school. This would mean that some physics now included in the course would have to be eliminated to make room for the needed mathematics, but we are interested mainly in quality, rather than quantity, in the content of the course. The cost in reduced coverage need not be great if the best secondary-school teachers and the best university physicists can be persuaded to join hands in the discovery of new ways of presenting physics with a high degree of rigor, yet with a minimum of formal mathematics. The history of physics and mathematics supports the amalgamation of the two subjects, for their developments have been so entwined that they are parts of the same intellectual activity. After all, Newton did invent the calculus in order to solve a physical problem.

Training Teachers

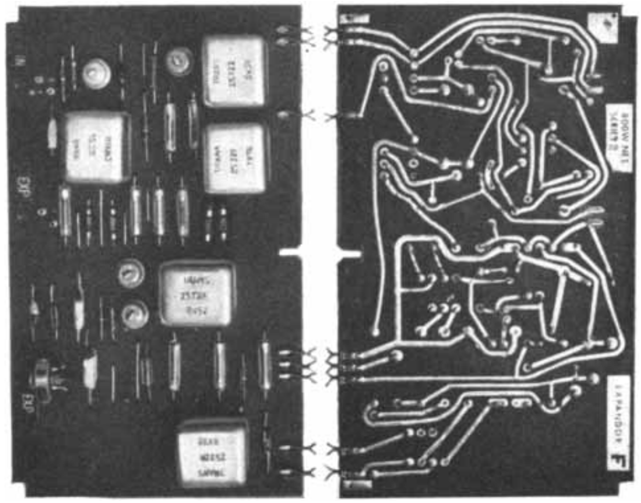
The new approaches I have been discussing may sound Utopian, but actually some very promising improvements in the teaching of physics are already under way. Among other things, active steps have been taken in recent years to improve the preparation of teachers. During the past decade a number of colleges and universities have started summer institutes for science teachers. They bring together for six to eight weeks groups of as many as 60 or 70 teachers. The programs include refresher courses, lectures and discussions of current research by active physicists, and laboratory work under better conditions than exist in most schools. The first institutes were financed by a few far-seeing industrial concerns and private foundations; the program is now being supported on a much larger scale by the National Science Foundation, supplying stipends to about 5,000 science teachers each summer, including several hundred in physics. A smaller program, providing teachers with fellowships for a full year of study, has been in operation for two or three years. There is growing support for in-service institutes on campuses near high schools, where teachers study for a few hours each week during the school year. All these training programs are already producing results, and they can be expected, within another five years, to increase greatly the number of well-prepared physics teachers.

To bring physics to many more students in our secondary schools may, however, require more teachers than our educational system and economy can supply. One possible solution would be to enable the good teachers to reach more students by the use of films and television. The Fund for the Advancement of Education made possible a large experiment in this direction. It furnished funds to the schools of the Pittsburgh area for a full-year program of television lectures and demonstrations. The school authorities brought in Harvey White, who had taught physics very successfully to nonscience students at the University of California for many years. He had had experience with television. During the school year of 1956-57 he delivered 162 lectures of 30 minutes each which were carried simultaneously by television to students in 44 schools. At the same time they were filmed. The films are now available through Encyclopaedia Britannica Films and are being used in a number of schools throughout the country. It is perhaps unfortunate that the pace at which this experiment was organized and run did not allow many of the faults of current physics courses to be corrected, but the films should nevertheless be of tremendous help to school systems that cannot find sufficient numbers of teachers who have been adequately trained in physics.

A New Course

A much larger endeavor is being carried out by the Physical Science Study Committee, an organization created by the daring imagination and inspired leadership of Jerrold Zacharias of the Massachusetts Institute of Technology. Supported by the National Science Foundation and a number of private foundations, this committee has brought into its service more than 100 highly qualified individuals, including high-school teachers, research physicists from universities, professional writers, film directors and selected college students. In the past year and a half the committee has considered in detail what might be omitted from the present crowded syllabus to make room for better and more fundamental teaching; it is preparing a radically new textbook; it has made a start on the preparation of new laboratory manuals, teachers' guides and reference materials; it has planned a series of about 70 films; it has designed simple laboratory apparatus, much of which can be built by the students themselves. The course is being developed further by use in a few selected schools, where it has been received with enthusiasm by teachers and students alike. Sufficient materials should be available to allow introduction of the course into many schools by the fall of this year. Five institutes will be conducted this summer to introduce the course to 200 or more teachers.

The work of the Physical Science Study Committee probably represents the most ambitious attack ever made on the problem of presenting any subject to high-school students. It has made use of earlier studies carried out by committees of the American Association of Physics Teachers, the National Science Teachers Association, the American Institute of Physics and others. It has brought together individuals with different backgrounds, including the Nobel laureates Isador I. Rabi and Edward M. Purcell, the Presidential advisers James R. Killian and Vannevar Bush, the writers Mitchell Wilson and Stephen White, the movie producers Frank Capra and Warren Everote, and outstanding teachers such as Judson Cross of Exeter and John Marean of the Reno High School. All those engaged in the enterprise are hopeful that it will produce large results, not only in the teaching of physics but also in elevation of the intellectual level of our schools.



This 7-foot high machine can handle up to 50 different components stored in the magazines on top. These components are mechanically selected and mounted on carrier circuit boards by use of a punched tape program control system. • Illustrations on the right show component and circuit sides of a typical circuit board assembly used in P Carrier telephone equipment.

Solved: the mechanized mounting of circuit components for carrier telephone equipment

Carrier telephone equipment makes possible the simultaneous, independent transmission of several messages over the same pair of wires. Modern carrier systems manufactured by Western Electric for the Bell System make extensive use of plug-in circuit units which are interconnected to form the terminal or repeater equipment.

Until recently, one of the knottiest problems faced by engineers responsible for manufacture of carrier equipment was to speed up slow, costly hand mounting of components onto the circuit boards. Possibility of mechanizing the process was made extremely complicated by reason of the large variety of component types, sizes and weights used. Furthermore, the mechanized process had to accommodate a large variety of circuit designs – each calling for selection of different combinations of components.

The Answer: Faced with this complex problem, Western Electric engineers developed a versatile machine in which components are stored in magazines and automatically selected, transferred and mounted onto circuit boards under the control of a punched tape programming system. This Automatic Component Insertion Machine, planned for line operation in the near future, will eliminate manual mounting of approximately 3,000,000 axial lead type components upon 150,000 P Carrier circuit boards each year.

How does it work? Using a punched tape program control system, the following operations are coordinated and performed:

1. The circuit board is moved and locked into position by a servomechanism to receive properly each component as it is selected.
2. The selected component is dropped into the pick-up position by an electromagnetic device (there is one at the release end of each magazine hopper).
3. A rotating transfer arm picks up the component and delivers it to the inserting head which has been adjusted to the length of the component by a servomotor.
4. The inserting head grasps the component by its axial leads, cuts them to the proper lengths and forms them into a U-shape ready for insertion into the circuit board.
5. The inserting head lowers the component to the circuit board where the leads are inserted and clinched against the under side by two rotating anvils.

The development of this ingenious machine is another example of the exploratory engineering constantly going on at Western Electric. It is another example of how Western Electric effects economies in the manufacture of Bell telephone equipment – to the end that your telephone service is ever better and more dependable, and at low cost.

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MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

FORUM was one of the principal centers of life in Pompeii. It is laid out on the plan of early Italic market squares, but is adorned with Greek colonnades. It was closed to vehicles and beasts of burden. In the distance is the profile of the volcano Vesuvius.

THEATER DISTRICT was another principal center of life in Pompeii. The city had two theaters, the larger of which is in the background. In the foreground is a spacious portico which served first as the lobby of this theater and later as a school for gladiators.

POMPEII

The city which was buried by Vesuvius has been excavated for two centuries. Two thirds of its 165,000 acres have now been cleared, providing a unique view of Roman life in the first century A.D.

by Amedeo Maiuri

The eruption surprised Pompeii on a warm August day in the year 79 A.D. The people of the town were not unaware that Vesuvius was a volcano, but it had been quiescent from time immemorial, and its slopes were covered with villas and vineyards. Although sections of the city still lay in ruins from a local earthquake which had shaken the region 17 years before, no one had taken that disturbance as a warning of the disaster to come. The volcano's awakening was sudden and unbelievably violent. Its crater abruptly collapsed and a great black column shot into the sky. Pliny the Younger (whose uncle, Pliny the Elder, was nearby and was among those killed) vividly described the eruption: it looked like an Italian umbrella pine—a tall "trunk" spreading out at the top to a dense cloud shot with flashes of lightning. From that cloud, driven by a strong northwest wind, there fell upon Pompeii a heavy hail of pumice stones, which smashed roofs, riddled the houses and buried the city under a blanket of pumice more than 12 feet deep. When the hail diminished, survivors who had taken refuge in cellars and vaults tried to escape to the shores of the bay nearby. But they were overtaken by a second, slower fall from the cloud—a rain of suffocating ashes that piled up to a height of six to nine feet. Like a palpable fog or a quicksand, it trapped and enveloped people in their houses and even those fleeing in the streets. Their bodies were encased in ash as in a mold, and these casts of hardened ash are today the most moving evidences of the tragedy of Pompeii. By pouring liquid plaster into the now hollow molds we can recreate the shape of the body, the form of the clothing, the footgear, even the last exhalation of men and women who lived and died in that ancient city.

Pompeii was so utterly wiped out that even its site was lost. But in the last two centuries the city has in a sense been reborn. In 1748 canal diggers came upon the buried houses, and the excavation has continued almost without interruption ever since. Generations of archaeologists and laborers, Italian and foreign, have devoted their entire lifetimes to uncovering or restoring the ruins of Pompeii. The 210-year excavation of Pompeii is the longest ever made of any city of the ancient world. In part the lure has been the dramatic circum-

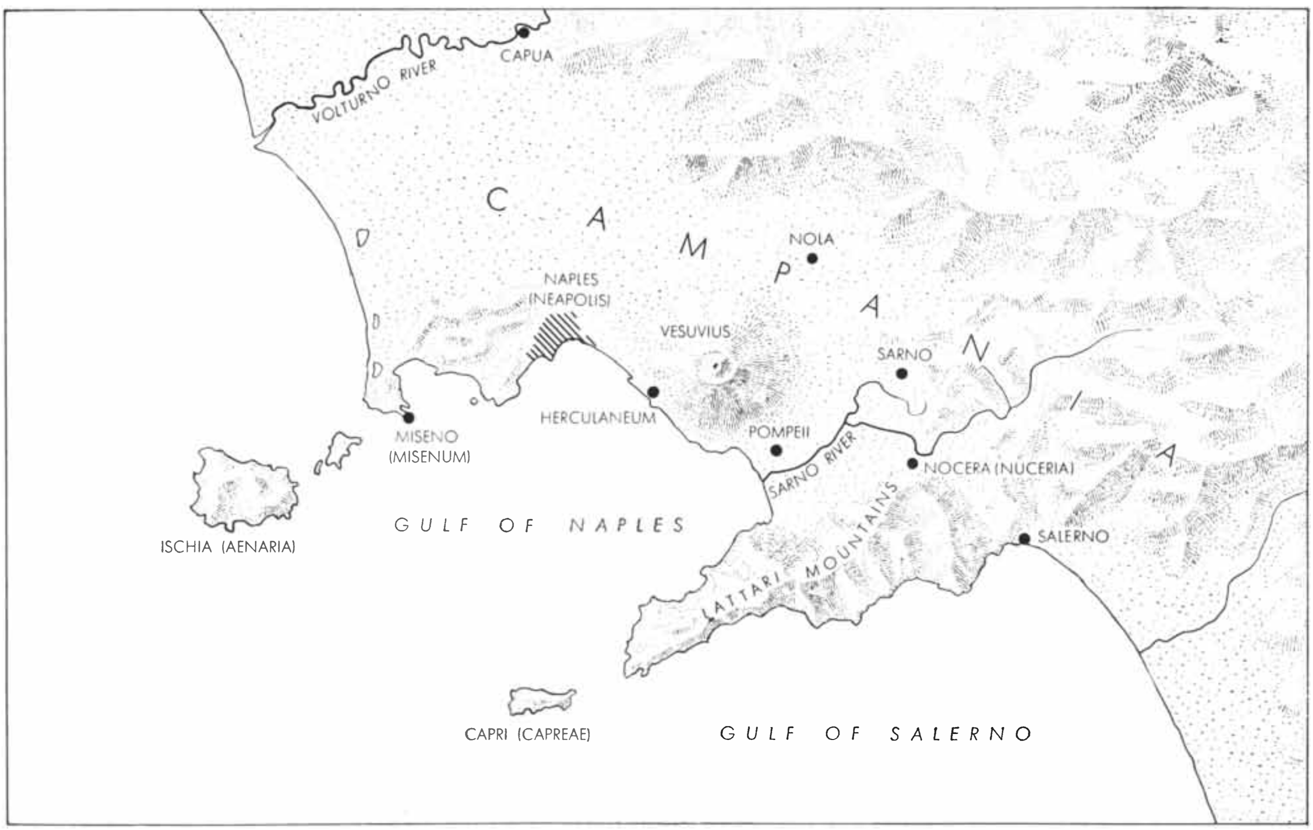
FALLEN INHABITANT of Pompeii was reconstructed by pouring liquid plaster into a cavity in volcanic material which covered the area. The cavity was located by tapping ground.

stances of the city's death; in part the fact that in Pompeii we can see an ancient city caught at a certain moment at the height of its career, showing its qualities unspoiled by the overlay or the wear and tear of history to which living cities are subject. But above all Pompeii has a special attraction for scholars interested in studying the everyday life of an ordinary town of an ancient time.

Pompeii was not a city of great events nor of great historical personalities (although Cicero had a villa nearby). We find no indication that its population included any immensely wealthy patricians or merchant princes or famous statesmen or dominant ruling families. Its citizenry was made up of well-to-do landowners, prosperous manufacturers and merchants, tradesmen, craftsmen, artisans, drifters, and slaves who could aspire to and achieve the condition of freedmen. The city was governed by a Council of Notables, chosen annually in elections conducted with all the vivacity and heat of a southern population. The balance of power among the various classes of citizens, and between the local autonomy of the city and the authority of the Roman state, created that mixed rule of the privileged and the populace which was, at bottom, the secret of the vitality of the Roman regime. And precisely because Pompeii was not a dominant metropolis but a medium-sized provincial town (of about 20,000 population) in a region of more powerful cities (among them Capua and Naples), it gives us a typical picture of the civilization and organization of the average city of its time.

When the excavation of Pompeii was started in 1748, the object of the diggers was to recover its works of art to enrich the museums of the kings of Naples. Consequently during the first hundred years the search concentrated on the most important buildings—the city's Forum, its theaters and its largest houses. After 1860 the new kingdom of Italy assigned direction of the excavation to Giuseppe Fiorelli, and he instituted a systematic uncovering of the whole city—street by street and building by building. But the true rebirth of Pompeii did not begin until about 50 years ago, when, with the discovery of the beautiful House of the Vetti, it was decided not to remove the city's treasures but to keep the decorations on the site and restore the houses so far as possible to their original condition. Since World War II the work has been helped immensely by funds made available by the Italian Government through the Fund for the Development of the South, which is interested in using the rich volcanic soil covering Pompeii for land reclamation in the surrounding area. More than 600,000 cubic meters of earth have been taken from the diggings and dumped on the marshes in the valley of the Sarno River and on the slopes of Vesuvius. With this impetus, nearly two thirds of the city's 165,000 acres have now been excavated. We can see much of the life and history of Pompeii in fine and rich detail.

Pompeii is intimately associated with the history of the Campania district, a region below Rome on the western coast along the gulfs of Naples and Salerno. The city was founded some time in the ninth or eighth century B.C. by the Oscan farmers of the region, who needed a marketplace and seaport. Because of its strategically important position, Pompeii became a prize in contests for control, not only among the Italic peoples but also on the part of the expanding Greeks. In the seventh and sixth centuries B.C. the Etruscans of mid-Italy



POMPEII IS LOCATED in the map at left. The map at right shows the plan of the city. The numbers indicate Forum (1), Capitolium (2), official halls (3), Comitium (4), market (5), Temple of Apollo (6), treasury (7), bureau of weights and measures (8), basilica (9), wool-industry building (10), sanctuary of the public lares (11), Temple of Vespasian (12), Sanctuary of Venus (13),

and the Greeks vied for rule of the area, and there are clear traces of their successive periods of domination in the sequences of architecture in Pompeii. Toward the end of the fifth century B.C. the Samnite people of Italy won control of Campania from the Etruscans, and Pompeii became an Italic commune. When Rome rose to power, Pompeii joined it as a federated city, but in 91 B.C. it rebelled for greater rights. After a long siege the town was taken by the army of Sulla. Thereafter Pompeii was a Roman city, but to the end of its life it retained its character as a mixture of Italic and Greek cultures.

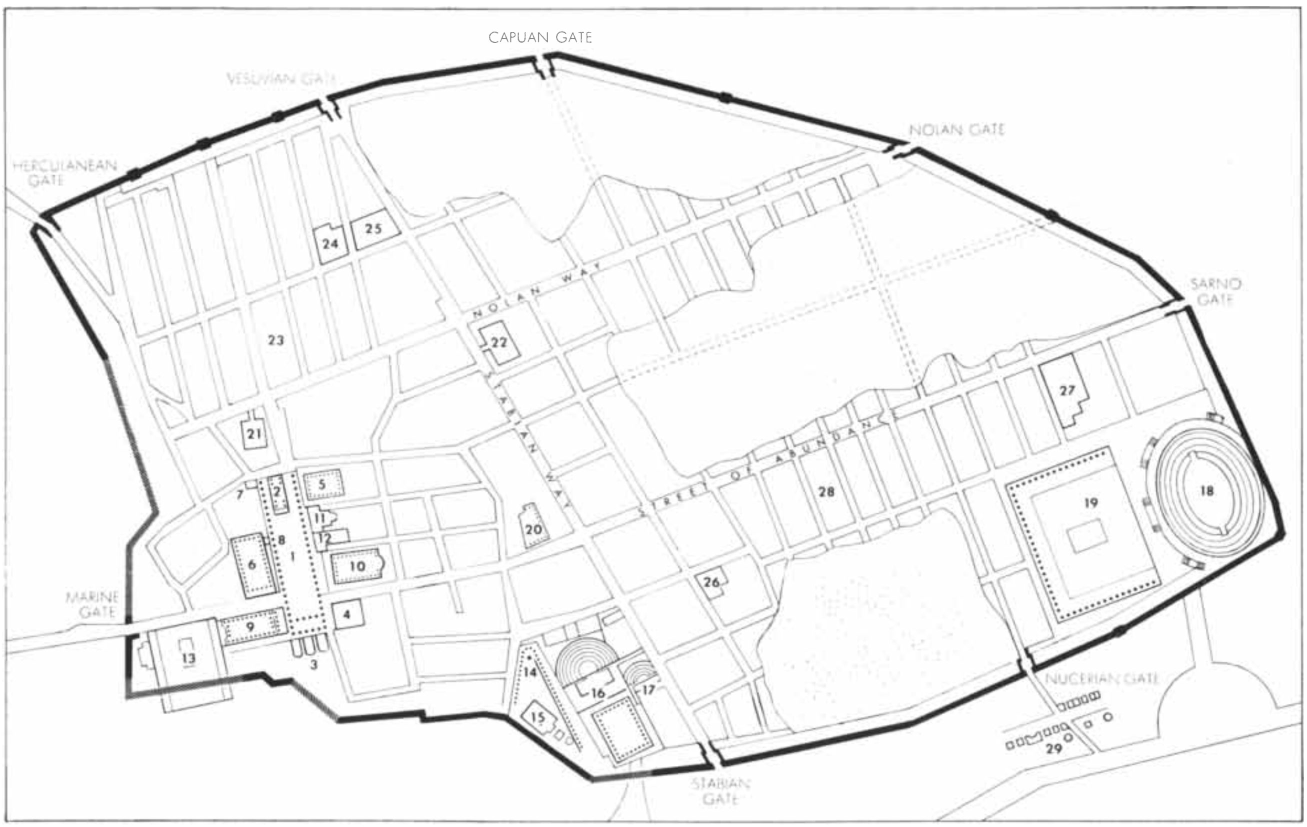
Its structures and institutions show that Pompeii was a healthy, well-managed city, whose citizens loved it so well that they took pains to preserve its form from century to century without drastic change. The crown of the city's pride was a beautiful porticoed forum with temples and public buildings, and statues of which a much larger city could have been proud. The town had a flourishing show district boasting two theaters, an amphitheater and two palaestras (sports parks). Three great public baths were distributed at strategic points in the city. It had a well-articulated street network, with an aqueduct and public fountains at every street crossing and even safety islands for pedestrians. There were inns and stables for country folk who came to town to sell their produce and merchandise. There was a bureau for the control of weights and measures. It was a town with well-ordered arrangements for living and conducting business, public and private.

Nor were the residents burdened with taxes. Possessing no great resources for public revenue, the city used to appeal to its richest and most influential citizens to meet its main needs. The town repaid these patrons with the honor of public office, of statues and honorary inscriptions in the Forum, privileges at the great public spectacles and special burial plots for their families. We know that Pompeii owed its large palaestra to the last will of a certain Vibius Vinicio; its amphitheater and the smaller of its two theaters to the generosity of C. Quintius Valgo; restoration and enlargement of the larger theater to the Olconius family; an imposing wool textile building to the private munificence of a lady Eumachia, and restoration of the Sanctuary of Isis to one Numerius Popipidius Celsino. Annual private donations also provided for many current public expenses, such as the spectacles in the amphitheater, the sacred festivals and maintenance of the sanctuaries.

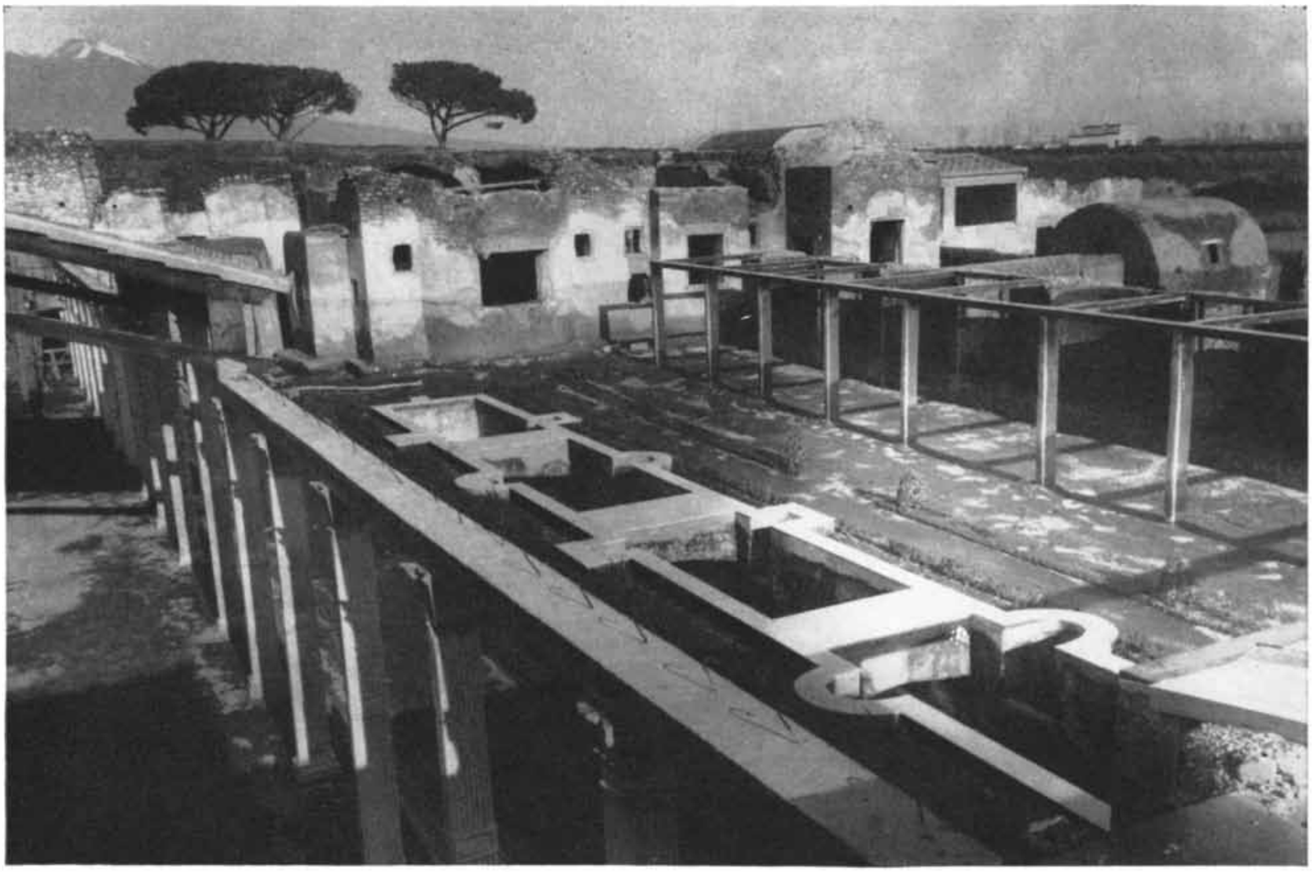
The public life of Pompeii revolved around three principal centers: the Forum, the theaters and amphitheater and the great palaestra. Besides these, the three public baths of course also played an important, if less formal, part in the life of the city.

Pompeii's Forum is one of the most beautiful of all ancient city squares [*see photograph on page 68*]. It stands against a background of the wooded chain of the Castellammare Mountains, with Vesuvius towering almost directly overhead. The Forum is modeled after Italian market squares, but it is also adorned with the grace of Greek colonnades. As a sacred place, the square was barred to vehicles and reserved for pedestrians alone.

The north end of the square was dominated by a temple known as the Capitolium, dedicated to the tutelary deities Jove, Juno and Minerva; on the south side stood the halls of the city officials and the Council of Notables—almost as



triangular forum of the theater district (14), Doric temple (15), large theater (16), small theater (17), amphitheater (18), palaestra (19), Stabian Baths (20), Forum Baths (21), Central Baths (22). **Famous houses of Pompeii are those of the Faun (23), the Vetti (24), the Gilt Cupids (25), Menander (26), Giulia Felix (27) and the Fruit Arbor (28). Outside walls of the city is its necropolis (29).**



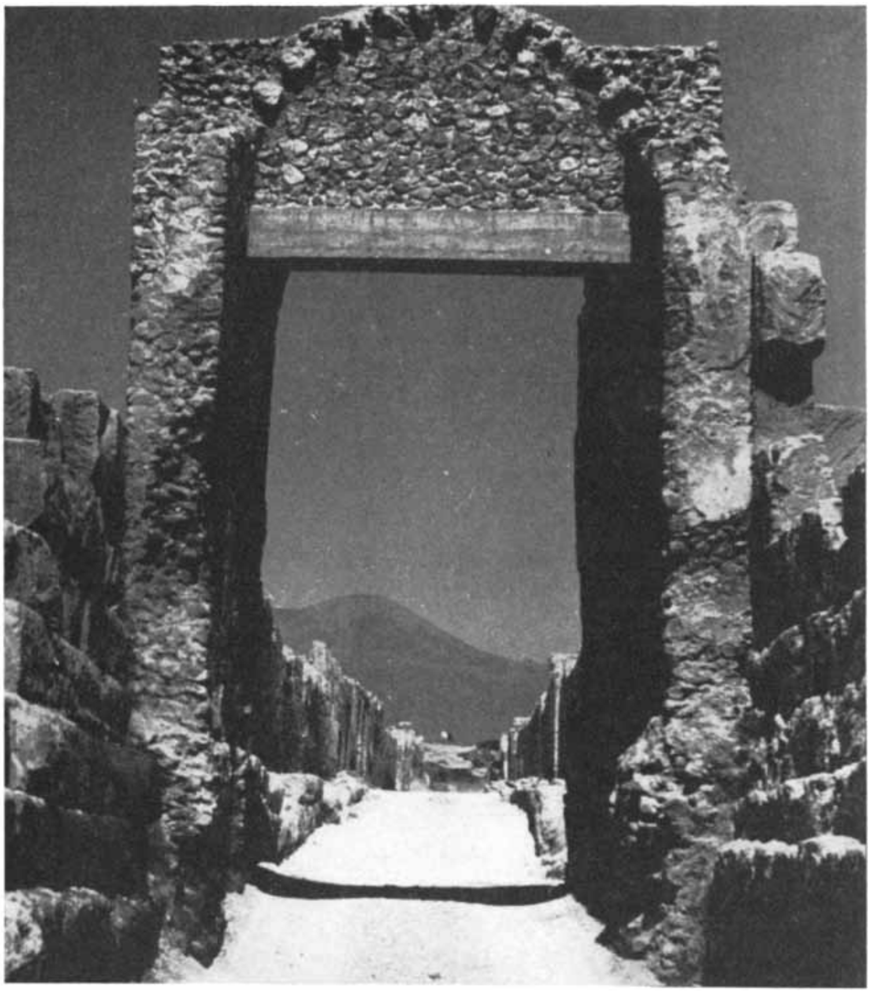
VILLA OF GIULIA FELIX lies on the outskirts of Pompeii. At the time the city was buried the owner of this villa was in the process of converting part of it into baths, shops and apartments. In the center is the garden of the villa and a pond for breeding fish.

HOUSE OF MARCUS OBELLIUS FIRMO is seen from its central court, or atrium. The houses of wealthy Pompeians were characterized by a traditional atrium, portico and bedrooms to which were added, under Greek influence, a peristyle, garden and other rooms.

if to counterpose human authority to divine authority. On the east side of the square were the hall of the Comitium, where the electors met annually to vote for town officers, and a covered food market. Opposite, on the west side, were the great temple of Apollo, the city treasury, the bureau of weights and measures and the basilica, a very large roofed hall with three naves which was the seat of the tribunal and a business meeting place. Sandwiched among these important centers were other buildings fronting on the square, some no less imposing: the magnificent headquarters for the wool industry built by the benefactress Eumachia; the sanctuary of the public lares, dedicated to the protecting gods of the city; the temple of Vespasian, dedicated to the rites of the Roman emperor. Not far from the square was the sanctuary of Venus, the protective goddess of the city. From some paintings found in the town we know also that the Forum of Pompeii was not entirely restricted to sacred or official activities: the shadows of its porticoes teemed with itinerant peddlers purveying sandals, ironware and foodstuffs to crowds of customers.

The theatrical district of Pompeii occupied a happy and convenient location against a hillside. On a high bastion there is a triangular open area with a Doric temple which, like an acropolis, commands the Sarno River valley and the port of the city. Off the triangle the two theaters lean against the hill. The large theater has a great porticoed square, originally used as a lobby and later as a school and shelter for gladiators. Behind the stage is a stupendous backdrop formed by the Lattari Mountains. The smaller theater, or odeon, had a roof sheltering the seats, thereby representing a transition from the ancient to the modern theater.

Pompeii's amphitheater is one of the earliest yet found—a pioneer in this form of architecture. Although it does not approach the grandeur of the Colosseum in Rome, it is an elegant and graceful structure, with an oval arena, arcades, external stairways and a series of little arches crowning the highest tier of seats. The amphitheater seated about 20,000 people, and it stood in a park against a wall of the city, where it was easily accessible by many roads to spectators from nearby towns as well as Pompeians. The citizens' passion for the gladiatorial games is attested by posters painted on their house fronts, by highly decorated arms found in the gladiatorial school and by scribblings on the walls by youngsters



NUCERIAN GATE was discovered during excavations after World War II. It stood athwart the road to Nuceria, a city to the east of Pompeii. Beyond gate is city's old cemetery.

MAUSOLEUMS line the road from Pompeii to Nuceria. These tombs are decorated with statues or busts of the dead. They were made largely of tufa, a soft stone of volcanic origin.

depicting memorable contests between gladiatorial champions and between men and wild beasts.

Alongside the amphitheater stands the large palaestra, main playground of the city. It is a great rectangular athletic field with a huge swimming pool in the center. Porticoes surrounded the field on three sides, and it was shaded by a double row of plane trees (whose existence has been deduced from the cavities left in the earth by their roots). Here the young men of the city periodically showed their prowess in racing, wrestling, boxing and swimming. These games were a Greek rather than an Italic tradition of sport, and Pompeii shows the two traditions side by side in sharp contrast: on one side the amphitheater, an arena of bloody spectacles; on the other the palaestra, where youth learned the lessons of the athletic field.

The three public baths of Pompeii are particularly noteworthy because they show the development of this Roman institution from the very beginning. The oldest of the three, the so-called Stabian Baths, dates back to the third century B.C. and is the earliest example of public-bath architecture yet found in Italy. It includes a small palaestra and rooms for exercise and recreation; the baths were originally heated by bronze braziers. The Stabian Baths stood at the intersection of the two main streets that quartered the city—the "Times Square" of Pompeii. The second public bath was near the Forum: it is known as the Forum Baths. The third, called the Central Baths, was being constructed at a convenient crossroads in another quarter of the city, but it had not quite been completed when Vesuvius erupted. This building, even more elaborate than the Stabian Baths, was to have been heated by a system of radiant heating through the floors and honeycombed walls.

But Pompeii's greatest gift to history and social science is its houses. Other ancient cities have furnished fine examples of temples, baths, theaters and governmental buildings, but nowhere else can we see so complete a documentation of ancient home life as at Pompeii and the nearby town of Herculaneum, also buried by Vesuvius's eruption. At Pompeii we have houses of various classes, perfectly preserved in the details of structure and decoration, and we can follow the evolution of home styles through at least three or four centuries. The evolution begins with the Italic *domus*, characterized by a central court (atrium), a living room, bedrooms and an attached orchard; on this basic plan

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COLUMNS OF PALAESTRA, or sports park, are exacavated from drifts of volcanic material. These columns were part of a portico which stood on three sides of a large athletic field.

there was later grafted the grace and beauty of Hellenistic house architecture—a peristyle and a garden, living and reception rooms, decoration of the walls and floors with paintings and mosaics. One of the finest examples of this happy union of Italic and Hellenistic architecture in Pompeii is the House of the Faun, with its two atriums, two peristyles, a bath, guest quarters and a reception room whose floor was paved with a great mosaic, picturing the battle of Alexander, which is regarded as perhaps the most spectacular work of artistic composition preserved from the ancient world.

There are many other mansions in Pompeii which have become famous for their richness and sumptuousness. Among these, of course, is the House of the Vetti, built in the first century of the Roman Empire by a member of the *nouveaux riches* who poured his wealth into a joyful and ostentatious abode. His theatrical house was opulent in color, in works of art and in the play of water in nymphean nooks and fish ponds. In the same genre is the House of the Gilt Cupids, with a peristyle raised like the stage of a theater above a garden strewn with statuettes and reliefs. There is also the House of Menander, so called because its owner (who, like Nero, did not hide his literary predilections for the Greek theater) had a portrait of the Greek dramatist painted in a sort of chapel sacred to the Muses, along with other paintings of major poets.

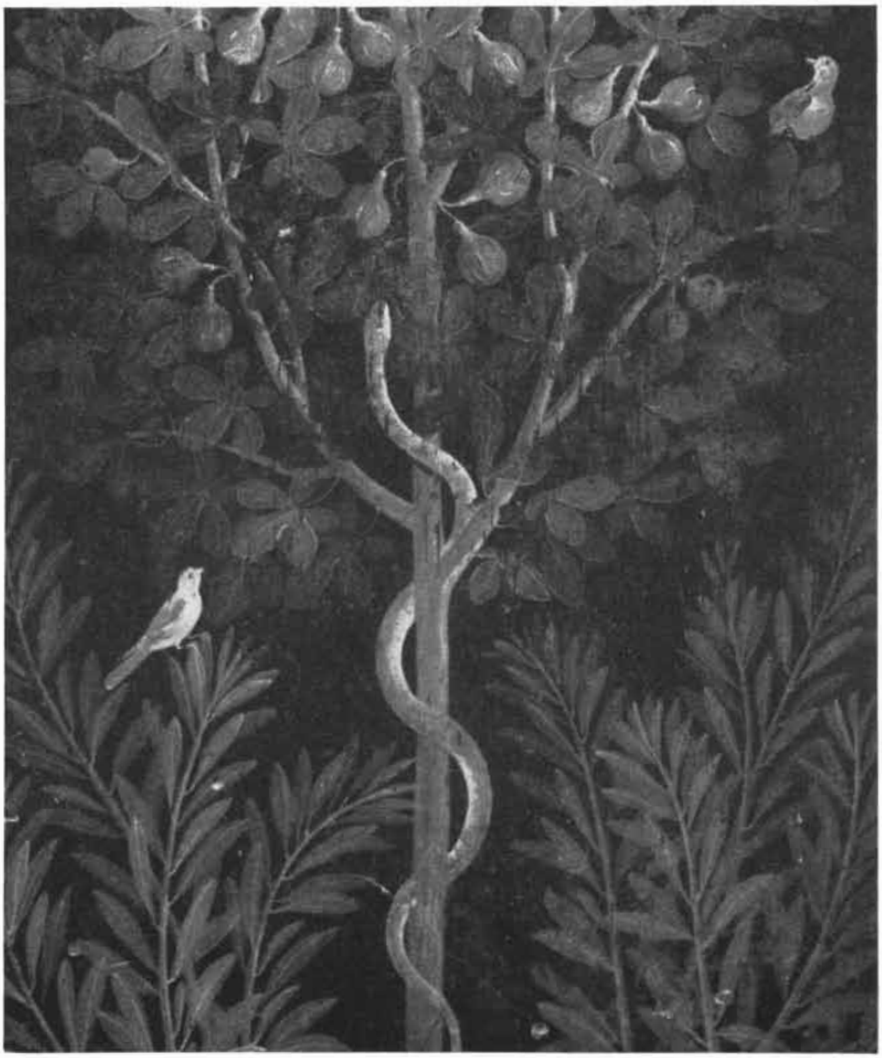
After the damaging earthquake of 62 A.D. some owners of the great man-

STONE FOUNTAIN stands beside a street intersection. In the middle of some Pompeian streets are islands where pedestrians could stop for traffic while crossing to the other side.

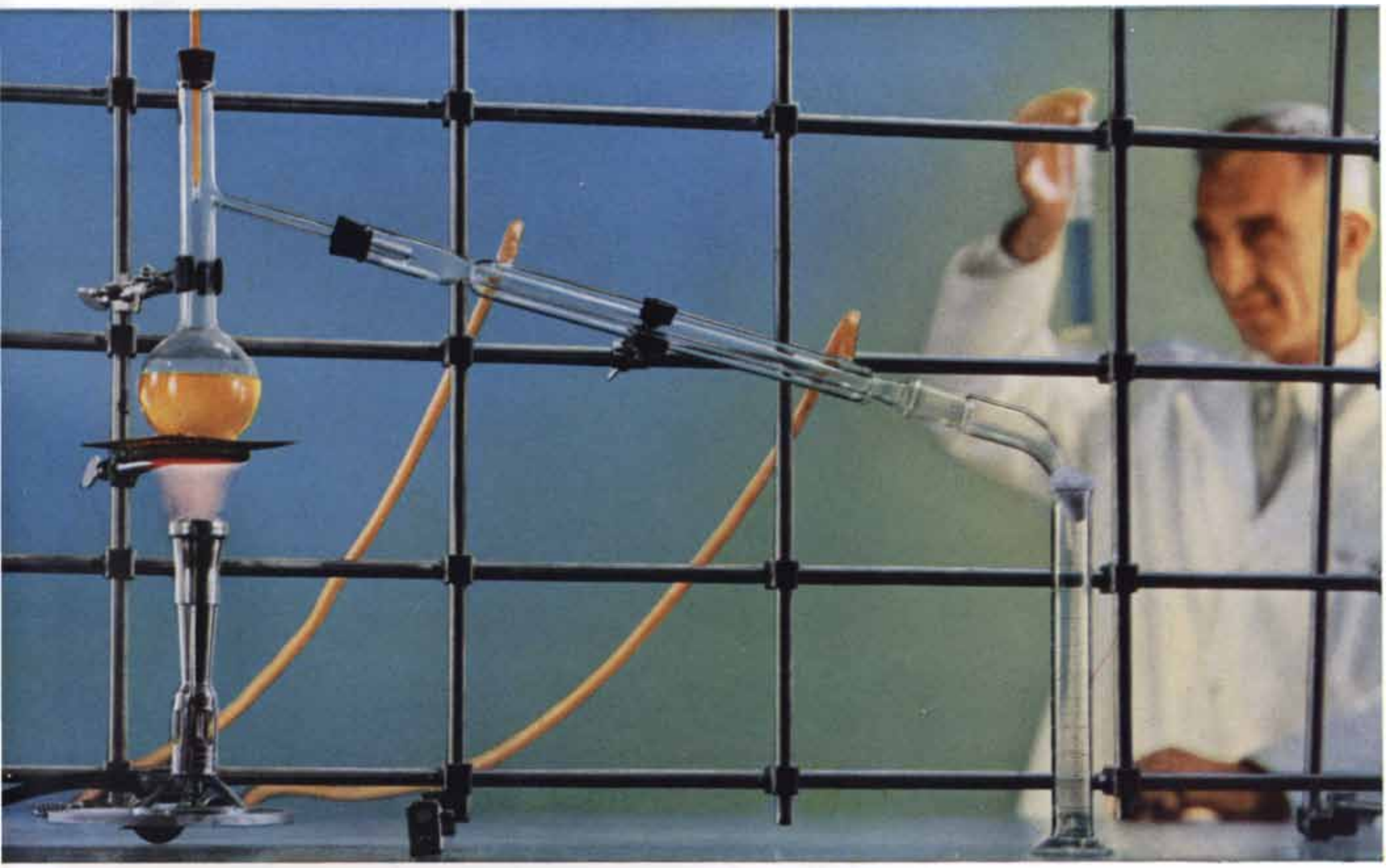
sions, overwhelmed by the costs of restoration and by the city's economic crisis, were induced to sell or rent part of their houses for shops to help restore the city's commercial life. Among these patricians was a singular woman named Giulia Felix, who had a rich villa with a vast orchard on the outskirts of town. She converted part of her home into a paying public bath (the city's baths having closed) and boldly advertised her commercial enterprise with a sign on the gate of her estate.

The Villa of Giulia Felix is a recent find. During the past 15 years we have devoted ourselves to clearing the southeastern quarter of the city, beyond the theater section, and the city's southern wall and adjoining suburban area. In the newly uncovered quarter we have found the typical pattern of a city's outskirts: widely spaced shopping centers, villas, large orchards and middle-class suburban homes. Especially interesting among the latter is the House of the Fruit Arbor, which contains wall paintings not only of fig, pear, plum and arbutus trees, but also a lemon tree—the first indication that citrus fruit was cultivated in Campania in ancient times.

The most important discoveries in the postwar excavation period have been the Nucerian Gate (the seventh gate of the city) and the nearby cemetery. Outside the gate, along an arterial road which connected Pompeii with Nuceria, a major city of south Campania, we found a long series of tombs, ranging up to stately mausoleums. Almost all have commemorative inscriptions and statues or busts in stone, marble or tufa (soft volcanic stone, the principal building material of Pompeii). Here in these proud tombs, with their dignified statues of magistrates and freedmen, we can see best epitomized the serene, normal career of the city whose life was so dramatically ended in 79 A.D.



WALL PAINTING was found in the House of the Fruit Arbor. The tree in the painting is a fig. Other paintings decorating the same house depict pear, plum, arbutus and lemon trees.



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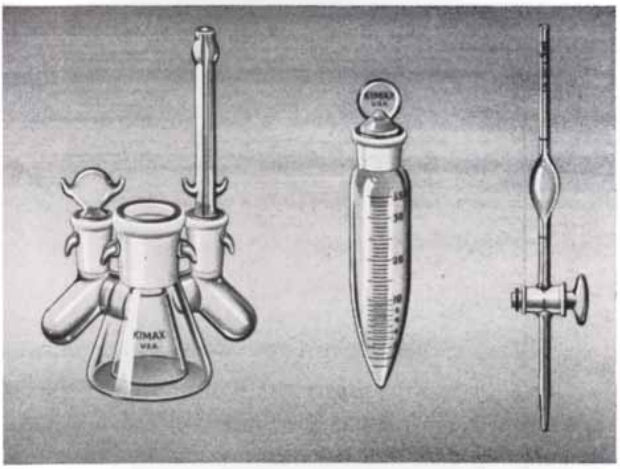

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THE ECOSPHERE

By examining how all living organisms on the earth interact with one another and with their inorganic environment we are able to estimate the amount of life our planet can support

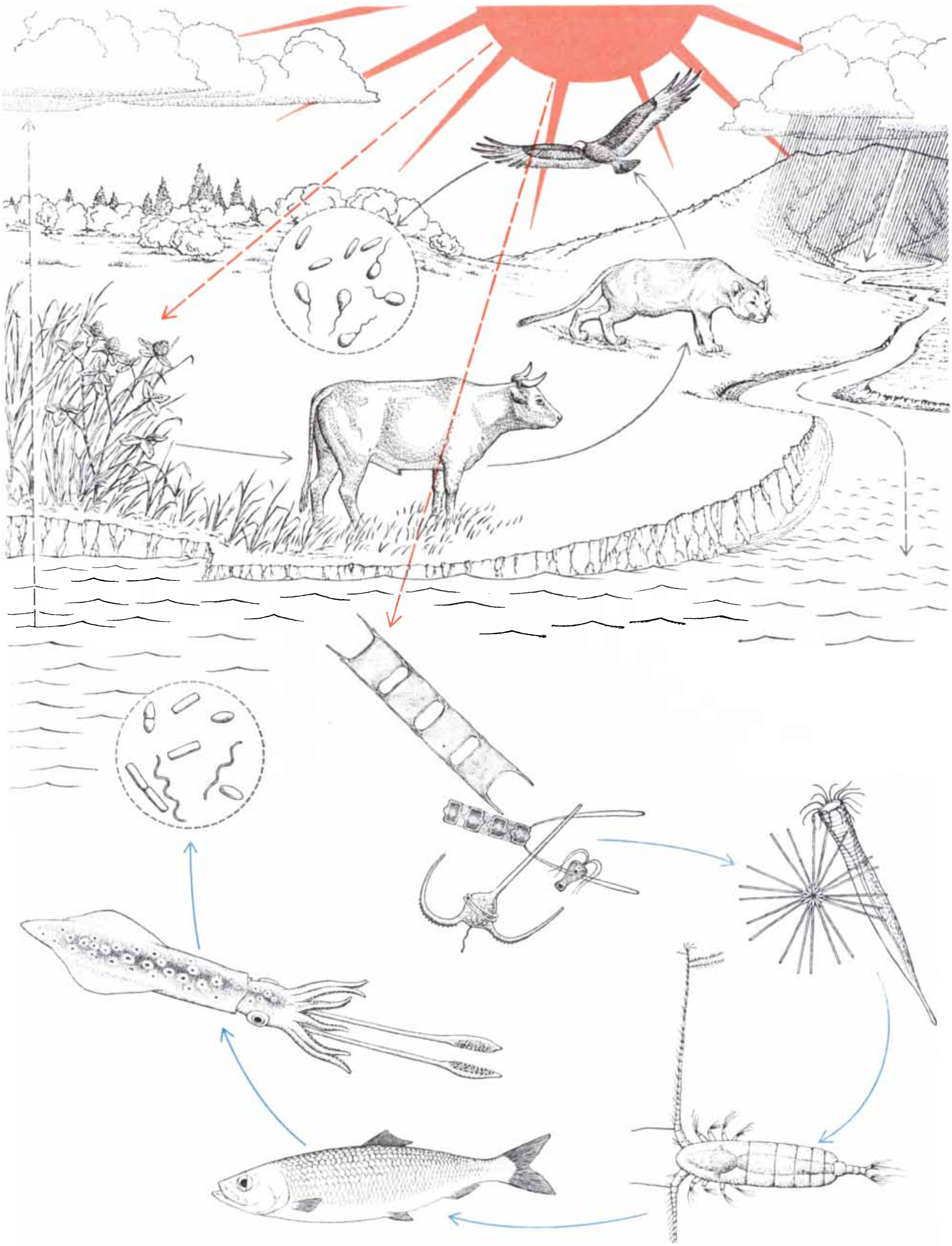
by LaMont C. Cole

Probably I should apologize for using a coined word like "ecosphere," but it seems nicely to describe just what I want to discuss. It is intended to combine two concepts: the "biosphere" and the "ecosystem."

The great 19th-century French naturalist Jean Lamarck first conceived the idea of the biosphere as the collective totality of living creatures on the earth, and the concept has been taken up and developed in recent years by the Russian geochemist V. I. Vernadsky. The word "ecosystem" means a self-sustaining community of organisms—plants as well as animals—taken together with its inorganic environment.

Now all these are interdependent. Animal life could not exist without plants nor plants without animals, which supply them with carbon dioxide. Even the composition of the inorganic environment depends upon the cyclic activity of life. Photosynthesis by the earth's plants would remove all of the carbon dioxide from the atmosphere within a year or so if it were not returned by fires and by the respiration of animals and other consumers of plants. Similarly nitrogen-fixing organisms would exhaust all of the nitrogen in the air in less than a million years. And so on. The conclusion is that a self-sustaining community must contain not just plants, animals and nitrogen-fixers but also decomposers which can free the chemicals bound in proto-

THE AMAZON, one of whose mouths is shown in this aerial photograph, plays an important role in the earth's circulation of water. Together with the Congo it carries more than 10 per cent of the 9,000 cubic miles of water that flow into the sea every year.



ENERGY CYCLES of the ecosphere are powered by the sun. Land plants bind solar energy into organic compounds utilized successively (*gray arrows*) by herbivore, carnivore and scavenger; residual compounds are decomposed by bacteria. Energy fixed by microscopic sea plants passes through a similar "food chain" (*blue arrows*). In the water cycle (*broken arrows*) water evaporated from the sea is precipitated on land and used by living organisms, eventually returning to the sea bearing minerals and organic matter.

plasm. It is very fortunate from our standpoint that some microorganisms have solved the biochemical trick of decomposing chitin, lignins and other inert organic compounds that tie up carbon.

A community must consist of producers or accumulators of energy (green plants), primary consumers (fungi, microorganisms and herbivores), higher-order consumers (carnivorous predators, parasites and scavengers), and decomposers that regenerate the raw materials.

Communities vary, of course, all over the world, and each ecosystem is a composite of the community and the features of the inorganic environment that govern the availability of energy and essential chemicals and the conditions that the community members must tolerate. But the system that I wish to consider here is not a local one but the largest possible ecosystem: namely, the sum total of life on earth together with the global environment and the earth's total resources. This is what I call the ecosphere. My purpose is to reach some conclusions on such questions as how much life the earth can support.

Organisms living on the face of the earth as it floats around in space can receive energy from several sources. Energy from outside comes to us as sunlight and starlight, is reflected to us as moonlight, and is brought to earth by cosmic radiation and meteors. Internally the earth is heated by radioactivity, and it is also gaining heat energy from the tidal friction that is gradually slowing our rotation. On top of this man is tapping enormous amounts of stored energy by burning fossil fuels. But all these secondary sources of energy are infinitesimal compared to our daily sunshine, which accounts for 99.9998 per cent of our total energy income.

This supply of solar energy amounts to 13×10^{23} gram-calories per year, or, if you prefer, it represents a continuous power supply at the rate of 2.5 billion billion horsepower. About one third of the incoming energy is lost at once by being reflected back to space, chiefly by clouds. The rest is absorbed by the atmosphere and the earth itself, to remain here temporarily until it is reradiated to space as heat. During its residence on earth this energy serves to melt ice, to warm the land and oceans, to evaporate water, to generate winds and waves and currents. In addition to these activities, a ridiculously small proportion—about four hundredths of 1 per cent—of the solar energy goes to feed the metabolism of the biosphere.

Practically all of this energy enters the biosphere by means of photosynthesis. The plants use one sixth of the energy they take up from sunlight for their own metabolism, making the other five sixths available for animals and other consumers. About 5 per cent of this net energy is dissipated by forest and grass fires and by man's burning of plant products as fuel.

When an animal or other consumer eats plant protoplasm, it uses some of the substance for energy to fuel its metabolism and some as raw materials for growth. Some it discharges in broken-down form as metabolic waste products: for example, animals excrete urea, and yeast releases ethyl alcohol. And a large part of the plant material it ingests is simply indigestible and passes through the body unused. Herbivores, whether they are insects, rabbits, geese or cattle, succeed in extracting only about 50 per cent of the calories stored in the plant protoplasm. (The lost calories are, however, extractable by other consumers: flies may feed on the excretions or man himself may burn cattle dung for fuel.)

Of the plant calories consumed by an animal that eats the plant, only 20 to 30 per cent is actually built into protoplasm. Thus, since half of its consumption is lost as waste, the net efficiency of a herbivore in converting plant protoplasm into meat is about 10 to 15 per cent. The secondary consumers—*i.e.*, meat-eaters feeding on the herbivores—do a little better. Because animal protoplasm has a smaller proportion of indigestible matter than plants have, a carnivore can use 70 per cent of the meat for its internal chemistry. But again only 30 per cent at most goes into building tissue. So the maximum efficiency of carnivores in converting one kind of meat into another is 20 per cent.

Some of the consequences of these relationships are of general interest and are fairly well known. For example, 1,000 calories stored up by the algae in Cayuga Lake can be converted into protoplasm amounting to 150 calories by small aquatic animals. In turn, smelt eating these animals produce 30 calories of protoplasm from the 150. If a man then eats the smelt, he can synthesize six calories worth of fat or muscle from the 30; if he waits for the smelt to be eaten by a trout and then eats the trout, the yield shrinks to 1.2 calories. If we were really dependent on the lake for food, we would do well to exterminate the trout and eat the smelt ourselves, or, better yet, to exterminate the smelt and live on planktonburgers. The same principles, of course, apply on land. If man is really determined to support the largest possible populations of his kind, he will have to shorten the food chains leading to himself and, so far as practicable, turn to a vegetarian diet.

The rapid shrinkage of stored energy as it passes from one organism to another serves to make the study of natural communities a trifle more simple for the ecologist than it would otherwise be. It explains why food chains in nature rarely contain more than four or five links. Thus in our Cayuga Lake chain the trout was the third animal link and man the fourth. Chains of the same sort occur in the ocean, with, for example, a tuna or cod as the third link and perhaps a shark or a seal replacing man as the fourth link. Now if we look for the fifth link in the chain we find that it takes something like a killer whale or a polar bear to be able to subsist on seals. As to a sixth link—it would take quite a predator to make its living by devouring killer whales or polar bears.

We could, of course, trace food chains in other directions. Each species has its parasites that extort their cut of the stored energy, and these in turn support other parasites down to the point where there is not enough energy available to support another organism. Also, we should not forget the unused energy contained in the feces and urine of each animal. The organic matter in feces is often the basic resource of a food chain in which the next link may be a dung beetle or the larva of a fly.

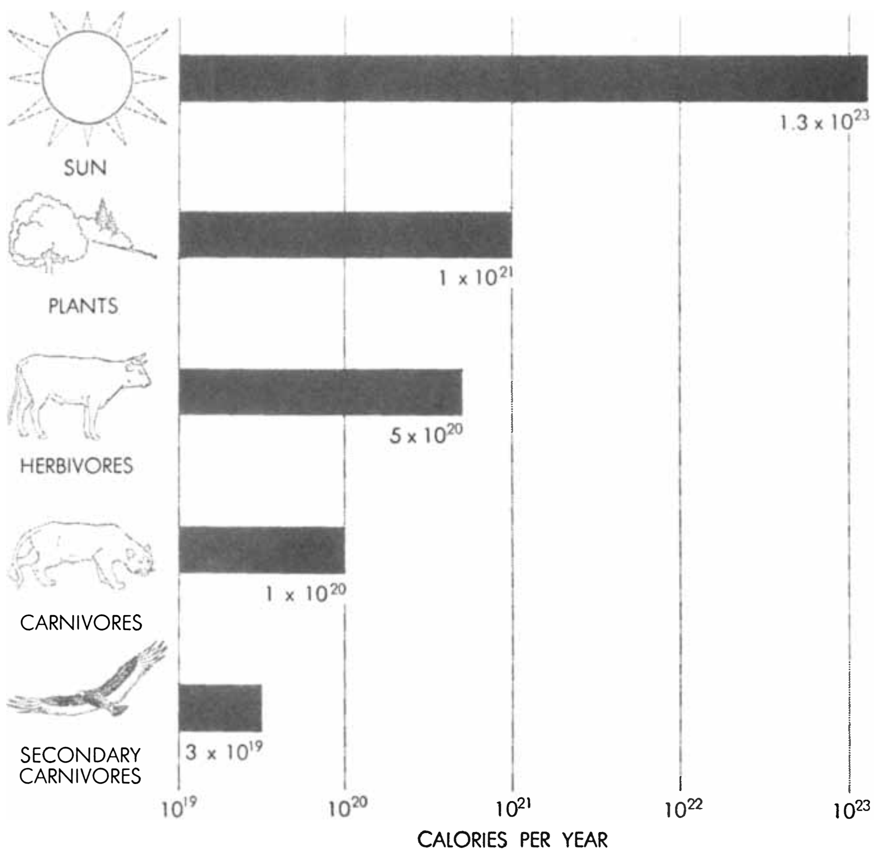
I estimate that the maximum amount of protoplasm of all types that can be produced on earth each year amounts to 410 billion tons, of which 290 billion represent plant growth and the other 120 billion all of the consumer organisms. We see, then, that the availability of energy sets a limit to the amount of life on earth—that is, to the size of the biosphere. This energy also keeps the nonliving part of the ecosphere animated, largely through the agency of moving water, which is the single most important chemical substance in the physiology of the ecosphere.

Each year the oceans evaporate a quantity of water equivalent to an average depth of one meter. The total evaporation from land and bodies of fresh water is one sixth of the evaporation from the sea, and at least one fifth of this evaporation is from the transpiration of plants growing on land. The grand total of water evaporated annually is roughly 100,000 cubic miles, and this must be roughly the annual precipitation. The precipitation on land exceeds the evaporation by slightly over 9,000 cubic miles, which therefore represents the annual runoff of water from land to sea. It is astonishing to me to note that more than one tenth of this total runoff is carried to the sea by just two rivers—the Amazon and the Congo.

Precipitation supplies nonmarine organisms with the water which they require in large quantities. Protoplasm averages at least 75 per cent water, and plants require something like 450 grams of water to produce one gram of dry organic matter. The water moving from land to sea also erodes the land surface and dissolves soluble mineral matter. It brings to the plants the chemical nutrients that they require and it tends to level the land surface and deposit the minerals in the sea. At present the continents are being worn down at an average world-wide rate of one centimeter per century. The leveling process, however, apparently has never gone on to completion on the earth. Geological uplift of the land always intervenes and brings marine sediments above sea level, where the cycle can begin again.

The rivers of the world are now washing into the seas some four billion tons of dissolved inorganic matter a year, about 400 million tons of dissolved organic matter and about five times as much undissolved matter. The undissolved matter represents destruction of the land where organisms live, but the dissolved material is of greater interest, because it includes such important chemicals as 3.5 million tons of phosphorus, 100 million tons of potassium and 10 million tons of fixed nitrogen. In order to say what these losses may mean to the biosphere we must review a few facts about the chemical composition of the earth and of organisms.

Every organism seems to require at least 20 chemical elements and probably several others in trace amounts. Some of the organisms' requirements are rather surprising. *Penicillium* is said to need traces of tungsten, and the common duckweed demands manganese and the rare earth gallium. There is a European pansy which needs high concentrations of zinc in the soil, and several plants in different parts of the world are so hungry for copper that they help prospectors to find the mineral. Many organisms have fantastic abilities to concentrate the necessary elements from dilute media. The sea-squirts have vanadium in their blood, and the liver of the edible scallop contains on a dry-weight basis one tenth of 1 per cent of cadmium,



UTILIZATION OF SOLAR ENERGY decreases with each step along the food chain. These bars (on a logarithmic scale) show that plants use only .08 per cent of energy reaching the atmosphere; plant-eaters use only part of this fraction and flesh-eaters even less.

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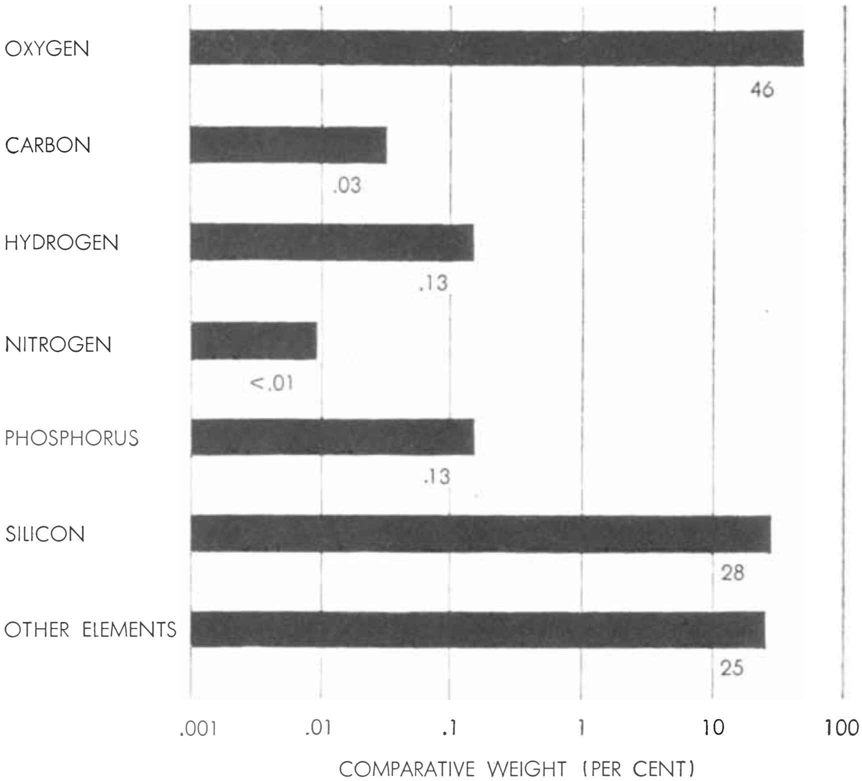
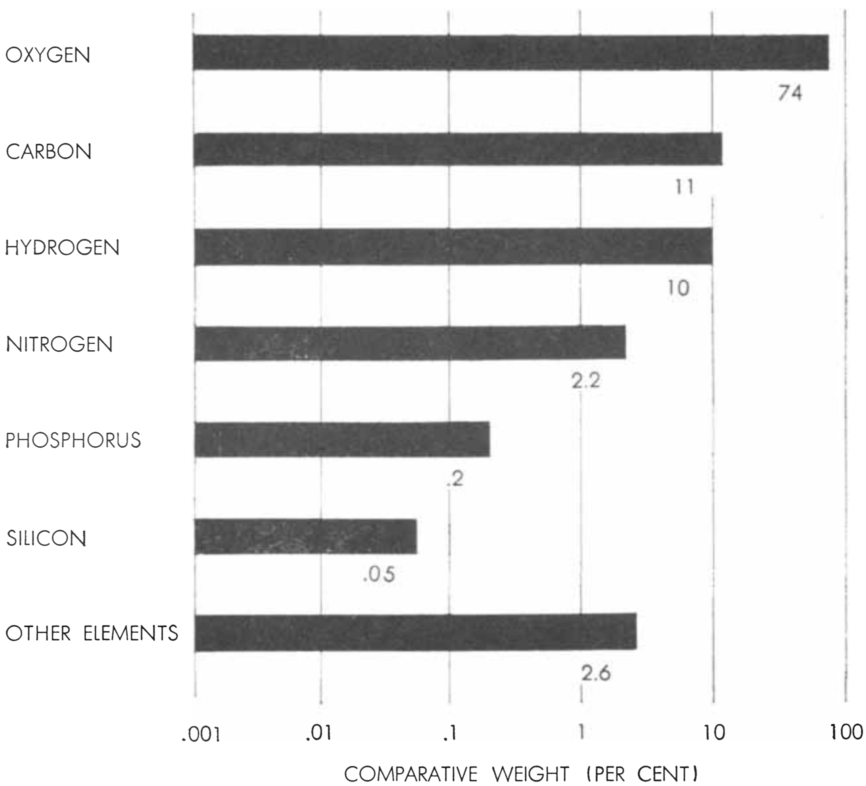


ESTIMATED RELATIVE ABUNDANCE of elements in the earth and its atmosphere (*above*) and in living matter (*below*) is compared in these charts; the scale is logarithmic. Silicon, with many stable compounds, is abundant on earth but rare in living organisms. Nitrogen, rare on earth, is important to life, making up as much as 18 per cent of proteins.



although the amount of this element in sea water is so small that it cannot be detected by chemical tests.

But the exotic chemical tastes of organisms are comparatively unimportant. Their main needs can be summed up in just five words—oxygen, carbon, hydrogen, nitrogen and phosphorus, which account for more than 95 per cent of the mass of all protoplasm. Oxygen is the most abundant chemical element on earth, so we probably do not need to be concerned about any absolute deficiency of oxygen. But nitrogen is a different matter. Whereas protein, the main stuff of life, is 18 per cent nitrogen, the relative abundance of this element on the earth is only one 10,000th of the earth's mass. It is apparent that our land forms of life could not long tolerate a net annual loss of 10 million tons of fixed nitrogen to the sea. Fortunately this nitrogen loss from land is reversible, so that we can speak of a "nitrogen cycle." Organisms in the sea convert the fixed nitrogen into ammonia, a gas which can return to land via the atmosphere.

Carbon also is not in too abundant supply, for it amounts to less than three parts in 10,000 of the total mass of the earth's matter. But once again the biosphere profits from the fact that carbon can escape from the oceans as a gas—carbon dioxide. This gas goes through a complex circulation in the atmosphere, being released from the oceans in tropical regions and absorbed by the ocean waters in polar regions. Because some carbon is deposited in ocean sediments as carbonates, there is a net loss of carbon from the ecosphere. But there seems to be no danger that a shortage of this element will restrict life. The atmosphere contains 2,400 billion tons of carbon dioxide, and at least 30 times that much is dissolved in the oceans, waiting to be released if the atmosphere should become depleted. Volcanoes discharge carbon dioxide, and man is burning fossil fuels at such a rate that he has been accused of increasing the average carbon dioxide content of the atmosphere by some 10 per cent in the last 50 years. In addition, lots of limestone, which is more than 4 per cent carbon dioxide, has been pushed up from ancient seas by uplifts of the earth.

The story of phosphorus appears somewhat more alarming. This element accounts for a bit more than one tenth of 1 per cent of the mass of terrestrial matter, is enriched to about twice this level in plant protoplasm and is greatly enriched in animals, accounting for more than 1 per cent of the weight of the human body. As a constituent of nucleic

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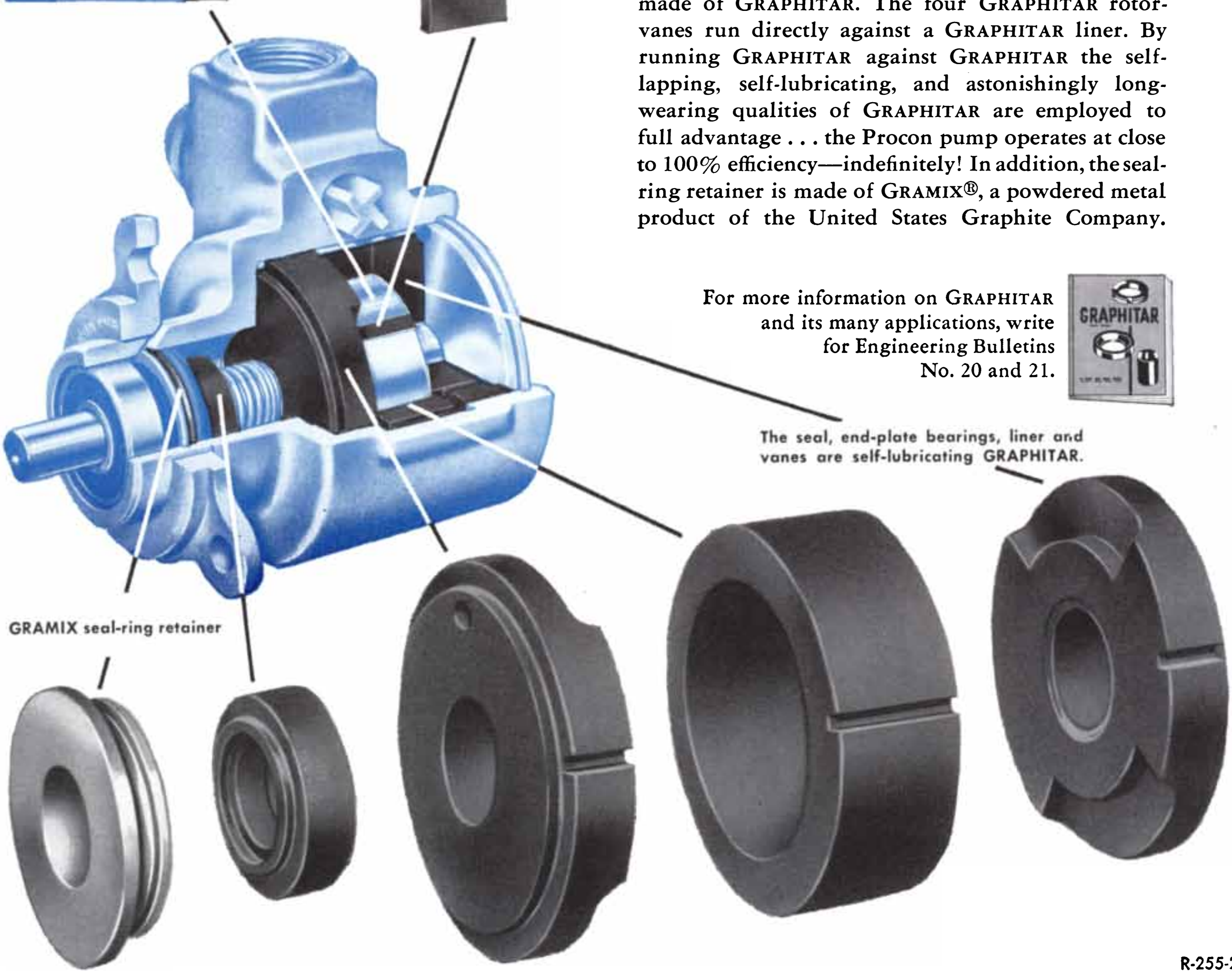

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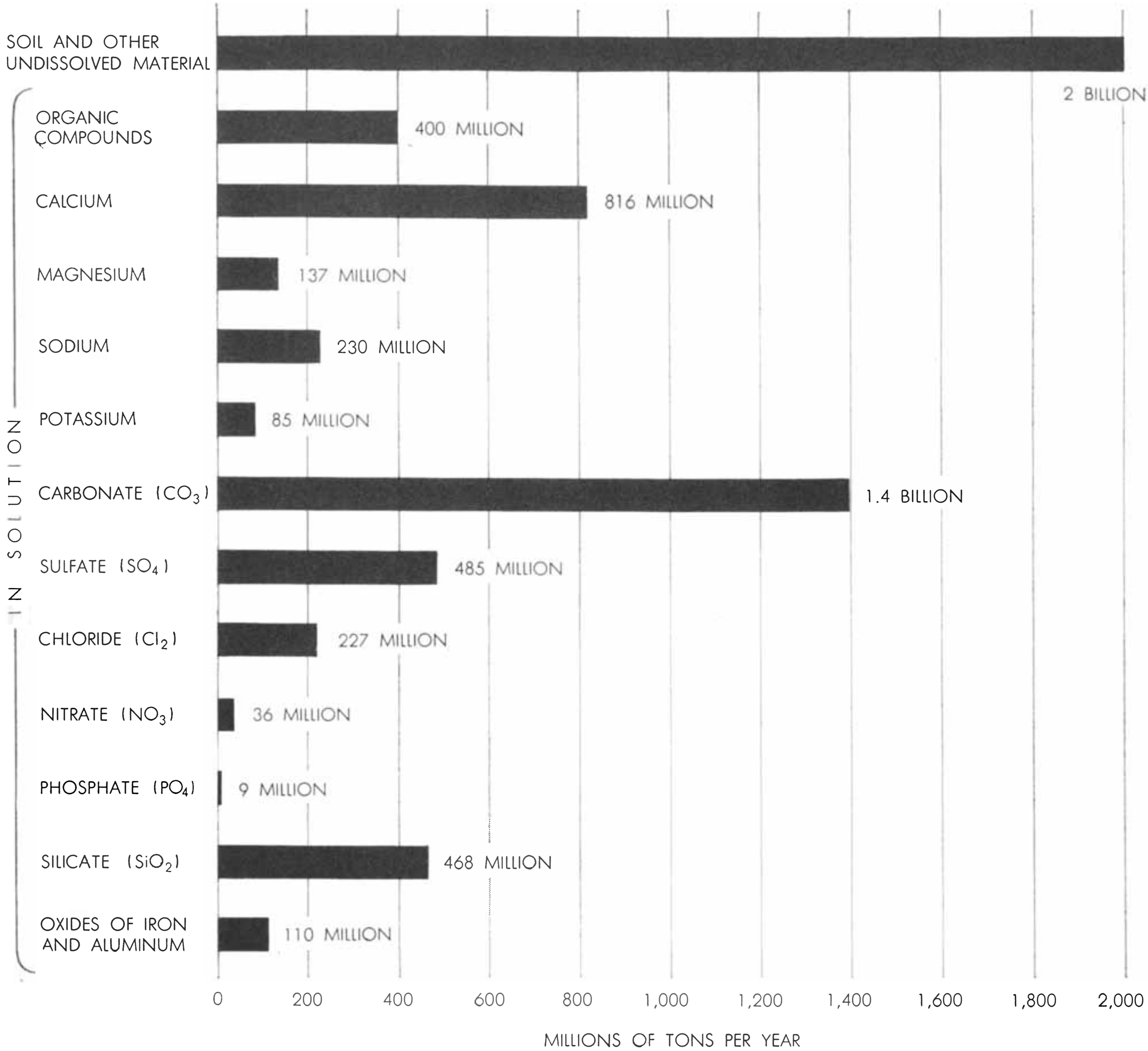

ANNUAL LOSS of minerals and organic matter washed into the sea amounts to billions of tons. Much nitrogen and carbon eventually return to the land via the atmosphere; the loss of phosphate is more serious since almost all of it remains in the oceans.

acids it is indispensable for all types of life known to us. But many agricultural lands already suffer a deficiency of phosphorus, and a corn crop of 60 bushels per acre removes 10 per cent of the phosphorus in the upper six inches of fertile soil. Each year 3.5 million tons of phosphorus are washed from the land and precipitated in the seas. And unfortunately phosphorus does not escape from the sea as a gas. Its only important recovery from the sea is in the guano produced by sea birds, but less than 3 per cent of the phosphorus annually lost from the land is returned in this way.

I must agree with agriculturalists who say that phosphorus is the critical limiting resource for the functioning of the ecosphere. The supply is at least shrinking (if dwindling is too strong a word) and there seems to be no practical way of improving the situation short of waiting for the next geological cycle of uplift to bring phosphate rock above sea level. Perhaps we should also worry about other essential elements, such as calcium, potassium, magnesium and iron, which behave much like phosphorus in the metabolism of the ecosphere, but the evidence clearly indicates that if present trends continue phosphorus will be the first to run out.

This brings me to the close of a very superficial summary of some of the physiological processes of the ecosphere. There are drastic oversimplifications in this treatment; the importance of some processes may be overestimated, and others (*e.g.*, dumping sewage in rivers and oceans) may not have received enough attention. The figures for the total quantity of energy received by the earth, for total annual precipitation and for the total supply of some chemical elements may overlook the very irregular distribution of these resources in time and space. Much solar energy falls on deserts and fields of snow and ice where it cannot be used by plants, and much precipitation arrives at unfavorable seasons or in such torrents that it does more harm than good to organisms. Yet I believe that there may be some merit, both intellectual and practical, in attempting to scan the entire picture.

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MAKING BETTER PRODUCTS . . . TO MAKE YOUR PRODUCTS BETTER justified in feeling some real concern about the problem of erosion. It should also make us aware of the important role played by organisms that we might otherwise ignore or even regard as pests. The dung beetles, the various scavengers and the termites and other decomposers all play important bit parts in this great production. At least six diverse groups of bacteria are absolutely essential for the proper physiological functioning of the nitrogen cycle alone. Man in his carelessness would probably neither notice nor care if by some unlikely chance his radioactive fallout or one of his chemical sprays or fumes should exterminate all of the microorganisms that are capable of decomposing chitin. Yet, as we have seen, such a tragedy would eventually mean an end to life on earth.

Finally, it is interesting to ask how large a role man plays in the physiology of the ecosphere. The Statistical Office of the United Nations estimates the present human population of the earth at 2.7 billion persons. Each of these is supposed to consume at least 2,200 metabolizable kilocalories per day. This makes a total food requirement of 22×10^{14} kilocalories per year. I have estimated that all of the plant growth in the world amounts to an annual net of 5×10^{17} kilocalories, of which not more than 50 per cent is metabolizable by any primary consumer. Thus if man were to feed exclusively on plants he would require almost exactly 1 per cent of the total productivity of the earth.

To me this is a very impressive figure. There are more than one million species of animals, and when just one of these million species can corner 1 per cent of the total food resources, this form is truly in a position of overwhelming dominance. The figure becomes even more impressive when we reflect that 70 per cent of the total plant production takes place in the oceans, and that our figure for productivity includes inedible materials such as straw and lumber.

If human beings were to eat meat exclusively, the present world population would require 4 per cent of all of the flesh of primary consumers of all types that the earth could support—and this means that much of our meat would be insects and tiny crustaceans. I suspect that the human population is already so large that no conceivable technical advances could make it possible for all mankind to live on a meat diet. Speaking as one who would like to live on a meat diet, I can't see very much to be optimistic about for the future. This opinion, however, cannot be expected to alter the physiology of the ecosphere.

A report to Engineers and Scientists from Lockheed

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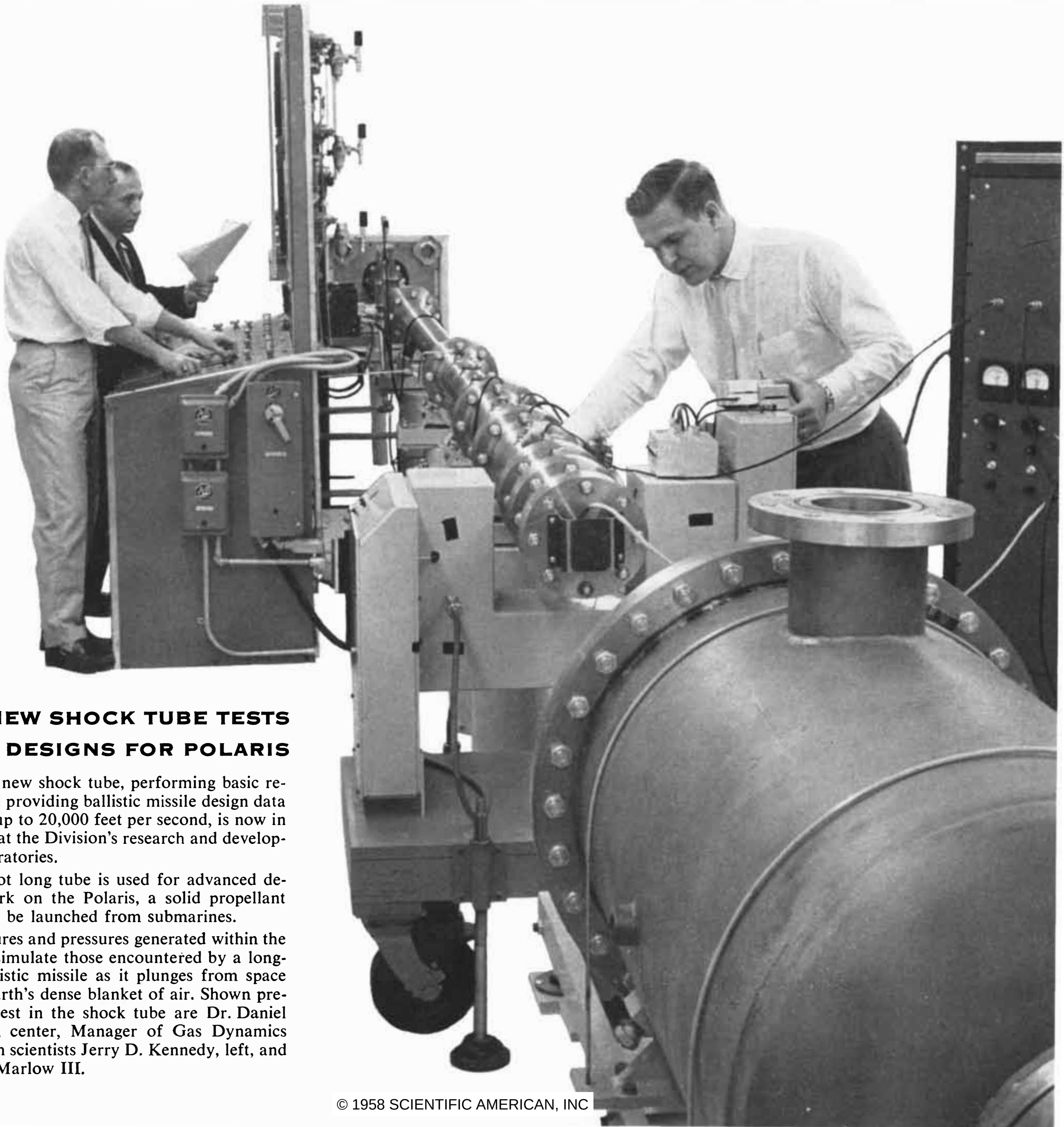

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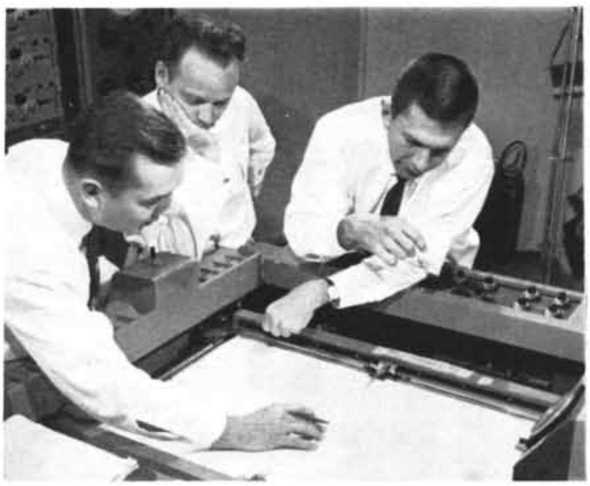

HOW LOCKHEED HUMAN ENGINEERS HELP MISSILES FLY BETTER

Polaris and other major Lockheed missile systems "fly" better through efforts of Division human engineers like Dr. Joseph W. Wissel, left, and Dr. John E. Mangelsdorf, right. They are shown with Flight Control Analysis engineer Roy J. Niewald, collecting flight control accuracy data on a display parameter.

Studies of man-machine systems like the missile control station enable engineering-psychologists to develop advanced equipment which minimizes the opportunity for human error.

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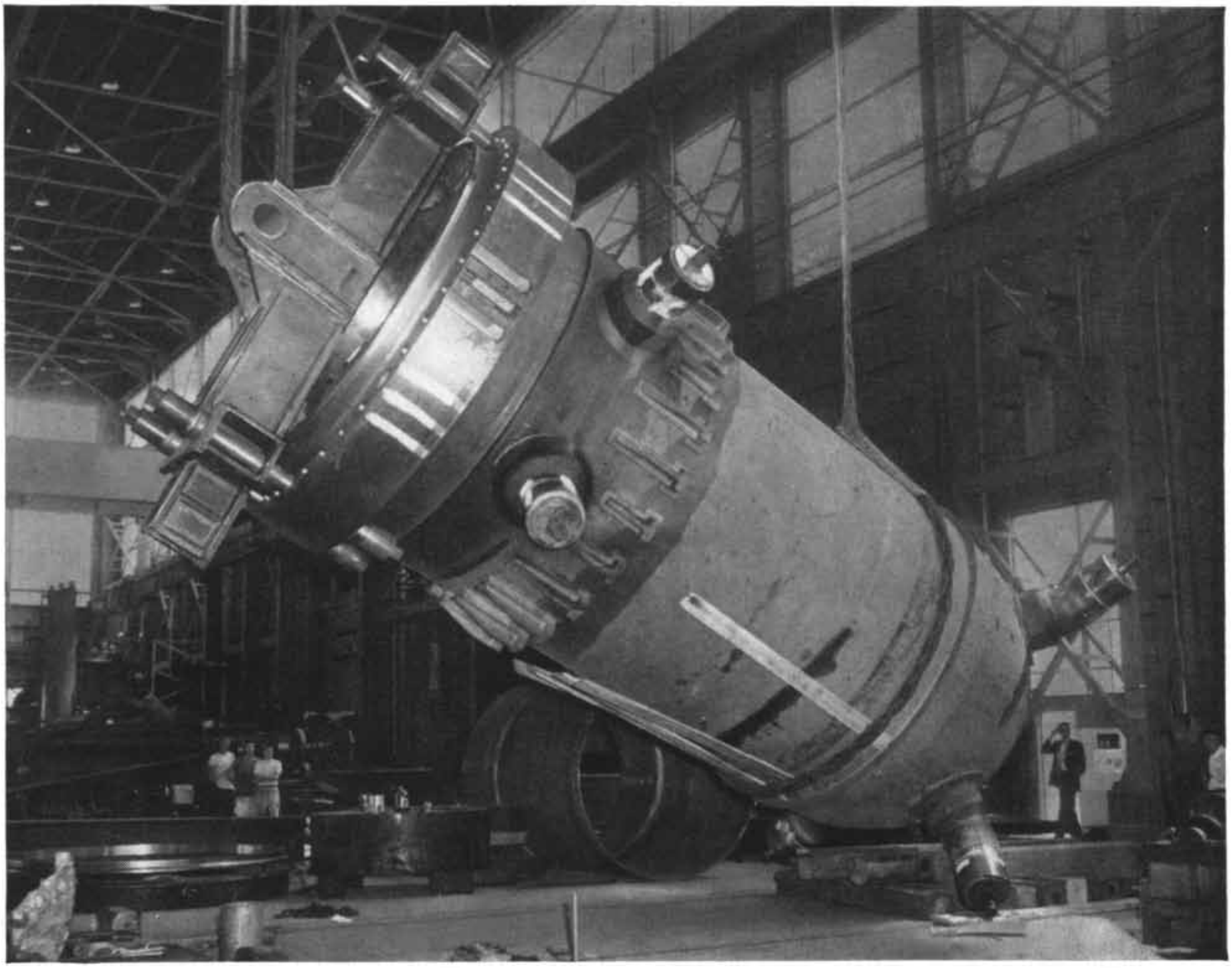
Above, Dr. J. P. Nash, left, and R. V. Middleton review instructions at a Univac control console before starting problem. The $1½ million computers are part of an installation which is one of the largest and most complete in the West.

LMS ENGINEERS DEVELOPING TRANSISTOR FLIGHT CONTROLS

Transistorized flight control systems for the Polaris ballistic missile program are being tested and developed under the direction of Gene Schott, Flight Controls Department Manager, right. Schott is shown discussing results of a recent test with design engineer Carlos Avila.

Transistorization of missile control systems is receiving top attention from Lockheed Missile Systems engineers and scientists in the interest of saving weight and space over present flight control systems. This work is being conducted in the Division's Palo Alto and Sunnyvale laboratories.



Bringing home the atom. Electricity will soon flow from the first full-scale nuclear power plant in America. This 235-ton reactor vessel was designed and built with alloy steels and nickel alloys by Combustion Engineering, Inc. It will supply power for the 60,000 kilowatt Shippingport plant designed by Westinghouse Electric Corporation.

In Shippingport atomic reactor...

Inconel "X" will keep "hungry water" on a starvation diet

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Other spring materials would relax long before operating temperatures hit their peak above 500°F. Or they might fail completely from what is called "stress-corrosion cracking", or embrittlement. In either event, it would be impossible to make repairs because of radioactivity.

It was this consideration that practically dictated the choice of Inconel "X" alloy. An exceptionally tough spring material, Inconel "X" alloy stands up to heat . . . corrosion . . . stress. In a lifetime of use, it's not expected to give "hungry water" a morsel of encouragement!

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The Chemical Senses

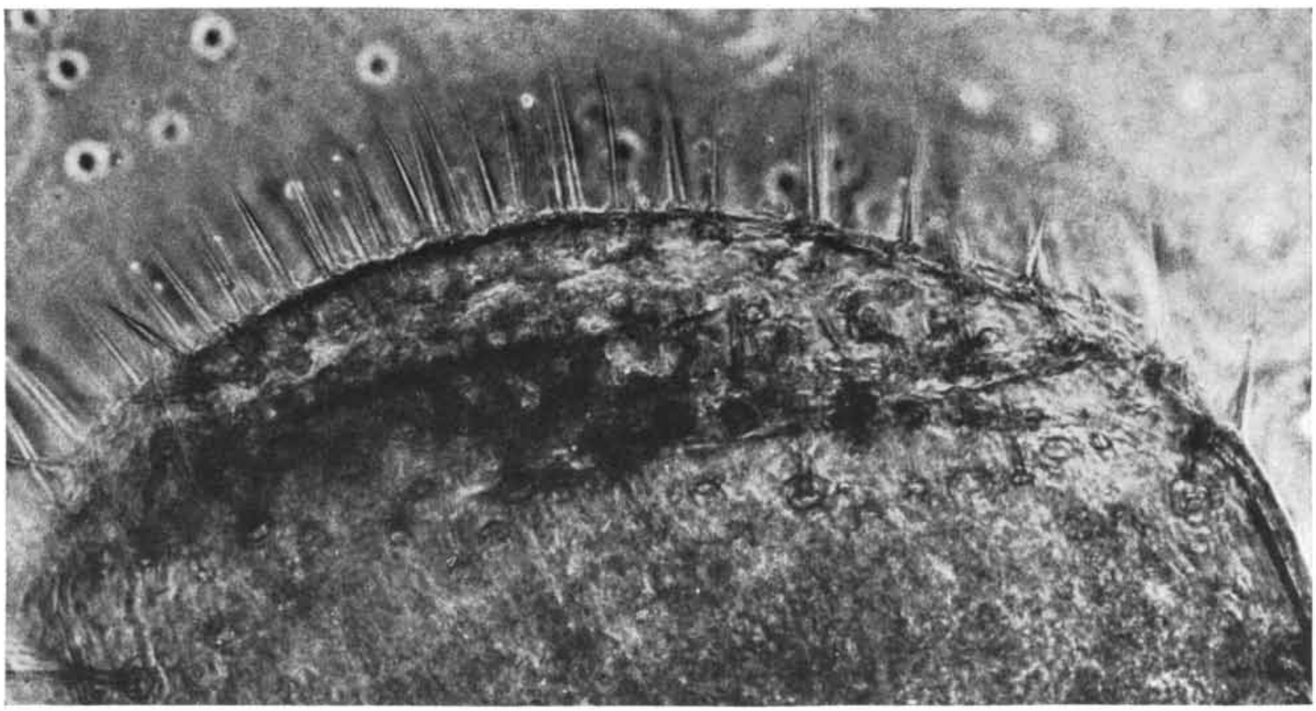
The senses of sight, hearing and touch receive physical stimuli; those of smell and taste, chemical stimuli. These latter senses have recently been the subject of numerous ingenious experiments

by Hans Kalmus

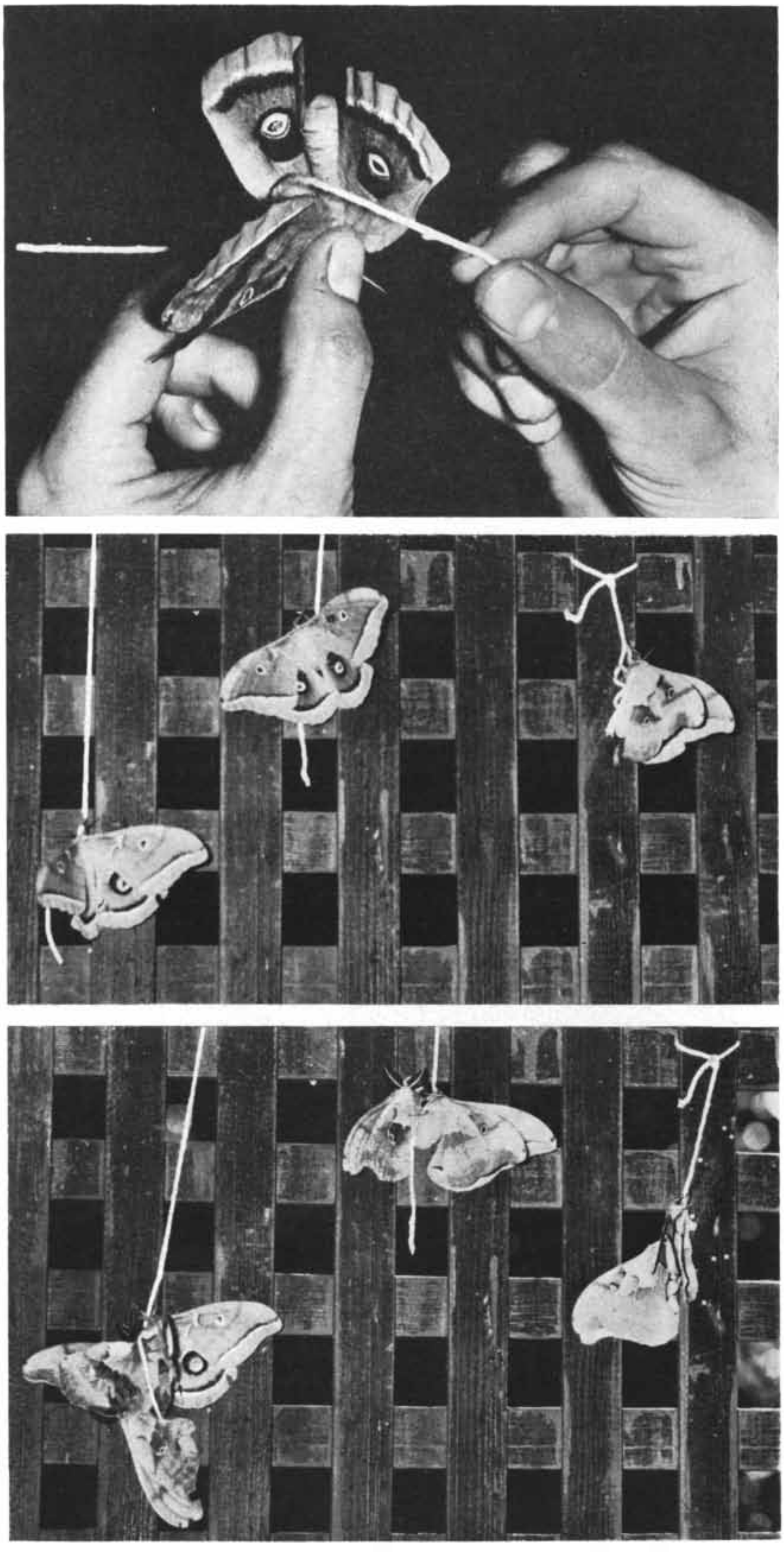
Tasting and smelling are usually considered "lower" senses, on the supposition that they contribute comparatively little to our knowledge of the world. Whereas blindness and deafness are recognized as tragic defects, we give so little heed to the inability to taste or smell that we do not even have vernacular names for these afflictions. Scientists seem to share the common indifference to the chemical senses, for few have done much research upon or with them. Actually, both as research instruments and as phenomena in their own right, these senses merit more attention. They play a much larger role in the life of man than is generally realized, and in the lower realms of life the chemical senses are all-important. As I shall try to show, even the limited studies that have been made of this subject have brought to light a good deal of otherwise unobtainable information about evolution, biochemistry and animal and human behavior.

At the lowest levels of life, many organisms depend almost entirely on some form of chemical perception for their vital necessities—to find food, avoid enemies or unite with a mate. A single-celled swimming animal may be attracted to its microscopic prey in the water by some substance released by the latter; a spermatozoon may be attracted similarly to an egg. Even in the plant world a kind of chemical "sense" controls movement and growth. Roots reach out toward water and other growth-promoting substances in the soil; on the other hand, some plant organisms may secrete poisons (antibiotics) to keep competitors away.

At higher and more complex levels, the existence of many animals is still dominated by chemical perception—now localized upon specific organs of smell and taste. A bee, or other insect, is attracted to a particular flower by its special odor; the plant is thereby assured of pollination. Experiments have shown that certain sea birds—among



CHEMICAL RECEPTORS on a mouth appendage of the cockroach are enlarged some 2,000 diameters. These receptors, which are associated with the small hairs visible at the end of the appendage, are involved in contact reception, which can be likened to taste. The cockroach also has chemical receptors for distance reception, which can similarly be likened to sense of smell, on its antennae.



FEMALE MOTHS of the American silkworm (*Telea polyphemus*) are tethered to a trellis in an experiment on the sense of smell in insects. At top a female moth is tied between its fore- and hindwings. In middle three female moths are tethered. Within a few hours they attract a swarm of male moths, one of which pairs with each female. At bottom are the mated males and females. At lower left is a fourth male which has stayed behind after the other surplus males have departed. These three photographs were made by Muriel Williams.

them petrels, shearwaters and albatrosses—possess a well-developed sense of smell, although most other birds probably do not. In the mammal world the females of many species emit odors (when in heat) which act as an irresistible invitation to sexual mating; it may shock young ladies to learn that their perfumes often contain musk substances of this nature. Then there are the well-known forms of chemical stimuli that perform a repellent or warning function: *e.g.*, the bitter taste of certain plants, the discharge of the skunk, which apparently serves it as a potent defensive weapon. Cats smell mice and mice smell cats and both act accordingly. The same applies to other ecologically paired species of animals.

The interplay of biological contention and survival through the chemical senses has developed some complex and devious ramifications; sometimes Nature even lies by means of chemical stimulation. For instance, certain flowers, such as the famous Rafflesia of Malay, give forth a fetid odor which is believed to have evolved originally by way of imitation of decaying substances, where flies would lay their eggs; the odor serves to attract carrion flies that pollinate the flowers.

Obviously there are some good practical reasons for studying the chemical senses of animals. If we want to arrange to attract or repel an animal, we need a rather good understanding of its reactions, for the problem is sometimes far from simple. For example, during World War II, when sugar was very scarce in Germany, the authorities faced the problem that sugar supplied to beekeepers was being bootlegged to human use. Investigators solved the dilemma by mixing into the sugar a bitter substance which made it unpalatable to man but did not bother the bees. The same kind of problem arises in insect repellents: the substance must repel mosquitoes and flies but not man or domestic animals. Similarly, researchers concerned about protecting honeybees from insecticides have been seeking a repellent additive which will keep the bees away without repelling the crop pests at which the insecticide is aimed.

Whatever the practical aspects may be, the most fascinating attraction of studies in the chemical senses is that they give us glimpses into the subjective worlds of various animals. Ingenious experiments with this tool have unraveled some remarkably interesting mysteries of animal behavior.

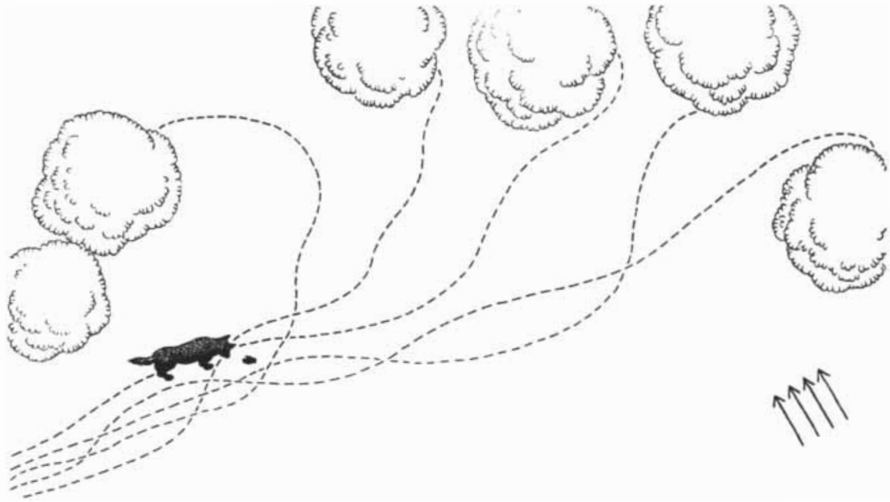
One of the most intriguing of these

problems was first raised a century ago by the famous French student of insects, Jean Henri Fabre. He observed that certain male moths (*e.g.*, the silk moth) could detect and fly to a female of the same species a great distance away—up to two or three miles! How could an insect locate another at this distance? Undoubtedly the male must pick up the female's faint scent, but how could it determine in what direction to fly? Some naturalists suggested that the moth found the direction by using its smelling antennae like a pair of ears, the antennae being on both sides of the head. But this was plainly an absurd idea: the two receptors, spaced less than an inch apart, could not possibly distinguish any difference in intensity of stimulation from a source miles away. Other theorists proposed the slightly more plausible idea that the moth might start searching in trial-and-error fashion and be led to the female by moving in the direction of increasing strength of the scent. But Ilse Schwink in Germany recently proved that this was wrong and discovered the solution of the century-old riddle. The answer is simple: on catching the scent of the female the moth starts to fly straight into the wind. That is to say, his sole clue to the location of the distant female is the direction of the wind. He flies upwind until he comes near enough to the female to find her by short-distance cues.

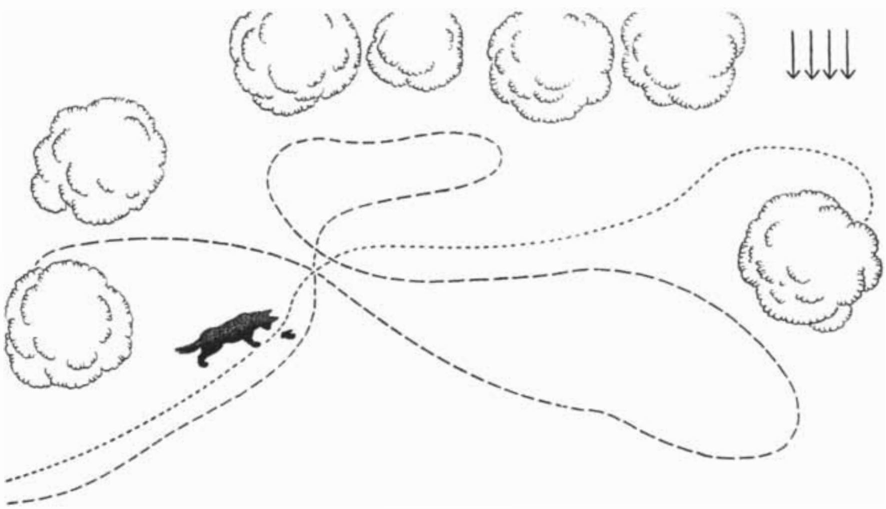
How does the insect know the wind direction? Apparently it learns this by noting the direction in which its own body is blown with relation to landmarks on the ground. On a completely dark night the moth cannot find its way toward a scent. In fact, I found that certain hawk moths will not fly in the dark but do take to their wings as soon as a faint light is provided.

Very likely many other insects, including mosquitoes, also find their way to their targets by heading into the odor-carrying wind. It is known that this is the cue that dogs use to follow an air scent. Contrariwise, many animals flee with the wind when they detect a predator's odor.

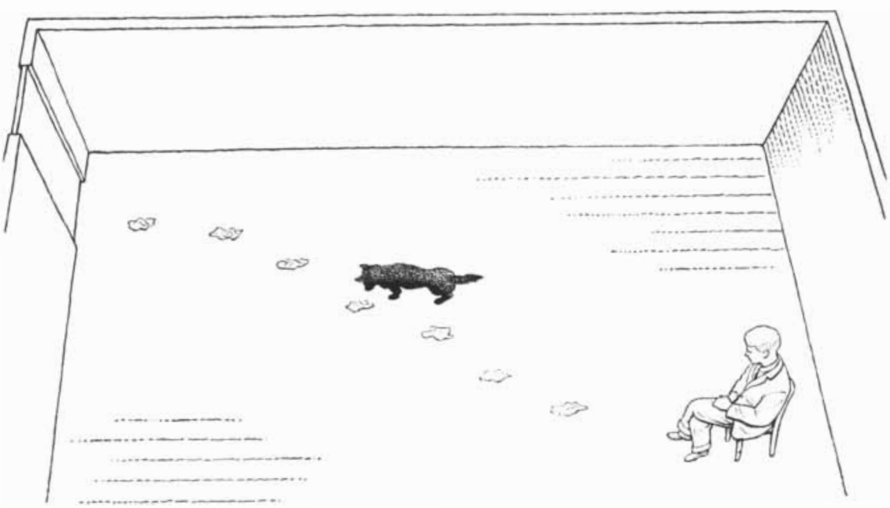
The olfactory powers of dogs, especially their tracking abilities, have impressed mankind ever since the dog was domesticated, and the dog's sense of smell is praised without stint by hunters and policemen. It is commonly supposed to be far more acute than that of human beings. Some physiologists do not share this view, although they agree that the dog has a well-developed odor



GROUP OF MEN, one of whom deliberately dropped a glove, followed the same track and then fanned out to hide behind trees (*dashed lines*). A well-trained dog was able to find the owner of the glove without difficulty. The arrows at lower right indicate wind direction.



IDENTICAL TWIN traced a complicated path (*long dashes*). The second identical twin then dropped his glove and traced a simpler path (*short dashes*). A well-trained dog had difficulty in picking the right twin, though it was able to do so in a slight majority of the trials.



ONE MAN'S HANDKERCHIEF was placed in a row of handkerchiefs. A well-trained dog which had been allowed to sniff the man's hand was usually able to pick right handkerchief.

sense. Actually there have been few sound and well-controlled experiments on the subject. Let us see what some of these show.

One of the studies was an analysis of the odor discrimination of trained police dogs by means of a tracking test. A group of people (mostly police officers) walked across a field; about 100 yards from their starting point one of them dropped a handkerchief (or a cap or glove). Then 25 yards farther on the men fanned out and proceeded on separate individual paths to a distant hedge where each hid from sight [*see diagram at left*]. Now a police dog was led from a car to the starting point and put on the track. The dog invariably picked up the dropped object; his handler then took it from him and sent him on. Certain precautions were taken to avoid extraneous clues: the dog's handler was kept ignorant of where the handkerchief's owner was hiding, lest he influence the dog, even unconsciously; the hidden men were downwind, so that their scents were not carried to the dog by air. It was also found that the test had to be made simple and clear cut, because the dogs were easily confused: if the dog's owner or usual handler was in the group, the dog would usually follow his track rather than that of the person who had dropped the scented clue; only a single scent could be given on any one day, for the animal became confused if put to the tasks of tracking two different persons on the same day.

When all the conditions were rigorously set up to avoid confusion and ambiguity in the results, it developed that an expert tracking dog could generally find the true quarry. There was just one exception: the dogs were unable to distinguish identical twins, at least most of the time. If only one member of a pair of twins was in the tracked group and the other twin's glove was left as the clue, the dog would follow the track of the twin who was present. If both twins were in the party and one dropped his glove, the dog frequently mistook one for the other: it pursued the right twin only slightly more often than the wrong one. If after such a test both twins appeared before the dog simultaneously, it became confused and excited. Seemingly there is some slight difference in body odor between identical twins, but the difference is so small that the dog behaves as if it were confronted simultaneously with two copies of the same person.

In another experiment, dogs were required to identify not a person but an object belonging to the person. For example, a handkerchief was scented in a man's armpit and then laid on the floor in a row of other handkerchiefs. The dog was brought into the room; its muzzle was clasped for about half a minute by the man who had scented the handkerchief, and the dog was then commanded to retrieve his handkerchief. Trained dogs usually succeeded at the first attempt. After a successful identification, the dog was then asked to retrieve that person's handkerchief from a row scented by various people. Good dogs as a rule immediately succeeded in this more difficult task also. But when the row of handkerchiefs included one belonging to an identical twin of the correct subject, the dog would pick up either twin's handkerchief indiscriminately, depending on which one it came across first. In other words, a dog readily takes one twin for the other when their scents are presented separately; but when it is confronted with both twins or their scents simultaneously, it can sometimes make a correct choice between them, just as we can tell one twin from another more easily when we see them together than when we see them separately and have only memory to go on.

Incidentally, experiments have shown that body odors can cling to objects for a considerable time, and that dogs have a long memory for odors. Sometimes they are able to track a person from an article of clothing that had been stored in a sealed container for many weeks.

The dog's ability to distinguish individual human body odors (and presumably the odors of individual dogs) is astonishingly sharp. For example, a dog that has taken a scent from a person's hands will correctly pick out that person's armpit-scented handkerchief even when an attempt is made to confuse him by scenting the handkerchief in another person's armpit as well. That is to say, to the dog's nose one scent does not entirely mask the other. Another surprising property is the dog's ability to recognize an individual's odor no matter what part of the body it comes from—*e.g.*, hands or armpit. To the human nose the armpits of two different persons may smell more alike than the armpit and the hands of a single individual, but the dog has finer powers of discrimination: after sniffing the hands it can recognize the armpit odor—as if a human being, after being shown a photograph of a person's face, could later recognize the person on seeing his hands!

Although the smelling powers of dogs are best known because they have been most studied, it must not be thought that they are in any way unique. Bees are known to be able to distinguish the odor of their own hive from those of other hives, and ants are even credited by some investigators with being able to recognize the odors of individual ants in their colony, although this is obviously hard to prove. Certain fish also seem to possess powers of olfactory discrimination. Minnows, for instance, show very strong flight reactions in water in which the scent of a pike is introduced, and they can even be trained to respond in a particular way to water in which an individual experimenter has put his hand—failing to respond in the same way to water scented by another person's hands.

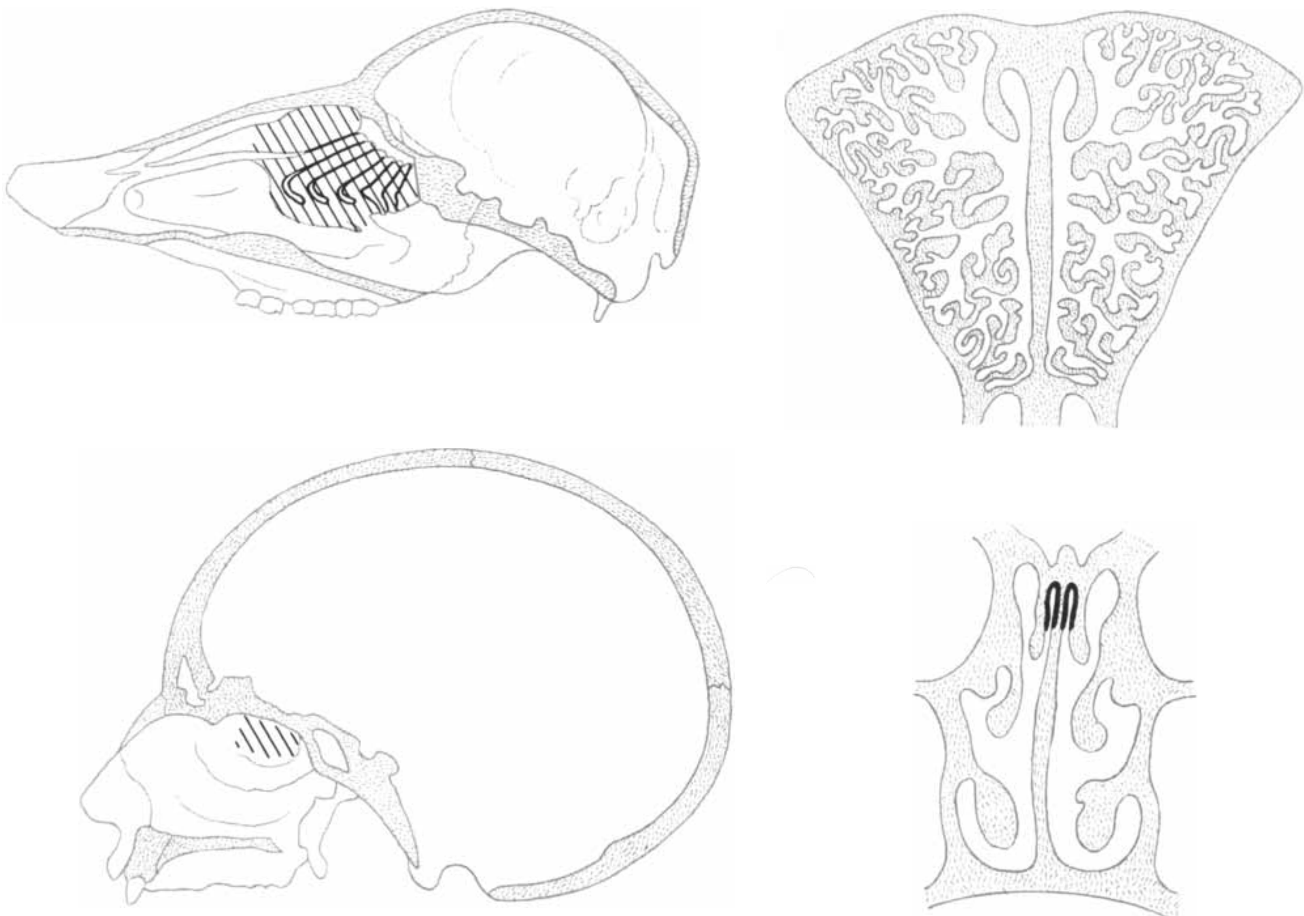
If the odor discrimination of man seems less acute than that of many lower animals, it is partly because he does not exercise his ability in the same ways or to the same ends. There is a well authenticated report of a blind girl working in an institutional laundry who was able to recognize and identify the owners of the clothes she sorted by their odor. Very probably some people could be trained to perform feats of odor discrimination as remarkable as those of trained dogs.

Just what is it that makes one individual's body odor different from another's? Judging by the experimental evidence of identical twins, the differences are largely genetic, and quite evidently they must have something to do with body chemistry. They cannot be due to an individual substance: the idea that each of the two and a half billion persons on earth produces unique odoriferous substances is too improbable to be seriously entertained. We must suppose that the odor distinctions arise from slight quantitative differences in the mixture of common components that make up the body. But this only makes the olfactory powers all the more astonishing: the organs of smell must indeed be remarkably sensitive and subtle.

Unfortunately we know very little about how the organs of smell and taste work. The two senses are closely related, but they operate in different ways and it is best to take them up separately.

Odor comes to us in the form of gaseous molecules or droplets of the odorous substance. The smelling organ is a small patch of yellow mucous membrane, called the olfactory cleft, in the upper cavity of the nose. To be smellable, a substance must be soluble in fat or water—preferably both. Some materials can be detected in extremely tiny traces: the human nose can smell a substance called skatole (an ingredient of excrement) and the antiseptic substance iodoform in submicroscopic quantities as small as 100 million molecules—which is a small amount indeed. A measure of the infinitesimal quantities involved in stimulation of the organ of smell is the fact that a lump of musk keeps emitting a strong odor for many years without any noticeable loss in weight.

Like the organs of sight and hearing, the olfactory membrane has receptor cells which fire when stimulated and generate electrical pulses that travel to the brain. When an odorous substance



ORGANS OF SMELL in the deer and in man are compared. At upper left is a section through the skull of a deer. At upper right is an enlarged section at right angles through the hatched area. At lower left is a section through a human skull. At lower right is an enlarged section at right angles through the hatched area. In man the chemical receptors of the nose are restricted to the two inverted-U-shaped areas to the left and right of the nasal septum. In the deer the receptors are distributed throughout a vast labyrinth.

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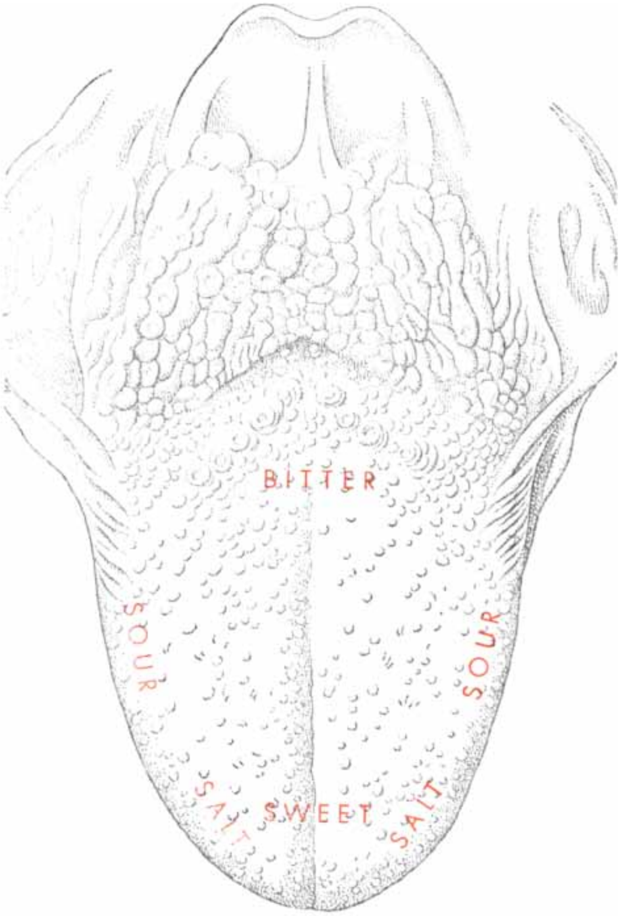
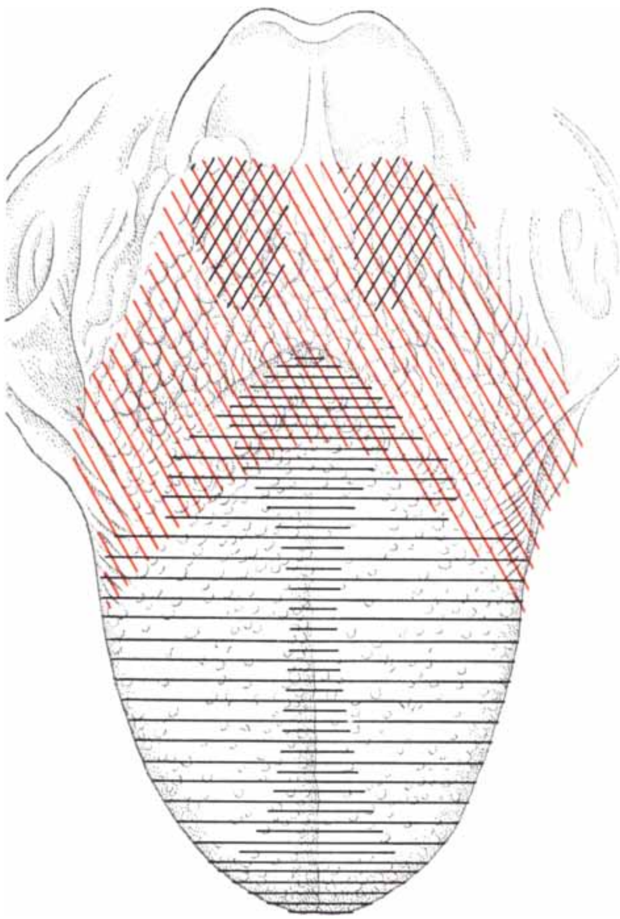




ORGANS OF TASTE in the tongue of man are analyzed. At left is a top view of the tongue showing the areas most sensitive to the four main sensations of taste. At right are the areas supplied by three kinds of nerves: the laryngeal branch of the vagus nerve (*black diagonal hatching*), the glosso-pharyngeal nerve (*colored diagonal hatching*) and the lingual nerve (*black horizontal hatching*).

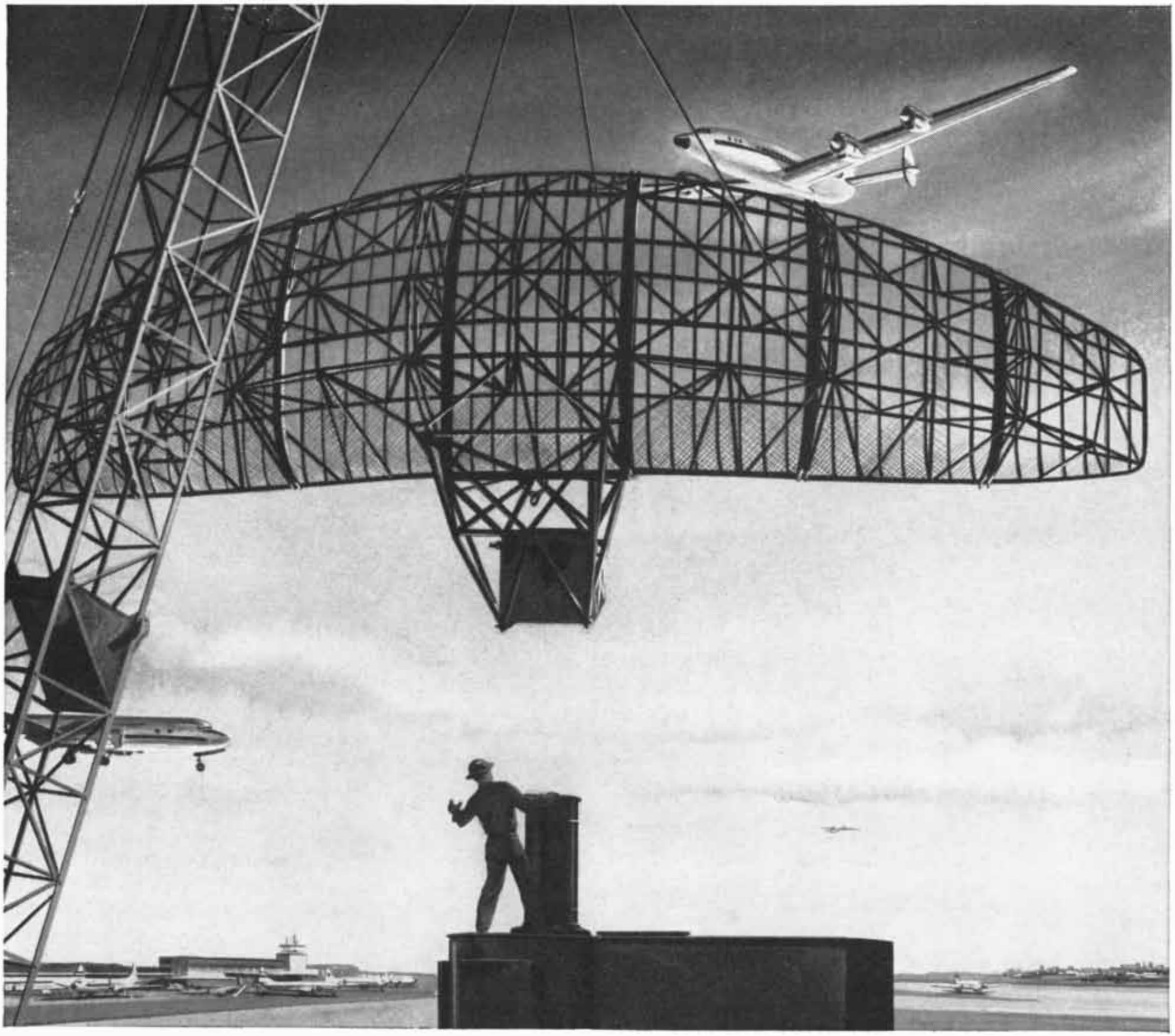
goes into solution in the olfactory tissues, it excites receptor cells to fire. Presumably the message carried to the brain—that is, the identification of the odor—depends on the location of the particular receptor cells that are excited, just as the nature of a picture or a sound is determined by the area of the eye or ear that is stimulated. The English physiologist E. D. Adrian found by experiments that the cat's nose seems to have about 10 types of receptor cells, differentiated by their responses to various vapors. Each type of receptor responded with special sensitivity to a particular substance. In human beings, too, tests with tiny electrodes inserted in the olfactory bulb show that different odors excite different sites in the organ. But beyond these few facts, not much more has yet been learned about the workings of the smelling organ.

Attempts to classify odors and describe them chemically have yielded similarly meager results. The investigators have not been able to agree on a standard scale for describing odors: they have either had to resort to vague terms such as flowery, fruity, fetid, spicy, resinous, burnt, foul and the like or have confined themselves to comparisons—*e.g.*, describing the odor of hydrogen sulfide as like that of rotten eggs (for which hydrogen sulfide itself is indeed responsible). No classification system yet proposed has stood the test of time.

Perfumery will long remain an art rather than a science, for the chemistry of odors is altogether bewildering. In the first place, no one has found any chemical rhyme or reason—no guiding rule—behind odors. For instance, a given odor, such as that of bitter almond, can be produced by many substances of widely different chemical composition and structure. In the second place, most scents, especially the pleasant ones, arise from a mixture of substances, and they must depend upon interactions about which we know very little.

While we are ill-informed about the precise origin of odors, this does not mean that smelling is still a useless tool in science. The chemist would not lightly forego the use of his nose in his work, and the doctor sometimes finds it helpful, as in detecting the acetone smell of severe diabetes. Perhaps we shall even be able ultimately to detect the much-debated "smell of death" which some think is detectable to a dog beside the deathbed of its master.

In our ideas about the sense of taste we are on somewhat surer ground, though here too only a small part of the story is known. The human organs of taste are situated in buds on the tongue and possibly on the palate. In order to be tasted, a substance must be soluble in saliva, which for practical purposes means soluble in water. When the substance comes into contact with certain long, hairlike cells in the taste buds, it causes these cells to fire. Four different types of taste buds, of various shapes, have been located on the tongue. Each seems to be mainly responsible for a certain taste quality, and of course stimulation of two or more types produces a mixed taste. Most investigators agree in



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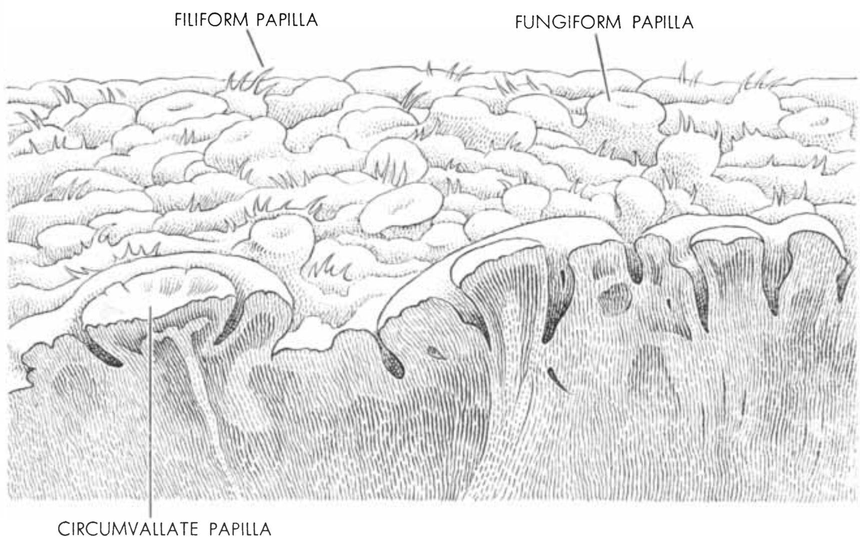
classifying tastes under four general heads: sweet, bitter, salty and sour. Some add one or two other categories—such as metallic and astringent.

There is a tremendous range in the taste thresholds for various substances. The bitter taste of quinine can be detected in a dilution of one part to a million; at the other extreme, few people can taste cane sugar unless its concentration is at least one part in 200. Gases, as well as solids and liquids, are tastable if delivered to the taste buds at a sufficiently high concentration. Oxygen, tasteless in its ordinary concentration in the air (one fifth of an atmosphere), has a very striking taste at high pressure. The author was one of the first people to taste oxygen: at a pressure 35 times the normal it tasted somewhat like ginger beer.

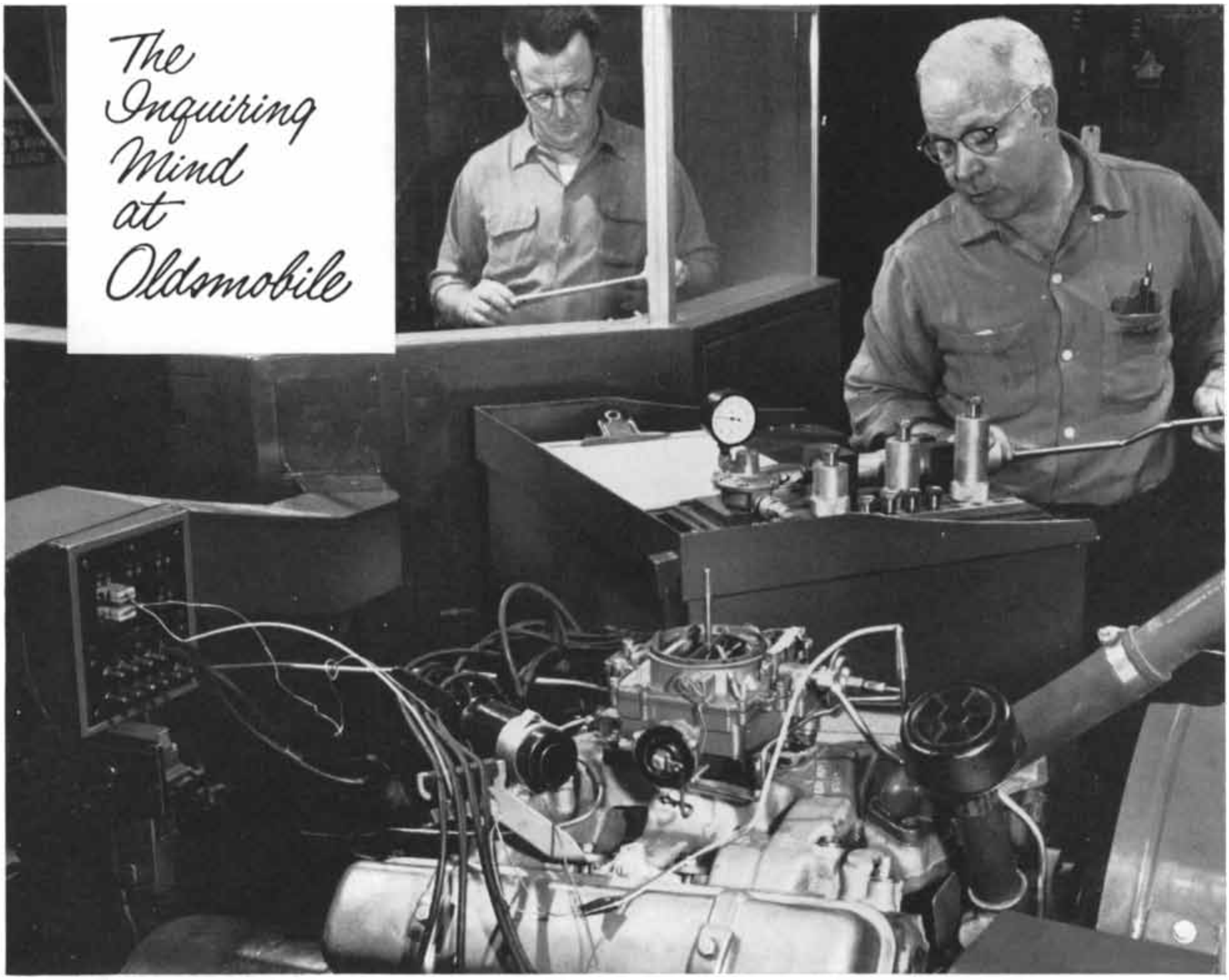
Strangely enough, some substances produce the same reactions in many different species of animals. Man, the dog, the bee and the butterfly are all repelled by ammonia and all attracted by alcohol; they dislike the strongly bitter taste of quinine but do like sugar. Some time ago Curt Richter at the Johns Hopkins University found that the taste threshold for salt was about the same in normal rats as in man. But when the rats' adrenal glands were removed, their sensitivity to salt increased about 20-fold—that is, the threshold dropped to three parts in 100,000. Evidently a change in metabolism can greatly alter tasting ability.

Some progress has been made in correlating specific tastes with chemistry. For example, acids always taste sour, because of their free hydrogen ions; many different types of salts have a salty taste; amino acids are sweet; nitrogen, nitrogen oxide and the sulfhydryl radical (SH) tend to produce or enhance a bitter taste in organic compounds. But here again, as in odor, it has been difficult to find general rules. Among the complications is the fact that the taste of a substance sometimes changes radically with different concentrations: thus phosphoric acid tastes sweet when diluted but becomes sour in high concentration. Another complication is that there are differences in people's taste reactions to the same substance, the difference being hereditary. For example, in the U. S. population a certain drug (phenylthiocarbamide in a solution of one part in 16,000 parts of water) is strongly bitter for about two thirds of the people, tasteless for most of the others and slightly sweet for a few.

When it comes to food and drink, attempts to establish scientific criteria of taste quality fail altogether. Too many factors enter in: not only differences of taste but also consistency, color and above all aroma. We savor food and beverages with the nose as much as with the tongue and palate. The tasting of tea and vintage wines has of course long been a fine art assigned to connoisseurs. But we have also taken to using panels of experts to judge the quality and palatability of common foods—such as butter, milk and fish—and these groups are beginning to develop reliable grading procedures. Research in the chemical senses is profiting from new statistical tools, in the way of sampling and ranking methods, which have proved useful in other branches of science.



KINDS OF PAPILLAE are depicted in this drawing of an enlarged section of the tongue. The foliate papillae, which lie along the sides of the back of the tongue, are not shown.



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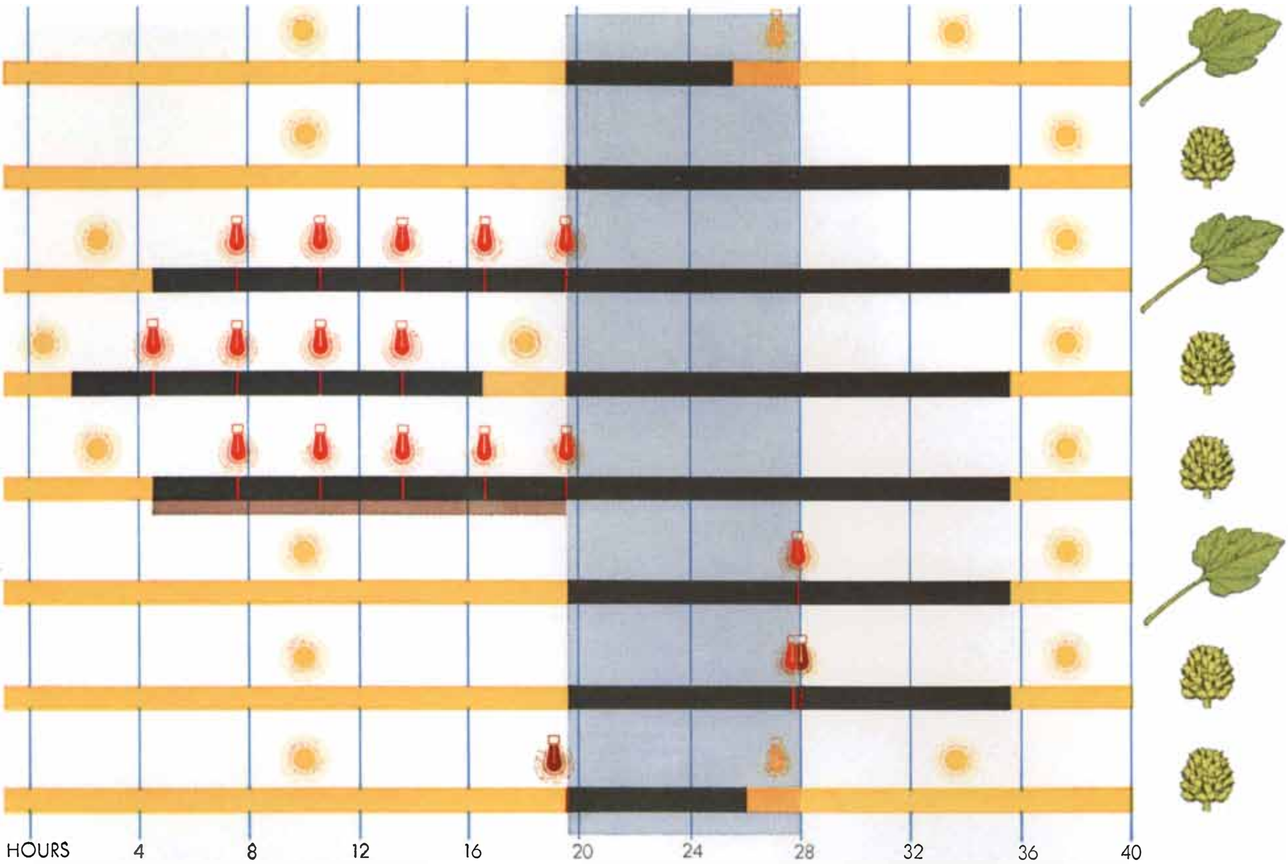
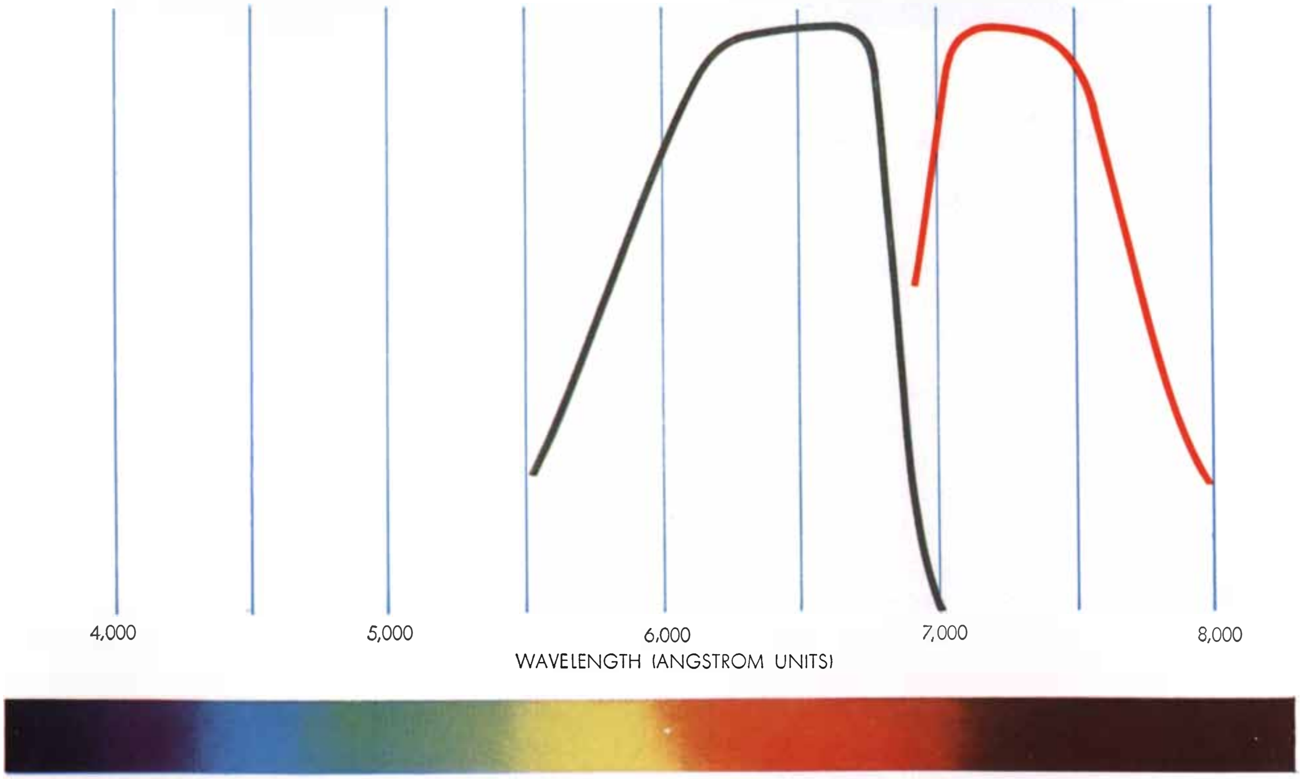


FLOWERING OF THE COCKLEBUR requires darkness (*black*) preceded and followed by intense light (*sun or yellow bulb*). Too short a night (*top bar*), or light interrupting it (*sixth bar*), results in no flowers (*leaf symbol*). The inhibiting effect of red light is reversed (*fourth*) by daylight. Plant starved of light (*fifth*) flowers if fed sucrose (*brown*) before the critical dark period (*blue band*). Far-red light (*dark red*) reverses the red-light effect (*seventh*). An intense dose (*eighth*) can shorten the dark period required.



LIGHT interrupting the critical night inhibits flowering most strongly if it is in the orange-red range (*dark curve*). Inhibition is reversed by light of longer wavelengths (*red curve*). Far-red light, near the end of the visible range, has the strongest effect.

The Flowering Process

At certain points in its development every flowering plant stops making leaf buds and produces flowers. The mechanism of the change is studied by experiments with the cocklebur

by Frank B. Salisbury

What makes a plant suddenly turn from producing leaf buds and begin to form flowers instead? There are at least two good reasons for exploring this mysterious process of nature. Firstly, the question goes to the heart of the origin of form, one of the most interesting and fundamental problems in modern biology. Secondly, if we learned how to control flowering, we could probably find radical and wonderful new ways of growing crops to our desires—in short, we could revolutionize agriculture.

A great deal of thought and experiment has been devoted to the attempt to understand the flowering process, and several years ago the findings up to that time were reviewed in an article in this magazine [see "The Control of Flowering," by Aubrey W. Naylor; Scientific American, May, 1952]. Since then there have been some rather exciting further developments.

As a preface to this sequel we must recall some of the basic facts that had been established at the time of Naylor's article. Experiments had shown that a plant begins to flower only after it has reached a certain maturity, known as "ripeness-to-flower"; that the main environmental factors which trigger or control flowering are temperature and light, particularly the length of day; that some plants need a long day to start to flower while others require a short day (*i.e.*, a certain extended period of darkness per day); and that the change-over which causes a plant's stem tips to begin forming flowers instead of leaves is controlled by some substance produced in the plant's leaves and transported to the growing tips. This substance has not yet been identified. But there is conclusive evidence that it exists. One of the clinching pieces of evidence is that a plant incapable of flowering (because it has been deprived of the necessary dark period) can be made to flower by grafting onto it a plant already in flower; clearly the graft must produce this effect by supplying some hormone.

Following up these findings, a number of investigators have tried to analyze the flowering process by breaking it down to a series of steps in the transformation of the plant. This effort is making headway, and I would like to tell about some of the experiments and describe the present picture as I see it.

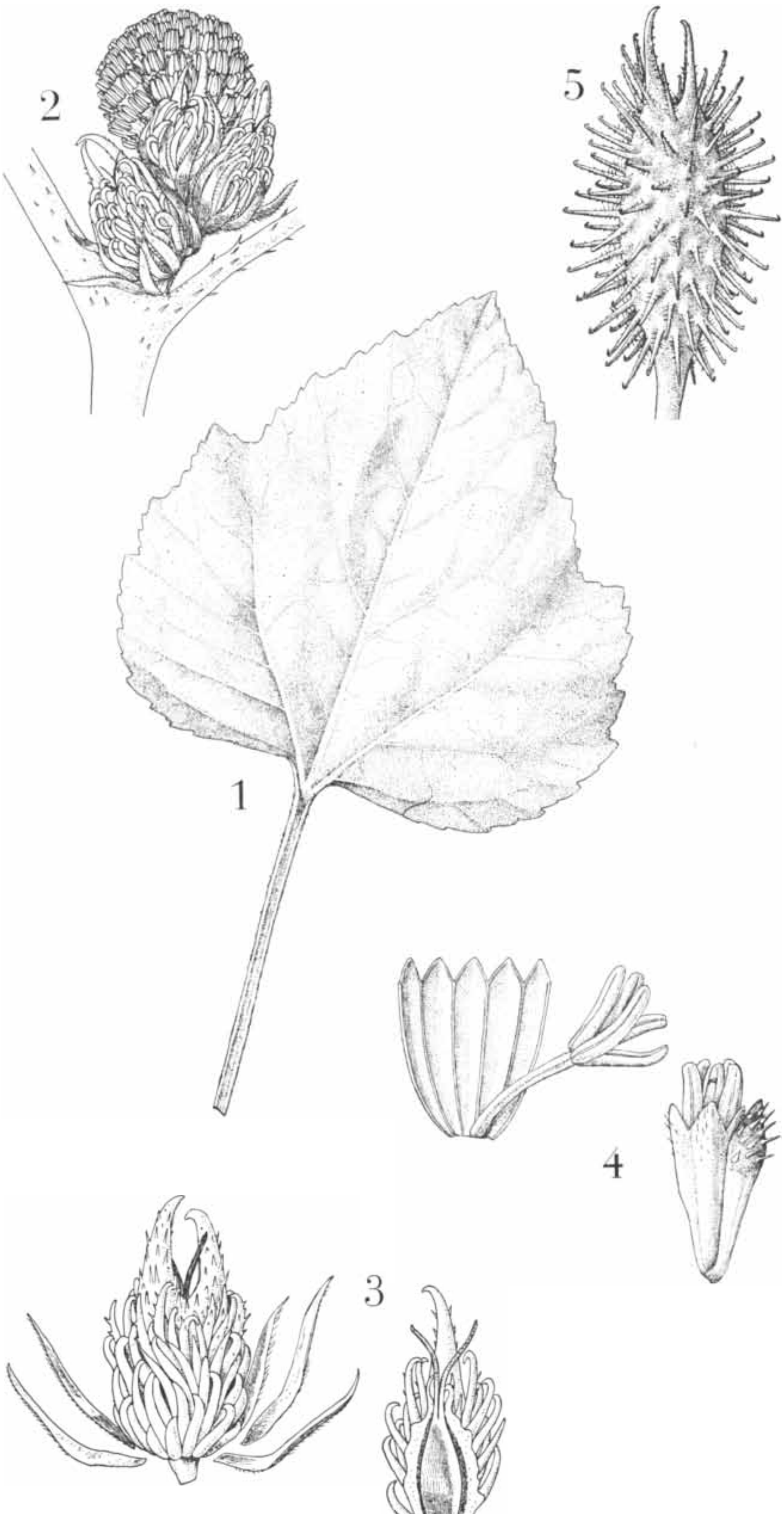
A favorite experimental plant of plant physiologists working on this problem is the cocklebur. This common weed is beautifully convenient for studying flowering. It is easy to cultivate; it grows well even when defoliated to a single leaf for experimental purposes; and it is highly sensitive to light conditions. It will flower only when its period of night is more than eight and a half hours long. A single exposure to a continuous dark period of the critical length will trigger it to come into bloom. Its growing points develop into clusters of little green flowers and finally into burs.

Apparently the first step toward flowering is accumulation of a sufficient food reserve by the plant. Karl C. Hamner at the University of Chicago discovered this by an elegantly simple experiment. A plant, of course, builds its material by photosynthesis, for which it needs light—the more intense, the better. Hamner starved cocklebur plants by greatly reducing their rations of light, allowing them only flashes at two-hour or three-hour intervals. Then he gave them the long night of more than eight and a half hours, which causes normal plants to start forming flowers. But these specimens refused to bloom. However, three hours' exposure to sunlight was enough to restore them so that they were able to flower after the necessary dark period. Later James Liverman and James Bonner at the California Institute of Technology showed that the plants' deficiency was indeed one of food substance. They found that they could endow light-starved cockleburs with the ability to flower simply by supplying sugar to the plants.

The first step, then, is the build-up of material in the plant. The second step toward flowering must take place in the required eight-and-one-half-hour dark period. What processes go on during this time? And how does a cocklebur measure eight and one-half hours?

Workers at the U. S. Department of Agriculture research station in Beltsville, Md., succeeded in tracking down one clear clue. It was known that the dark period must be continuous: if it is interrupted by even a single flash of ordinary light, the cocklebur will not flower. The Beltsville workers proceeded to experiment with light of various wavelengths (colors). They discovered that light at the far-red end of the spectrum did not inhibit flowering: on the contrary it counteracted the effect of inhibiting wavelengths. Red light at the shorter wavelengths (*i.e.*, orange-red) was most effective in preventing flowering. But if, after interrupting the dark period with a flash of this light, the experimenters then followed with a flash of the longer-wavelength red light, the cocklebur would flower. In other words, the far-red light reversed the effect of the orange-red light. The plant's behavior depended on which wavelength it was exposed to last: if orange-red, the plant could not flower; if far-red, it did flower.

The Beltsville group developed the



PARTS OF THE COCKLEBUR are shown in these drawings. In the center is the leaf (1). The flower head (2) with both male and female flowers is drawn about seven times natural size. A single female flower is shown whole and in cut section (3). A single male flower is shown whole and cut open (4). The seed pod or bur (5) develops from the female flower.

following theory. Light can produce chemical effects only through some absorbing pigment. Therefore a pigment must be involved in the chemical reactions that lead to the plant's flowering. Apparently this pigment, upon absorbing orange-red light, is converted to a different form which is sensitive to far-red light, and *vice versa*. The form produced by exposure to orange-red light must be the one that inhibits flowering. Since sunlight contains more orange-red than far-red light, when a plant is removed from ordinary light to darkness most of its pigment must be in the inhibitory form. This means that one function of darkness in preparing the plant to flower must be to allow the pigment to change spontaneously to the noninhibitory form.

The next question was: How long does the spontaneous conversion of the pigment take? Does it account for the full critical period; is this the clock that tells the cocklebur when eight and a half hours have elapsed? The Beltsville group investigated by exposing cockleburs to intense far-red light before retiring the plants to darkness, the object being to convert all of the pigment to the noninhibitory form. They found that at most this treatment shortened the critical dark period by only two hours—that is, the plant still needed six and a half hours of darkness to flower. Thus the experiments indicated that complete conversion of the pigment takes about two hours, and this conclusion has been supported by other evidence.

This leaves six and a half hours to account for. What are the further preparations for flowering that go on during that time? Unfortunately we do not yet have any idea: this is still a dark chapter (figuratively as well as literally) in the story of the flowering process. For want of any definite information this unknown step is merely labeled the "preparatory reaction."

The next step is somewhat clearer. The cocklebur needs *more* than eight and a half hours of darkness to flower normally. If it is exposed to light shortly after the end of that critical period, it will flower eventually, but the flower buds develop very slowly. If the dark period is extended further, the buds then develop more rapidly; in fact, the rate at which they will develop after exposure to light depends on the length of the dark period beyond eight and a half hours. This was shown by systematic experiments in which groups of plants were submitted to dark periods of various lengths and then examined

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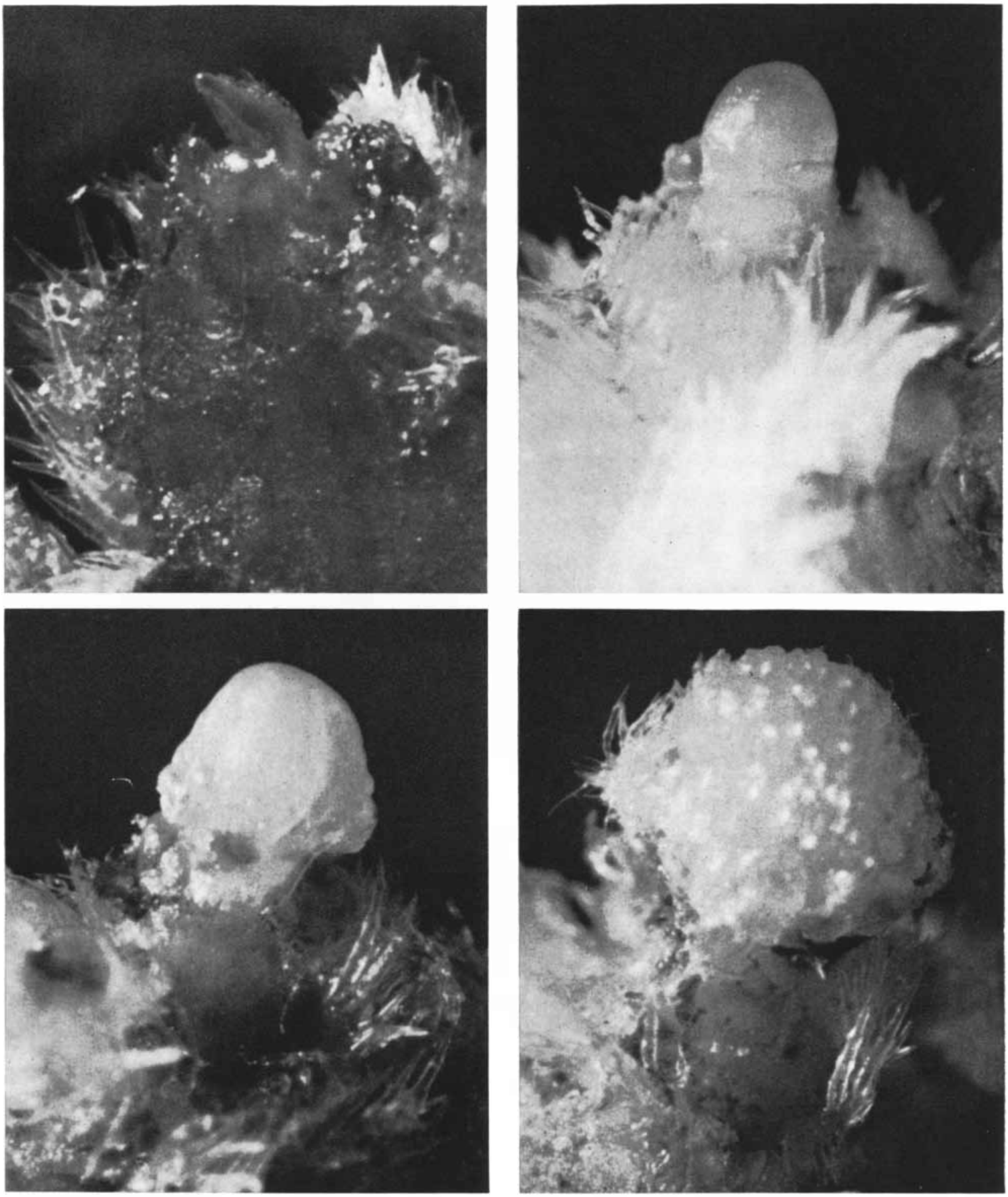
under a microscope nine days later. The progress of each group's flower-bud development was directly proportional to the excess of its dark period over eight and a half hours, up to a certain limit.

What does this mean? The simplest and most plausible explanation is that the plant synthesizes the flowering hormone in the late stages of the dark period, and the more time it has for synthesizing the hormone, the faster the flower bud will develop. However, diminishing returns set in after about 12 hours of darkness; in fact, it appears that when the dark period is prolonged to 20 hours or so, the hormone begins to be destroyed.

This brings us to the somewhat controversial next step. The cocklebur will often flower even if it is left in the dark for nine days. But James Lockhart and



DEVELOPMENT OF THE MALE FLOWER of the cocklebur is divided into eight stages. At upper left is the apical meristem from which the bud emerges, as seen in the third-stage bud at upper right. Small bumps which begin to appear at the fourth stage (*lower left*) develop into flowerets seen in the seventh stage (*lower right*). Floral stages are used to measure rate of flowering.

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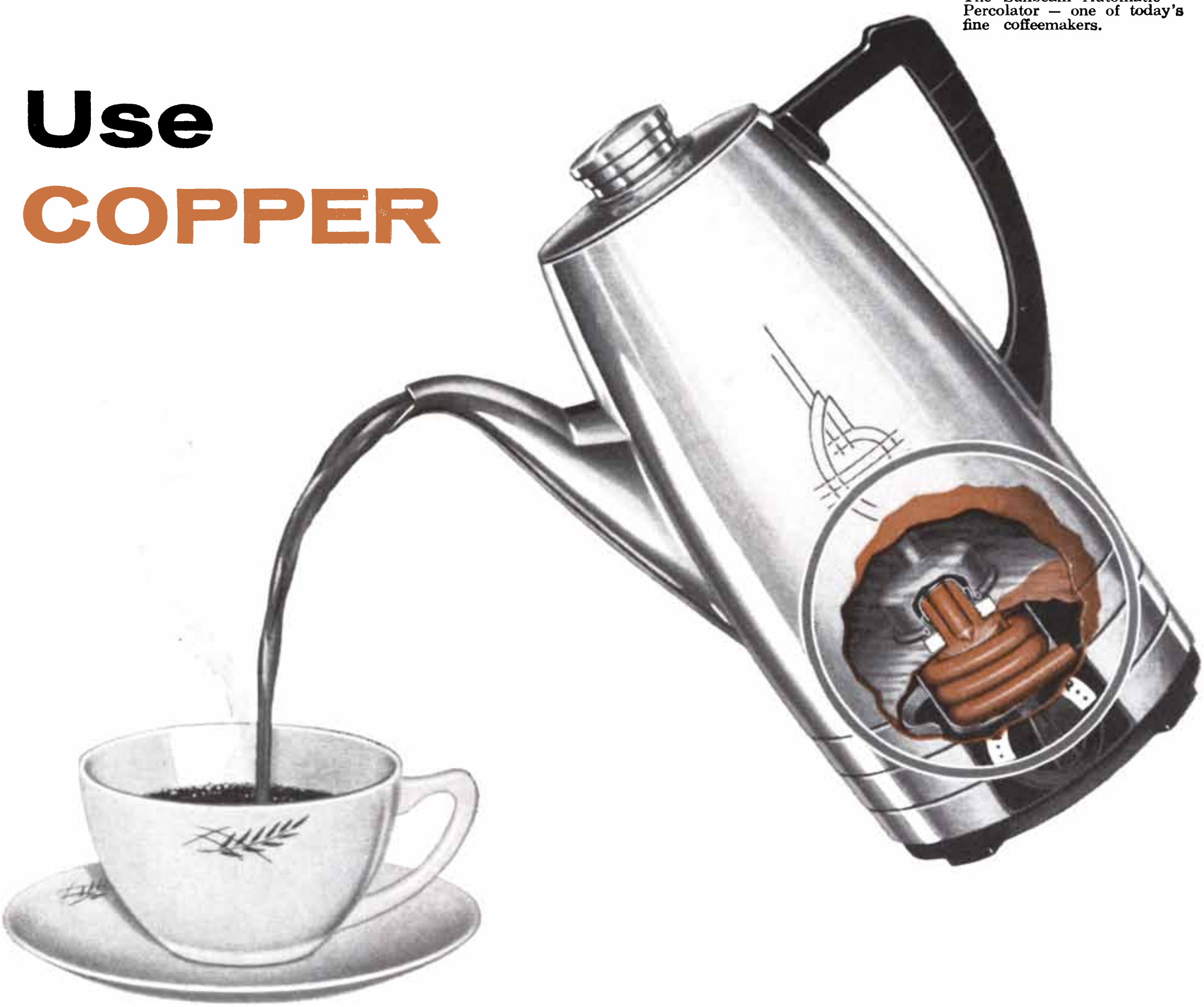

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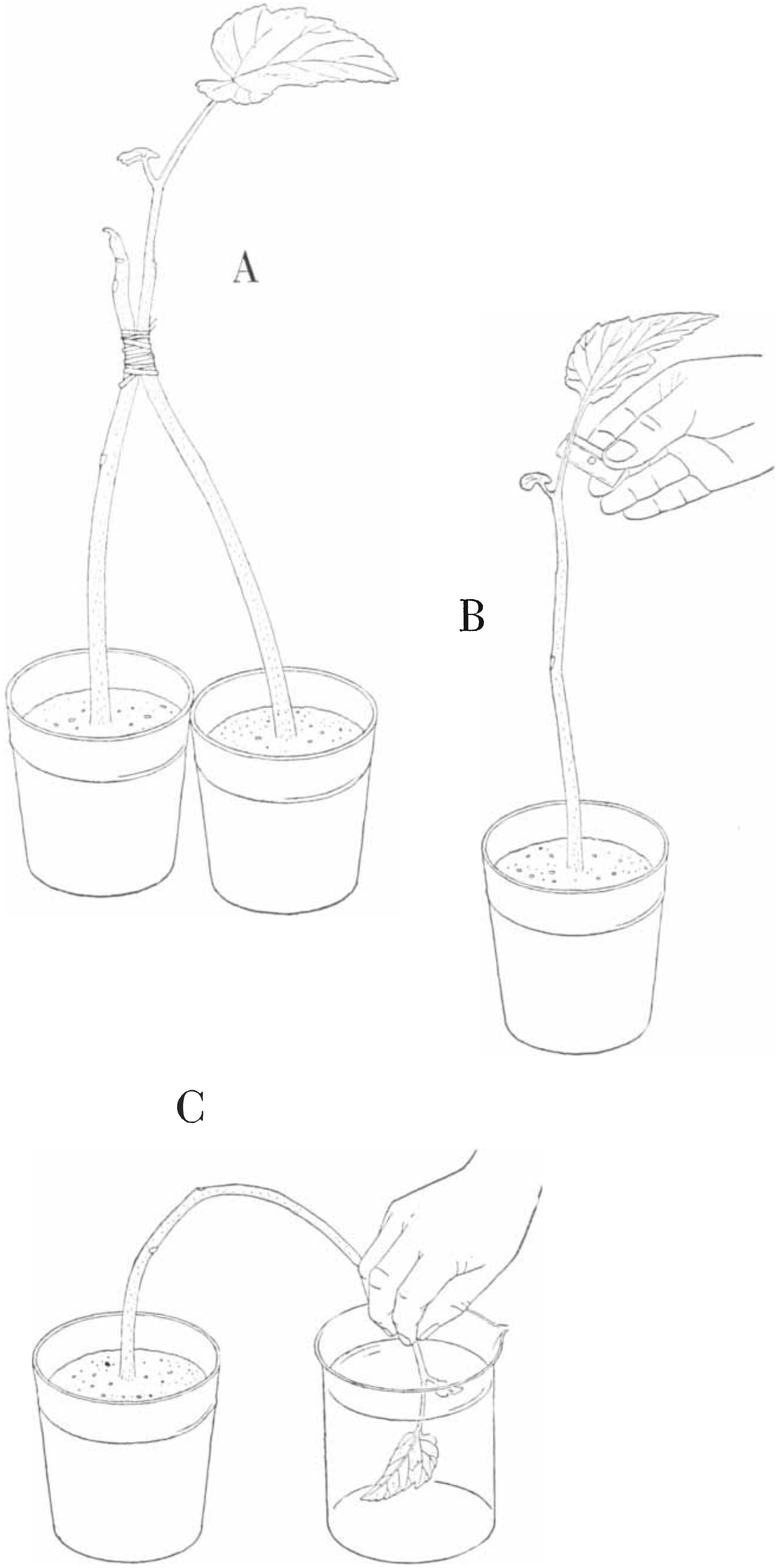


EXPERIMENTAL PROCEDURES used in flowering studies are depicted. A rubber band holds two grafted plants together (A) so that hormone can pass from one to the other. The one leaf on an experimental cocklebur plant is cut off with a razor blade in order to stop translocation—the passage of hormone from the leaf to the bud (B). Cocklebur plants are treated with chemicals by dipping a leaf into a solution of the chemical (C).

Hamner, working at the University of California at Los Angeles, have found that for full flowering development the plant seems to need a re-exposure to high-intensity light, *e.g.*, sunlight, after the dark period. Consequently it may be that this exposure represents another chemical step in the normal flowering process: the light may be needed to "stabilize" the flowering hormone or to stop some process in the leaves that destroys the hormone.

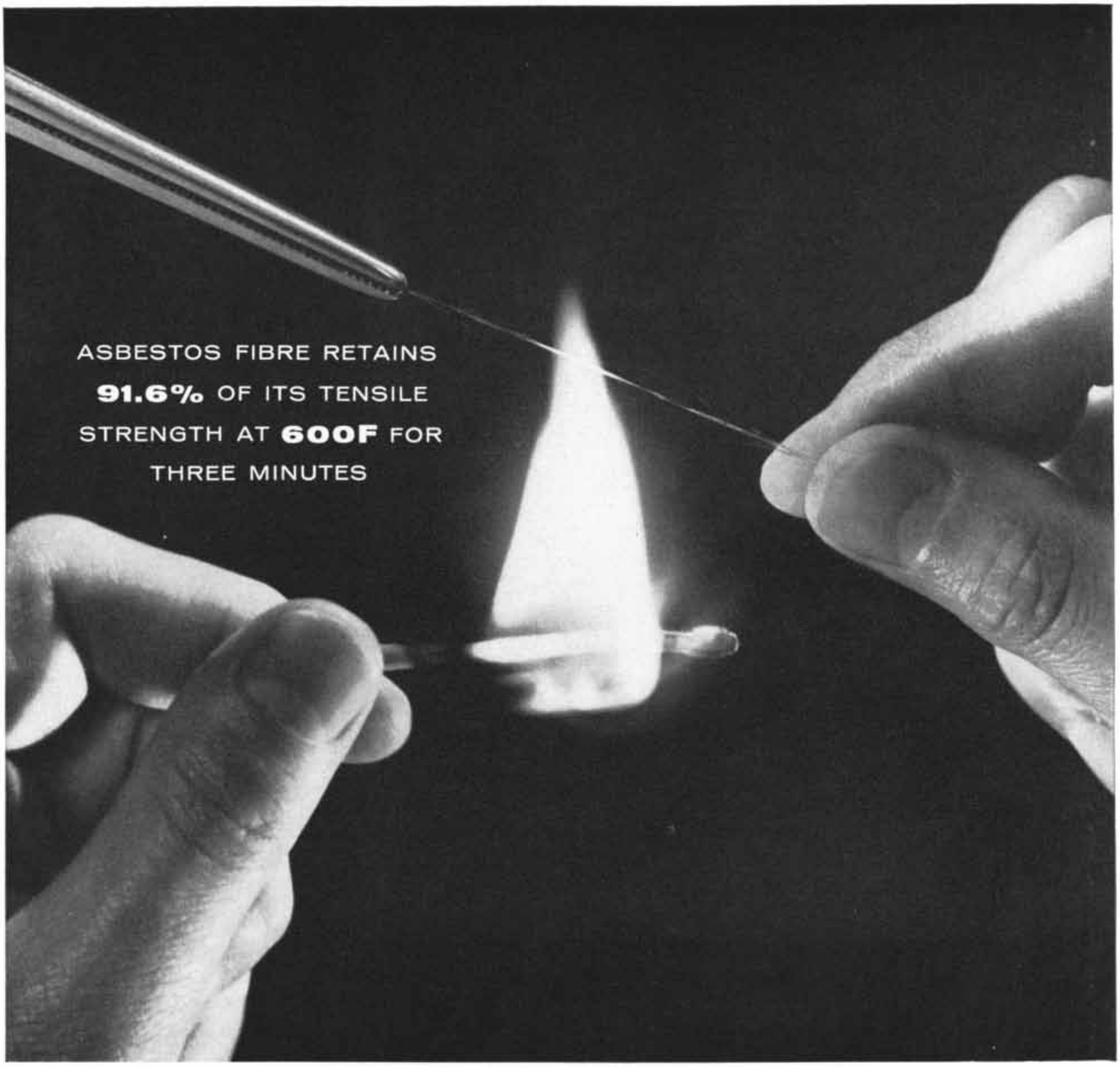
A very simple experiment has disclosed another distinct stage in the requirements for flowering: namely, transport of the flowering hormone from the leaves to the growing stem tips where the flowers form. If a cocklebur's leaves are removed at the end of the critical dark period, the plant will not flower. This must mean that the flowering hormone is still in the leaves and none has yet reached the stem tips.

Finally, there are obviously two more steps in the flowering process: the flowering hormone acts upon the cells in the growing tips in some way to transform, or differentiate, them from the vegetative to the flowering form of growth, and the bud then develops into the specific structures that make up a flower.

To sum up, the flowering of a plant has been resolved so far into about eight steps: (1) the build-up of needed substances in the plant by photosynthesis, (2) conversion of a pigment in the leaves to the noninhibitory form in darkness, (3) another preparatory reaction in the darkness, (4) synthesis of the flowering hormone, also in darkness, (5) a possible further chemical reaction requiring exposure to intense light, (6) transportation of the flowering hormone from the leaves to the growing stem tips, (7) alteration of the vegetative cells there to the flowering mode of growth, (8) development of the flower bud.

All this gives us only a tantalizing general view of the process, as if we were watching the building of a house and could see the foundation, floors, walls and roof go up but were too far away to see any of the details (wiring, plumbing, etc.) that make it a living home. We long for a more intimate view, which means a closer and more direct look at the chemical reactions involved in generating a flower.

At Colorado State University we have recently been doing some experiments which are opening some enticing new avenues of approach. Mainly these experiments take the form of testing the effects of various chemicals applied to



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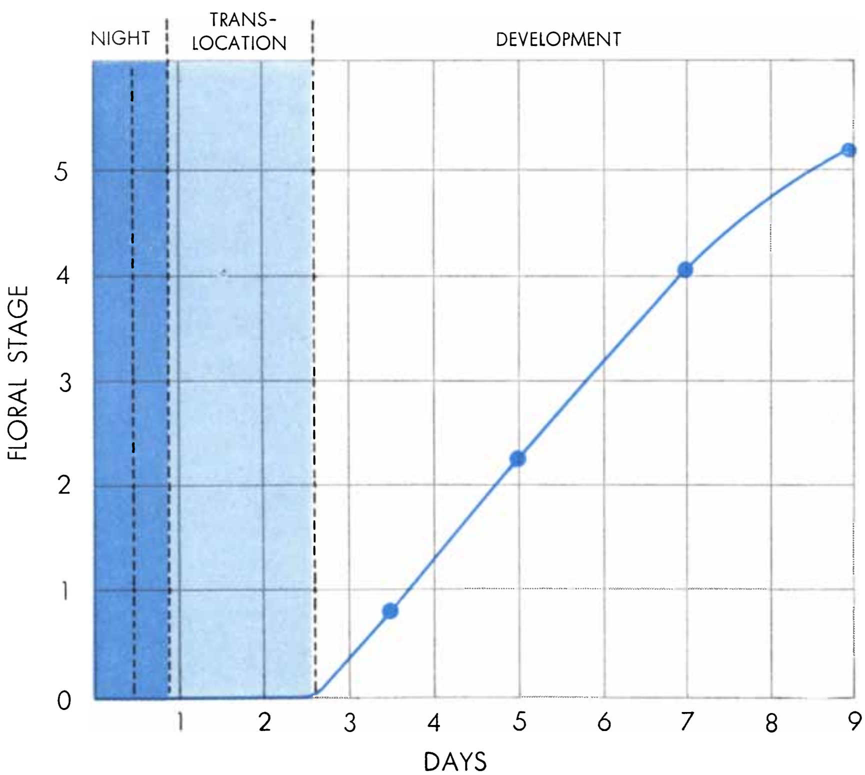
the plant before, during or after the dark period.

Some chemicals, known to be general inhibitors of plant growth (*e.g.*, maleic hydrazide), have proved to inhibit flowering in our cockleburs regardless of when they were applied. Others seem to exert a more specific action. For example, the growth hormones (auxins) interfere with flowering only if they are applied before the flowering hormone has traveled from the leaves to the growing tips. Our experiments suggest that they may play some part in destruction of the hormone in the leaves. Another chemical, the growth inhibitor dinitrophenol, prevents flowering only if it is applied to the cocklebur during the dark period. We think that it probably blocks synthesis of the flowering hormone. Dinitrophenol is known to interfere with the production of energy-rich phosphate bonds. If such bonds are the source of energy for the synthesis of the flowering hormone, dinitrophenol may exert its inhibiting effect by cutting off the power supply, so to speak.

One of our most useful tools for dissecting the flowering process has been the ion of cobalt. This chemical inhibits flowering only if applied during the early hours of the dark period. Thus we can narrow down its action to interference with one of two processes: the conversion of the pigment involved in flowering or the "preparatory reaction." Furthermore, among all the chemicals tested so far the cobalt ion is the only one that affects the length of the dark period needed for flowering. In some experiments plants treated with cobaltous chloride did not flower unless their dark period was at least 11 hours long. In other words, cobalt slows down the clock that ticks off the critical night for the cocklebur.

With refined probing tools such as cobalt and other specific growth regulators we have hopes of eventually being able to pinpoint the substances and reactions that bring the cocklebur to flower. But already the experiments have opened wider horizons. The specific wavelengths of orange-red and far-red light that so powerfully influence the flowering of cockleburs seem to control many other plant processes—not only the flowering of many plants but also the coloring of tomato skins, the germination of lettuce seeds, the growth of seedlings in the dark, the winter dormancy of tree buds, and so on. Perhaps we are on the track of a key pigment which plays a large role in the plant kingdom, and possibly even among some species of the animal kingdom.



DEVELOPMENT OF THE FLOWER begins after hormone reaches the bud, and continues at a fairly constant rate. In a typical experiment the cocklebur bud reaches the first floral stage in about four days, fourth stage in seven days and fifth stage in nine days.

MATHEMATICAL GAMES

Concerning the celebrated puzzle of five sailors, a monkey and a pile of coconuts

by Martin Gardner

In the October 9, 1926, issue of *The Saturday Evening Post* appeared a short story by Ben Ames Williams entitled "Coconuts." The story concerned a building contractor who was anxious to prevent a competitor from getting an important contract. A shrewd employee of the contractor, knowing the competitor's passion for recreational mathematics, presented him with a problem so exasperating that while he was preoccupied with solving it he forgot to enter his bid before the deadline.

Here is the problem exactly as the clerk in Williams's story phrased it:

"Five men and a monkey were shipwrecked on a desert island, and they spent the first day gathering coconuts for food. Piled them all up together and then went to sleep for the night.

"But when they were all asleep one man woke up, and he thought there might be a row about dividing the coconuts in the morning, so he decided to take his share. So he divided the coconuts into five piles. He had one coconut left over, and he gave that to the monkey, and he hid his pile and put the rest all back together.

"By and by the next man woke up and did the same thing. And he had one left over, and he gave it to the monkey. And all five of the men did the same thing, one after the other; each one taking a fifth of the coconuts in the pile when he woke up, and each one having one left over for the monkey. And in the morning they divided what coconuts were left, and they came out in five equal shares. Of course each one must have known there were coconuts missing; but each one was guilty as the others, so they didn't say anything. How many coconuts were there in the beginning?"

Williams neglected to include the answer in his story. It is said that the offices of *The Saturday Evening Post* were showered with some 2,000 letters during the first week after the issue appeared. George Horace Lorimer, then editor-in-chief, sent Williams the following historic wire: FOR THE LOVE OF MIKE, HOW MANY COCONUTS? HELL POPPING AROUND HERE.

For 20 years Williams continued to receive letters requesting the answer or proposing new solutions. Today the problem of the coconuts is probably the most worked on and least often solved of all the Diophantine brain-teasers. The term Diophantine is descended from Diophantus of Alexandria, a Greek algebraist who was the first to analyze extensively equations calling for solutions in rational numbers (positive or negative whole numbers and fractions).

Williams did not invent the coconut problem. He merely altered a much older problem to make it more confusing. The older version is the same except that in the morning, when the final division is made, there is again an extra coconut for the monkey; in Williams's version the final division comes out even. Some Diophantine equations have only one answer (*e. g.*, $x^2 + 2 = y^3$); some have a finite number of answers; some (*e. g.*, $x^3 + y^3 = z^3$) have no answer. Both Williams's version of the coconut problem and its predecessor have an infinite number of answers in whole numbers. Our task is to find the smallest positive number.

The older version can be expressed by the following six indeterminate equations which represent the six successive divisions of the coconuts into fifths. N is the original number; F, the number each sailor received on the final division. The 1's on the right are the coconuts tossed to the monkey. Each letter stands for an unknown positive integer.

$$\begin{aligned} N &= 5A + 1 \\ 4A &= 5B + 1 \\ 4B &= 5C + 1 \\ 4C &= 5D + 1 \\ 4D &= 5E + 1 \\ 4E &= 5F + 1 \end{aligned}$$

It is not difficult to reduce these equations by familiar algebraic methods to

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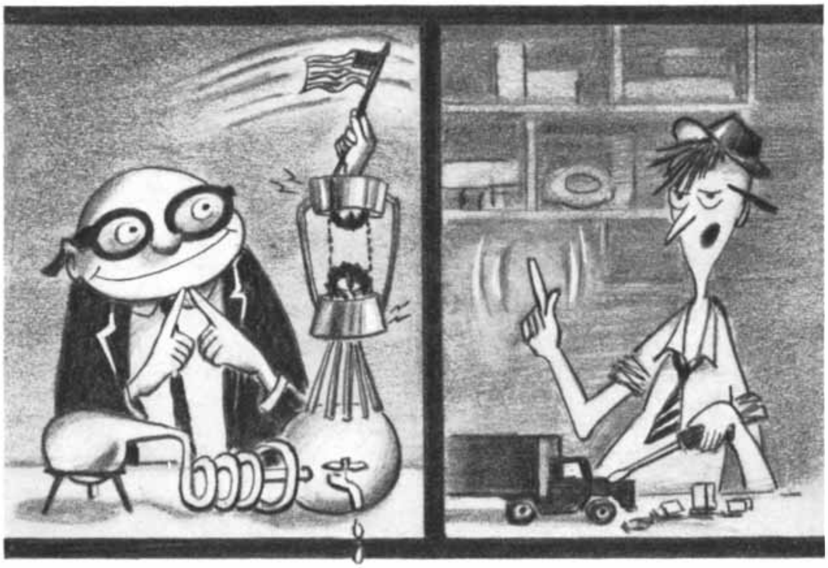
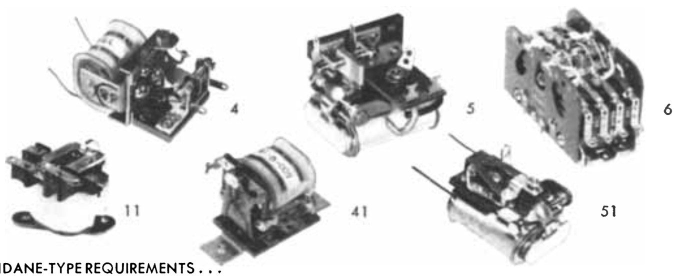




the following single Diophantine equation with two unknowns:

$$1{,}024N = 15{,}625F + 11{,}529$$

This equation is much too difficult to solve by trial and error, and although there is a standard procedure for solving it by an ingenious use of continued fractions, the method is long and tedious. Here we shall be concerned only with an uncanny but quite elegant solution widely attributed to the University of Cambridge physicist P. A. M. Dirac. Professor Dirac informs me, however, that he heard it explained by J. H. C. Whitehead, professor of mathematics at the University of Oxford.

Professor Whitehead (or whoever gave *him* the solution) may have reasoned something like this. Since N is divided six times into five piles, it is clear that 5^6 (or 15,625) can be added to any answer to give the next highest answer. (The first division adds 5^5 to each pile; the second division adds 5^4 to each pile; and so on down to the sixth division which gives each sailor one additional coconut.) In fact any multiple of 5^6 can be added, and similarly any multiple can be subtracted. Subtracting multiples of 5^6 will of course eventually give us an infinite number of answers in negative numbers. These will satisfy the original equation, though not the original problem, which calls for a solution that is a positive integer.

Obviously there is no small positive value for N which meets the conditions, but possibly there is a simple answer in negative terms. It takes only a bit of trial and error to discover the astonishing fact that there is indeed such a solution: -4. Let us see how neatly this works out. The first sailor approaches the pile of -4 coconuts, tosses a positive coconut to the monkey (it does not matter whether the monkey is given his coconut before or after the division into fifths), thus leaving five negative coconuts. These he divides into five piles, a negative coconut in each. After he has hidden one pile, four negative coconuts remain—exactly the same number that was there at the start! The other sailors naturally go through the same ghostly ritual, the entire procedure ending with each sailor in possession of two negative coconuts, and the monkey, who fares best in this inverted operation, scurrying off happily with six positive coconuts. To find the answer that is the lowest positive integer, we now have only to add 15,625 to -4 to obtain 15,621, the solution we are seeking.

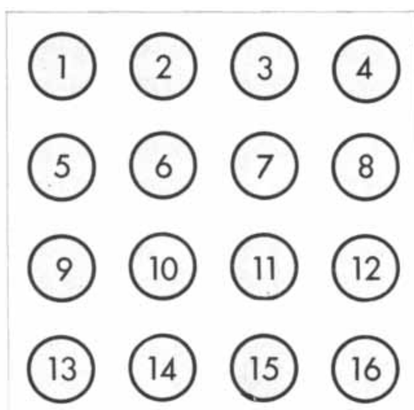
This approach to the problem pro-

vides us immediately with a general solution for n sailors, each of whom takes one nth of the coconuts at each division into $n$ths. If there are four sailors, we begin with three negative coconuts and add 4^5. If there are six sailors, we begin with five negative coconuts and add 6^7, and so on for other values of n. More formally, the original number of coconuts is equal to $k(n^{n+1})-m(n-1)$, where n is the number of men, m the number of coconuts given to the monkey at each division, and k an arbitrary integer called the parameter. When n is 5 and m is 1, we obtain the lowest positive solution by using a parameter of 1.

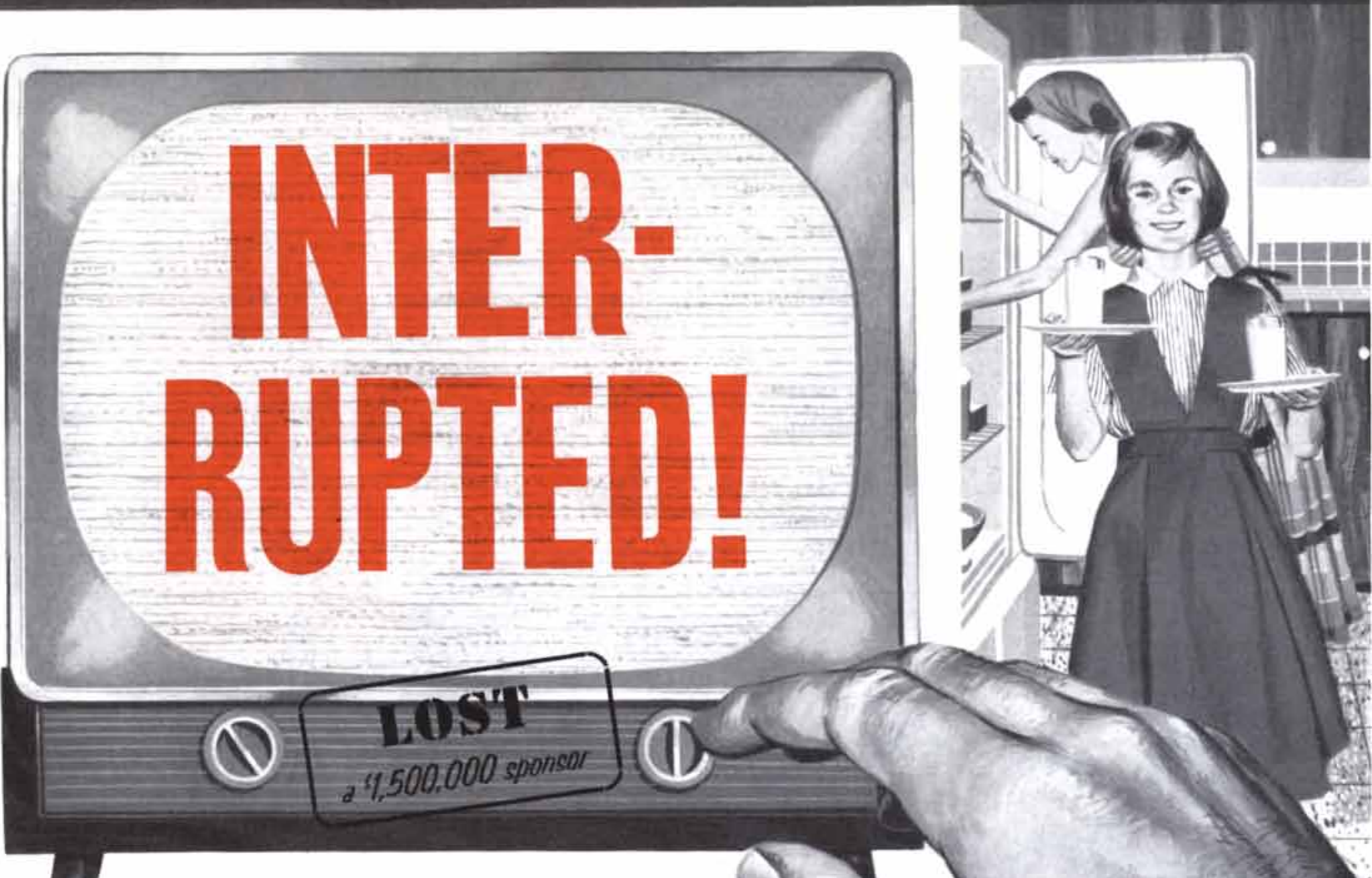
Unfortunately this diverting procedure will not apply to Williams's modification, in which the monkey is deprived of a coconut on the last division. I leave it to the interested reader to work out the solution to the Williams version; the answer will be given in this department next month. The solution can of course be found by standard Diophantine techniques, but there is a quick shortcut if you take advantage of information gained from the version just explained. For those who find this too difficult, here is a very simple coconut problem free of all Diophantine difficulties.

Three sailors come upon a pile of coconuts. The first sailor takes half of them plus half a coconut. The second sailor takes half of what is left plus half a coconut. The third sailor also takes half of what remains plus half a coconut. Left over is exactly one coconut which they toss to the monkey. How many coconuts were there in the original pile? If you will arm yourself with 20 matches, you will have ample material for a trial-and-error solution.

Two months ago this department introduced Piet Hein's intriguing game of Tac Tix, played with 16 counters arranged in the square formation shown



The game of Tac Tix



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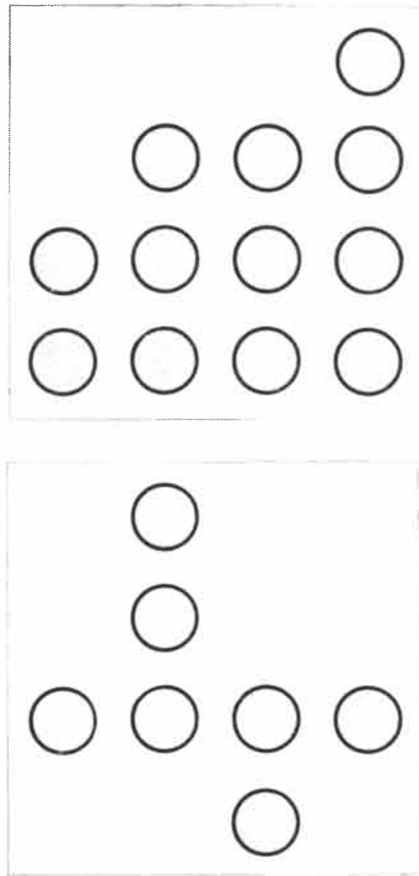

Two problems of Tac Tix

on page 122. Players alternately remove from one to four counters with the restrictions that they must all come from the same row or column, and must be adjoining pieces with no gaps between them. The person forced to take the last counter loses. Many readers have written in to say that symmetrical play insures a win for the second player with only a trivial modification on his last move. This is easily shown to be unsound by the following game.

The first player takes 7 and 8. Second player follows by symmetrically taking 9 and 10. First player takes 1; second player, 16. First player, 4; second player, 13. The first player now wins easily by removing 2 and 6.

The game is more complex than it first appears. In fact it is not yet known whether the first or second player can force a win even on a 4-by-4 board from which the four corner pieces have been removed. On this page are two interesting Tac Tix problems sent in by Hein. On each board you are to find a move that ensures a win. The answers to the problems will be published in this department next month.

new *-hp-* 560A

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Prints 11-digit information at 5 lines per second

Controlled by electronic or mechanical devices

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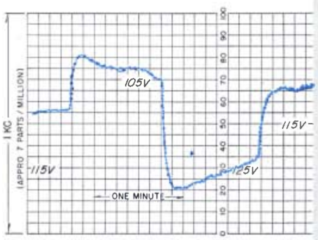
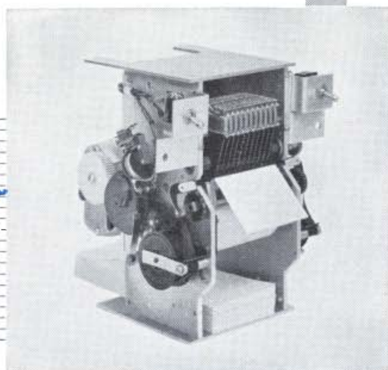
Frequency stability vs. line voltage; 150 MC oscillator





SPECIFICATIONS

Accuracy: Identical to that of basic counter used.
Printing Rate: Controlled by counter, 5 lines/sec. max.
Digit Capacity: 11 digits per line.
Driving Source: Parallel entry staircase voltages derived from standard digital frequency counters such as Hewlett-Packard types. Staircase descends from +135 v to +55 v as the count progresses from 0 to 9. Internal impedance of staircase source should be approximately 700,000 ohms.
Print Command Signal: 1 µsec or greater, positive or negative pulse, 15 volts p-p or greater.
Paper Required: Standard 3″ roll or folded paper.
Line Spacing: Single or double, adjustable.
Analog Signal: Any three consecutive digits may be selected by selector switch. Output is function of selected digits. For example, if consecutive digits were 3, 8, and 6, output voltage would be 38.6 millivolts or 0.386 ma.
Output Available: 1 milliamp for galvanometer strip-chart recorders. 100 millivolts for potentiometer strip-chart recorders.
Power: 105/125 volts, 60 cycles, 250 watts.
Dimensions: Cabinet Mount: 20½″ wide, 12½″ high, 18½″ deep. (Rack Mount available).
Weight: Net 60 lbs. Shipping 100 lbs.
Accessories Available: 1052-24, 3″ folded paper, 48/carton.
Price: Price on request.

Data subject to change without notice
Price f.o.b. factory

Model 560A is a new kind of continuous duty instrument designed from the chassis up for digital recording of frequency counter output and similar information. It is specifically useful in recording time functions, telemetered data, information to be monitored, tabulated and plotted and system drift phenomena. It is also a convenient digital/analog converter for strip-chart production.

Frequency counter accuracy

Since *-hp-* 560A is a slave to its information source, accuracy is that of the counter or other source. The instrument's motor-driven print mechanism comprises 11 number wheels and associated mixing-comparator circuits. The print mechanism is controlled by a staircase voltage and external print command pulse. The availability of 11-digit lines means secondary or coding data may be printed on the same line as primary data.

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THE AMATEUR SCIENTIST

An amateur builds a spectroheliograph to observe details on the disk of the sun

Conducted by C. L. Stong

Ten years ago a young coal miner in West Virginia sent a letter to this department which began: "Those who helped make the amateur-telescope-making books possible have caused me to live two years of my life in complete contentment." The letter went on to tell how its author, Walter J. Semerau, who now lives in Kenmore, N.Y., had constructed a six-inch reflecting telescope. In the intervening years Semerau has had a remarkable career both in amateur optics and in his daily work. He left coal mining to become an electrician, then an instrument-maker, then a laboratory technician and finally an engineer. Meantime, as regular readers of this department have learned, his six-inch telescope has been succeeded by a whole galaxy of bigger and better instruments, including a 12½-inch reflector complete with a coronagraph and a spectrograph. Semerau now informs us that his telescope mounting supports a new apparatus which has long been the dream of amateur telescope makers; a spectroheliograph of the Hale type. This instrument provides him with a view of the sun rarely enjoyed by laymen.

"Although the sun is a fairly stable body of gas," writes Semerau, "it is neither as amorphous nor as placid as the casual viewer might suppose. Immense clouds of ionized hydrogen, calcium and other substances thrown up from the interior account for features as distinct as the earth's oceans and land masses. Although each of these features emits light of unique color and intensity which distinguishes it from its surroundings, they are lost in the white glare of the sun as it is seen by the naked eye. To see the details clearly the observer is obliged to examine the sun in light of a single color.

"One might suppose offhand that the details could be brought into view by looking at the sun through a filter of colored glass. This stratagem would fail because colored glass, however deeply it is stained, transmits a broad band of colors, just as a radio set of poor selectivity permits several broadcasting stations to be heard at the same time. One must use a filter with an extremely narrow 'pass-band.'

"Such a device was hit upon about a century ago in India by the French astronomer Pierre Janssen. Janssen was using a spectrograph equipped with two slits to observe a total eclipse of the sun. The image of the sun's edge was focused on one slit. Rays proceeding through the slit were spread out by the prism into the familiar ribbon of spectral lines. Janssen was examining one of the lines through the second slit—the dark red line characteristic of glowing hydrogen—when he saw a tongue of flame standing out from the solar edge. Opening the slit brought more and more of the prominence into view until the width of the slit exceeded that of the red line. At this point the image became blurred. To examine slit-shaped portions of the solar disk in other colors Janssen simply shifted the viewing slit to other lines of the spectrum.

"Some 40 years later George Ellery Hale and Henri Deslandres independently devised a method of using the double-slit spectrograph to make photographs of the whole solar disk. The two slits were simply coupled mechanically so that they could be moved as a unit. When the entrance slit is swept across the sun's image, the exit slit keeps in step with the similarly moving spectral line of any selected color. Solar features emitting light of that color are focused on a photographic plate and build up a composite image that resembles the scanned image of a television picture. The device, called the spectroheliograph, was only a step away from the spectrohelioscope, which presents the composite image to the eye. To make a spectroheliograph into a spectrohelioscope one simply arranges for the slits to oscillate across the sun's disk at a rate of 20 or more sweeps per second and substitutes an eyepiece for the photographic plate.

"Not many spectroheliographs have been built by amateurs because of the difficulty of procuring the element which disperses white light into its constituent colors. This may be either a glass prism or a diffraction grating. Prisms large enough for the job are hard to make, and no amateur has succeeded in ruling a diffraction grating of the required fineness and precision. In recent years, however, the Bausch & Lomb Optical Company has introduced an excellent and relatively inexpensive 'replica' grating: a plastic cast of an original grating. A replica grating two inches square with 15,000 rulings per inch costs no more than a set of good golf clubs. With it the amateur can build a spectrograph of exceptional performance and equip this basic instrument with an accessory for making spectrohelioscope observations. [For a description of Semerau's spectrograph see "The Amateur Scientist"; September, 1956.]

"Although it is possible to fit out a spectroheliograph for mechanical scanning, the arrangement is bulky, difficult to maintain and a remarkably effective generator of unwanted vibrations. For these reasons I adopted the optical-scanning system devised by Hale in 1924. The conventional rocker arm which carries the entrance and exit slits in the mechanical system is replaced by a pair of rotating glass cubes, or Anderson prisms. The image of the sun is focused on the fixed entrance-slit of the spectrograph through one prism. The image of the similarly fixed exit-slit is focused on the plateholder (or on the focal plane of the eyepiece) through the second prism. As the prisms rotate, refracted light sweeps past the slits as though the slits had been moved across the rays mechanically. The prisms are mounted on the ends of a shaft which turns on ball bearings; the unit can be assembled on the mounting of even a small telescope without introducing perceptible vibration.

"The spectroheliograph assembly consists of (1) a main housing to which the moving parts are attached and (2) a tube for the eyepiece, reflex mirror and 35-millimeter camera [*see drawing on page 130*]. The unit is relatively light, compact and simple in construction. It weighs 10½ pounds complete with eyepiece and camera, and measures 15 inches over all. An adapter makes the assembly interchangeable with the plateholder of the spectrograph, which is mounted beside the telescope. The bearings of the equatorial mounting have enough friction to offset the added weight of the unit; thus no change is required in the counterbalance when the spectroheliograph is used.

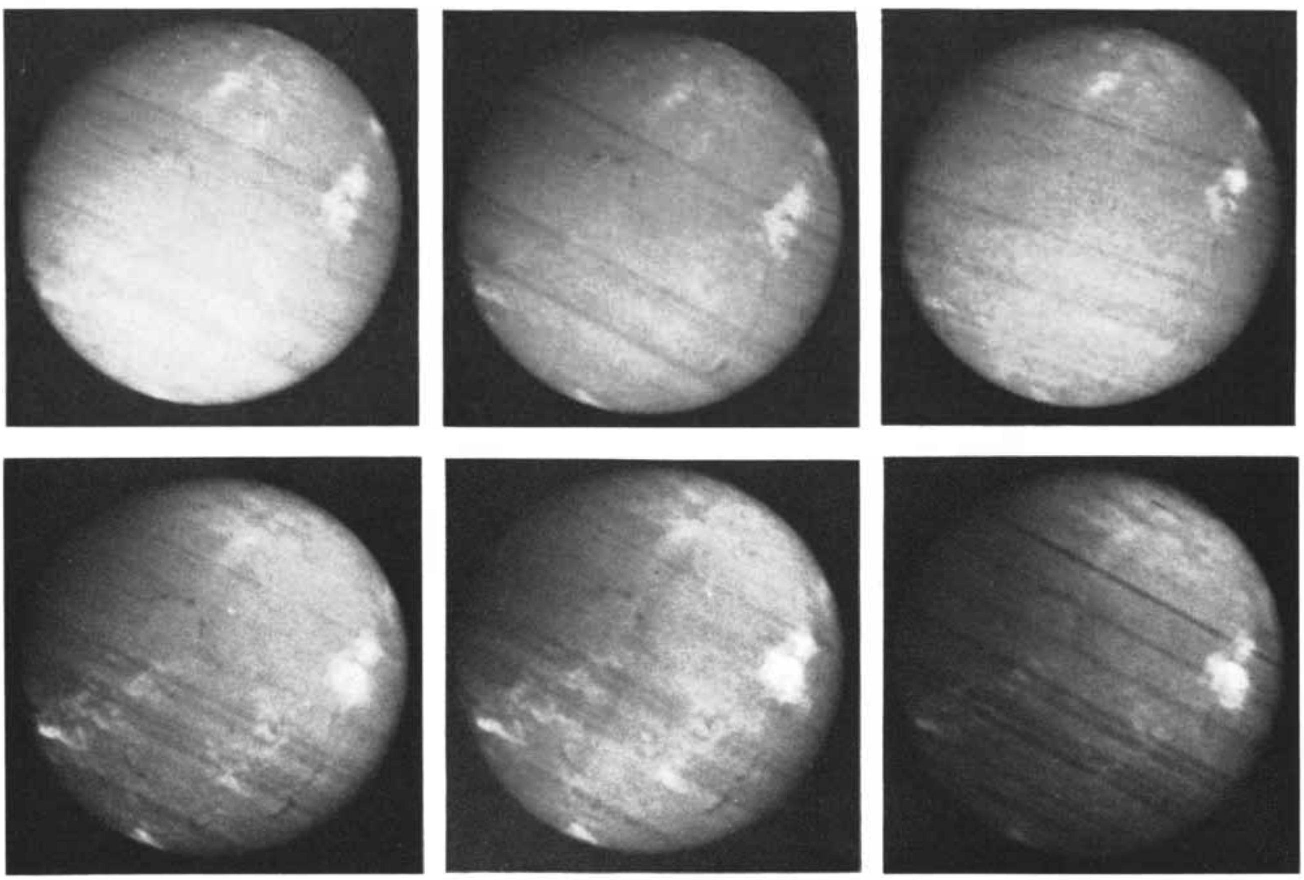
"Each prism is clamped between a flange at the end of the shaft and a metal disk held in place by through bolts. Rubber sheeting between the glass and metal protects the prisms against excessive mechanical strain. Center to center the prisms are 3.625 inches apart, the distance between the entrance and exit slits of the spectrograph. The flange supporting the outer prism is grooved for an 'O' ring belt through which the rotating assembly is coupled to a miniature direct-current motor. The facets of the prisms must be adjusted to lie in a common plane or the image will flutter when the unit is started up.

"Parallel rays entering my telescope come to a focus at a distance of 62.5 inches from the 12.5-inch objective mirror, a focal ratio of *f*/5. The focal ratio of the spectrograph is *f*/23. To feed the spectrograph with light from the telescope a set of negative achromatic lenses was introduced into the optical path between the objective and the spectrograph. This compensates for the difference between the focal ratios of the two instruments. A pair of front-silvered optical flats was mounted at the upper end of the telescope to receive rays reflected from the objective and bend them 180 degrees into the spectrograph.

"Incoming rays pass through one rotating Anderson prism, scan the entrance slit and diverge to an eight-inch spherical mirror at the opposite end of the spectrograph tube, where they are reflected as parallel rays to the diffraction grating at the other end of the tube. Here the white light is dispersed into its component colors and returned to the spherical mirror, which brings the resulting spectrum to a focus in the plane of the exit slit [*see drawing on next page*]. The exit slit may be adjusted to match the width of any spectral line. The most useful lines are the red 'alpha' line emitted by glowing hydrogen and the 'H' and 'K' calcium lines in the violet region of the spectrum. Light transmitted by the exit slit proceeds through the second Anderson prism, the scanning action of which, together with a final lens assembly, reconstitutes a highly monochromatic image of the source in the focal plane of the camera. A reflex mirror in the beam permits the image to be examined visually through the eyepiece.

"The operating procedure is relatively simple. After the instrument is assembled and aligned, the angle of the diffraction grating is adjusted to bring the desired spectral line into view in the eyepiece.

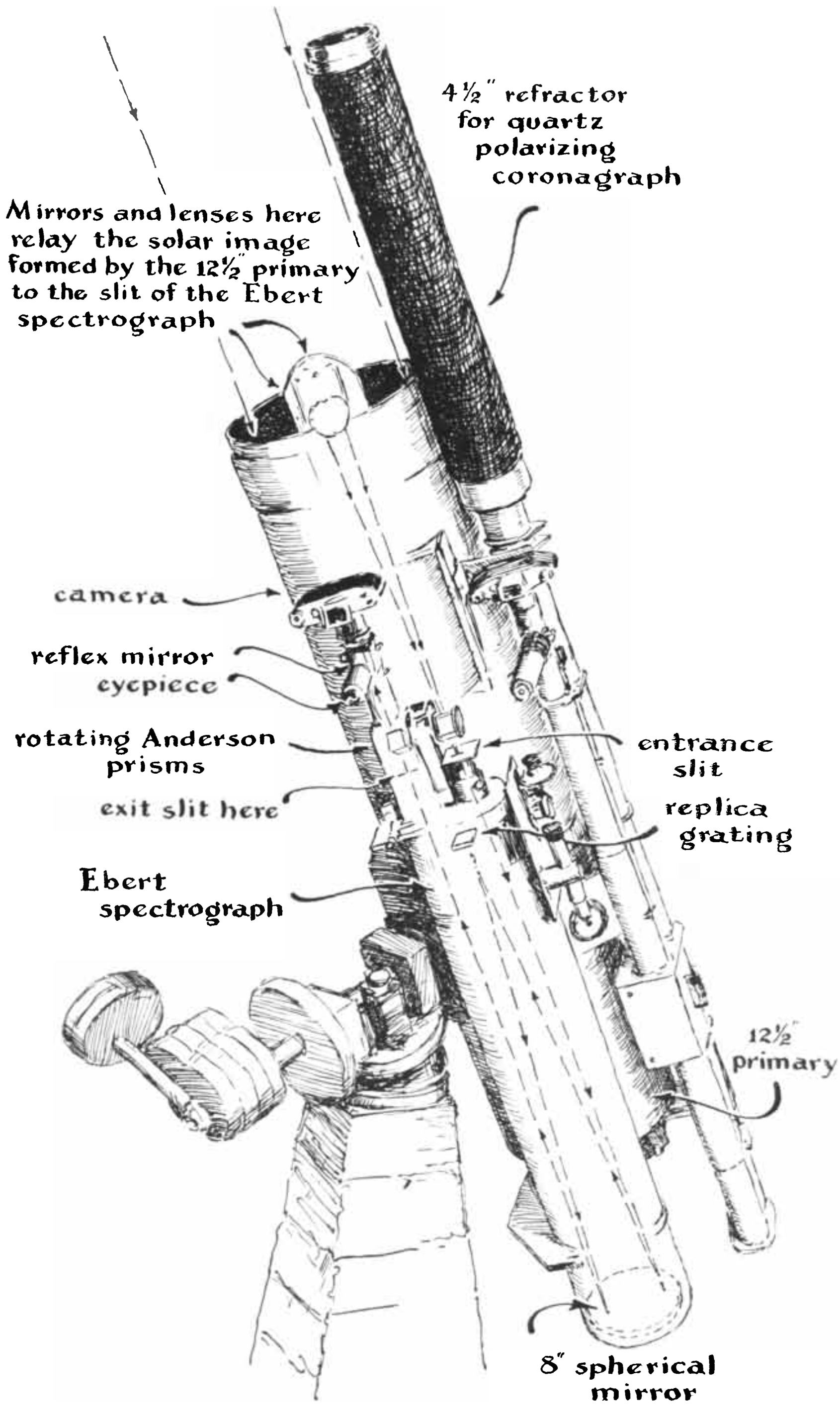
"Diffraction gratings produce a series of spectra (spectral orders), an effect analogous to a multiple rainbow. The extent to which the colors are dispersed increases with the 'higher' orders at the



These spectroheliograms were made on October 20, 1957 at 14:15, 14:18, 14:29, 16:51, 16:53 and 16:57 Greenwich mean time

cost of brightness. When used in the first order, the grating of my spectrograph can spread 14.5 angstrom units of the spectrum enough to fill the exit slit when its jaws are spaced one millimeter apart. In other words, dispersion in the first order is 14.5 angstroms per millimeter. The second order gives a dispersion of 7.5 angstroms per millimeter, and the succeeding orders proportionately more. Thus, were it not for the fact that the brilliance of the diffracted light diminishes with each successive higher order, one could observe an extremely narrow band of color through an exit slit of substantial width. My grating is ruled for use in the second order (it is 'blazed' for 10,000 angstroms in the first order and 5,000 in the second). Hence, to observe a band of color one angstrom wide the jaws of the exit slit must be spaced about a seventh of a millimeter apart.

"The spectral orders produced by the grating tend to overlap; that is, the



Semerau's telescope, showing the optical path used during spectroheliograph observations

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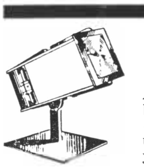

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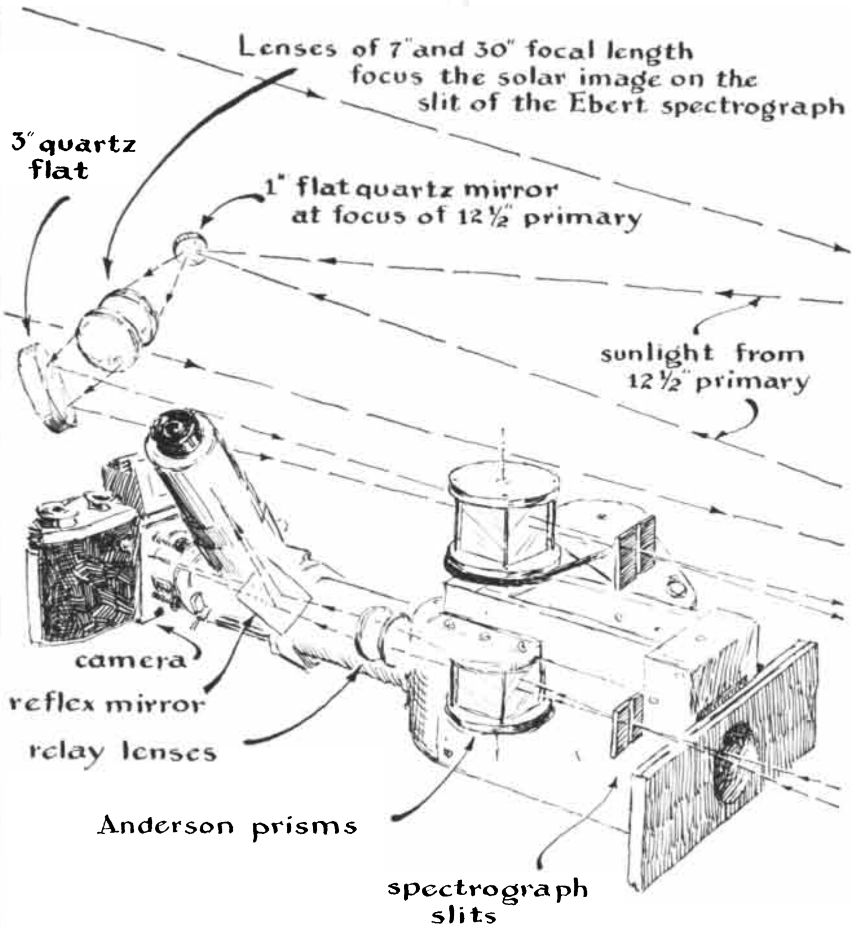

Details of Semerau's spectroheliograph

red end of the first order falls on the violet end of the second, the red end of the second order overlaps the violet end of the third, and so on. The effect must be minimized or the quality of the final image will suffer. This is accomplished by inserting in the optical path a glass filter which has maximum transmission in the region of the spectrum under observation. If one is observing the alpha line of hydrogen, for example, violet light from the unwanted order will be suppressed by a red filter such as the Corning Glass Works' No. N1661. Similarly, a violet filter is used when observing the H or K lines of calcium. The filter may be inserted at any point in the system, but a filter located at or near the primary focus may heat unevenly and break. Hence the filters are usually placed at a point between six and eight inches from the primary focus.

"With the filter in place, the entrance slit is opened to a width of about .02 inch. This admits considerably more light than is needed for observing but simplifies subsequent adjustments. The exit slit is opened so the spectral lines can be seen easily between the jaws. The desired line is selected and focused sharply by moving the entrance slit back and forth. The image of the exit slit is then focused so that the jaws appear sharp when viewed through the eyepiece. If spectroheliograms are to be made, the camera is similarly adjusted to bring the slit into sharp focus on the film. The instrument is next adjusted for maximum resolution. First, the jaws of the entrance slit are closed to the point where the spectral lines appear dark and sharply defined against a light background. Then the jaws of the exit slit are closed until they just frame the line selected. In the case of the alpha line of hydrogen the optimum width will be approximately a fifth of a millimeter. The motor is started. As the prisms reach a speed of about 16 revolutions per second, a monochromatic image of the sun, complete with the flaming detail of the solar surface, will come into view.

"This of course assumes that all adjustments have been carefully made. Each element of the instrument, from the objective to the eyepiece and cam-

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Dr. Sidney L. Simon

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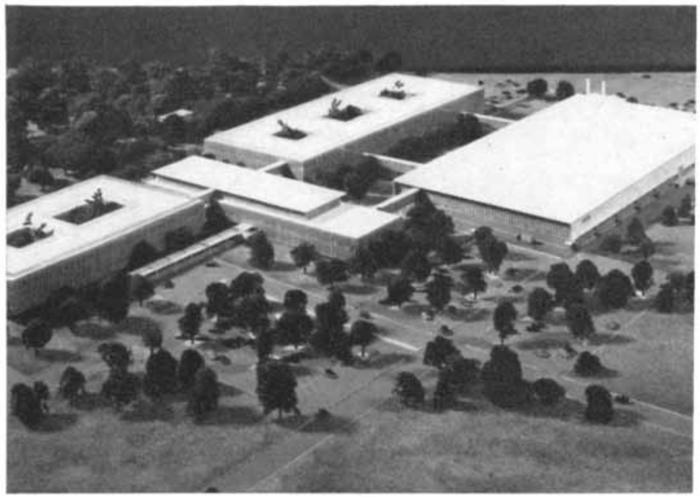
Sidney L. Simon

Dr. Sidney L. Simon
Assistant to the President



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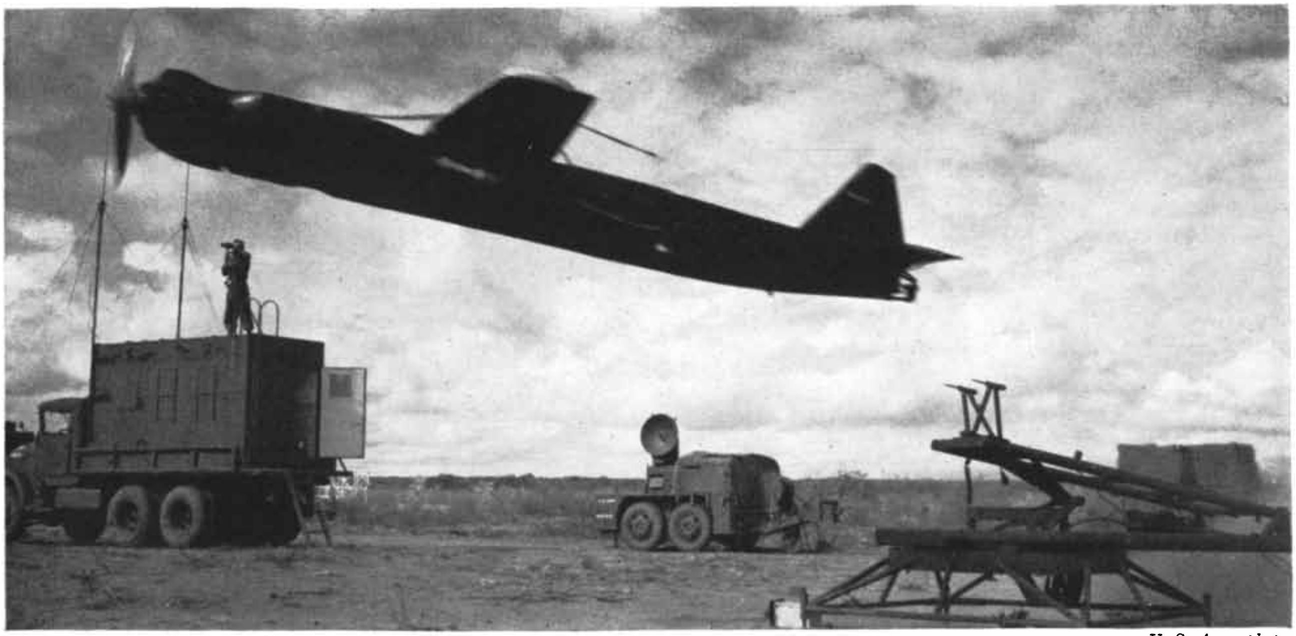
era, must be aligned with the optical axis of the system. If the telescope and spectrograph are out of line, for example, only part of the light will fall on the diffraction grating. The final image will not be as bright as it could be. In addition, the unused light will be reflected from the housing, will mix with the diffracted rays and reduce the contrast of the image. Similarly the system should be adjusted so that white light from the entrance slit approximately fills the diffraction grating. If the grating is not fully illuminated, its efficiency suffers. Conversely, rays which extend beyond the edge of the grating are lost to the final image and impair its contrast.

"The final adjustment consists in gradually narrowing the exit slit. This brings progressively finer details into view; prominences, mottling near the region of sunspots, dark filaments, flocculi and so on. It also reduces the brilliance of the image and sets a limit to visual observation. At this point the camera comes into use. The average exposure time is from two to four seconds; the instrument is guided during a time exposure as it is in conventional astronomical photography. The camera is also used in the violet region of the spectrum beyond the range of the eye. In this region lie the H and K lines of calcium.

"Although the instrument has many desirable features, I should also mention one disadvantage. The Ebert spectrograph, as I constructed it, introduces some distortion; the image of the sun's disk is somewhat elliptical. This is explained by the fact that the slits must be located somewhat off the axis of the spherical mirror. The distortion is partially compensated by tilting the camera. Curved slits would provide a better correction, but I have no way of making them. The distortion does not impair resolution but it introduces some complication in locating details accurately on the image. Advantages of the design include simplicity, lightness, relatively low cost and a cylindrical form that is easy to assemble on an equatorial mounting. In addition, desired portions of the spectrum can be brought into view at the twist of a dial.

"The spectroheliograph is mounted beside the coronagraph previously described in 'The Amateur Scientist' [September, 1955]. The two are used simultaneously. The coronagraph shows prominences at the edge of the sun in great detail, but gives no hint of the solar disturbances responsible for them because the central disk is masked by



U. S. Army photo.

Aerial drone being launched in test at Fort Huachuca. Remotely controlled by van equipment, it serves as a "flying camera" to spot enemy movements and installations.

U. S. ARMY SIGNAL CORPS DEVELOPS ELECTRONICS FOR ATOMIC-AGE AT FORT HUACHUCA PROVING GROUND

Fort Huachuca, once a sleepy cavalry post, has come of age in the last few years. When the United States Army Electronic Proving Ground was established here in early 1954, this mile-high post was set upon a new trail marked by electron tubes, transistors, radar antennae, and television cameras.

Nestled against the base of the rugged Huachuca mountains about 100 miles south of Tucson, its 70,000 plus acres are a beehive of electronic activity under United States Army Signal Corps direction. The many types of different terrain are ideal for the testing of electronic equipment.

Nearly 5,000 military personnel and approximately 2,000 civilian employees, many of them highly skilled scientists, are engaged in work at the Proving Ground.

The new look in defense is placing heavier burdens on the United States Army Signal Corps. This, of course, means more communications with new doctrines suited for employment in atomic war. The Combat Development Department at the Proving Ground has been experimenting along these lines. A new area system of battlefield communication designed to meet the threat of mass destruction from nuclear attack is now in the planning stages.

Meanwhile, the Signal Communications Department is conducting tests on both standard and experimental United States Army Signal Corps equipment to determine their future with the new look in defense. Under atomic attack, the use of extensive wires will not be practical. More radio communication is the answer, but ways to put more channels on radio frequency must be found.

With the spread-out of troops under atomic attack, increased surveillance of combat areas is a necessity. The Combat Surveillance Department of USAEPG is presently developing and testing a surveillance system with devices on the ground and in the air to bring reconnaissance and fire control information to the field commander.

Another important Proving Ground product is the "Flying Camera." A high speed camera is mounted in the fuselage of a remote-controlled drone aircraft. The aircraft is launched into the air by means of jet assist. When its mission is completed, the drone parachutes to the ground near the original launching site. Its up-to-the-minute pictures are developed, and the troops proceed to hit the pin-pointed areas of resistance.

These are just a few of the many projects under way at Fort Huachuca, helping to keep our country's military offense and defense the world's best.

This is one of a series of ads on the technical activities of the Department of Defense.

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a diaphragm. In contrast, the spectroheliograph reveals faculae, flocculi, filaments, spots and even prominences of exceptional brilliance.

"Amateurs often ask which instrument I prefer. The choice is difficult. Both were interesting projects. The cost is influenced, particularly in the case of the coronagraph, by the extent to which the final image is made monochromatic. The filtering element in my coronagraph is a quartz monochromator, a multilayered sandwich of crystal quartz and Polaroid film. It was designed to transmit a band of color four angstroms wide. At current prices the raw crystalline quartz from which it was made would cost about $150. Four times this amount would be needed to narrow the passband to one angstrom. If, for example, a monochromator designed for a passband of four angstroms requires a stack of crystal slabs four inches high, one for a pass-band of one angstrom would require a 16-inch stack. Moreover, each successive slab in the stack must be twice as thick as its predecessor. This means that the final slab in a 16-inch stack would have to be cut from a raw crystal more than eight inches long. Crystals of this size—and of the necessary optical perfection—are not common in nature, and are priced accordingly.

"Monochromators are not easy to build. I would rather make two sets of prisms for a spectroheliograph than any two quartz slabs for the monochromator. Not only is glass softer and easier to work than quartz, but the prisms may be cut in random directions from any location in a block of glass. Quartz crystals must be put through a complex series of tests to determine their optical properties in advance of cutting. The defects of quartz are many, and the substance is so hard that a diamond-edged saw is almost a necessity.

"But one look through the eyepiece of a coronagraph, even one with a passband of four angstroms, justifies the investment of time and labor. When they are seen in detail, solar prominences are among nature's most impressive spectacles. I did not keep an accurate record of my cash outlay for the two instruments, but an estimate of $300 for each would not be far wrong.

"I had the good fortune to observe and photograph an interesting pair of solar events on October 20, 1957. No outstanding disturbance was evident when I began to observe at 14:15 Greenwich mean time, but within 15 minutes a scarlet flocculus appeared near the southwest edge of the sun. The intensity of the flocculus remained constant during the following two hours, but at 16:51 a small flare brightened near the east edge. At about this time the cloud first observed also started to brighten; thereafter both regions grew in size and brightness to the International Geophysical Year standard of 'Importance 3.' By 17:15 the east flare had diminished to normal brightness and 45 minutes later the one near the southwest edge similarly faded. The visual image was sharp and crisp. Poor seeing caused some blurring of the photographs, but conditions improved somewhat at 16:51 [*see photographs on page 127*]."

Semerau states that he is now working on an electronic servo guiding-mechanism, two 35-millimeter time-lapse cameras and a heavier equatorial mounting for his instruments. What he hangs on the mounting next is anybody's guess!

The following letter reminds the editor of this department of a statement attributed to the late Fiorello H. La-Guardia: "When I make a mistake, it's a beaut."

"Sirs:

"In 'The Amateur Scientist' for January the statement is made that a satellite gradually loses speed in the rarefied air above 100 miles. This is not correct. In fact, frictional drag by an atmosphere actually causes an orbiting body to fly faster!

"A satellite orbiting a planet with an atmosphere is a very interesting dynamical system, in which dissipative energy-loss is combined with the usual laws of astronomical dynamics to produce surprising effects.

"One can show very simply that any change in the total energy of a satellite in a circular orbit (kinetic energy plus gravitational potential energy) is equal to minus the change in its kinetic energy. That is, for every unit of energy dissipated by the satellite by interaction with the atmosphere, the satellite loses two units of potential energy and gains one unit of kinetic energy. These relationships are determined by the connection between velocity and radial distance for a circular orbit.

"For convenience, let the zero of potential energy be at infinity. Then the potential energy is:

$$P = -\frac{Gm}{r}$$

"Here G is the gravitational potential constant of the earth; m, the mass of the

MAGNETIC TAPE APPLICATIONS BY AMPEX

12

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Sometimes pretending can be better than the real thing — or at least cheaper (by millions or billions). For such purposes magnetic tape is a master mimic with a talent for recreating or synthesizing almost any physical, mechanical or electrical effects.

Simulation control console showing the Ampex FR-100 behind

CHECKOUT AND PERSONNEL TRAINING WITH "INDESTRUCTIBLE TARGETS"

U. S. Army's Land Based Talos unit* at White Sands Proving Ground tests its weapon system for response to "enemy engagements." Missiles and suitable targets could be a frightful expense — limited in number at best — and destructive of much of the evidence of performance. But magnetic tape bypasses the hardware carnage by providing the signals that the missile would "see."

** Developed by RCA under U.S. Navy Sponsorship.*

The Talos Missile "flies" its collision trajectory toward an enemy on tape. Correlation between target signals and weapon-system response is recorded. Without the missile ever leaving the ground, the weapon system proves its ability to find the aerial invader.

Similarly, tapes are used to train personnel. Complex "enemy engagements" on tape actuate the instruments and indicators requiring human judgment. Crew reactions are recorded for study and improvement.

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Magnetic tape is able to make these complex simulations because its output is electrical. When tape signals are suitably amplified, they are identical to the voltages that occur in the sensing, guidance and instrument systems of the missile and launcher. Tape can reproduce almost any desired analog or digital pattern. Successive replays will be completely identical.

For the Army's Talos installation in New Mexico, tapes are prepared on the east coast. Compatibility, an important feature of Ampex Tape Recorders, makes it possible to send these "enemy attacks" across the country on reels of tape with assurance that correct tests will be made.

Simulation from magnetic tape is used by others in innumerable ways. It records vibrations in aircraft and vehicles to drive shake tables that test components. It records operating sequences or performance standards to test production assemblies. It reproduces sounds. And tape has even been used to reproduce mountain highway grades to test truck axles under laboratory observation.

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satellite; and *r*, the radial distance from the center of the earth.

"The kinetic energy is:

$$K = \frac{mv^2}{2}$$

"The condition for a circular orbit is that the centrifugal force equal the gravitational force:

$$\frac{mv^2}{r} = \frac{Gm}{r^2}$$

"Multiply by r/2:

$$\frac{mv^2}{2} = \frac{Gm}{2r} = -\frac{P}{2} = K, \text{ or } P = -2K$$

"We find therefore that the potential energy as defined above is constrained to be in a fixed ratio to the kinetic energy for any circular orbit. The total energy is: $T = P + K = -K = P/2$. Therefore any changes in total, kinetic or potential energy also follow the same relationship:

$$\triangle T = -\triangle K = \frac{\triangle P}{2}$$

"A more elaborate theory can be developed for noncircular orbits, but this simple case suffices to show the basic idea.

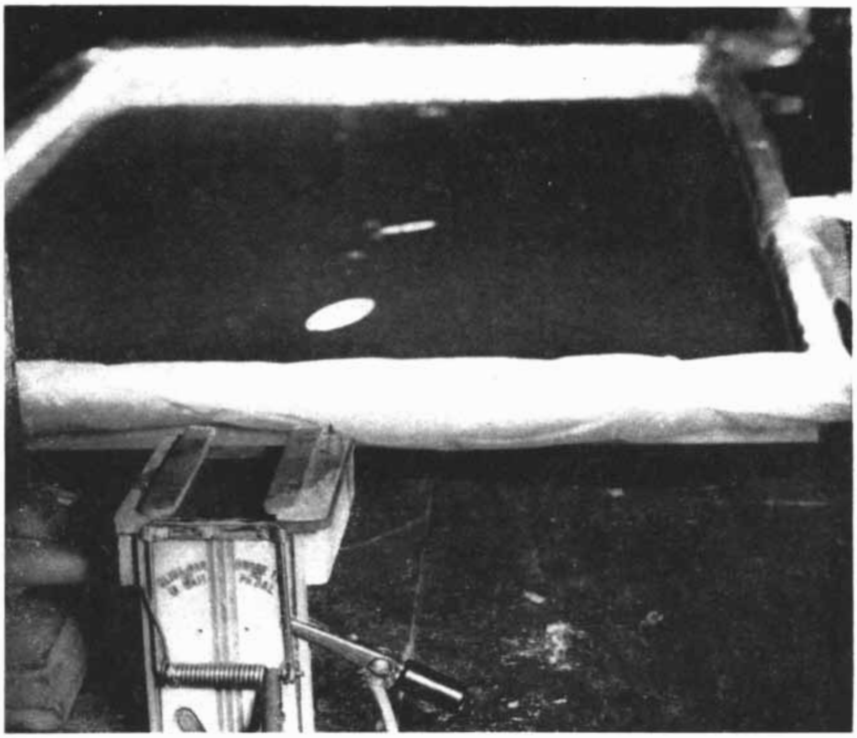
"Incidentally, it may be interesting to ask your readers for suggestions of nonastronomical examples of this effect, or a scheme for building a valid demonstration model of a system which speeds up as a result of frictional dissipation."

Sylvan Rubin

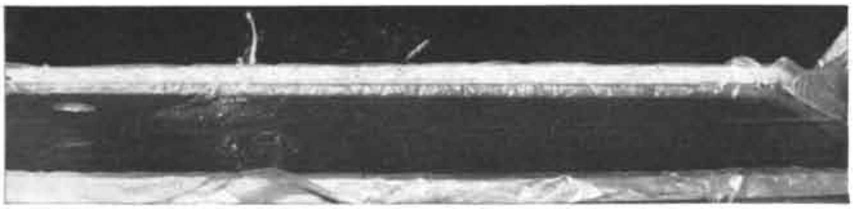
Manager
Atomic Physics Section
Stanford Research Institute
Menlo Park, Calif.

Walker Van Riper of the Denver Museum of Natural History has used the high-speed camera to make numerous studies of animals such as rattlesnakes and hummingbirds ["The Amateur Scientist"; March, 1957]. He has now turned his camera in a new direction to explode a charming little puzzle presented in this department a year ago.

"In 'The Amateur Scientist' for April, 1957," writes Van Riper, "Ernest Hunter Wright described an interesting experience of his with skipping stones on wet sand. What he observed was that the stone does not behave in accordance with the usual notion; that is, it does not move in a series of leaps of decreasing length, but rather, after the first contact with the sand, it takes a short bounce of about four inches, then a long leap of, say, seven feet, a short bounce of four inches, a leap of five feet, then another four-inch bounce and so on, each suc-



Van Riper's apparatus for making high-speed photographs of a skipping button



Button strikes water flat and makes a long leap, leaving a single splash

ceeding short bounce being 'unmistakably recorded by two neat little marks on the sand.'

"He said he was satisfied that the stone does not turn over, nor does it hit with the rear end first, then do a little flop and strike with the front edge before taking off for the next leap; the marks show that the stone strikes the sand flat. And he said that he felt that 'the same thing happens on the water, though in the water there is no imprint left to tell the story.'

"One of my friends suggested that this was a question which might be studied by means of high-speed flash photography, so I set up the following experiment. Limitations of the apparatus, such as the fact that camera and lights must be fairly close to the subject and that a black, nonreflecting background is required for multiple-exposure photography, made it necessary to operate on a small scale. A shallow pool of water was made by laying weather-balloon plastic over a frame on a long table with water added to a depth of about one inch. The missile finally chosen was a white button one inch in diameter; it was launched from a horizontal slot by striking its rear edge with a mousetrap spring. This act closed a circuit which tripped the camera shutter set at 1/10 second and at the same time triggered a falling-weight device which set off three high-speed flashes at predetermined intervals. In some cases a timer was placed in the background to record the intervals exactly. One side of the slot through which the missile was fired was lined with rubber; the other side was not. This served to put a spin on the button.

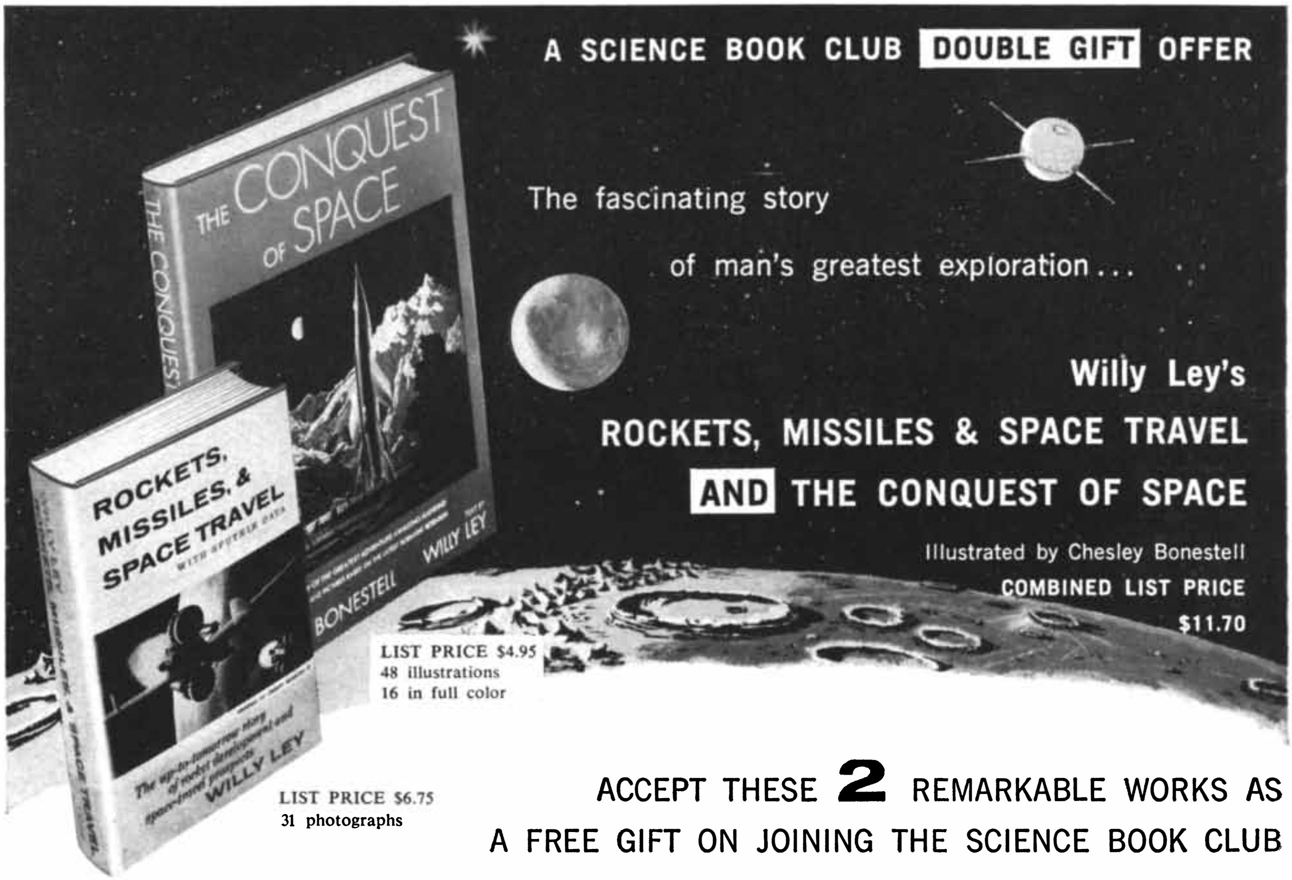
"The pictures tell the story. The first one [*see page 136*] shows the firing device in operation. The second [*above*] shows a normal trajectory, the button hitting the water flat and flying ahead with no short bounce. The third picture [*below*] shows an abnormal operation in which the missile was for some reason propelled with its plane nearly vertical to the surface. In this case two splashes are plainly recorded, showing that the button did take a short hop before flying ahead in a longer leap. A number of records of both kinds were made—enough to make it evident that the short bounce did not occur when the firing was normal, that is, with the button's plane parallel to the surface of the water. It only occurred in abnormal cases such as that described above.

"With the aid of the timer the speed of the missile could be estimated. It was about 14 feet per second—9 to 10 miles per hour. A thrown stone would go faster, probably 25 to 30 miles per hour.

"Some friends and I also tried skipping stones on water and on wet sand. We thought that an observer on a high bank overlooking a still pool should be able to see evidence of the short bounce if it occurred. But we were unable to get it. A lot of throwing over wet sand produced a few aberrations which might have been interpreted as a bounce, but, on the whole, we could not satisfy ourselves that the thing happened with even a slight degree of regularity.

"All this suggests that Dr. Wright's phenomenon might be due to some individual method of throwing. He states that he can throw a flat stone with no spin, which my friends and I were all sure we could not do. And if he habitually throws so that the plane of the missile is vertical to the surface, then he might regularly get the short bounce."

Button strikes water on edge and makes a short hop, leaving two splashes



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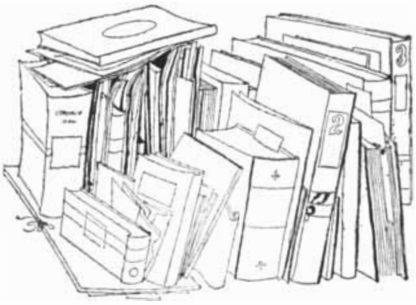

BOOKS

A study on the nature of scientific discovery

by James R. Newman

REASON AND CHANCE IN SCIENTIFIC DISCOVERY, by R. Taton. Philosophical Library ($10).

The world rewards discovery. The first man to discover a planet, a cure or a natural law is a hero. It is not always certain, to be sure, that the discoverer made the discovery. Especially in the realm of ideas the true inventors are apt to be unknown. Everything of importance, Alfred North Whitehead observed, has been said before by somebody who did not discover it. But the hunger for heroes is as great as the hunger for scapegoats; and as some innocent men are hanged lest murder go unpunished, some undeserving men are rewarded lest discovery remain anonymous.

Scientific discovery is a subject of lively interest. Almost everyone is curious about the events leading up to a new drug or mechanical contrivance. Who thought of it? What gave him the idea? And so on. The circumstances are embroidered and dramatized; they grow into legends: "Suddenly Edison perceived..."; "Pasteur happened to glance at the cage and all at once he realized . . ." Lately this harmless subject has attracted the notice of politicians. They pursue it more heavily. How, they demand to know, are inventions made? What shall we feed our children to make more Einsteins? Lincoln suggested that his generals might profit from drinking the same whisky as Grant; statesmen will subsidize any diet which promises a crop of Bohrs.

Are there special factors which stimulate invention? Various eminent scientists have divulged their working secrets. One must "think aside" said Claude Bernard. Creativity, said the chemist J. Teeple, is promoted by two warm baths in succession. Others have suggested black coffee, the study of dreams, long walks, a vegetable diet. The pattern is not clear. We must look elsewhere.

It is not generally appreciated that science is a creative activity closely resembling other creative activities. For some reason science is thought to be a special case. No systematic effort is made to discover Rembrandt's formula; no one supposes that the origins of Mozart's inventions can be laid bare. How does their case differ from Newton's or Fermat's? Cultural historians examine the general conditions of creativity—social circumstances, contemporary thought and so on—but they are not concerned with minute analyses of invention. (John Livingston Lowes's masterly detective story about the genesis of Coleridge's poems "The Rime of the Ancient Mariner" and "Kubla Khan" is almost unique.) It is rightly assumed to be too difficult to trace the intricate weave of creative endeavor in the arts. We readily accept the fact that we cannot explain the genesis of Beethoven's Fifth Symphony; is it easier to explain the genesis of Kepler's laws?

There is a common notion that scientific discovery is sudden, like stumbling upon a treasure. The story of Archimedes running naked from the baths shouting "Eureka!" is the archetype of discovery legends. The truth is scientific discoveries are never sudden. Ideas have ancestors; ideas come in families. The culmination of a family of ideas is of course easily identified. Here is Gregor Mendel's paper of such and such date; here is the first edition of *Madame Bovary*. But what led to this result? How many generations of thought? What traditions? What errors and false starts? What part was played by chance? Reason? Experience? We are scarcely better able to answer these questions for the laws of genetics than for Flaubert's masterpiece.

Still, there is a strong urge to try. René Taton's little book, published in Paris in 1955 and now translated (at times quite awkwardly) into English, is the most recent attempt along these lines. It has the merit of being a modest work. There have, as he points out, been many studies concerned with the origins, conditions and character of scientific discovery. The authors of these studies have striven for general conclusions, but Taton considers this "dangerous territory." Instead, he has restricted himself to "a description of the different realms of scientific discovery, its principal factors and its essential aspects, with examples drawn from the various fields." As an unpretentious catalogue, with some interesting entries, his book is useful. It helps us to understand how subtle and many-sided is the process of discovery and how inadequate are the pronouncements purporting to schematize it.

Of the different forms of scientific creativity, mathematical invention has had perhaps the most serious attention. French scientists in particular have concentrated on the subject. In 1905 in *L'Intermédiaire des Mathématiciens* the question was raised: Do "mathematical dreams" promote the solution of problems "vaguely studied" in the waking state? The replies were not enlightening. Most of the correspondents had enjoyed neither algebraic nor geometric dreams; the few who were so fortunate emphasized that a solution appeared "at the very moment of waking." A much more ambitious inquiry was undertaken by *L'Enseignement mathématique*. Elaborate questionnaires were sent out, and the answers were carefully analyzed by a group of mathematicians and psychologists. The majority of first-rate mathematicians who received questionnaires were unwilling to take the time to reply in detail, and the bulk of the answers came from less gifted research workers. Still, it would be interesting to know what they said; unfortunately Taton doesn't tell us.

In 1908 Henri Poincaré gave his famous lecture "L'invention mathématique." This essay read to the General Institute of Psychology of Paris is so well known that I scarcely feel the need for an extended comment. Poincaré speaks of the nature of mathematical aptitude. It cannot, in his view, be reduced to a fine memory or extraordinary powers of concentration. Mathematicians, he says, are rarely good calculators or strong chess-players. He confesses that he himself is incapable of doing a sum without making a mistake; and over the chessboard, after examining the various possible consequences of several moves, he would end by making the very first move that had occurred to him, forgetting that its obvious dangers had led him to reject it and to enter upon his calculations. In place of memory the mathematician relies upon a certain "intuition." With this to preside over his thoughts, to carry him along, he need not be concerned over mislaying bits and pieces of the argument. They will reappear when needed, and meanwhile the forward march of the demonstration will be guided by the "intuition of a mathematical order which enables [him] to guess the hidden harmonies and relations."

There follows his definition of mathematical discovery: "What, in fact, is mathematical discovery? It does not consist in making new combinations with mathematical entities already known. That can be done by anyone and the combinations that could be so formed would be infinite in number and the greater part of them would be absolutely devoid of interest. Discovery consists precisely in not constructing useless combinations but in constructing those that are useful, which are an infinitely small minority. Discovery is discernment, selection."

This is a celebrated definition, but I see no reason to celebrate it. It is not trenchant; it does not light up the dark. It says that discovery is hard, that originality is rare and that a clever man can tell a good thing when he sees it.

Nor does the rest of the essay—though it is a vivid and wonderful fragment of autobiography—carry us much further along. We have Poincaré's dramatic account of how he discovered the Fuchsian functions ("As I put my foot on the step, the idea came to me . . ."; "As I was walking on the cliff, the idea came to me . . . ," etc.), which ascribes inspiration to the working of the unconscious. After days of apparently unfruitful work, and periods of rest, "the unconscious arranges the results of previous periods of work of which the conscious mind is no longer aware." Under the influence of "some esthetic sensibility" the breakthrough is made; thereafter "the mind must implement the inspiration, deduce and order its immediate consequences, arrange a proof, and above all verify the results." Does this explanation get to the heart of anything?

Other mathematicians whom Taton quotes have even less to reveal. It has always seemed to me that Jacques Hadamard's much-praised *Essay on the Psychology of Invention in the Mathematical Field* is a tedious book, filled with platitudes and irrelevancies. Error, he tells us, plays a part in some discoveries. He also says that there are different kinds of mathematical aptitude; that there are intuitive and logical minds; that precision, "mental order" and "mental pictures" are useful; that some mathematicians look for applications of their theories or are spurred by physical problems while others are indifferent in this regard. There is no discernible pattern in the history of mathematical invention, at least none shown by Hadamard.

Suppose we take another tack. Is it easier to identify the conditions of discovery in the experimental sciences than in mathematics or other theoretical discourses? Claude Bernard described the stages in the making of scientific discovery: the scientist discovers a fact; an idea connected with this fact suggests itself; this leads to further experiments; new phenomena appear, and so forth. Bernard was a great biologist, but this pronouncement is insipid.

It cannot be denied that there have been many "systematic discoveries." In such cases it has often happened that the problem itself was plain, that no sudden illuminations were required to indicate a fruitful path of inquiry. The right instruments, ingenious method, thorough analysis, systematic exploitation of previous work—each contributed to the successful result. An excellent example is the discovery of the planets Uranus, Neptune and Pluto.

Five planets visible without instruments were known since antiquity. The invention of the telescope in the 17th century immediately enlarged the picture of the solar system. Galileo identified the satellites of Jupiter, and a few decades later Huygens discovered Titan, the largest satellite of Saturn. More than a century passed, however, before the list of planets was enlarged. In 1781, with the help of a powerful new telescope which he had constructed, William Herschel methodically swept the different regions of the sky. Near the constellation of Gemini he noticed what he first supposed to be a comet. But on the basis of calculations by Laplace, Bochart de Saron, Joseph Lalande and others, Herschel came to realize that he had found a new planet whose orbit lay beyond Saturn's. The path of this planet—now called Uranus—proved to be very hard to predict. Despite repeated observations and considerable improvement in computational methods, "prediction did not agree with reality." Alexis Bouvard therefore advanced the hypothesis that a still unknown planet perturbed the motion of Uranus. Other

astronomers were skeptical: it seemed indecent to keep jiggling and rearranging the order of the universe. But in time the hypothesis was accepted.

The next step was to try to confirm it. Several attempts were made, but they involved such complex calculations that the interested astronomers gave up before making substantial headway. In 1841, however, John Couch Adams, a 22-year-old student at St. John's College, Cambridge, tackled and solved this enormously difficult problem. On the basis of refined observations of Uranus he was able to make a much closer estimate than had yet been achieved of the mass, position and trajectory of the hypothetical planet. Eager with his news, he called upon the director of the Royal Observatory at Greenwich. There ensued a tragicomedy. It was not permitted to disturb the director, Sir George Airy, at his dinner, so Adams was obliged to leave his card and a summary for the great man to peruse at his leisure. When Airy got around to the task he was not impressed with the result and did little to follow it up. Meanwhile a young French astronomer, Urbain Leverrier, had quite independently of Adams described the location of the new trans-Uranian planet. The data Leverrier had to rely on were highly inaccurate. He had to construct the orbit of the as yet unseen planet from its effect on the motion of Uranus; and this effect was of an order of magnitude "never greater than that of the errors of observation." Yet such was his virtuosity—and boldness—in carrying out this involved and delicate calculation that he was able to send a remarkably accurate set of directions for finding the planet to the German astronomer Johann Galle. Galle received the letter at his observatory in Berlin on September 23, 1846; that very evening he discovered the planet we now call Neptune only 52 seconds of arc away from the position Leverrier had suggested. "The planet of which you have given the position," Galle wrote him, "really exists."

In announcing his discovery to the French Academy of Sciences, Leverrier expressed the hope that continued observation of Neptune would lead to the discovery of another planet more distant from the sun, and this in turn would afford a basis for further discoveries. This expectation had partial confirmation. The American astronomers Percival Lowell and Edward C. Pickering, building on the work of Adams and Leverrier, and with the help of modern instruments, succeeded in forecasting the position of Pluto. Thus a sequence of plainly linked discoveries stretches from the 17th century to the present day. Each has its special features, yet common to all is patient and methodical research. There are no flashes of genius, no sudden inspirations; but the discoveries are neither less dramatic nor less important on that account.

Chance "happeneth to all," but rarely with profit. Luigi Galvani observed the twitching of a frog's leg when an electric spark was produced in the neighborhood of his specimen. In this curiously indirect fashion was discovered the electric current. But Galvani, though he repeated the experiment in different ways, interpreted it incorrectly, and it was Alessandro Volta who gave an explanation which led to his invention in 1800 of the voltaic battery. Galvani, in other words, had had the scientific imagination not to disregard what he saw, though he could not fathom its meaning; Volta, a gifted physicist, followed up the observation and transformed it into knowledge.

Another accidental discovery was made by the French mathematician Etienne Malus, who, while looking from his house at the sunlit windows of the Luxembourg Palace through a double-refracting crystal of Iceland spar, observed to his surprise that when he turned the crystal about its axis, each of the two images would vanish in turn. He realized that the phenomenon was somehow connected with the reflection of light by the windows, and from this inference he deduced the theory of polarization by reflection. (The phenomenon was not fully explained until some years later, when Augustin Fresnel and Thomas Young broached their theory of the transverse nature of light waves.) Taton points out that Malus's fortuitous observation "could not have fallen on a mind better prepared to draw the consequences." Undoubtedly the phenomenon had been observed before, but it took a physicist interested in geometrical optics to appreciate its significance.

Alexander Fleming's discovery of penicillin makes an intriguing story. One day in September, 1928, while studying mutation in some colonies of staphylococci, he noticed that a Petri dish had been contaminated by a microorganism from the air outside. This was not an uncommon accident, but Fleming was unwilling to dismiss it. On examining the contaminated dish in greater detail he found that a fungus had made a large region of the staphylococci transparent. He concluded at once that an antibacterial substance produced by the fungus had destroyed the staphylococci. Now it is

ENGINEERS

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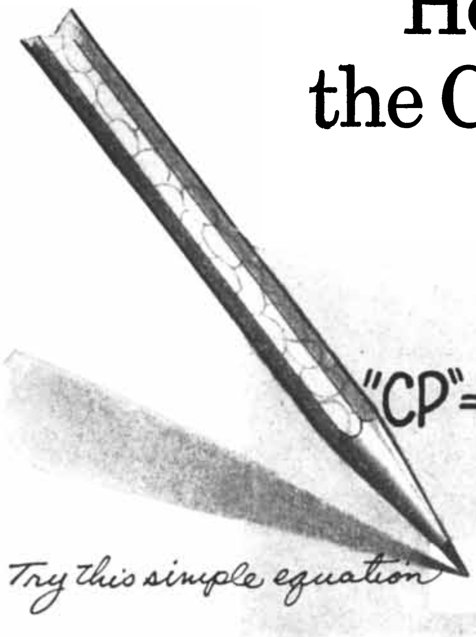

$$\text{"CP"} = EA + 2\,[F+M] + \frac{2\,[RS+B-G]+I^2}{4} + 2$$

My Present "CP"= ____________

"CP" VALUES; to test your "CP," circle the value you'd give each symbol below, substitute, AND SOLVE. *(Top value obtainable, 99.5)*

	"CP" VALUES	LOW			HIGH
E	Encouragement to Exercise Initiative & Creative Imagination	2	3	4	5
A	Assignment (Nature of)—from Routine to Very Challenging	5	6	7	8
F	Field—Conventional Product to Area where Technical Breakthroughs Expected	2	3	4	5
M	Modern Facilities—from Limited to Extensive Equipment for Testing and Research	2	3	4	5
R	Recognition of Individual Contributions—Chief Reason for Advancement	2	3	4	5
S	Salary—from Unsatisfactory to Excellent for Level of Work	5	6	7	8
B	Benefits—from Limited to Best in Industry, including Encouragement to Join Professional Societies; Liberal Support for Graduate Study	2	3	4	5
G	Increases—Primarily by Seniority Rather than Merit.	2	3	4	5
I	Your Individual Skill, Creativeness and Ability to Take Responsibility	5	6	7	8

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important to recall that 50 years earlier John Tyndall, Louis Pasteur and Jules Joubert had made similar observations; but their discoveries, while contributing to the foundations of modern bacteriology, lay relatively unattended for years. Fleming's great advance consisted of a brilliant demonstration of the selective properties of the substance secreted by the fungus and of its action on different species of bacteria.

These results were published in a classic paper which appeared only eight months after his initial observations. The reception it got was restrained; physicians are not a conspicuously imaginative breed. It is true that Fleming himself did not fully realize the power of the substance he had discovered and its potentially revolutionary consequences. It took several years of concentrated laboratory work by various bacteriologists and biochemists to master the difficulties of preparing even small quantities of pure and stable penicillin. Finally, as a by-product of the outbreak of the Second World War, the developmental phase was brought to a successful climax. Urgent medical needs led to a massive assault by U.S.-British teams of scientists and technicians on the problems of large-scale industrial manufacture of the new antibiotic.

For the student of scientific discovery these circumstances comprise a most illuminating case history. Consider how many elements had to be brought together: a number of precursor experiments by physicists and chemists; an accident caused by inadequate precautions in the laboratory; a talented and perceptive biologist who insisted on worrying an apparently unimportant phenomenon until he had shaken loose its meaning; a follow-up multidisciplinary program of research; the support of industry and government; lavish public expenditures. All these elements went into the complex process of "the discovery of penicillin."

Some discoveries are forgotten for many years (Gregor Mendel's famous researches in heredity are the most obvious example); some are narrowly missed. The little less, as Browning wrote, is "worlds away." Poincaré and Hendrik Lorentz, among others, "approached" the theory of relativity but lacked, in Taton's words, "the courage to make their thoughts explicit." Louis de Broglie ascribes Poincaré's failure to the fact he was a pure mathematician with a "somewhat skeptical attitude towards physical theories." In his view such theories were not "true" but merely "convenient." He was therefore loath to plump for this or that physical model since any number of others logically equivalent to it were equally valid. Einstein's great achievement is of course in no way diminished by these circumstances.

Blaise Pascal in his studies of the roulette problem invented a method which opened the way for Leibniz's invention of the infinitesimal calculus, but Pascal himself regarded his method as no more than an aid to calculation. He had fame enough.

We come now to André Marie Ampère's strange failure to discover induction. Hans Christian Oersted's famous experiments in 1819 had shown the magnetic effects of an electric current. Physicists at once began to search for a reciprocal phenomenon—the electrical effects of a magnet. The first attempts to demonstrate induction failed, for they were based on the mistaken notion that if a magnet were merely placed close to a wire, something interesting would happen. A magnet at rest with respect to a conductor produces no current; indeed, if this were not so, the principle of conservation of energy would fail. It remained for Michael Faraday a decade later to show that, for a current to flow, magnet and wire have to be in relative motion; the accepted explanation is that the current depends on the cutting of the magnetic lines of force.

Meanwhile, in the course of other experiments with a different purpose, various instances of induction came into view, but no one recognized them. One of these experiments was performed by Ampère and his friend Auguste de La Rive. A ring made of a thin strip of copper was suspended by a silk thread over a coil of wire wound parallel to the ring. The ring was then placed in the field of a powerful permanent magnet. When a current was set up in the coil, the ring was displaced; when the current was shut off, the ring returned to its original position. What did this mean? The copper ring was a conductor; the turning on and off of the current in the coil produced a magnetic flux which induced a current in the ring, causing it to move in its magnetic field. This was no surprise to Ampère, who had already demonstrated the attractions and repulsions produced by magnetic forces between adjacent wires carrying currents in opposite directions. But while he recognized what he called the "production of currents by influence" (*i.e.*, induction), the essential idea of relative motion as a necessary condition eluded his understanding. He simply inferred that since the ring remained in a displaced

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position while the current flowed in the primary circuit (the coil), the induced current in the ring kept flowing during the same period; and when the primary current ceased, the ring went back to its original position because the induced current ceased. Because of this erroneous inference Ampère missed the discovery of induction.

When Faraday announced his own achievement, Ampère reproached himself for having failed to draw the logical consequences of his work. Having, with La Rive, been the first to obtain a current by induction, he neglected to exploit this epochal feat. Why? His explanation is only partially convincing. "I assure you," he wrote Faraday in 1833, "that at the time I never once tried to find out in which sense a current is produced by induction. I had but one aim in making these experiments, and by taking a look at what I published at the time, where I described the apparatus that I used, you will see that I was only concerned with solving the question whether electric currents are due to the magnetic attraction and repulsion present before magnetization in the molecules of iron, steel and two other metals, in a state which does not allow them to exercise any action outside, or whether they are produced at the moment of magnetization by the influence of neighboring currents."

That Faraday succeeded where not only Ampère but many others failed is a typical puzzle of scientific discovery. Taton does not pretend to pierce it.

The serious student's outlook on the subject has undoubtedly become more mature. The realization is growing that science, like other creative work, is strongly influenced by social, economic and political circumstances; that the general style of contemporary thought in religion, philosophy and other spheres profoundly affects scientific thought. Indeed, it may be said that these notions are already commonplace. But the nature of the relationships is only dimly perceived and requires much study. It is also increasingly recognized that the acquisition of knowledge is a cooperative task. This does not mean, I should emphasize, that the best research has to be expensive, or that progress in tackling complex problems is assured when everyone gets into the act. It is still possible to make important discoveries in the head, and even to make them in one head.

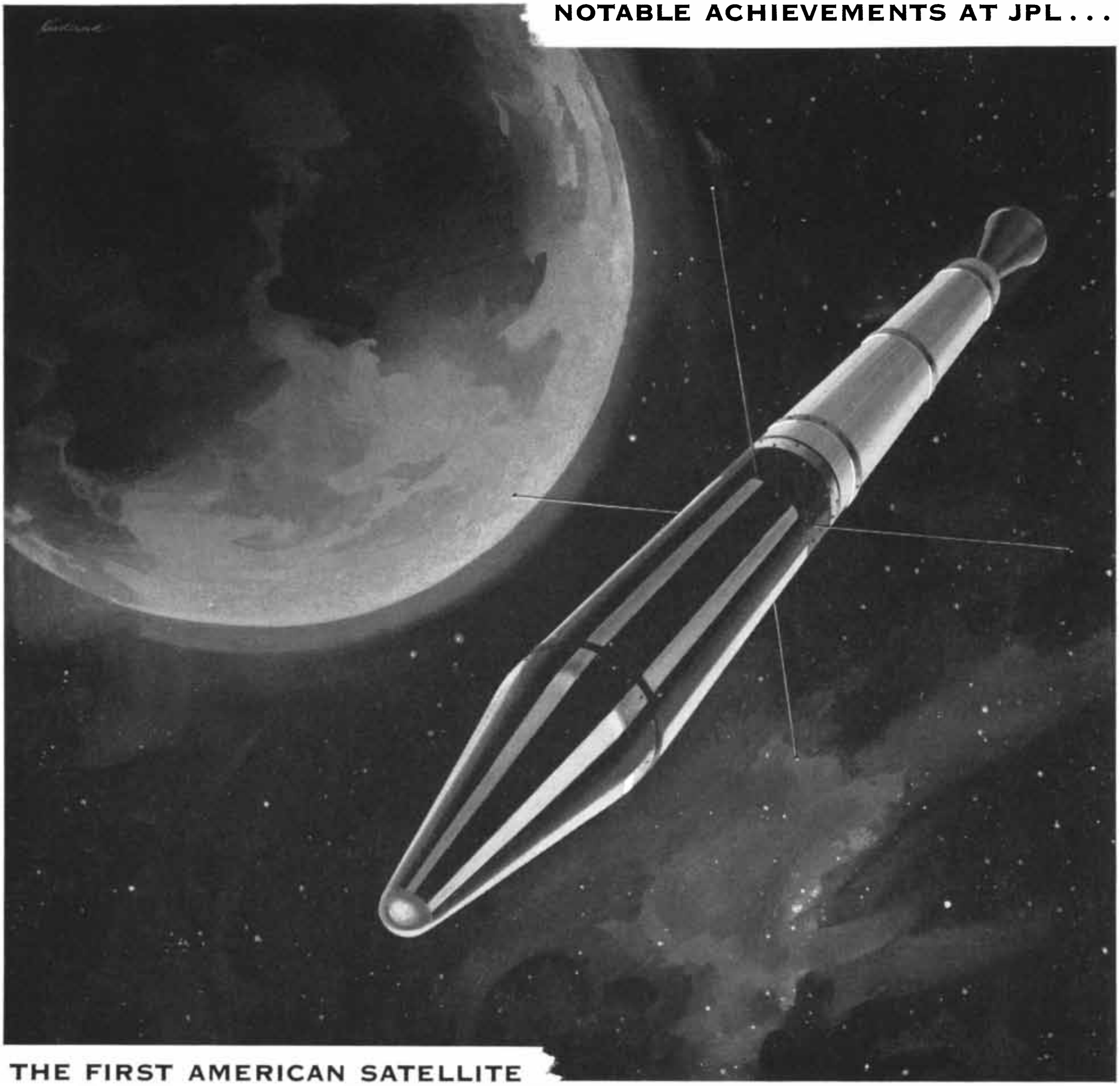
Some years ago Lord Rutherford concluded a lecture entitled "The Development of the Theory of Atomic Structure" with these words:

"I have tried to give you a general idea of the way in which we started to investigate these matters forty years ago, and of the way in which the ideas have developed stage by stage. I have also tried to show you that it is not in the nature of things for any one man to make a sudden violent discovery; science goes step by step, and every man depends on the work of his predecessors. When you hear of a sudden unexpected discovery—a bolt from the blue as it were—you can always be sure that it has grown up by the influence of one man on another, and it is this mutual influence which makes the enormous possibility of scientific advance. Scientists are not dependent on the ideas of a single man, but on the combined wisdom of thousands of men, all thinking the same problem, and each doing his little bit to add to the great structure of knowledge which is gradually being erected."

Short Reviews

A HISTORY OF AMERICAN MAGAZINES, by Frank Luther Mott. Harvard University Press (Vol. I, 1741-1850, $10; Vol. II, 1850-1865, $8.50; Vol. III, 1865-1885, $9; Vol. IV, 1885-1905, $12.50). When the fourth volume of this masterly survey of American magazines appeared a few months ago, the publisher wisely took the opportunity to reprint the earlier volumes so that the entire history would be available. Rarely in the annals of historical writing has there been such a successful confection of the solid stuff of fact with the spices of wit, lively anecdote and urbanity. The same method of presentation is followed in each volume. The first part is a running general account of the magazines founded during the period, of their purposes, content and policies, of the problems and personalities of the magazine-publishing business. The second part consists of excellent sketches—some are 40 or 50 pages long—of particular magazines. Each sketch considers the whole record of the magazine to the present time (or the magazine's end date), and appears in the volume covering not necessarily the founding period of the magazine but that during which it reached full flower. Mott discusses the weeklies and monthlies; the mail-order journals and the learned journals; the magazines that cost a penny and those that gave "nude art" for a nickel; the magazines that were born and died in a single issue (*e.g., The Long Island Magazine;* June, 1796), and those that survived a century and a half and are still going (*e.g., Herald of Gospel*

NOTABLE ACHIEVEMENTS AT JPL . . .



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Liberty, founded in Portsmouth, N. H., in 1808); the publications with a few hundred circulation and those with a few million; the family and women's magazines, including the famous *Godey's Lady's Book* which, its publisher said, "brought unalloyed pleasure to the female mind"; the literary messengers and the early Western magazines; the children's periodicals (among which was *Juvenile Port Folio,* which ran for more than 200 weekly issues and was edited and published by Thomas G. Condie, Jr., "who was not fourteen years old when the work was commenced"); the comic papers, from the New York weekly *The John-Donkey* to *Life* and *Judge.* Also treated are the quarterlies and eclectics; the theatre and book reviews; the journals of religion, literary gossip, politics, philosophy, dentistry, cockfighting, science, agriculture, law, medicine, reform, railroading, checkers, mining, geography, pugilism, art, music, hardware, shell collecting, wine, abolitionism, military affairs, gaslight, hydropathy, leather goods, phrenology, hogkeeping, insurance, snappy stories, butchering, fashions, bee culture, automobiles, tobacco, roller skating, furniture, croquet, dogs and cats, barbering, prostitution and white slavery (*e.g., Light,* published in La Crosse, Wis., from 1898 to 1936, whose publisher declared in the first number "that a young girl was ruined every eight minutes in this country"). This is a scholarly, enormously entertaining work, which despite its size and detail has not frayed the author's energy, sense of humor and enthusiasm.

PERSEPOLIS II: CONTENTS OF THE TREASURY AND OTHER DISCOVERIES, by Erich F. Schmidt. The University of Chicago Press ($85). The first volume of this notable archaeological report, reviewed two years ago in these pages, dealt principally with the remains of the structures on the Terrace of Persepolis, founded by Darius I between 520 and 510 B.C. and destroyed by Alexander in 330 B.C. The Macedonian soldiers burned and wrecked the most imposing public buildings—the marks of the conflagration are still plainly visible—and they plundered whatever seemed worth plundering. But the fire accidentally contributed to our knowledge about Persepolis, for as the roofs and walls collapsed the debris sealed objects which the soldiers either rejected or lost during the pillage, and it is with these objects, now recovered, that the present volume is mainly concerned. Detailed descriptions and illustrations are presented of signet rings, seals, and objects such as clay tablets bearing seal impressions; foundation records inscribed on slabs of metal and stone; ritual vessels, mortars and pestles; votive objects such as inscribed beads and eyestones; a fragment of a beautiful Greek statue evidently transported to Persepolis by the Persians (either as booty of war, a gift, tribute or item of trade); personal ornaments, including buckles, bracelets, rings, earrings, clasps and pins; royal tableware of stone and composition, mostly smashed by the Macedonians (whose conduct may be accountable not to senseless vandalism but the desire to get at the precious metal shell or lining of the tableware); glass vases; vessels of bronze, silver and gold; pottery; weapons, horse harness and other martial equipment; coins, weights and measures; and various tools and utensils from curtain rings and knives to bolts and what appear to be pulley-wheels. Also covered in the report are the many earthenware coffins of a cemetery found near a spring. One of the most interesting and puzzling of the Persepolis discoveries is a set of nine artificial beards made of a blue substance which imitates lapis lazuli. Each beard has a dowel, fastened with two nails of bronze, which was to be inserted in the chest of the figure to be provided with the beard, but there are no other clues as to their manner of use.

OXFORD MATHEMATICAL CONFERENCE: ABBREVIATED PROCEEDINGS OF THE OXFORD MATHEMATICAL CONFERENCE FOR SCHOOLTEACHERS AND INDUSTRIALISTS. The Times Publishing Company Limited (two shillings sixpence). A number of interesting papers on the applications of mathematics appear in this publication, as well as G. E. Felton's approximation of *pi*, running to 10,000 digits and calculated in about 33 hours of machine time on a Ferranti Pegasus digital computer, described as a medium-sized machine. Compare this with the fandango of our much larger electronic computer, NORC, which in 1955 worked out *pi* to 3,089 places in 13 minutes of machine time.

GAMES AND DECISIONS, by R. Duncan Luce and Howard Raiffa. John Wiley & Sons, Inc. ($8.75). About game theory, with emphasis on the social-science point of view. Having in mind the interests of a wide group of scholars—economists, political scientists, sociologists, experimental psychologists, philosophers—the authors have selected their problems and examples from these fields

and have tried to hold down the mathematical details to a minimum. But the hard fact is that game theory is essentially a mathematical discipline: so the text is neither free of mathematics, nor is the mathematics accessible to babes, nor is the discussion easy to follow even when it is bare of mathematics. This is no reflection on the book but intended only to avoid misunderstanding on the part of the prospective reader.

THE INNER METAGALAXY, by Harlow Shapley. Yale University Press ($6.75). From his "awkward position near the edge of one dusty spiral" man has somehow been able to derive a "fair picture" of the whole universe of billions of galaxies, though less than a dozen are within a million light years. Scores of investigators are engaged in this exciting exploration, new techniques and instruments have come into use, among them radio telescopes, and as a result the great galaxy survey will soon reach close to the 20th magnitude and to a billion years of light travel. With his customary mastery of subject matter and skill in presentation, Shapley here summarizes the progress of galactic research during the past 30 years.

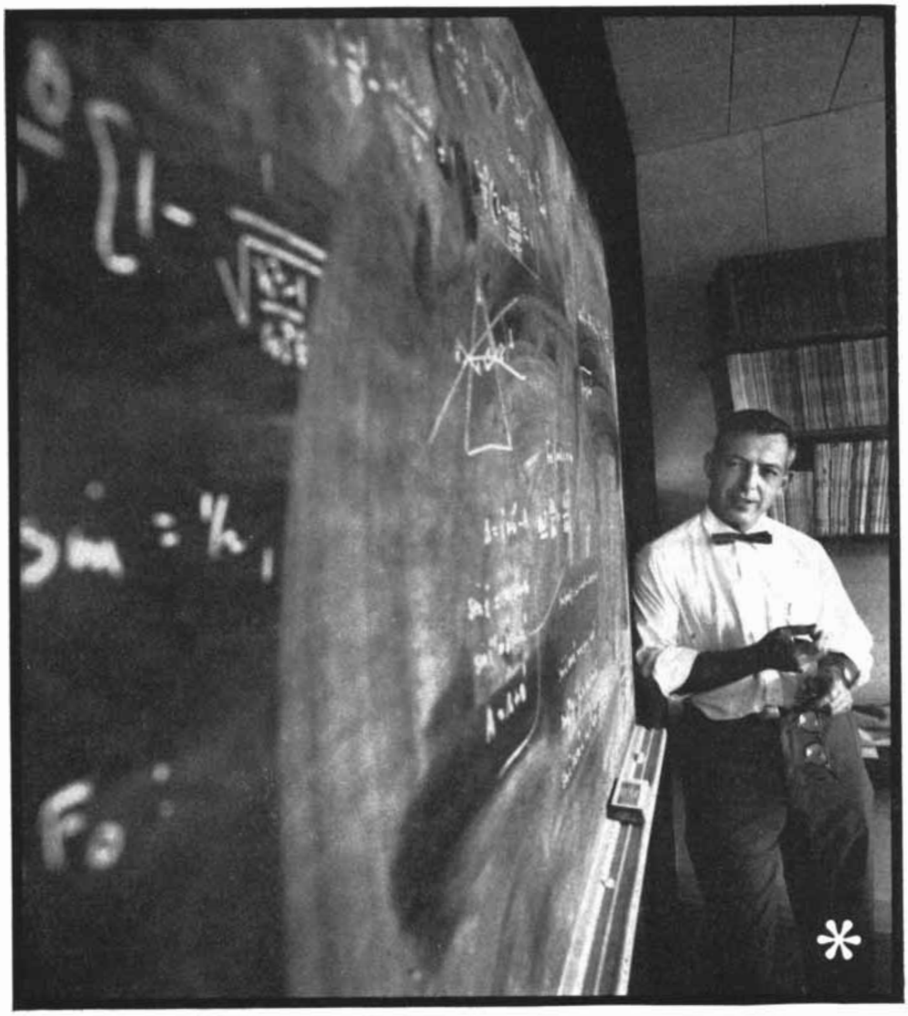
THE ELIZABETHANS, by Allardyce Nicoll, Cambridge University Press ($5). ELIZABETHANS AT HOME, by Lu Emily Pearson. Stanford University Press ($8.75). These two books complement each other to give a colorful picture of life in the Elizabethan age. Nicoll's is a brief picture-document history made up of passages from Elizabethan writings and many contemporary illustrations. The subjects include Queen Elizabeth and her court, astrology and astronomy, parliament, the law courts, the church, London, the countryside, the plague, education, the practice of medicine, music and literature, the arts of war, the Royal Navy and navigation. Pearson's detailed survey describes Elizabethan homes and gardens—everything from ovens, chairs and garden maizes to clocks, outhouses and beds (a bed prepared for James I when he was visiting the Earl of Dorset had embroidered cloth of gold hangings said to have cost the owner 8,000 pounds), the relations between parents and children, the education of children, preparation for marriage, the maintenance of the home, the daily habits and domestic arts of rich and poor.

THROUGH ALCHEMY TO CHEMISTRY, by John Read. The Macmillan Company ($3.75). A distinguished British chemist and historian of chemistry presents a short account of the evolution of chemistry from its magical and mystical beginnings to the powerful, sophisticated science of today. Read describes the major contribution of alchemy—that extraordinary potpourri of philosophy, art, religion, astrology, observation and skilled craft—to the growth of chemical knowledge. The great goal of transmutation was not achieved, but it was imagined and foreshadowed. In the 16th century Paracelsus pointed a new direction by insisting that the true object of alchemy was to prepare healing drugs and not to make gold; in the 17th century Robert Boyle began to lay the foundations for a "wholly scientifical chymistry" by exposing the long-established confusions of chemical thinking and enunciating what is essentially the modern conception of an element. The concluding chapters of Read's survey deal with the researches of Joseph Black, Lavoisier, Dalton, atomic theory, the rise of organic chemistry, molecular structure, space chemistry. This is a sound and charming primer, flavored by the author's broad culture and humanistic outlook.

ATLAS OF WORLD HISTORY, edited by R. R. Palmer. Rand McNally and Company ($6.95). A group of historians have collaborated to produce a handy atlas whose maps and text offer the general reader a summary of world history from ancient times through the Second World War. The maps, while certainly not beautiful, are informative and clear; the commentary is excellent; the price is right. This is a fine book for the home reference shelf.

FUNDAMENTALS OF MATHEMATICS, by Moses Richardson. The Macmillan Company ($6.50). Revised edition of one of the best general surveys of mathematics for college students whose major interests are in the arts and social sciences. Among the topics newly treated are computers, information theory, Boolean algebra, linear programing, theory of games, mathematics of political structures. A text that deserves readers.

CITIES IN THE SAND, text by Kenneth D. Matthews, Jr.; photographs by Alfred W. Cook. University of Pennsylvania Press ($10). The ancient Roman towns of Leptis Magna and Sabratha on the Mediterranean coast of Libya were populous and prosperous communities of the Roman Empire. They decayed as the Empire decayed and were finally abandoned and buried by the desert sands. In the present century the cities were



uncovered by archaeologists. The text of this book briefly recounts the history of the region of Tripolitania, describes the life of the towns and explains the ruins which have been dug up. The photographs, some of which are admirable, present views of the remains of the great forums, theaters, temples, public baths, homes and markets.

Notes

INTRODUCTION TO RIEMANN SURFACES, by George Springer. Addison-Wesley Publishing Company, Inc. ($9.50). A self-contained modern treatment of the fundamental concepts and basic theorems of Riemann surfaces.

THE GREEKS AND THE IRRATIONAL, by E. R. Dodds. The Beacon Press ($1.95). This paper-back reprint makes available at a moderate price a rich, admirably written study of the irrational element in the mental life of ancient Greece, a relatively unfamiliar aspect of that society.

PHYSICAL PROPERTIES OF CRYSTALS, by J. F. Nye. Oxford University Press ($8). The physical properties of crystals expressed in tensor notation.

TOPOLOGY, by Solomon Lefschetz. Chelsea Publishing Company ($4.95). A corrected edition of Lefschetz's well-known monograph, originally published in 1930.

THE GRAMMAR OF SCIENCE, by Karl Pearson. Meridian Books ($1.95). A paper-back reprint of Pearson's famous essay on the philosophy of science, with an introduction by Ernest Nagel.

ZOOGEOGRAPHY, by Philip J. Darlington, Jr. John Wiley & Sons, Inc. ($15). A monograph on the patterns, causes and consequences of the geographical distribution of animals.

ARTIFICIAL STIMULATION OF RAIN, edited by Helmut Weickman and Waldo Smith. Pergamon Press, Inc. ($15). Proceedings of the first conference on the physics of clouds and precipitation held at Woods Hole Oceanographic Institution in 1955.

BRITISH GUIANA, by Michael Swan. Her Majesty's Stationery Office ($4.50). One of a series of illustrated volumes sponsored by the British Colonial Office describing the way the peoples live and how they are governed in the United Kingdom's dependent territories. Readable, informative, well produced.

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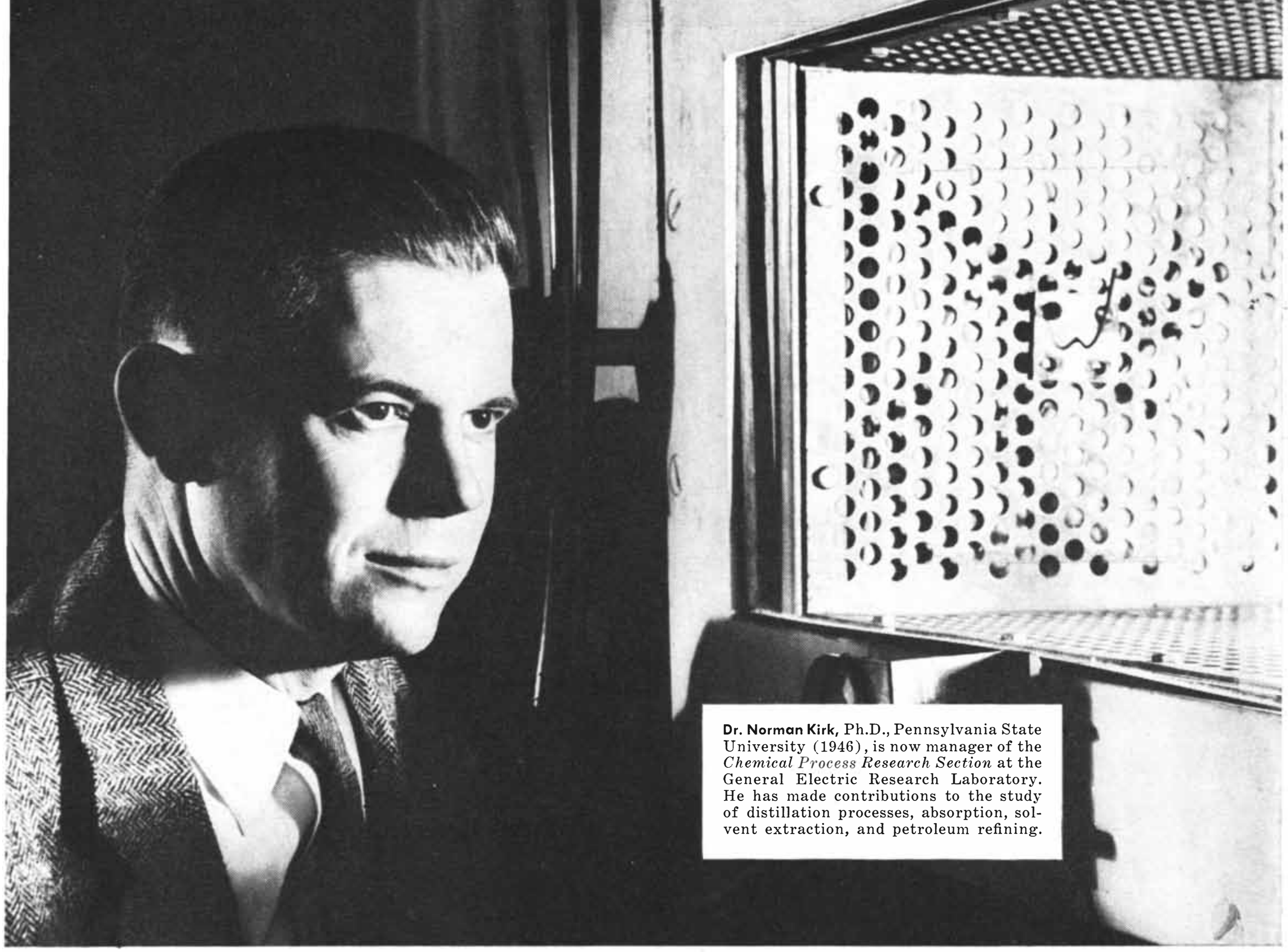

Dr. Norman Kirk, Ph.D., Pennsylvania State University (1946), is now manager of the *Chemical Process Research Section* at the General Electric Research Laboratory. He has made contributions to the study of distillation processes, absorption, solvent extraction, and petroleum refining.

Research in exotic fuels

12 years ago Dr. Norman Kirk began contributions to this field at the General Electric Research Laboratory

During the past year, headlines have begun telling the exciting possibilities of new high-energy chemical fuels for jet engines and rockets. These boron-based fuels can produce half again as much energy per pound as the best petroleum products, and they are expected to give longer range and higher speed to missiles as well as aircraft.

The transition of *boron hydrides* from a test-tube novelty to an important factor in national defense began shortly after World War II when a group of chemists at the General Electric Research Laboratory entered upon a seven-year program to seek methods of manufacturing *diborane* (B_2H_6) and *pentaborane* (B_5H_9) in large quantities.

Dr. Norman Kirk had a key role in the development and construction of the first pilot plant for these early exotic fuels. He and his associates combined scientific knowledge and engineering skill to develop practical methods for making and handling boron hydrides. By the time General Electric's pioneering program had been completed in 1953, Dr. Kirk's group had successfully solved the problems created by the fact that boron hydrides have a toxicity equal to deadly war gas, and some have explosive characteristics so critical that contact with only a small amount of air can be catastrophic.

Until now, national security requirements have delayed public recognition of past work in boron hydrides by Dr. Kirk and his associates. But their contributions were an outstanding example of the kind of fundamental groundwork that must be done before new scientific knowledge can actually be applied to the defense of our nation.

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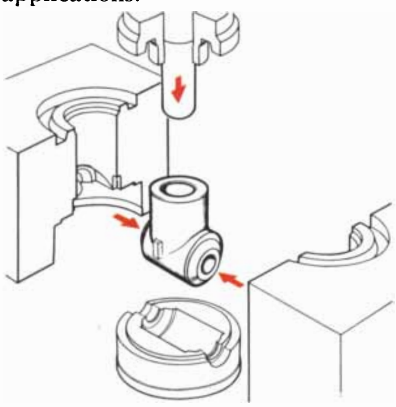

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